Excursion 11 Glencoul

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Purpose: To see the classic exposure of the Glencoul Thrust, and the ductile mylonite zone that forms the Moine Thrust on the Stack of Glencoul.

Aspects covered: Glencoul Thrust exposure, Moine mylonites.

Maps: OS: 1:50,000 Landranger sheet 15 Loch Assynt; 1:25,000 Explorer sheet 442 Assynt and Lochinver. BGS: 1:50,000 special sheet, Assynt district.

Terrain: If done entirely on foot, this excursion represents a serious day out, with around 16 km of walking and 600 m of climbing, through remote and largely pathless country. In particular, around the Glencoul Thrust exposure at Tom na Toine it is necessary to traverse steep grassy slopes above a high cliff. This section of the route can prove treacherous, especially in wet conditions, and serious injuries have occurred here. Only experienced, well-equipped parties should take this route. At the time of writing, the Stack of Glencoul (Localities 11.2 and 11.3) can also be reached during the summer as part of a trip on the MV Statesman, from Kylesku — it should be possible to walk to the Stack from the Glencoul landing between the morning and afternoon sailings (Tel: 01971 502345 for information). It may also be possible to take the boat in and walk out, although this involves arranging for a vehicle pick-up on the A894 or a long, tiring tramp back along the tarmac road to Kylesku.

Time: The entire excursion represents a full day out, and is one of the most strenuous routes in this guide. If the boat trip is available, the walk from the boat landing at Glencoul to the Stack of Glencoul will take around 4–5 hours there and back.

Access: There should be no significant problems with access, although during the stalking season (July to October), phoning Westminster Estates in advance is advised. The excursion is not recommended in poor weather, and after a period of heavy rain the river crossings below the Stack may prove difficult.

For the Stack of Glencoul only, take the MV *Statesman* morning sailing and ask to be landed at the Glencoul jetty. From there, make your way to where the stalkers' path (Figure 75) comes down to the loch side at [NC 271306], using the wooden bridge. Walk up this path for approximately 2 km to where the path begins to climb steeply at [NC 285 295]. Find a convenient place to cross the river and then head SSE up the boulder-strewn and grassy hillside towards the skyline ridge, in order to join the excursion at Locality 11.2.

If instead you wish to complete the entire excursion, park at a lay-by on the A894, at the mouth of a gorge cutting through the escarpment of Cambrian quartzites [NC 240 295]. Walk along the road and follow the foot of the escarpment north, then east to the shores of Loch Glencoul. This route starts on Torridon Group sandstones, but crosses onto Lewisian gneisses beneath the sub-Cambrian unconformity (Figure 76). There are good views back to Quinag and the double unconformity from the ridge just north of the A894 [NC 239 300] and north onto the Glencoul Thrust on the Aird da Loch peninsula from the slopes above the loch, around [NC 249 303]. Once at the shore, walk east, taking in good outcrops of Basal Quartzite Member with 0.5–1.5 m sets of planar cross-bedding, e.g. at [NC 255 304], and then excellent examples of *Skolithos* in the Pipe Rock Member, e.g. at [NC 258 303]. These outcrops are worth examining for they show undeformed pipe geometries, perpendicular to bedding, for comparison with the strained pipes at the Stack of Glencoul.

Follow the loch shore to a point where steeper slopes rise in front of you, with a line of small trees marking the outcrop of imbricated repetitions of Fucoid Beds and Salterella Grit. Ascend via narrow sheep tracks onto a grassy bench, where a series of inclined panels of Salterella Grit can be found, e.g. at [NC 258 301]. These imbricate slices are capped by the Glencoul Thrust. The main cliff line above the shelf is formed by Lewisian gneisses of the Glencoul Thrust Sheet.

Locality 11.1 Glencoul Thrust Plane at Tom na Toine. [NC 2570 3000] to [NC 2600 3010]

The thrust itself is exposed in a few sites along the back of the shelf. If time permits, it is worth visiting the western exposure [NC 257 300]. Here the gneisses are strongly deformed into mylonites within a metre of the thrust plane, resting on a few centimetres of strongly sheared, buff-coloured carbonates of the Durness Group. These lie in turn on Salterella Grit underlain stratigraphically by Fucoid Beds.

Although it is possible to follow the Glencoul Thrust along the shelf towards Loch Glencoul, this ground is steep and the sheep trails particularly tenuous. A better alternative is to return to the gentle slopes at the foot of the escarpment and the shore line of Pipe Rock. The way ahead is now guarded by the Tom na Toine escarpment of imbricated An t-Sròn Formation, but a faint sheep path climbs a steep grassy slope to above the sea cliffs. Great care should be taken, especially in damp weather, as serious accidents have resulted from slips here.

The path leads up to a grassy amphitheatre defined by steep dark cliffs of Lewisian gneisses of the Glencoul Thrust Sheet. The Glencoul Thrust Plane is very well exposed at the base of the overhanging cliffs (Figure 77). Above the thrust lies Lewisian gneiss of the Glencoul Thrust Sheet, and beneath lies buff-coloured Durness Group dolostone, presumably from the Ghrudaidh Formation. The thrust plane itself is very sharp and marked by a discrete gouge zone. The Lewisian gneiss above is strongly deformed into mylonite within a few metres of the thrust plane. Closest to the thrust is a 10 cm. thick zone of very fine chloritic mylonite, followed by 30–50 cm. of chloritic mylonite with small feldspar porphyroclasts. The feldspar porphyroclasts increase in size upwards, and a metre above the thrust plane there are lenses of fractured feldspar in a matrix of chloritic mylonite to protomylonite. The carbonate below is strongly recrystallised and shows fractures at right angles to the thrust plane

From here, a narrow path follows the shelf below the Glencoul Thrust eastwards, with cliffs both above and below; this eventually picks its way between boulders back down to the loch shore, which should then be followed south-eastwards. Much of this ground is rough and progress is commonly rather slow. At the head of Loch Beag, continue up the Abhainn an Loch Bhig, crossing it where possible; fording this river may be very difficult, if not impossible, after heavy rain. At [NC 280 284], leave the valley floor and climb north-east along a stream to a small lochan at [NC 283 288], passing outcrops of Lewisian gneiss.

Locality 11.2 Imbricates below the Stack of Glencoul. [NC 283 288] to [NC 288 289]

The hillside to the east of the lochan is formed of Eriboll Formation quartz arenites, here downthrown by a fault to lie adjacent to the Lewisian gneisses of the Glencoul Thrust Sheet. The geology of this area is best investigated by continuing north a short distance from the lochan onto a ridge, which overlooks the river valley of Glen Coul, and then turning to climb south-east towards the Stack of Glencoul. The ridge, which provides an entertaining scramble with plenty of outcrops to be seen, straddles an oblique fault that juxtaposes Lewisian gneisses on the lower slopes to the north, against the Cambrian quartz arenites on the ridgeline.

On the lower parts of the ridge, the Basal Quartzite Member is imbricated with Lewisian gneisses. Within the quartz arenites are sills of hornblende microdiorite; these are part of a large swarm of intrusions that occur throughout Assynt, and were emplaced into the quartz arenites shortly before the onset of thrusting. Good examples can be seen around [NC 2860 2905].

Continuing up the ridge, careful observation will allow the stratigraphic transition from Basal Quartzite Member up into Pipe Rock Member to be identified and then, near the top of the ridge, the top of the Pipe Rock Member. A grassy terrace obscures Fucoid Beds, Salterella Grit and a few metres of Durness Group carbonates. These units are capped tectonically by Pipe Rock Member quartz arenites that continue on to the east, towards the Stack of Glencoul. A well-exposed portion of the base of the upper Pipe Rock Member, thrust onto Durness Group carbonates, occurs around [NC 288 287] and can be found by tracing a grassy shelf above cliffs to the south, about 80 m from the crest line that overlooks Glen Coul. The thrust contact forms a 2 m wide overhang, a feature that provides the only shelter from bad weather hereabouts. The fault is strongly cataclastic and decorated with cemented gouges derived from Pipe Rock Member. The Durness Group carbonates in the footwall are strongly fractured and veined. Notwithstanding these classic faulting characteristics, it is the base of the carbonates here that is especially interesting. At the overhang outcrop, the carbonates rest directly on Pipe Rock – the expected Fucoid Beds and Salterella Grit members are missing. This

omission implies the local action of extensional tectonics.

After debating the significance of the outcrops at the overhang, walk up onto the plateau above [NC 288 289], overlooked by the Stack of Glencoul. This site provides spectacular views south onto the NE slopes of Beinn Uidhe, dominantly formed of folded Pipe Rock and Basal Quartzite. These quartz arenites overlie Lewisian gneisses of the Glencoul Thrust Sheet, which form the steep cliffs crossed by Eas a' Chual Aluinn, Britain's highest waterfall.

The outcrops on the plateau are of Pipe Rock Member. With care, examples of *Skolithos* can be found, with moderately elliptical sections on bedding planes. In profile the burrows are inclined with respect to bedding, implying shear strains of about one. These values are intermediate between the undeformed examples found below the Glencoul Thrust on the shores of the loch, and the strongly deformed examples that can be found on the slopes of the Stack of Glencoul.

Cross the shelf and ascend the lower slopes of the Stack of Glencoul to Locality 11.3.

Locality 11.3 Stack of Glencoul. [NC 2888 2876]

This classic locality offers opportunities to examine the mylonitic Moine psammites and Cambrian quartz arenites in the hangingwall and footwall to the Moine Thrust at the Stack of Glencoul. These mylonites belong to a belt of high strain plastically deformed Neoproterozoic and Cambrian rocks that are variably preserved along much of the length of the Moine Thrust. Arguably the Stack of Glencoul provides the most spectacular exposures of mylonite anywhere along the length of the Moine Thrust. This is a Site of Special Scientific Interest (SSSI), and is a frequently visited site for undergraduate teaching, so please do not hammer or collect any samples.

The high western cliffs of the Stack of Glencoul itself are largely composed of mylonites derived from Moine metasedimentary rocks. However, in the flatter, peaty ground beneath the cliffs, exposures are of deformed quartz arenites of the Pipe Rock Member with highly sheared pipes. Strain in these quartz arenites increases upwards, so that at the base of the cliffs the mylonites are actually derived from quartz arenite. This has led to significant controversy over the tectonic junction that should be taken to represent the Moine Thrust (*sensu stricto*). The gently ESE dipping, foliation-parallel ductile contact (Figure 78) between the mylonitic Cambrian quartz arenite and similarly deformed overlying Moine metasedimentary rocks (and possible Lewisian gneisses) was regarded by C. T. Clough (in Peach *et al.,*1907) as marking the position of the Moine Thrust. This theory has been supported since by a number of workers, including Christie (1963, 1965), Coward (1983), Law *et al*. (1986), and Law (1987, 1998). However, Johnson (1965) and others, including Elliott and Johnson (1980), considered the Moine Thrust (*sensu stricto*) to be a late brittle feature (as seen at Knockan Crag). In this case, the thrust would be placed at the base of the mylonitic Cambrian quartz arenites (Johnson 1967) in the unexposed ground between these strongly deformed tectonites and the underlying, relatively weakly deformed, Cambrian quartz arenites. Here, we adopt the former (and historically earlier) definition of the Moine Thrust at the Stack of Glencoul.

The macroscopic and microscopic features associated with these intensely deformed rocks were first described and interpreted by Callaway (1884). Of particular importance are: the horizon of intensely deformed Pipe Rock Member at the base of the Stack; metre-scale foreland-dipping extensional faults (or shear bands) and cm-scale back thrusts cutting the mylonitic foliation in the Cambrian quartz arenites; and isoclinally folded quartz veins in the platy pelitic Moine rocks.

The microstructures of these greenschist facies, mylonitic Cambrian quartz arenites and Moine rocks at the Stack of Glencoul were first comprehensively described by Christie (1956, 1963). The mylonites are characterised by a strongly developed foliation, which dips gently to the ESE, and a rather weak grain shape stretching lineation which plunges down the dip of the foliation planes parallel to the transport direction inferred from thrust geometries. At the Stack of Glencoul these mylonites are typically S>L tectonites. Christie recognised that the intense internal straining and ribbon-grain development of quartz grains in these mylonites was due to crystal plastic processes, and he was also amongst the first geologists world-wide to recognise that the small (<10 micron) equant quartz grains in such rocks were due to dynamic recrystallization rather than cataclasis (Christie 1960).

Quartz crystal fabrics are exceptionally well developed at the Stack of Glencoul, particularly in the mylonitic Cambrian quartz arenites. Optically measured c-axis fabrics from the mylonitic quartz arenites were first described by Christie (1956); these fabrics later became internationally renowned following publication of his seminal paper (Christie, 1963). These c-axis fabrics were famous for their high degree of symmetry relative to foliation and lineation, and were regarded by Christie (1963) as indicating a relatively late stage period of vertical coaxial shortening (pure shear) overprinting asymmetric fabrics (simple shear) produced during thrust-related shearing. Unfortunately, no records were kept of the outcrop positions of these Cambrian quartz arenite samples relative to the position of the Moine Thrust at the Stack of Glencoul (J. Christie, pers. comm. to R. D. Law in 1988).

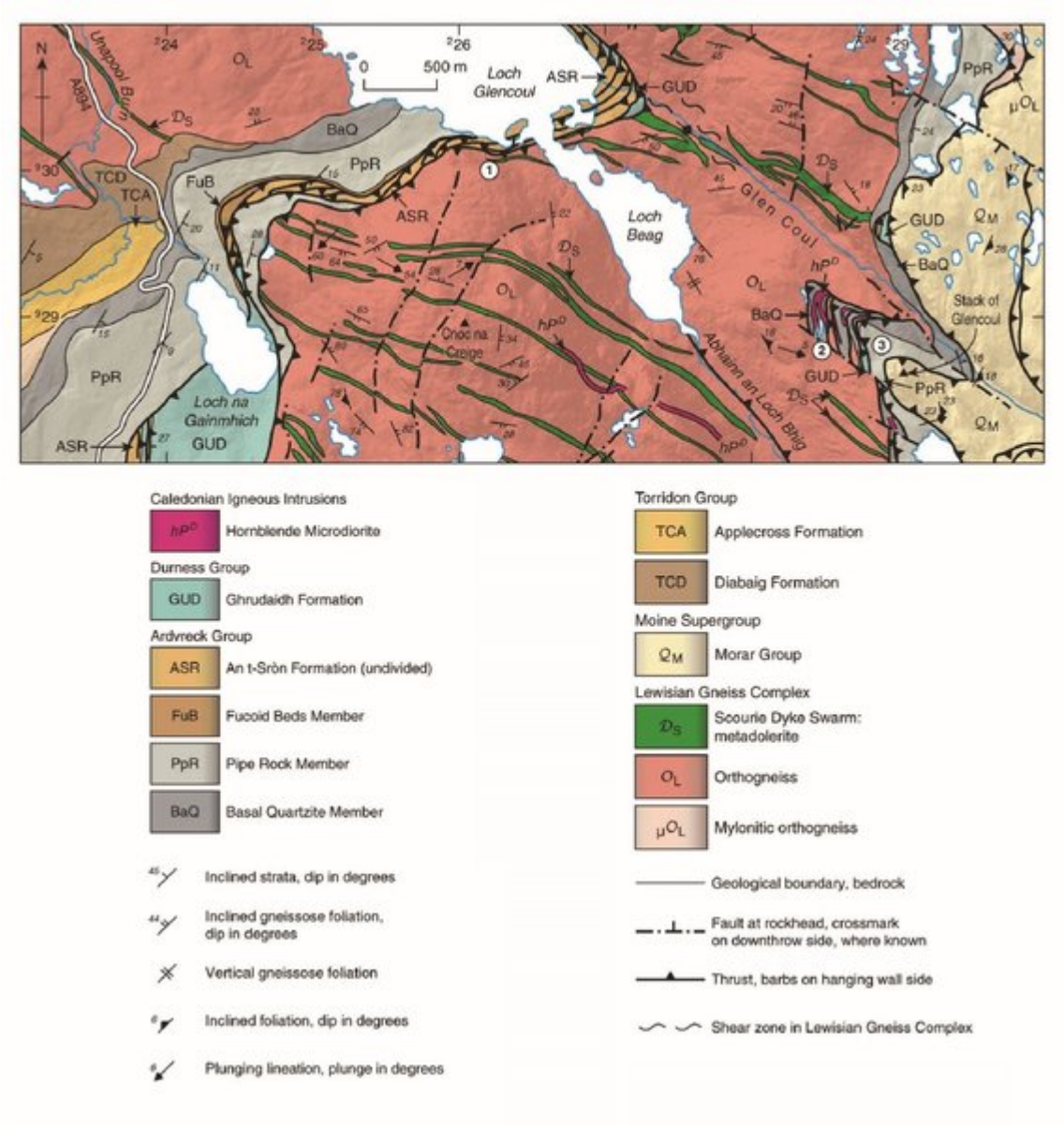
Resampling of the Cambrian quartz arenites at the Stack of Glencoul (Law e*t* al.,1986, 2010b) led to recognition of a major change in quartz fabrics with depth beneath the Moine Thrust, demonstrating that formation of asymmetric fabrics (top to the WNW shear sense) in the hangingwall and immediate footwall to the Moine Thrust must either be contemporaneous with, or later than, formation of the symmetrical fabrics at greater distances beneath the thrust. This interpretation, which is based on spatial variation in fabric symmetry, is in marked contrast to the original interpretation by Christie (1963) that the symmetric fabrics at the Stack of Glencoul indicated a relatively late stage of vertical coaxial shortening over-printing asymmetric fabrics produced during thrust-related shearing. Quantitative vorticity analysis (Law e*t al*., 2010b) indicates that flow in both the Moine and Cambrian mylonites exposed at the Stack involved a significant (45–50%) pure shear component, with only mylonites at less than 15 cm. beneath the thrust being dominated by simple shear deformation (less than 30% pure shear). Integration of vorticity and 3D strain data indicates a vertical shortening of approximately 50–75% (assuming constant volume deformation) perpendicular to thrust plane/foliation in these gently dipping mylonites, with along-strike stretches of 30–50% and stretches of approximately 100–130% parallel to the thrust transport direction. These data indicate that extrusional flow was an important tectonic process during thrusting at the base of the Moine nappe.

From the Stack of Glencoul, the only reasonable return is by retracing one of the routes detailed above.

References

(Figure 75) View of the Stack of Glencoul from the boat up Loch Glencoul, with the stalkers' path visible on the left. The grassy areas on the shore are underlain by imbricates of the An t-Sròn and Ghrudaidh Formations, overlain by craggy Lewisian gneisses in the Glen-coul Thrust Sheet. The cliffs forming the prominent summit of the Stack of Glencoul are

composed of Moine mylonites in the Moine Thrust Sheet. (BGS photograph P531993, © NERC)



(Figure 76) Simplified geological map of the Glencoul area, after British Geological Survey (2007), showing the localities described in Excursion 11.

(Figure 77) The Glencoul Thrust exposure at Tom na Toine (Locality 11.1), with dark grey, mylonitic Lewisian gneisses thrust over buff-coloured Durness Group carbonates. (BGS photograph, © NERC)

(Figure 78) The Moine Thrust at the base of the Stack of Glencoul cliffs (Locality 11.3). The scale marker rests on pale grey mylonitic Cambrian quartz arenite, which is overlain by darker grey Moine mylonites at the top of the photograph. (BGS photograph, © NERC)