Moine geology of the Great Glen - an excursion

From Earthwise

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By Martyn Stewart

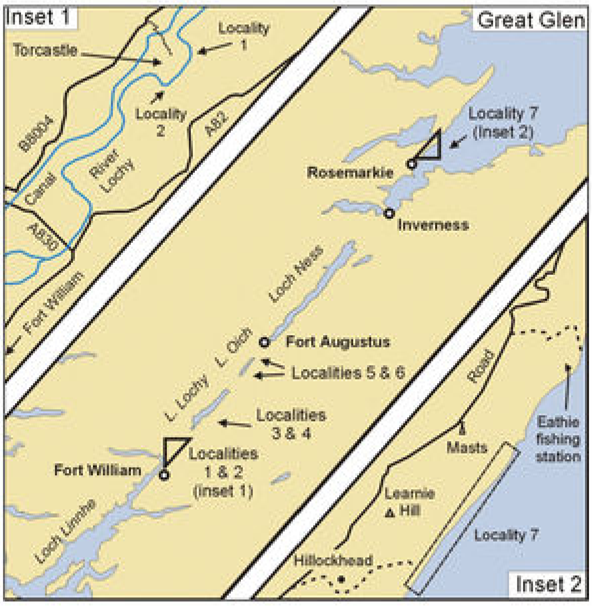

Fig. 14.1 Map of the Great Glen showing localities referred to in the text. The arrows indicate site localities adjacent to the fault.

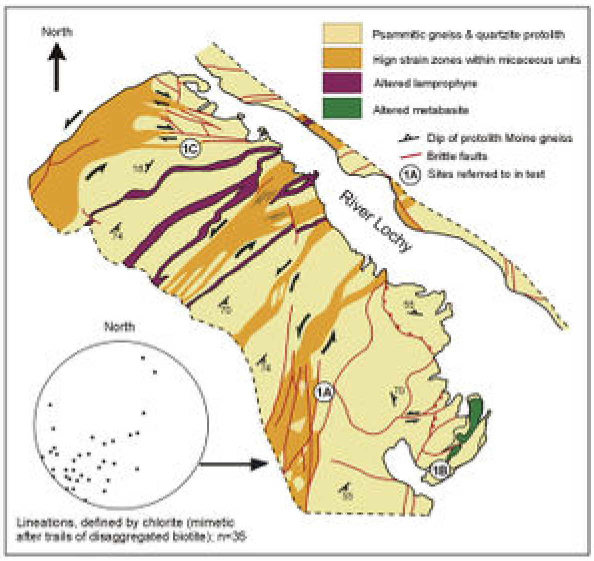

Fig. 14.2 Map of Locality 14.1, on the banks of the River Lochy to the north of Torcastle.

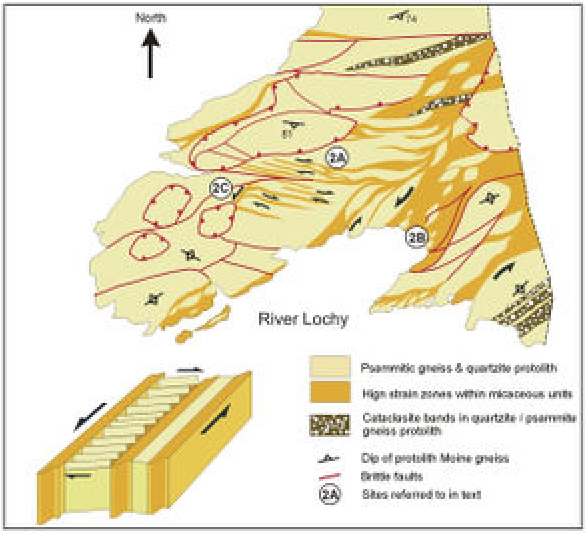

Fig. 14.3 Map of sheared Moine protolith exposed at Locality 14.2, to the south of Torcastle.


Fig. 14.4 View southwest across Loch Lochy to Coire Lochain and the Clunes Tonalite.

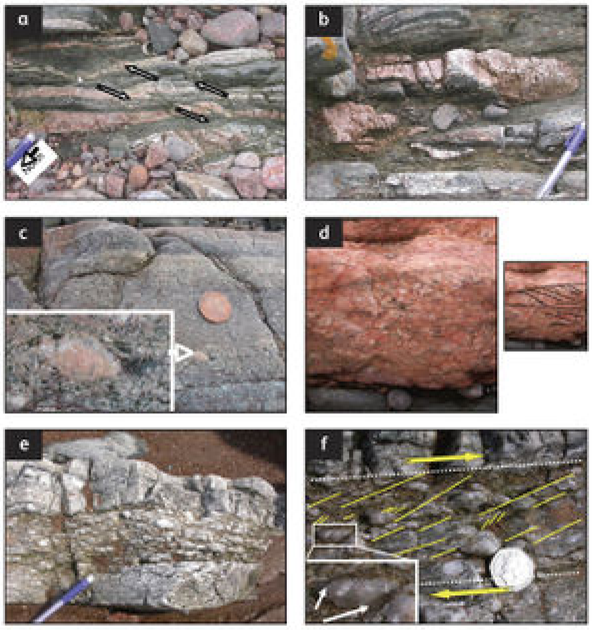

Fig. 14.5 (a) Plan view of shear fabrics within hornblende gneisses at Locality 14.7A [NH 773 627]. (b) Plan view of amphibolite-grade shear fabrics. (c) Foliated microgranite at Locality 14.7B [NH 772 626] . (d) Shear banding within granite sheet at Locality 14.7B.(e) White foliated leucogranite at Locality 14.7C [NH 769 621] (f) Detail of leucogranite vein at Locality 14.7C.

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Contents

Excursion 14 Great Glen

Purpose:	To examine deformation that may be related to displacements along the Great Glen Fault and hence to consider late stage events in the Caledonian orogeny.
Aspects covered:	Fault-bounded blocks of Moine within the centre of the fault zone; strike-slip related shear fabrics from different crustal levels; interleaved Lewisian basement and Moine adjacent to the fault zone.
Maps:	OS: 1:25,000 sheets 399 Loch Arkaig, 400 Loch Lochy & Glen Roy and 432 Black Isle; BGS: 1:50,000 sheets 62E Loch Lochy, 63W Glen Roy, 1:63,360 sheet 94 Cromarty.
Type of terrain:	Localities 14.1-14.6 are each within 20 minutes walk from a vehicle on roadsides or established forest tracks and riverside paths. Locality 14.7 involves a steep walk on established paths and a 3km walk along pebble beaches; it is also tide-dependent.
Distance and time:	A long distance excursion along the length of the Great Glen. Localities 14.1-14.6 can be completed in a single full day. Locality 14.7 will take most of a day.
Short itinerary:	Localities 14.1 and 14.2 can be completed in half a day from Fort William and provide an appreciation of the main aspects of the geology along the Great Glen Fault Zone.

Localities 14.1 and 14.2 are a related pair of exposures that occur in the River Lochy within the valley bottom of the Great Glen north of Fort William. Due to ease of access, it is suggested to visit Locality 14.1 first and then from here proceed to Locality 14.2. Allocate 2-3 hours for these sites.

Locality 14.1 Torcastle, River Lochy: northern outcrop. [NN 135 791]

Torcastle, River Lochy: northern outcrop. ((Fig. 14.1), inset 1). A highly deformed fault-bounded sliver of probable Glenfinnan Group protolith within the core of the Great Glen Fault Zone, with structural evidence for sinistral shear.

From Fort William, drive NE along the A82 and take the A830 Mallaig road. Just past the Caledonian Canal crossing at Neptune’s Staircase, take the B8004 towards Gairlochy. Loch Eil Group psammites are exposed in occasional cuttings. After approximately 4 km, just after the sign for Muirshearlich, turn off to the right at the small restaurant by the side of the road. Continue down this track for 100m, and then take the right-hand fork following the track downslope. At the bottom there is a flat area to park just in front of the tunnel that runs beneath the Caledonian Canal [NN 132 793].

Localities 14.1 and 14.2, referred to here as Torcastle North and South respectively after the nearby ruins, are found at the banks of the River Lochy exposing sheared Moine rocks within the core of the Great Glen fault. These are the closest exposures found to the central axis of the fault anywhere along its length. Examination of exposures at Locality 14.1 provides a good introduction to the macro-scale shear fabrics associated with the fault, whilst meso- to micro- scale textures and shear fabrics can be examined more easily at Locality 14.2.

From the car-parking, bay walk through the tunnel and then turn immediately left up onto a path that leads to the canal towpath. At the towpath turn right to head NE. After a few minutes walking, go through the large metal gate at the side of the path at a junction with a forestry track and walk down the track to the point where it changes from deciduous woodland to coniferous forestry. At this point, head downslope to the River Lochy. At the riverbank is the north end of the large exposure shown in (Fig. 14.2) which is Torcastle North ([NN 135 791], Locality 14.1). Exposures here are estimated to lie less than 200m from the interpreted central axis of the Great Glen Fault (Stewart *et al*., 1999). The rocks are commonly obscured by frequent mud-draping at periods of flooding. The best place to view the detailed lithology and texture is at the SE tip of this outcrop or at Locality 14.2, but a traverse over the outcrop here provides a good impression of the macro-scale distribution of fault-related deformation.

Carefully walking over the rocks towards the SE, it is clear that the outcrop surface comprises high standing areas and flat, low-lying areas. These correspond with, respectively, areas of low and high strain related to fault movements. The high-standing blocky areas comprise psammitic gneiss and quartzite protolith that represent domains of relative low strain during faulting. These rigid areas are typically heavily fractured and dissected by discrete faults. In contrast, the low-lying flat areas, which are often covered by loose boulders or flooded, correspond with mica-rich material that preserves a highly penetrative shear fabric. These high strain belts are between 0.5m to 10m wide.

A good place to view the fabric within the high strain shear zones is to clamber up onto the high-standing ridge (1A on (Fig. 14.2)) and to look down onto the flat low-lying area immediately to the SSW; this is usually flooded by a few inches of water which actually enhances the appearance of the shear fabric. The intensely cleaved, shattered and fragmented nature of this fabric should be evident, as should the more prominent faults that cut through it. Use of a hand-lens reveals sub-horizontal slickenfibre lineations ((Fig. 14.2) inset) on the surfaces of the augen around which the microshears envelop. This fabric comprises an intense and diffuse connected network of mm-wide shear bands that contain both mechanically fragmented and crystal-plastic deformed muscovite and chlorite with subordinate quartz. These shears anastomose around lenses of undeformed feldspar and quartz that have experienced weak to moderate levels of crystal-plastic strain.

Rare shear-sense indicators, such as mm to cm-scale truncated folds, indicate a sinistral sense of displacement (Stewart *et al*., 2000).

A good place to study the original protolith is at 1B (Fig. 14.2). Here, the rocks are polished clean by the river water and reveal bands of quartzite and arkosic psammite along with micaceous partitions. Within the latter, the fine mm-scale through-going shears can be seen. Also note the presence of a retrogressed metabasite. These Moine rocks are lithologically most similar to the Glenfinnan Group (Stewart *et al*., 2000). In the northern third of the exposure, altered lamprophyre dykes are assigned to a regional Permo-Carboniferous swarm (Baxter & Mitchell, 1984). These are locally truncated by minor faults, indicating that at least some of the deformation here relates to later, post-Caledonian movement. In the area by the narrow rapids in the northern corner of the exposure (1C on (Fig. 14.2)), note how the fractures that trend WNW swing round from the main flat low-lying belt that occurs in the shallow stream bed north of this outcrop. These faults are thought to represent antithetic shears to the main NE-trending high strain belts and is a pattern repeated at the next set of exposures.

Locality 14.2 Torcastle, River Lochy: southern outcrop. [NN 132 786]

Torcastle, River Lochy: southern outcrop. ((Fig. 14.1), inset 1, and (Fig. 14.3)). A highly deformed fault-bounded sliver of probable Glenfinnan Group protolith within the core of the Great Glen Fault Zone, with structural evidence for sinistral shear.

Leave the Torcastle North outcrops along the small track along the riverbank and follow this downstream. After a while, the track passes onto the pebbly point-bar and then back onto the riverbank path. Walk upslope above the cliffs to the overgrown ruins marked 'Tor Castle' on the map and then down to the flat-lying exposures ahead which are Locality 14.2, Torcastle South [NN 132 786].

The exposures here are generally cleaner than at the previous locality. Semi-pelitic gneiss, quartzite and feldspathic psammite protoliths are clearly visible, albeit with a strong overprint of fault-related fabrics. A Glenfinnan Group origin is again suggested by the semi-pelitic composition and supported by the presence of garnetiferous amphibolites which are common elsewhere within the group (Johnstone *et al*., 1969; Holdsworth *et al*., 1987). If indeed these correlate with the Glenfinnan Group, it implies that rocks at both exposures are part of a single fault-bound unit that has been either uplifted relative to Loch Eil Group strata to the west (along the road), and/or moved laterally here by strike-slip displacement.

Locate the prominent upstanding blocks and note how at their base they are cut by a low angle fault. Much of the flat surface here is the eroded footwall of this fault. On the surface itself, where it is polished and fabrics are well-exposed (e.g. 2A on (Fig. 14.3)), note cm- to dcm-wide, WNW- trending, steeply-dipping to vertical micaceous shear-bands forming a pervasive and anastomosing network. Detailed examination of shear-sense indicators here and the overall sense of asymmetry suggests formation in response to localised dextral shearing.

In the low-lying area at 2B, which may be partly submerged depending on the height of the river-level, the rocks have a more fractured, slaty appearance and NE trend, comparable to the high-strain belts seen at Torcastle North. Lineations plunge at shallow to moderate angles to both NE and SW. Examination of the fabric here reveals a few truncated folds and anticlockwise-deflected fabrics, indicating a sinistral shear sense. It appears that these sinistral fabrics are contemporaneous with the dextral fabrics seen at site 2A. This interpretation is based largely on the geometric relationship between the two sets of fabrics. The WNW trend of the dextral shears suggests an antithetic relationship to the larger NE-trending sinistral belts, accommodating anticlockwise (sinistral) rotation of low strain material between the high strain belts ((Fig. 14.3), inset). This is supported by observations of WNW-trending dextral shear-bands that curve into NE-trending shears, rather than truncating them (see 2C on (Fig. 14.3)). This relationship is thought to explain similar fault patterns seen at site 2C at Torcastle North ((Fig. 14.2)). Taken together, these macro-scale kinematic indicators, supported by lineation data, meso-scale shear-sense indicators seen in the field and those seen in oriented thin-sections, provide compelling evidence for sinistral strike-slip shearing along the Great Glen Fault (Stewart *et al*., 1999, 2000).

The evidence at these localities indicates that the Great Glen Fault was initiated at a late stage in the Caledonian orogeny. The style of deformation is characteristic of deformation within the brittle-ductile transition zone, broadly equivalent to depths of 10-15km (Snoke *et al*., 1998; Holdsworth *et al*., 2001b). This is consistent with the growth of chlorite and muscovite in shear-zone fabrics, implying shearing at depths equivalent to greenschist facies metamorphic conditions (Stewart *et al*., 2000). In addition, it would appear that most of this shearing was completed within the mid crust, with no evidence for progressive overprinting by brittle deformation during exhumation to the surface. Retrace the route back to vehicles.

Locality 14.3 View over Loch Lochy towards the Clunes Tonalite [NN 235 892]

View over Loch Lochy towards the Clunes Tonalite (Fig. 14.1), (Fig. 14.4).

From Torcastle, continue northeast towards Gairlochy and take the B8004 towards the A82 and Spean Bridge. Turn left at the Commando Memorial along the A82 towards the northeast. After ~9km pull into the lay-by where the overhead power cables cross the road. Look to the opposing side of the valley towards the southern end of Loch Lochy and different bedrock should be identifiable from different colours of the exposure (Fig. 14.4). The bulk of the hillside comprises feldspathic psammites of the Loch Eil Group Moine (pink-orange colouration), but to the southern half of the hill occurs a tonalite pluton, marked by a darker grey-coloured rock.

A study of this Clunes Tonalite pluton has concluded that intrusion occurred synchronous with sinistral displacements along the Great Glen Fault (Stewart *et al.,* 2001). This is based on observations of a sinistral swing of the magmatic fabric at its northeastern margin, together with intrusion into a ductile sinistral shear zone within the marginal Moine host rock. U-Pb zircon dating of the tonalite has yielded an age of 428 ± 2 Ma which is thus interpreted to date early sinistral displacements (Stewart *et al.,* 2001). Near the shoreline of Loch Lochy the northeastern end of the pluton is displaced by a post-Caledonian brittle fault demonstrating dextral offset. As you proceed to drive north, note the deeply incised gorges running down the eastern side of the valley. The streams flowing down-slope here are actually very small, and the deep-cutting incision is an indicator as to how intensely fractured and shattered the bedrock is adjacent to the fault.

Locality 14.4 Loch Lochy shoreline [NN 255 918]

Loch Lochy shoreline (Fig. 14.1). Fault-bounded block of gneiss of probable Moinian affinity on the SE side of the Great Glen Fault.

Continue along the A82 for a few km until the road drops down to run straight alongside the shoreline of Loch Lochy and pull into the parking layby on the left-hand side. Cross the road to exposures of steep-dipping psammitic gneisses by the waterfall; this is best seen by following the track up just above the fall. These rocks are part of a narrow fault-bounded block that makes up most of the lower valley side south of the Great Glen Fault in this area and northwards until pinching out into the centre of the fault zone near Fort Augustus. They are unlike rocks of the Grampian and Dalradian groups seen locally, which are more flaggy, finer grained and less gneissic in appearance. Also in thin-section, metamorphic textures of Dalradian and Grampian rocks are almost always polygonal in appearance, suggesting a single major phase of metamorphic growth. In contrast, thin-sections of the rocks exposed here reveal complex textures with sutured grain boundaries and very coarse crystals enclosing subgrains, indicating a secondary grain growth over an earlier metamorphic texture, typical of microtextures seen throughout the Moine. The status of these rocks is uncertain, but they appear Moine-like and it is possible that they represent a slice of Moinian material derived from the NW side of the fault and transplanted SE of the axis during strike-slip displacements. Alternatively they may correlate with gneissic basement material underlying the Grampian terrane (Badenoch Group) that has been uplifted adjacent to the fault in response to transpressional displacements.

Locality 14.5 Loch Oich shoreline [NN 304 985]

Loch Oich shoreline (Fig. 14.1). Moinian rocks SE of the Great Glen Fault, severely altered by fault-zone fluids.

Continue NE along the A82 towards North Laggan. Just before the road turns sharp left to cross the swing-bridge at the head of Loch Oich, take the road on the right to the Great Glen Water Park. Follow this until the entrance of the park, marked by 'No Entry' signs, and continue down the forestry track on the right. Park where the ground opens out – this is the old Laggan Station from the disused Fort William to Fort Augustus railway line [NN 304 985]. Continue NE along this track by foot for about 10-15 minutes until the path crosses a great scree slope.

The bedrock here is again Moine-like and belongs to the same fault-bound sliver visited at Locality 14.4. However, examination of hand specimens from the scree reveals that even in very fresh samples, the rock itself is extremely difficult to identify, quite grubby in appearance, and often with an original coarse crystalline texture replaced by a very fine grained speckled matrix. It is primarily composed of retrogressive and alteration mineral phases formed during intense fluid-enhanced reaction-softening. The protolith, seen occasionally within the scree, is coarse grained psammitic gneiss. In most cases, however, feldspars are either heavily or completely altered to sericite with fine quartz and chlorite within the matrix. Cataclastic deformation of these highly altered rocks has subsequently produced an extremely fine-grained, fractured rock which varies in colour from black, green, grey or cream, and contains 'clasts' of less altered material, occasionally with relict gneissic textures.

Continue along the disused railway line past the concrete retaining wall. About 50m along from here, look for scree amongst the woodland on the slope to your right and examine the textures. Here are a mixture of rocks which include: (1) pale psammitic gneiss in which feldspars have experienced partial to complete sericitisation; (2) 'hydrated' cataclasite comprising clasts of quartz and feldspar within a black, fine-grained, often laminated matrix of alteration product; and (3) various rocks representing intermediate phases of this alteration and cataclasis process.

These highly retrogressed, altered and cataclastically deformed rocks, perhaps best termed 'hydrated cataclasites', dominate most of the outcrop within this sliver of Moine-like rock and suggest deformation occurred within a seismogenic upper-crustal environment characterised by brittle fragmentation and dilatancy leading to high fluid influx. This deformation is interpreted as pre-Devonian in age on the basis that a fault-bounded sliver of Old Red Sandstone is seen to lie unconformably upon these cataclasites and is comparatively free of fracturing and evidence of fluid flow. Similar highly altered and shattered cataclasites may well underlie the whole core of the fault zone, explaining why the fault zone was so prone to excavation during glaciation. The Moinian protolith seen here (and at the previous locality) is similar to that seen at Torcastle, but the type of fault rock produced is quite different, a product of shearing in the upper crust, in contrast to inferred mid-crustal shearing seen at Torcastle. Such comparisons suggest the present configuration of fault-bound units is a consequence of late-Caledonian or later differential uplift along the length of the structure.

Locality 14.6 Kilfinnan Burn [NN 277 957]

Kilfinnan Burn (Fig. 14.1). Granite veining within Loch Eil Group in the Great Glen Fault Zone.

Drive back onto the A82, cross the Laggan Swing Bridge at the head of Loch Oich, and then after *c.*200 m turn left onto the single track road running SW towards Kilfinnan along the northern side of the valley. By the farm at Kilfinnan, park near the bridge over the stream Kilfinnan Burn. Walk about 40m upstream to exposures in the stream bed of dcm-scale microgranite and microdiorite veins of the Glen Garry Vein Complex (Fettes & McDonald, 1978) intruding Loch Eil Group psammitic gneiss. This vein complex is defined by intense granodiorite veining over an area of over 300km^2. Although typically randomly oriented, a NE trend is more common in the vicinity of the Great Glen Fault. At this locality, the ENE-trending gneissic foliation is rotated towards these veins so that a sinistral sigmoidal fabric results. This relationship is seen elsewhere in the Moine along the fault zone and suggests that vein emplacement was synchronous with sinistral shearing along the fault.

Before leaving, look across Loch Lochy to the huge gulleys incised into the valleysides on the SE of the Great Glen, indicating the weak nature of the highly shattered bedrock. Note also how the gulleys are very wide upslope, but then narrow abruptly. Thus sudden change marks the boundary between, upslope, shattered Moine (e.g. Locality 14.4) and Grampian Group bedrock and, downslope, less fractured Old Red Sandstone which occurs as a local fault-bounded sliver. Such evidence suggests that the majority of fracturing observed along the Great Glen Fault Zone relates to pre-Old Red Sandstone sinistral displacements. From here continue on to Inverness and then to Locality 14.7.

Locality 14.7 Rosemarkie [NH 773 627 to NH 765 615]

Rosemarkie ((Fig. 14.1), inset 2, and (Fig. 14.5)). Interleaved Lewisian and Moine rocks with intrusive granites, showing evidence for ductile deformation that may be related to displacement along the Great Glen Fault.

This locality exposes psammites, semi-pelites and hornblendic gneisses that lie adjacent to the Great Glen Fault and are interpreted as interleaved Moine and Lewisianoid basement (Rathbone & Harris, 1980; Mendum *et al*., 2010). These outcrops represent the most southeastern outcrop of basement north of the Great Glen, implying that Lewisian-like basement underlies the whole of the Moines. Amphibolite facies fabrics contain a strong sub-horizontal lineation that may record ductile, strike-slip movements along the adjacent Great Glen Fault. Microgranites and pegmatites appear to have been injected synchronous with this deformation. These metamorphic rocks occur as two inliers either side of the Cromarty Firth, surrounded by Old Red Sandstone sediments.

The 3km section described here is the best-preserved and most accessible section to have survived later brittle brecciation. Exposures are tide-dependent and occur along a narrow shoreline backed by steep grassy and wooded cliffs. The section described is a circular route that traverses the whole 3km shoreline section and will take most of a day. It requires either two cars, parked at either end, or a 5km walk back along the road to the start point. The route as described below approaches the shore at the NE end of the section, but if a shorter excursion is required, or only one car is available, it is best accessed and returned to from the SW end.

From Inverness take the A9 north and then at Tore take the A832 for Rosemarkie. Drive through Rosemarkie and after approximately 1.5km turn right onto the single-track road to Eathie ((Fig. 14.1), inset 2). Approximately 3km along the Eathie road take the right-hand turn at Hillockhead [NH 742 604]. This is where the excursion ends, so if two vehicles are available, one can be left off here. There is room for parking in the small cutting 50m down the track. To reach the start (4.5km from here), continue along the Eathie road, 1.5km past the prominent TV Mast Station at Eathie Hill, and then pull into the parking area [NH 769 635]. Follow the track here down to the shoreline to an old fishing station. From here walk SW for 1km along the boulder and cobble shoreline.

The first exposures at [NH 773 627] are Locality 14.7A. These are of coarse-grained hornblende gneisses with a foliation trending SW, parallel to the trace of the Great Glen Fault, and dipping 60° to the SE. This is interpreted by Rathbone & Harris (1980) to be composite S_1/S_2. Hornblende and stretched quartz define a prominent lineation that plunges at 0-20° to the NE. This foliation trend and lineation plunge is largely typical of the whole section. It is this fabric that is thought likely to be the result of ductile deformation during displacement along the Great Glen Fault, the trace of which is only 1km offshore. The foliation encloses micro- to meso-scale lenses of quartzo-feldspathic material ((Fig. 14.5)A). Shear-sense indicators include the sense of overturning of ptygmatically folded veins, sigmoidal quartzo-feldspathic lenses ((Fig. 14.5)B), asymmetric pressure shadows accompanying rigid grains, asymmetric micas, and the rotation of foliation from lower- to higher-strained horizons. Both sinistral and dextral shear-sense indicators are commonplace.

To the SW the gneiss is intruded by mm- to dcm-scale veins and sheets of pink microgranite. The microgranites often have transitional boundaries and appear as migmatitic segregations concordant with the gneissic foliation. These usually carry a foliation which is concordant with the composite S_1/S_2 foliation in the gneiss. Many contain feldspar augen that may represent deformed phenocrysts. The thicker veins more typically have sharp boundaries that cross-cut the foliation at shallow angles, suggesting they are post D_1, although they too carry a foliation parallel to the gneiss, suggesting a syn-D_2 age of emplacement.

Locality 14.7B is ~40 m from the first outcrops. Beneath a large Lewisian-like erratic [NH 772 626], a granite vein contains a foliation and an internal shear-band fabric. A sinistral sense of asymmetry is shown by porphyroclasts and synthetic shear bands that cut an earlier foliation (see (Fig. 14.5)C, (Fig. 14.5)D). There is also evidence of cataclasis in the core of the vein, which might be consistent with a continuum of ductile to brittle deformation, presumably late- to post-D_2, as the granite sheet cooled and crystallized. The logic behind this arises from the tendency of cataclasis to nucleate within weak horizons or along boundaries with contrasting rheological properties, rather than within the core of a rigid, crystalline granite. If veins like this were emplaced post-D_2, the internal foliation may be a high strain magmatic fabric rather than the S_1/S_2 foliation present within the host gneisses. The comparable orientation might simply reflect the fact that the vein intruded along the grain of the gneissic fabric.

Various horizons have experienced retrogression, probably as a result of the migration of fault-related fluids. These are finer-grained, schistose and pale green, reflecting the growth of muscovite, biotite and chlorite as reaction products of hornblende and biotite. Microgranite veins occur within some of these horizons, again suggesting that vein intrusion was not a single event but occurred at multiple stages during uplift and cooling. One such example is a leucogranite within a retrogressed band exposed at the headland just north of an upstanding stack which is Locality 14.7C ([NH 769 621], (Fig. 14.5)E, (Fig. 14.5)F. Lineations within such retrogressive horizons are harder to identify due to finer grain sizes and predominance of platy minerals, but slickenfibres and elongate hornblende reveal a sub-horizontal to shallow plunge. Surfaces perpendicular to this lineation contain dextral shear bands (Fig. 14.5)E, (Fig. 14.5)F.

Near the headland and stack, prominent late stage folding is likely related to late movements along the Great Glen Fault. Earlier, small and medium-scale similar folds (i.e. thickened hinges) fold the main gneissic fabric and are accompanied by an axial-planar schistosity which appears retrogressive as it breaks down the earlier coarse fabric. This may be coeval with retrogression described above, as it is associated with new growth of finer biotite and muscovite. Rathbone & Harris (1980) interpret these folds as D_3 structures. Pre-D_3 folds are rare but typically isoclinal and carry the main (S_1/S_2) gneissic foliation within the axial plane. This S_1/S_2 foliation appears to be the result of progressive D_1 and D_2 events as indicated by the complex deformation history of microgranite veins intruded at different stages.

The boundary between the Moine and Lewisian is exposed at Locality 14.7D [NH 765 615], and to the SW of here exposures comprise Moinian psammite and micaceous schist, interleaved with Lewisian acidic and hornblendic gneisses. The Moine-Lewisian boundary is parallel to S_1, and is folded by a small-scale isoclinal D_2 fold which is itself affected by a D_3 fold. The relationship between folding and the numerous granite veins present is complex and intrusion was probably long-lived or multi-phase. Some, if not most, granite veins are strongly deformed and carry the S_1/S_2 high-grade metamorphic foliation and associated low-angle lineation. Monazite and zircon data from one of these deformed veins shows that it was intruded ~399 Ma (Mendum & Noble, 2010). Other veins however, are post-D_2, because they cut these folds (e.g. [NH 766 616]) and many seem either synchronous with or post-D_3 (Rathbone & Harris, 1980), intruding lower-grade retrogressive horizons and experiencing cataclastic deformation at late stages of crystallisation.

In summary, the rocks of the Rosemarkie locality record a protracted history, from the D_1/D_2 development of amphibolite facies tectonites, through subsequent phases of down-temperature refolding with accompanying retrogressive fabrics and semi-brittle shear plane development. Later warping, cataclasis, brecciation and pervasive fracturing reflects upper-crustal deformation. The shallow-plunging lineation within the S_1/S_2 gneissic fabric appears to record ductile displacement along the Great Glen Fault during the Devonian and thus the Rosemarkie section could represent an exhumed portion of the fault zone from the ductile lower crust. The kinematic history of these early ductile movements is, however, difficult to decipher because of the lack of any consistency in the shear-sense indicators.

The path back to the road is signposted [NH 754 604] and steps should be visible up the hillside. Continue uphill along the track to Brown Hill with its radio mast at the summit [NH 747 604]; to the SW are visible the houses and track of Hillockhead that leads back up to the Eathie road.

References

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