# Excursion 4 Invergarry to Kinloch Hourn

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| *Purpose:* | An east-west traverse through the Sgurr Beag Nappe to examine the internal structure of the nappe and its basal thrust. |
| *Aspects covered:* | Curvilinear, recumbent folds in the Loch Eil Group; sedimentary structures in the Glenfinnan/Loch Eil group transition; the Quoich Granitic Gneiss; the Loch Quoich Line and intense Caledonian upright folds; curvilinear folds in the Glenfinnan Group; syn-deformational pegmatites; Lewisianoid inlier in the Sgurr Beag Thrust Zone; reworking of the ductile thrust-related fabric by steep-belt structures; a lower (Knoydart?) ductile thrust within the Morar Group. |
| *Maps:* | OS: 1:25,000 sheets 399 Loch Arkaig, 400 Loch Lochy & Glen Roy, and 414 Glen Shiel & Kintail Forest; BGS: 1:50,000 sheets 63E Loch Lochy, 62W Loch Quoich and 72W Kintail. |
| *Type of terrain:* | A mixture of roadside, lochside and off-road exposures involving some hill-walking. |
| *Distance:* | by car 40km (25 miles), one-way from Invergarry, plus *c.*10km walking. |
| *Time:* | By car *c.*2 hours return journey plus a long day's fieldwork. Could usefully be split into two days, after visiting the Quoich dam spillway. Coaches can proceed no further than Locality 4.7 (Quoich bridge). |
| *Useful information:* | This section is best studied while staying at Invergarry, where there are two hotels, two campsites and many B&B establishments. If you wish to take a large party into Coir' an t-Seasgaich during the stalking season (1 September to mid-October), it is best to seek advice first from the keeper (Mr A. L. MacNally, Tel: 01809 511220) in the small village of Kingie, 3km east of the Quoich dam. |
| *Short itinerary:* | Locality 4.1 (Garry Quarry), Locality 4.3 (Quoich dam spillway), Locality 4.5 (Quoich shore), Locality 4.8 (Coire Shubh Beag, 4.8D and 4.8E only), Locality 4.9 (Kinloch Hourn, omit 4.9A and walk as far as time permits). |

## Locality 4.1 Garry Quarry [NH 196 023]

**Garry Quarry (Figure 4.1). Curvilinear, recumbent folds in Loch Eil Group psammite.**

The first locality is reached by driving west from Invergarry on the A87 until the turnoff for Kinloch Hourn and Tomdoun is reached [NH 243 029]. Turn left onto the Kinloch Hourn road (single track with passing places) and continue along it for 5km until you reach a small quarry adjacent to the road, just short of the Greenfield bridge across Loch Garry. Parking is available opposite the quarry for no more than two cars. The quarry exposes Loch Eil Group psammites within the regional flat belt and allows an unequalled opportunity to examine the geometry of structures within the psammites in three dimensions. A detailed structural analysis of this quarry, including a map, 3D diagram and stereographic plot of structural elements can be found in Holdsworth & Roberts (1984).

The psammites are folded by tight, recumbent folds that can be traced laterally for some distance. Holdsworth & Roberts (1984) drew attention to the fact that the hinges of individual folds at this locality are curved rather than linear. The curvature of the hinges of the folds in the quarry is symmetrical about a very weak, north-south extension lineation. Such an extension direction is distinctly different in orientation from the usual WNW-directed extension lineations associated with overthrusting during the Scandian phase of the Caledonian orogeny, both in the Moine and the Moine Thrust Belt. It has therefore been suggested that the folds seen in the quarry ($D_2$ in the local deformation sequence) formed during an earlier tectonic event. Titanites aligned within the north-south extension lineation near Invergarry have yielded a U-Pb zircon age of 470 ± 2 Ma, perhaps indicating that the lineation and associated curvilinear folds formed during the Grampian phase of the Caledonian orogeny (Rogers *et al.,* 2001). Garry Quarry also exposes post-tectonic granitic veins belonging to the Glen Garry Vein Complex (Fettes & MacDonald, 1978), together with mineralised (pyrite, haematite, calcite) faults and joints.

## Locality 4.2 Coir' an t-Seasgaich [NH 076 035] to [NH 082 0390]

**Coir' an t-Seasgaich (Figure 4.1) and (Figure 4.2). Sedimentary structures and cross-cutting amphibolite sheets preserved in a 'low-strain window' around the Loch Quoich Line.**

From Locality 4.1 drive west for 12km until the road crosses the Allt Coir' an t-Seasgaich at [NH 078 023] (Figure 4.2). Parking is available for several cars or a small coach on the southwest side of the road. About 1.5km north of here, on the east flank of Spidean Mialach, lies Coir' an t-Seasgaich, a corrie that contains many large, glacially-scoured exposures visible from the road. The corrie is best reached by walking up beside the Allt Coir' an t-Seasgaich, aiming eventually for the lower exposures in the corrie 2A (Figure 4.2). A practised and fit hillwalker will reach these slabs in just over half an hour; others should allow longer and all should wear stout footwear. In total, a visit to this locality involves about 4km of walking and 550 m of ascent.

The walk up the Allt Coir' an t-Seasgaich takes you from the Upper Garry Psammite of the Loch Eil Group (Figure 4.2) through granitic gneiss, the Garry Banded Formation, another sheet of granitic gneiss, and finally into the Lower Garry Psammite that forms the slabs in Coir' an t-Seasgaich. This section is part of the Glenfinnan/Loch Eil group transition zone described by Roberts & Harris (1983).

On reaching the slabs, 2A (Figure 4.2), the most obvious difference between the psammites here exposed and those seen in the flat belt at Locality 4.1 is the common preservation of sedimentary structures. A slow traverse across the corrie from this initial location to a point on the east ridge of Spidean Mialach at 2C (Figure 4.2) should reveal abundant cross-lamination (younging towards the SE), graded beds, slump folds, contorted bedding and pebbly beds. Such excellent preservation of sedimentary structures is unknown elsewhere in this part of the Sgurr Beag Nappe, and illustrates the low state of strain of these rocks. Also indicative of low strain are the amphibolite sheets and pods. As will be seen at Locality 4.3, amphibolites normally occur as concordant sheets; however, the low strain state in Coir' an t-Seasgaich has allowed their original cross-cutting intrusive relationships to be preserved. An excellent example of a cross-cutting amphibolite is exposed in the slabs at 2B (Figure 4.2). Such preservation of strongly cross-cutting relationships is rare within the Sgurr Beag Nappe.

Although the psammites in the corrie are generally at a low state of strain, local areas of high strain, into which sedimentary structures are progressively deformed, can also be seen. Within these zones of higher strain, pebbles in conglomeratic horizons have been deformed to an elliptical shape.

On reaching the ridge 2C a rest should be taken to enjoy the view. Only 1km to the west is the peak of Spidean Mialach, one of many Munros (3000-foot-high mountains) in this area, to the north the view extends to the high peaks above Loch Cluanie, to the east can be seen Ben Tee adjacent to the Great Glen, and the Monadhliaths beyond, and to the south (weather permitting!) can be seen Ben Nevis and the surrounding mountains.

The psammites observed at Locality 4.1 had a nearly flat sheet-dip, while those seen in Coir' an t-Seasgaich are steeply inclined or vertical. This is because the Loch Quoich Line, the boundary between the regional flat and steep belts (Leedal, 1952; Clifford, 1957; Roberts & Harris, 1983) has been crossed (see 'Summary of Moine Geology' for regional

significance of the Loch Quoich Line). The synform marking the course of the Loch Quoich Line in this area can be examined by traversing the ridge on which you are now standing. At stop 2B, and elsewhere throughout the slabs examined so far, the psammites strike approximately NE–SW and young towards the SE. At 2E, 400m to the east the psammites strike NW–SE and young towards the SW; the Beinn Beag Synform (= the Loch Quoich Line *sensu* Roberts & Harris, 1983) has been crossed. The axial trace of the synform, where the psammites young due south, can be seen at 2D (Figure 4.2). The rocks immediately east of the Loch Quoich Line do not become flat immediately, but rather their sheet-dip decreases gradually across several kilometres. Walk back down the hill and rejoin the vehicles.

## Locality 4.3 Quoich dam spillway [NH 071 023]

**Quoich dam spillway (Figure 4.1) and (Figure 4.3). Quoich Granite Gneiss, metasedimentary country rock within the Glenfinnan/Loch Eil group transition zone, amphibolites, microdiorite.**

From the parking place for Locality 4.2, drive west for about 1km and park in one of the large lay-bys beside the Quoich dam (Figure 4.2). Descend SE from the lay-by, alongside the spillway, keeping to the north of the fence. At 3A (Figure 4.3), the contact is exposed between the Quoich Granitic Gneiss and the structurally overlying Garry Banded Formation. The granitic gneiss lying west of the contact is pale pink, medium-grained and consists mainly of K-feldspar, plagioclase (An15-20) and quartz. The pervasive $D_1/D_2$ tectonic fabric is defined by discontinuous biotite-rich laminae and by concordant migmatitic *lits*. These have mafic selvedges and probably formed by *in situ* metamorphic segregation. The Quoich Granite Gneiss (part of the West Highland Granitic Gneiss) is regarded as a deformed and metamorphosed granite that was intruded at *c*.870 Ma (Friend *et al*., 1997; Rogers *et al.,* 2001). Whether migmatization also occurred at *c*.870 Ma (Friend *et al*., 1997) or much later during the Caledonian orogeny (Dalziel & Soper, 2001) is uncertain. The gneiss-metasedimentary rock contact is sharp but lacks the platy fabrics associated with tectonically emplaced basement bodies (see Locality 4.9). No transitional rocks indicative of a metasomatic origin are developed. The migmatitic pelite adjacent to the granite gneiss grades over about 5 m into interbedded psammite and pelitic gneiss. Leucosomes within the pelites are deformed by intrafolial isoclines and an unusual, antiperthitic-bearing variety was probably formed by partial melting (Barr, 1985).

At 3B, the core of a large Z-profile fold is occupied by a patch of remobilised granite gneiss with an undeformed, granitoid appearance. An early amphibolite traced through this locally pegmatitic body is progressively deformed, and altered to biotite and feldspar. Textures within this remobilised rock suggests an origin by partial melting but its chemistry favours subsolidus segregation or re-equilibration after consolidation (Barr, 1985), perhaps related to the intense retrogression evident in its vicinity.

At 3C, a metasedimentary enclave crops out in the spillway wall. It defines an S-profile, reclined $D_2$ fold pair, and consists of a thin but extensive band of psammite with concordant hornblende schist. At 3D, a second enclave comprising micaceous psammite and quartzite intruded by hornblende schist is also deformed by $D_2$ folds. Barr *et al*. (1985) interpret these and other enclaves as deformed xenoliths within an original magmatic granite. Also at 3C, a coarse granitoid patch disrupts the $D_1/D_2$ foliation and agmatizes an amphibolite sheet (Barr, 1985, (Figure 7.7)b). It appears to be associated with a sinistral, extensional shear zone, one of several present in this area.

Return to the spillway at 3D and proceed upslope observing a number of sinistral, NW–SE-trending shear zones within the granitic gneiss. Pegmatitic segregations have developed within some but not all of these shear zones, destroying the foliation in the gneiss. Barr (1985) concluded that partial melting had been localized in the shear zones. This part of the section also exposes numerous isoclinal $D_2$ folds that deform pegmatites and an earlier $D_1$ gneissic fabric. In the SW wall of the spillway, an upright $D_3$ fold pair indicates an antiform to the west, the Spidean Mialach Antiform of Roberts & Harris (1983).

Over the next 30m of section, numerous amphibolite sheets crop out within the granitic gneiss. The margins of these amphibolites are generally concordant with the foliation in the gneiss, but the intrusive origin of one body at 3E is confirmed by the presence of several *c*.10cm diameter xenoliths of granitic gneiss. In this central portion of the gneiss, $D_2$ isoclinal folds of the earlier $D_1$ fabric are common, transposing the foliation everywhere but in the relic fold cores. Similar structures can also be seen in the Ardgour Granite Gneiss (Excursion 2, Localities 2.7 & 2.8; Barr *et al*., 1985, figure 4b).

Where these $D_2$ folds deform amphibolite sheets, an axial planar hornblende fabric is produced.

At 3F (Figure 4.3), a 2m-thick SE-dipping microdiorite sheet cuts the spillway. This sheet bifurcates and includes xenoliths of granitic gneiss. Unlike the older hornblende schists and amphibolites, the microdiorite cross-cuts the $D_2$ fabric in the gneiss. It also cuts across an earlier concordant amphibolite and is largely post-tectonic. It retains a coarse-grained centre and a fine-grained, amygdaloidal margin, but has recrystallized to an amphibolite-facies mineral assemblage. Several smaller microdiorites are present upslope.

At 3G (Figure 4.3), a sharp contact is exposed between granitic gneiss and a 1m-thick, antiperthite-bearing migmatitic pelite. Upslope from this pelite band, the ground to the top of the spillway is occupied by psammites and quartzites of the Lower Garry Psammite (Roberts & Harris, 1983). These psammites are along strike from those seen in Coir' an t-Seasgaich (Locality 4.2), but lack their abundant sedimentary structures. Only a few highly deformed cross-beds are preserved, and the uniform, finely banded appearance of the psammites, which contain reclined, isoclinal folds, is thought to indicate that they have been highly strained. This high strain has obliterated any original angular discordances, and Roberts & Harris (1983) attribute it to severe upright Caledonian reworking, during the $D_3$deformation that produced the regional steep belt west of the Loch Quoich Line.

A 4m-thick amphibolite sheet lies 10m into the psammites. Its northern margin has been interfolded with the psammites by reclined $D_2$ structures, and the amphibolite carries an axial planar $D_2$ fabric. Upslope, several north-south-trending pegmatites cut $D_2$ structures within the psammites and are deformed by late, semi-brittle kink bands. They are little deformed internally, and probably late Caledonian in age.

At 3H (Figure 4.3), a 1.5m-thick, NE–SW-trending microdiorite sheet is displaced *c*.2m by a NW–SE-trending fault. This fault passes along its length into a brittle, dextral kink band. Adjacent to this fault, in the NE wall of the spillway, the psammites are intruded by a fine-grained, intermediate igneous rock that may be a member of the minette suite of Smith (1979). Complete this section by walking up to the concrete-floored part of the spillway, and look up at the SW wall to observe a mesoscopic, gently-plunging $D_3$fold pair verging westwards to the Spidean Mialach Antiform.

Return to the bridge and climb back up to the road. Whilst walking past the dam buildings, note the presence, in psammites of the road section, of several south-plunging $D_3$fold pairs that verge westwards towards the Spidean Mialach Antiform. These are cut by SE-dipping microdiorite sheets but fold an earlier amphibolite sheet. At [NH 069 025], opposite the dam, a stream passes beneath the road. On the north side of the road, on the left side of the stream, a deformed pebbly unit is exposed within the psammites. The pebbles of quartz and feldspar are much more strongly deformed than those seen in Coir' an t-Seasgaich. The quartz pebbles define a steep extension lineation and have axial ratios of approximately 3:1:0.2. They help to quantify the amount of ductile strain recorded by the enclosing platy psammites.

## Locality 4.4 Quoich Quarry [NH 062 018]

**Quoich Quarry (Figure 4.1). Highly deformed Glenfinnan Group psammites; microdiorite and felsic porphyrite sheets.**

Return to the vehicles and drive *c*.1km west to [NH 062 021], where a steep track descends to the lochside quarry. En route, check that the nearer of the two islands in Loch Quoich is connected to the shore; if not, the quarry floor may be flooded and access difficult. Coaches and minibuses should discharge their passengers on the main road and park in the large lay-by 250m further SW. Once in the quarry, examine the steeply-dipping, planar-banded psammites exposed in the south and west walls. These psammites form part of the Quoich Banded Formation, lie on the eastern limb of the $D_3$Spidean Mialach Antiform ((Figure 4.1): Roberts & Harris, 1983) and are very similar in rock type to the Reidh Psammite seen later at Locality 4.9. The psammites are quite extensively migmatized and the regular, planar banding, largely unaffected by minor folding, is typical of a structural setting on the limb of a major, upright Caledonian fold. Foliation surfaces within the psammites carry a steeply-plunging mineral and intersection lineation, that is related to a cleavage lying in places at a low angle to the main lithological/metamorphic banding. The cleavage strikes clockwise of banding and is related to the north-plunging Spidean Mialach Antiform. Between here and the Quoich dam, $D_3$fold axes

have rotated through the horizontal such that the adjacent Spidean Mialach Antiform and Beinn Beag Synform both open southwards (figure 4.1: Roberts & Harris 1983, figure 2).

Two sets of Caledonian pegmatites cut the psammites in the quarry: an early biotite-bearing, deformed set, typically dipping at 60° towards 270°, and a later, less-deformed, muscovite-rich set, typically dipping very steeply towards 250°, and comparable to those in the spillway.

At the east end of the south face of the quarry, a microdiorite sheet dipping at 45° towards 108° cuts across the psammites. It has a chilled margin and a coarse-grained core, and cuts both sets of pegmatites. It also forms a prominent feature in the north face of the quarry.

If time is pressing, return now to the vehicles. If not, the eastern side of the 'island' lying 200m SE of the quarry can be visited. The level of the loch is commonly low enough for the island to be reached on foot. The island consists of typical Glenfinnan Group migmatitic pelitic gneiss (the Quoich Pelite; Roberts & Harris, 1983), and the eastern side exposes complexly folded pelitic gneiss containing numerous pods and sheets of metabasic garnetiferous amphibolite. Having examined the pelitic gneiss and amphibolites, best exposed at the SE corner of the island, return to the vehicles.

## Locality 4.5 Loch Quoich shore section [NH 042 019] to [NH 046 016]

**Loch Quoich shore section (Figure 4.1), (Figure 4.4). $D_2$ sheath folds, fold interference patterns, boudinage, members of the microdiorite and appinite suites.**

From Locality 4.4, drive west for about 2km and park in the large lay-by at [NH 045 018], below the radio mast. This parking space lies above a remarkable stretch of exposures along the north shore of Loch Quoich between [NH 042 019] and [NH 046 016]. The lower the level of the loch the more rock is exposed, but even if the water level is high there is much of interest to be seen.

The rocks of the shore section lie within the Quoich Banded Formation of the Glenfinnan Group (Roberts & Harris, 1983), but unlike the Quoich Banded Formation at Quoich Quarry (Locality 4.4), these rocks lie not on a major fold limb affected by high $D_3$ strains, but rather within the hinge zone of the $D_3$ Spidean Mialach Antiform (Figure 4.1). The low $D_3$ strain within the hinge zone provides a 'window' back to the pre-$D_3$ history of the area. A similar low-strain hinge zone was examined in Coir' an t-Seasgaich (Locality 4.2).

The structural history of the shore section is extremely complex, and for a full structural analysis accompanied by detailed maps the reader is referred to Holdsworth & Roberts (1984) and Roberts (1984). In this account, only the salient features of the shore section, of interest to the general reader, are described.

Folds produced by all the major deformation events recognized in the area, $D_1$-$D_4$ *sensu* Roberts & Harris (1983) and Holdsworth & Roberts (1984), can be seen in the shore section. $D_1$ folds are generally small-scale (1m) and most easily recognized where they are folded around $D_2$ folds. Quartzofeldspathic migmatitic segregations lying within $S_1$ occur in some pelitic units, but later deformation has resulted in this fabric being almost entirely transposed. Evidence for the early age of this migmatization is clear only in $D_2$ fold hinges, where $S_1$ passes around the fold. $D_2$ structures are ubiquitous in the southern two-thirds of the section. The folds are tight to isoclinal, with an axial planar crenulation fabric that is commonly so strongly developed that it appears penetrative to the naked eye. Open to close $D_3$ folds have nearly upright NE–SW-trending axial surfaces and an axial planar crenulation cleavage (S3). These folds commonly reorientate the earlier, much tighter $D_2$ structures. A solitary, NW–SE-trending $D_4$ antiform, with no related axial planar fabric, occurs at [NH 043 018].

The shore section is best traversed from SE to NW, and in this guide will be discussed in three sections: (1) [NH 046 016] to [NH 044 017]; (2) [NH 044 017] to [NH 043 018] (Figure 4.5); (3) [NH 043 018] to [NH 042 019].

### (1) [NH 046 016] to [NH 044 017]

Begin this traverse at the most southerly set of exposures on the small headland. At this end of the section, tight to isoclinal $D_2$ folds are exposed, unaffected by later refolding. The folds, both here and throughout the section, are best defined by *c.*1m-thick bands of quartzite that occur within a striped unit of pelitic gneiss, semipelite, psammite and quartzite. The competence of the quartzite bands in relation to the surrounding metasediments has commonly resulted in tight $D_2$ fold hinges being cut through by small thrust faults as the folds developed. This phenomenon is well developed in the southeastern part of the section. Examples of $D_1$ folds and an $S_1$ fabric can also be seen folded around the $D_2$ folds in the first 50m of the traverse.

About 60m into the traverse, the first effects of upright, NE–SW-trending $D_3$ folding can be seen, in the form of an antiform-synform pair with an associated axial planar crenulation cleavage. These $D_3$ folds are superimposed on earlier, tight $D_2$ folds. The $D_2$ hinges are in places cut through by small thrusts and spectacular boudinage occurs within quartzite bands on the long limbs of $D_2$ folds.

Continuing northwestwards, the slabs are dominated by interference between reclined $D_2$ folds and upright $D_3$ folds. Where the quartzite bands were boudinaged during $D_2$ the boudins have been refolded during $D_3$, adding to the complexity of the deformation. $D_3$ refolding of $D_2$ folds and boudins continues to the end of exposure within section 1 at [NH 045 017], some 140m NW of the start of the traverse.

Several examples of easterly-inclined felsic porphyrites, cutting across all structures within the host rocks, are exposed in this section, at 80m and 100m into the traverse, and at the last exposures 140m into the traverse. This final example is unusual in that the felsic porphyrite has been intruded into an already-present microdiorite sheet. Both sheets cut across minor $D_3$ folds and fabrics but the microdiorite has been extensively foliated whereas the porphyrite is unfoliated, indicating that the microdiorite is late-tectonic but the porphyrite is probably post-tectonic. Nevertheless, both microdiorites and felsic porphyrites have recrystallized to amphibolite facies mineral assemblages in this area.

From this multiple intrusion walk across *c.*115m of unexposed ground to the start of section 2 at [NH 044 017].

**(2) [NH 044 017] to [NH 043 018]**

A published map (reproduced here, (Figure 4.4)) of this part of the section can be found in Holdsworth & Roberts (1984, figure 4). An unpublished map of the whole shore section can be found in Roberts (1984).

Section 2 is again dominated by $D_3$ refolding of $D_2$ structures, although $D_2$ boudinage and fold hinges cut by thrust faults are less common than in section 1. Occasional examples of $D_1$ folds and fabrics can be seen in $D_2$ fold hinge zones, and a solitary, upright, NW–SE-trending $D_4$ antiform has been recognized.

The distinguishing feature of section 2 is the curved nature of the hinges of the $D_2$ folds. As at Garry Quarry (Locality 4.1), $D_2$ folds are curved about a N-S extension lineation; however, the curvature of individual folds is here much greater. In some cases the hinges of individual folds curve through nearly 180° in about 1m, giving them a conical or sheath-fold geometry. When such folds are viewed along their extension direction, closed outcrop patterns are seen (similar to those produced by dome-and- basin interference) as well as double vergence (S and Z) within a single fold pair (e.g. Holdsworth & Roberts, 1984, figure 6). The best examples of such closed outcrop or 'eye' structures are exposed in quartzite and psammite bands at stop 5A (Figure 4.4), (Figure 4.5). Note the strong extension lineation parallel to the hinges of the folds. Eye structures can also be seen elsewhere in section 2, and less spectacular examples occur in section 1.

Further NW, a number of quartzite bands trace out several upright, NE–SW-trending $D_3$ folds. However, at 5B (Figure 4.4), two quartzite bands trace out a very obvious, reclined $D_2$ pair (openly folded during $D_3$), showing S vergence. The vergence of this fold pair should be compared with that of a train of $D_2$ folds exposed in a quartzite band 40m further northwest, 5C (Figure 4.4), where the $D_2$ folds consistently show Z vergence. Examination of the completely exposed section between the S and Z folds shows no evidence for a major $D_2$ fold core. The absence of a major $D_2$ fold is also indicated by sparsely preserved cross lamination within the quartzites, that shows overall younging to the NE. The change in fold vergence from S to Z is attributed to the curved nature of the $D_2$ folds producing 'double vergence', the

hinges of the $D_2$ folds having swung through *c*.180° between the S and Z folds. This phenomenon represents a larger scale version of the eye structures seen earlier in the traverse.

From 5C to the end of section 2, approximately 70m, the main structural features seen are a number of upright, S-profile $D_3$ fold pairs.

A number of late Caledonian igneous rocks are also exposed in section 2.

At 5D (Figure 4.4), a *c*.5m-wide plug of typical hornblendic appinite is well exposed, cutting across the stratigraphically highest quartzite band. Two easterly-inclined microdiorite sheets are exposed in section 2. At 5C, a *c*.1m-thick microdiorite has been intensely sheared by late, localized movements within the sheet. The margins of the sheet, however, truncate $D_2$, $D_3$ and $D_4$ structures in the surrounding rocks. A larger, non-foliated microdiorite is exposed 60m further NW (Figure 4.4). A single, 3m-wide felsic porphyrite is exposed at stop 5F immediately west of the quartzite band at

5C. The porphyrite sheet is inclined 30° to the east and is foliated internally. It clearly truncates the $D_2$ folds, although its relationship to later structures cannot be demonstrated. At 5G a number of structurally early pegmatites are exposed. These pegmatites are folded by $D_2$ structures and carry the strong north-plunging $D_2$ lineation present throughout section 2. The age of these pegmatites is unknown.

**(3) [NH 043 018] to [NH 042 019]**

There is no exposure gap between section 2 and 3. Section 3 starts at a 20m-wide, south-facing cliff and is approximately 100m long.

Only $D_3$ folds are exposed in section 3, accompanied by an axial planar $S_3$ crenulation fabric. The overall structure of section 3 is that of an open, NNE-plunging $D_3$ antiform, around which several quartzite bands can be traced. Sparse but consistent cross-lamination within the quartzites shows the antiform to be upward facing. There is therefore no major structural inversion between sections 2 and 3.

Three foliated microdiorite sheets, all inclined at *c.*60° to the east, crop out in section 3, at 25m, 30m and 60m into the traverse. These sheets cut across minor $D_3$ structures, and across the major antiform. The largest and most easterly microdiorite contains xenoliths of country rock quartzite, and also interbanded psammite and pelite containing a pre-existing $S_3$ fabric. This sheet shows a classic example of the sigmoidal internal fabric described by Smith (1979). The margins of the sheet are intensely foliated at a low angle to the contact, but as the centre of the sheet is approached the fabric weakens and its angle to the contact increases. The centre of the sheet is non-foliated.

Having completed section 1 to 3 of the shore section, most people will now wish to return to their vehicles. However, if time permits, those with more than a passing interest in the Moine will find the complete shore section between here and Quoich Bridge, *c*.3km west, extremely interesting. It affords a well-exposed traverse across the Loch Eil Group outlier, and its Glenfinnan Group envelope, cropping out in the core of the Gleouraich Synform (Roberts & Harris, 1983), the northward continuation of the Glen Dessarry Synform (Roberts *et al*., 1984).

## Locality 4.6 Quoich Bridge [NH 015 041]

**Quoich Bridge (Figure 4.1). Short stop to examine spectacular $D_2$ eye structures refolded by upright $D_3$folds.**

From Locality 4.5 drive west for *c.*3.5km and park (space available for about five cars) on the west side of the bridge (weight limit 10 tons) over the north arm of Loch Quoich. Look over the SW corner of the bridge, and if the rocks are exposed approximately 6m or more above the level of the loch, descend to them. If not, continue to Locality 4.7 as the level of the loch is too high.

This locality exposes the Garry Banded Formation (Roberts & Harris, 1983) on the west limb of the Gleouraich Synform. Numerous upright, NNE-plunging $D_3$ folds, verging west away from the Gleouraich Synform to the east, can be seen

(Figure 4.6). These tight folds refold earlier, isoclinal $D_2$ folds. The $D_2$ folds have intensely curved hinges, and numerous three dimensional eye structures, with an accompanying axial extension lineation, are exposed. Some of the eye structures are folded by $D_3$folds. When well exposed this locality is extremely photogenic. Return to the vehicles and proceed to Locality 4.7. Coaches, however, should proceed no further than the sheepfolds 1.5km to the SW [NH 004 033], where there is space to turn around.

## Locality 4.7 Coire Shubh road section [NG 9668 0407]

**Coire Shubh road section (Figure 4.1). Short stop to examine the envelope of the Coire Shubh Pegmatite Complex, $D_3$folds in Glenfinnan Group semi-pelites, both cut by late-$D_3$ pegmatites.**

From Locality 4.6, drive on past the western end of Loch Quoich and across the watershed (5.5km). Drive down the first steep hill (with a stone embankment on the left) and park on the firm ground to the right of the road at [NG 9668 0407], 70m past a stone bridge at the foot of the hill. A *roche moutonnée* beside the passing place consists of migmatitic Glenfinnan Group semipelite and contains several upright, NNE–SSW-trending, reclined refolds of $D_3$(steep belt) age. Early leucosomes are folded and/or transposed into the strong axial-planar crenulation cleavage. Several NW–SE-trending white pegmatite veins are ptygmatically folded about $D_3$axial planes. These belong to the suite of late-$D_3$, Caledonian pegmatites that will be visited at the next locality. Several large, white pegmatites are visible in surrounding exposures. The semi-pelites and pelites form the envelope to the Coire Shubh Pegmatite Complex, which is developed in a psammite-cored $D_3$ antiform. Proceed to Locality 4.8.

## Locality 4.8 Coire Shubh Beag [NG 960 045]

**Coire Shubh Beag (Figure 4.1), (Figure 4.7). Late Caledonian Pegmatite Complex in core of $D_3$steep-belt fold.**

From Locality 4.7, drive on *c*.900m until the road crosses a major stream, the Allt Coire Shubh Beag, at [NG 9610 0468], 200 m after cutting through a rocky spur. One car can be parked 100m east of the stream without blocking the passing place, and there are also two large passing places *c.*800m to the west, on either side of the abandoned building at Coire Shubh [NG 958 053]. The pegmatite complex is developed in the core of a major, SW-plunging $D_3$ antiform (Figure 4.7). The psammites and semi-pelites that occupy the core of the fold are probably equivalent to the Reidh Psammite or the Quoich Banded Formation (Tanner, 1971; Roberts *et al*., 1987). They define a major fold interference pattern, occupying the core of a (sheath-like?) $D_2$ recumbent fold that has been refolded by $D_3$. Climb the hillside to the top of the rocky spur, keeping *c*.100m SE of the Allt Coire Shubh Beag, observing the white pegmatite dykes visible in slabs across the stream. About 120m from the road, at 8A [NG 9612 0449], bedding strikes almost east-west on the SE limb of the $D_3$ antiform close to its core. Open to close, Z-profile $D_3$ folds have a weak NNE–SSW-trending axial planar fabric. Compare these with the tight $D_3$ folds at Locality 4.7 on the fold limb. Intrafolial, isoclinal $D_2$ folds of bedding and of early migmatitic leucosomes are locally preserved. These folds are present throughout the centre of the psammite, i.e. in the core of the major $D_3$fold. Move WSW towards the stream and observe late pegmatites of the complex forming ESE–WSW-trending dykes. They define open $D_3$folds and carry a weak axial-planar fabric.

Proceed upstream to the confluence, noting the small dams that divert water via a conduit to Loch Quoich. Between the two streams, 8B, bedding strikes WNW–ESE in the core of the $D_3$ fold and is disrupted by numerous pegmatites carrying a weak, NNE–SSW-trending $D_3$ fabric. At 8C, a number of sloping exposures consist almost entirely of pegmatite. Several generations of pegmatite are present, along with patches and streaks of micaceous restite and some little-modified psammite blocks. Some of the larger psammite rafts in the centre of the exposure contain tight to isoclinal, E–W-trending $D_2$ folds. The core of the $D_3$antiform runs up the Allt Coire Shubh Beag to the ridge, and to the north it runs through the tree-covered crags below the pylon line. Walk downhill on a bearing of 025° to 8D, a large sloping exposure with abundant white pegmatites. Bedding trends NW–SE and the psammites are broken up by concordant, weakly foliated pegmatites to form a migmatite. This is cut by NE–SW-trending, muscovite-rich pegmatite dykes up to 4m thick, that in turn are cut by weakly foliated, muscovite-poor dykes striking at 120°. These dykes belong to two major swarms, one approximately axial planar to the major $D_3$fold of bedding, and one that defines an open fold having the same axial plane as the major fold of bedding but a smaller interlimb angle. Apophyses of the axial planar set define open $D_3$folds.

Sheets, patches and swarms of micaceous restite are common.

Cross the gully and proceed to the large rocky spur at 8E. This locality contains the strongest evidence for the origin of the micaceous restite. The psammites strike at 100° and are cut by 025°-trending pegmatites that have micaceous reaction rims against the host psammite. These zones probably represent restite after extraction of quartzofeldspathic components from the psammite, possibly by partial melting (Barr, 1985). The pegmatites contain streaked-out relics of psammite and restite and, locally, zones of restite are developed with little or no pegmatite. The varying ratios of pegmatite to psammite and restite indicate that quartzofeldspathic material has moved some distance, perhaps as a melt, so that all stages are seen from restite with virtually no pegmatite to pegmatite with virtually no restite.

Walk NNW across the exposure, noting the presence of S-profile $D_3$folds indicating that we are now on the NW limb of the major antiform. The $D_3$fabric also becomes stronger to the NW. Both on the exposure scale and on the scale of the NW–SE dyke swarm (Figure 4.5), the pegmatites show evidence for emplacement after some $D_3$shortening, i.e. they cut tight $D_3$folds but themselves carry a weak $D_3$fabric or have been gently folded. Walk down the hillside to the road and return to the vehicles.

## Locality 4.9 Kinloch Hourn to Skiary [NG 953 064] to [NG 933 072]

**Kinloch Hourn to Skiary (Figure 4.1), (Figure 4.8). Knoydartian pegmatite, steep-belt folds, Sgurr Beag Thrust, Lewisianoid inlier, Caledonian pegmatites, Knoydart Thrust.**

From Coire Shubh, drive NW along the road for *c.*2km to Kinloch Hourn Farm where parking is available for a nominal sum. Overnight parking is also available, as well as a toilet, tea room and accommodation. Details can be obtained by contacting Martin Riley (Tel: 01809 511253). Return on foot to the road cutting 70m east of the junction with the private road to Kinloch Hourn Lodge, 9A, [NG 954 064]. The Kinloch Hourn fault forms a marked topographic feature north of here and is followed closely by the pylon line. A transitional contact is exposed between the Sgurr Beag (= Quoich or Lochailort) pelite to the east and the Reidh Psammite to the west (Tanner, 1971). This locality lies on the eastern limb of the $D_3$ Kinloch Hourn Antiform and so a $D_3$synform is inferred to lie within the Sgurr Beag Pelite, between here and the Coire Shubh Antiform (Figure 4.1). The rocks are steeply ESE-dipping and moderately platy, with early migmatitic leucosomes and garnets that form augen ('eyes') within the dominant fabric. Feldspar porphyroclasts are wrapped by a quartz ribbon fabric that is present in the pegmatites and in the more psammitic metasedimentary rocks. A number of deformed pegmatite and quartz-muscovite veins and pods are also present. If these are interpreted as syn-metamorphic segregations, the Rb-Sr muscovite age of 755 ± 19 Ma obtained from one of these veins by Piasecki & van Breemen (1983) suggests that the early high-grade metamorphism of these rocks occurred during the Neoproterozoic Knoydartian event.

The exposure of Reidh Psammite behind the fence on the south side of the road contains several reclined, tight-to-isoclinal S-profile fold pairs that occupy low strain augen. These have a strong axial planar quartz fabric but fold a fine lamination and, in more micaceous bands, an earlier fabric. Follow the exposure southwards for *c.*50m, to a point on a bearing of 152° (from grid north) from the south end of the bridge. A tight, upright fold pair deforms a planar fabric in which the early leucosomes are streaked out and form augen. The fold pair has an associated axial planar and an open-folded pegmatite, similar to those of the Coire Shubh Complex, supporting assignation of at least some of the upright folds to $D_3$(steep belt), but much of the platiness to an earlier event.

Walk 70m west to the foot of the next spur. This platy semipelite is relatively non-migmatitic and fine-grained. It lies structurally below the Reidh Psammite in the core of the Kinloch Hourn Antiform, and may represent an upfold of the Morar Group lying below the Sgurr Beag Thrust (Barr, 1983, 1985). The semipelite is thoroughly recrystallized, but quartz and feldspar grains define a shape fabric, and quartzofeldspathic segregations, garnets and mica form augen in a manner typical of rocks from the vicinity of the Sgurr Beag Thrust. The platy fabric is crenulated by upright, steeply-plunging folds with variable vergence. Associated quartz rodding plunges at 75° to 148°. The Kinloch Hourn Antiform is inferred to be sheath-like, with variable plunges in an east-west zone near its centre and steep plunges at its northern and southern closures. The northern closure of the semipelite/ psammite contact is not exposed, and is inferred from fold and foliation trends within the semipelite to be a steeply south-plunging *synform*. This is because fold axes have

rotated from north-plunging, through vertical, to south-plunging in approaching the steeply south-plunging extension direction. Return to the parking place and walk along the crags south of the tidal pool towards 9B [NG 9475 0675]. These crags expose the transitional contact between Reidh Psammite (east) and Sgurr Beag Pelite (west). Quartzose psammites and highly migmatitic micaceous psammites and semi-pelites all carry an intense planar fabric whose strike varies from north-south to east-west on open, south-plunging $D_3$fold pairs verging towards the Kinloch Hourn Antiform to the east. Early leucosomes, quartz veins and large pegmatite pods are intensely deformed (Barr, 1985, (Figure 7.4)), feldspar augen being wrapped by quartz ribbons. In non-migmatitic psammites, quartz ribbons parallel this fabric and intrafolial, S-profile isoclines are preserved.

The platy fabric is present throughout the Reidh Psammite, and is probably related to the presence of the Sgurr Beag Thrust at its base.

Pelites exposed by the roadside strike north-south, and swing anticlockwise to east-west in the core of a steeply south-plunging D3 synform. A down-dip mineral lineation is observed in the synform core, but the platy fabric clearly passes around this fold. Immediately before the jetty, at the top of the exposure south of the road, intrafolial $D_2$ folds can be seen in low strain augen within the platy fabric. Descend west of the jetty to the point at 9C [NG 9470 0683], where a series of south-plunging D3 folds carry a north-south trending axial-planar crenulation cleavage. The earlier, $D_2$ platy fabric contains augen of leucosome and garnet, and in thin section it too is observed to be a crenulation cleavage. Walk west to the next bay, where a body of feldspathic augen gneiss occupies the core of a complex south-plunging antiform. It lies close to the boundary between the Reidh Psammite and the Sgurr Beag Pelite and contains isoclinally folded pegmatites to which the platy fabric is axial-planar. Also present are some late, cross-cutting pegmatites, and towards the western end of the exposure, several concordant pods and sheets of somewhat biotitized hornblendite. These hornblendites comprise one of the Lewisianoid basement bodies recognized by Tanner (1965, 1971) and interpreted as a tectonically-emplaced inlier along the course of the Sgurr Beag Thrust. The augen gneiss could also be part of the basement sheet, but it has a metasedimentary bulk chemistry (Barr, 1983) and could represent a basal Moine arkose.

Proceed to the west of the jetties, crossing a synform cored by Sgurr Beag Pelite that contains several tight, north-south trending $D_3$folds. The exposure to the west of the boathouses comprises platy, migmatitic Reidh Psammite, intruded by late Caledonian pegmatites. The final 10m is more quartzitic, and the Sgurr Beag Thrust is inferred to lie in the rubble-choked gully at the end of this exposure (Tanner, 1965, 1971; Barr, 1983). The platy fabric within the Reidh Psammite and the lower part of the Sgurr Beag Pelite is considered to result from intense ductile strain (simple shear) in the hanging-wall of the Sgurr Beag Thrust, and the fact that this fabric is folded by the upright north-south $D_3$structures indicates that thrusting occurred prior to formation of the steep belt.

The sequence of events observed within the Sgurr Beag Nappe at Kinloch Hourn is: $D_1$ – early fabric, high-grade metamorphism, migmatization, garnet growth; $D_2$ – ductile thrusting, development of platy fabrics; $D_3$ – upright refolding on NNE–SSW axial planes with curved hinges, pegmatite emplacement. It is not possible at this low level within the nappe to identify unambiguously the north-south curvilinear folds seen at Localities 4.1 and 4.5.

The Morar Group west of the Sgurr Beag Thrust carries an intense planar fabric with a down-dip mineral lineation, contains ribboned quartz veins and ?syn-thrusting pegmatites, and becomes less micaceous westwards. All planar discordances (e.g. cross-bedding, cross-cutting quartz veins and cleavages) have been eliminated (see also Rathbone & Harris, 1979; Rathbone *et al*., 1983). Towards the end of the road, micaceous psammite bands become common. The concordant quartz veins are joined by long-limbed isoclinal folds of quartz veins, pegmatites and calc-silicate ribs, indicating a westward reduction in ductile strain.

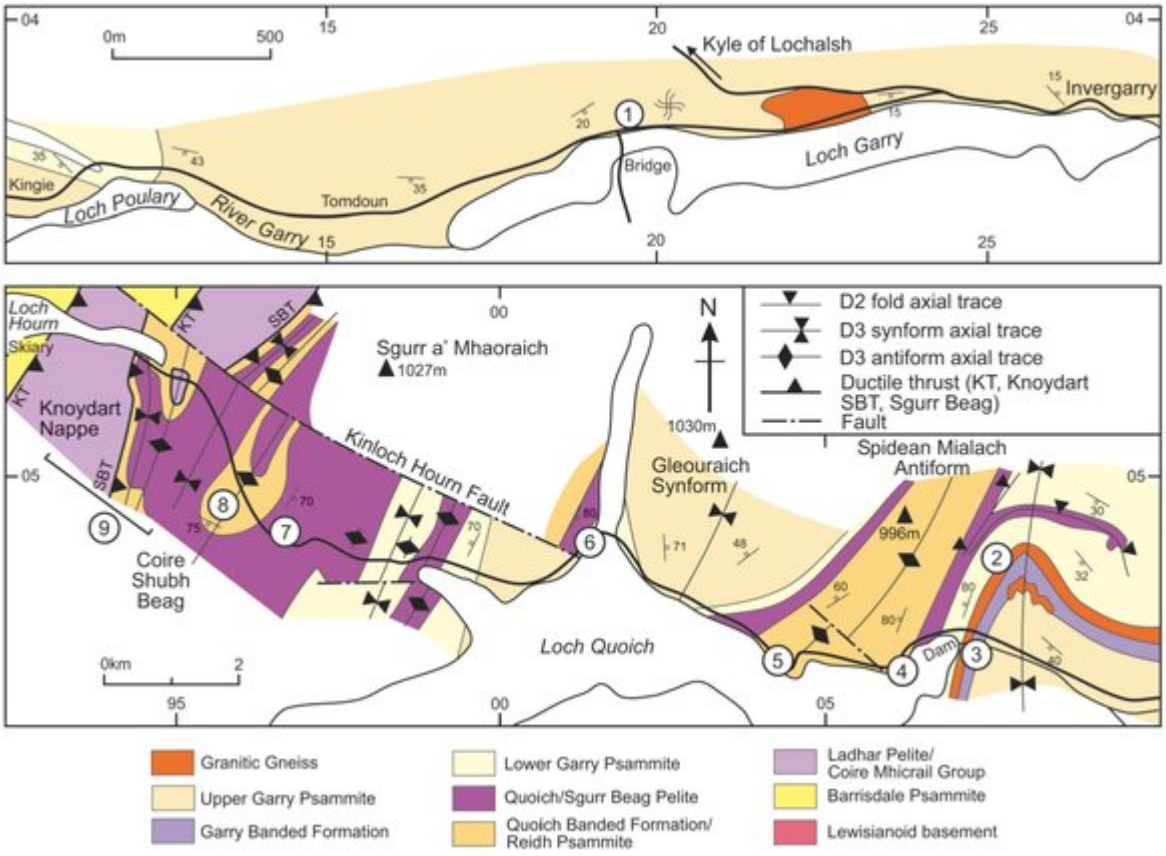
The calc-silicate rocks, seen as pale coloured pods and ribs a few centimetres thick, were described in detail by Tanner (1976). They contain garnet, hornblende, calcic plagioclase and occasional pyroxene, and indicate middle to upper amphibolite facies conditions (Tanner, 1976). The enclosing psammites were assigned to the Coire Mhicrail 'Group' by Tanner (1971), who suggested that they represent a local psammitic variant of the Morar Schist, rather than Lower Morar (= Barrisdale) Psammite.

Beyond the jetty at 9D, semi-pelites carry a semi-penetrative mica fabric with a strong down-dip lineation, presumably related to the Caledonian Sgurr Beag Thrust, and an earlier, slightly oblique schistosity lying anticlockwise of the dominant foliation. Together with garnet augen within the platy fabric, this observation demonstrates that the Morar Group had been deformed and metamorphosed prior to Caledonian ductile thrusting.Continue westwards around the promontory to 9E where the psammites trend east-west and lack a strong fabric but are folded on north-south axial planes. In the next bay, open-folded zones with ESE–WNW-trending bedding and discordant pegmatites and quartz veins alternate with NNE–SSW-trending zones where a strong fabric dips at 70° towards 110° and is axial planar to tight folds of pegmatites. Pegmatites in the east-west domains both cut and are folded by north-south structures or are axial planar with folded east-west apophyses; they are probably syn- to late-tectonic. Also present are earlier, intrafolial folds and somewhat-deformed sedimentary structures. By 9F the east-west domains preserve sedimentary structures, younging southwards. Some cross-beds are oversteepened, either as a result of east-west shortening or as an original sedimentary feature. Round the promontory at the western end of the bay, isoclinal folds are seen in a north-south zone and boudins of Caledonian pegmatites become common. The age of these north-south folds is unclear. They could be related to the $D_2$ Sgurr Beag Thrust, the north-south trending platy zones representing minor ductile shear zones within the Morar Group, or they could be of D3 'steep belt' age. The latter interpretation is favoured by the presence of syn-tectonic pegmatites, but it is also possible that these pink-weathering pegmatites are not the same as the white-weathering ones at Kinloch Hourn and Coire Shubh.

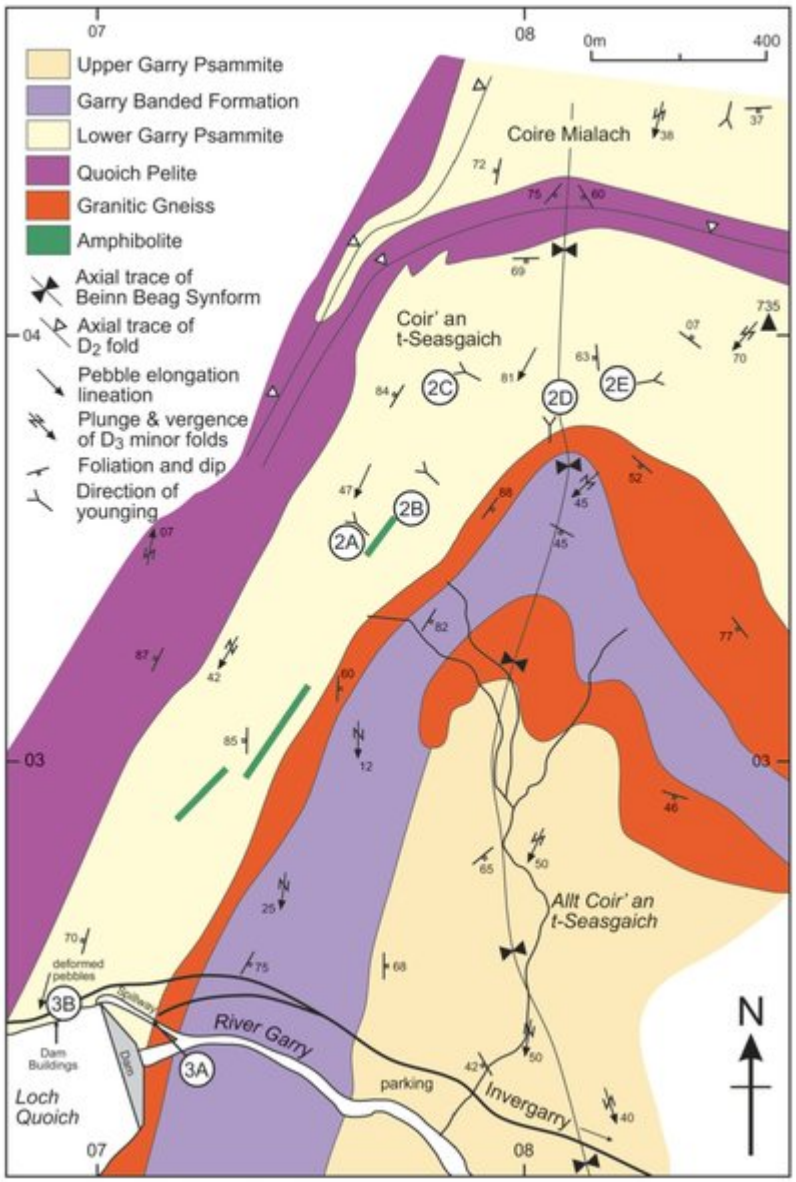
Continue to walk westwards along the straight section of coast. Note the general steep ESE dip of the psammites, that are flaggy but contain discordant quartz veins and occasional steeply-plunging upright folds. At 9G a Z-profile fold pair is succeeded westwards by a 50m-wide platy zone with abundant concordant quartz and pegmatite veins as well as some that are slightly cross-cutting. About 20m east of the small promontory in the centre of the bay, the micaceous and calc-silicate-bearing psammites of the Coire Mhicrail 'Group' give way abruptly to the grey and featureless Barrisdale Psammite. Both units are finely laminated and carry a strong platy fabric.

Walk westwards along the track and descend to the foreshore by the cairn, 9H, observing the variably platy psammites that include a pegmatite-rich zone of late, east-west folding. Towards the western end of this exposure, intrafolial folds and possible deformed cross-beds begin to appear. The next exposure, 50m further along the shore, contains quite large (0.5m wavelength) isoclinal folds. Return along the fence to the track, to a zone of tight to isoclinal folds that deform bedding and ribbon-like quartz veins, 9J. Some of these appear to define sheath folds with steeply-plunging axes. The strain gradient is similar to that observed at the Sgurr Beag Thrust, and, if anything, the high-strain zone in the footwall is wider (200m). As at the Sgurr Beag Thrust (Rathbone *et al*., 1983), the footwall platy zone is much wider than the hanging-wall platy zone. The sharp boundary between the two psammitic units is considered by Barr *et al*. (1986) to represent the Knoydart Thrust, emplacing the Coire Mhicrail 'Group' onto the Barrisdale Psammite. The thrust cuts up-section to the west so that in Glen Barrisdale it lies at the base of the Knoydart Pelite (line 'C' of Tanner, 1971, figure 2) and in western Knoydart it lies at a low level within the Knoydart Pelite. Return along the track to Kinloch Hourn, but if the weather is clear it is worth diverting to the high point on the track, 800 m SW of Skiary, from where excellent views may be had of the surrounding hills. To the WSW lies Meall nan Eun, and in the background, Ladhar Bheinn and Beinn na Caillich. To the north lies Carn nan Caorach, with the Saddle ridge in the background, to the NE lie Sgurr na Sgine and Sgurr a' Bhac Chaolias, and to the ENE, Buidhe Bheinn.

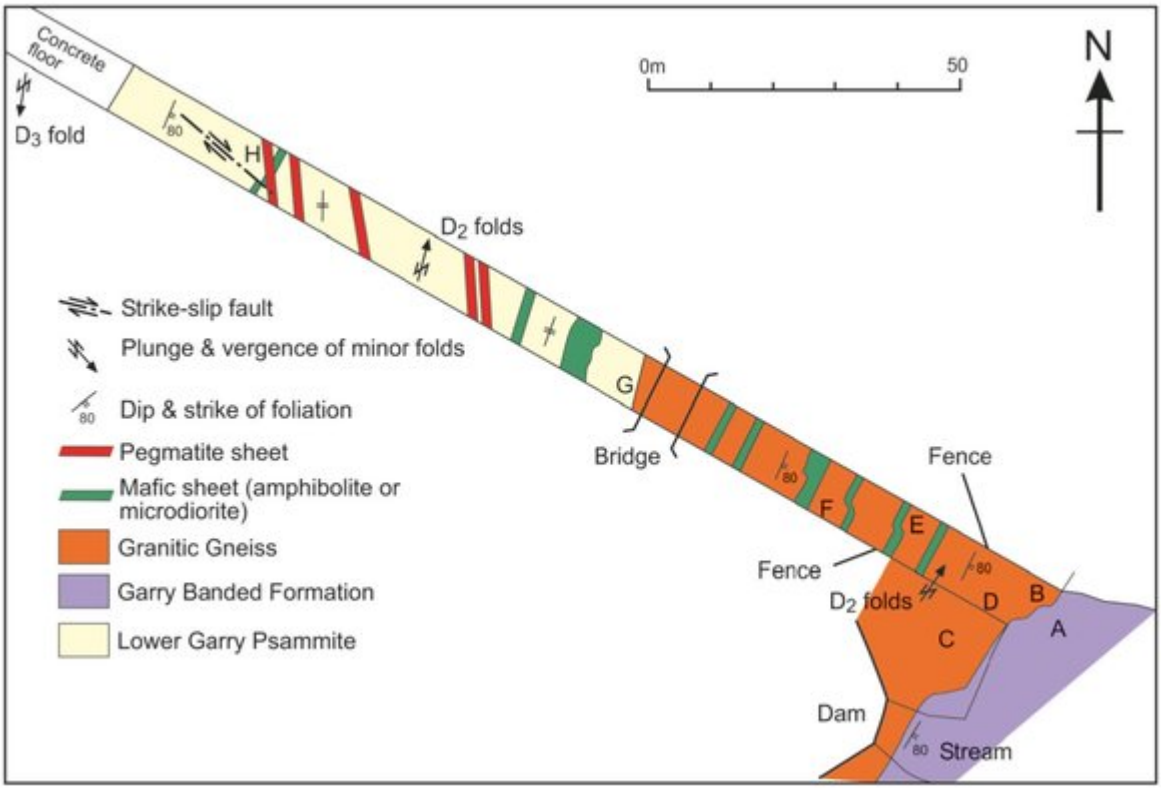
**References**




*Location map and general geology of Excursion 4.*

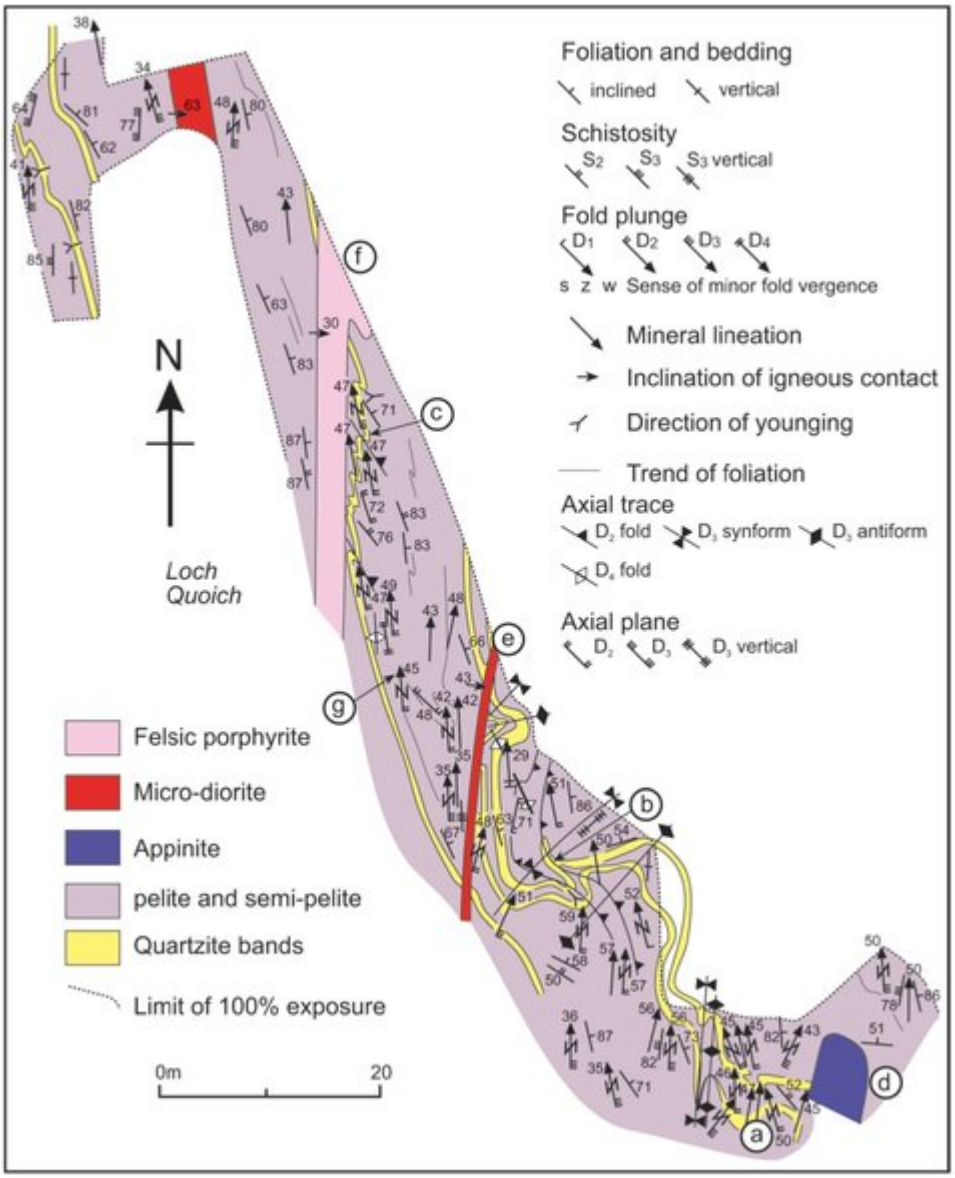



*Geological map of Locality 4.2, also showing location of Locality 4.3.*



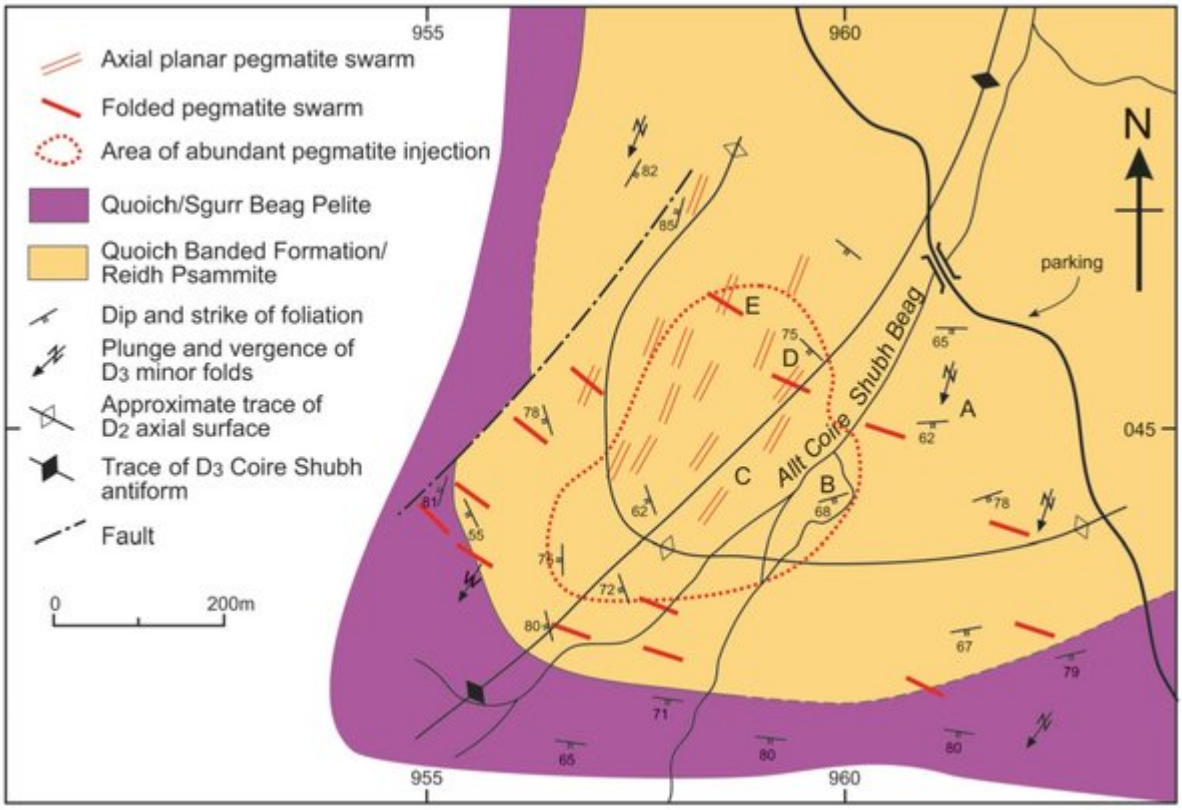

*Geological map of Locality 4.3, the Quoich dam spillway.*

*$D_2$ sheath fold viewed looking NW. Note the intense $L_2$ mineral lineation above coin (15 mm diameter) (Locality 4.5 [NH 0438 0174]).*




*Geological map of the central part of the Loch Quoich shore section (Locality 4.5) (from Holdsworth & Roberts, 1984).*

*West-vergent $D_3$ folds directly below Quoich Bridge (viewed north at Locality 4.6 [NH 0148 0406]).*




*Geological map of Locality 4.8, Allt Coire Shubh Beag.*