
Excursion 1 Loch Assynt and the Achmore Duplex

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Purpose: To examine the stratigraphy and sedimentology of the foreland succession and the lower part of the Achmore Duplex, and to study the structural architecture of the duplex. A good general introduction for any party visiting the North-west Highlands.

Aspects covered: Clastic and carbonate sedimentology, Precambrian–Lower Cambrian stratigraphy, structural geology of duplexes.

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: Roadside outcrops on the first part of the itinerary; rough but low moorland and stream sections for the second half of the excursion. No part of the excursion is more than 500 m from the road. There are a number of lay-bys at which it is possible to park, but the roadside part of the excursion is most easily accomplished by walking along the road, paying due attention to the traffic.

Time: The two halves of the trip divide conveniently into separate half-day excursions or a single full day.

Access: There are no access constraints for this excursion, although care should be taken at roadside stops. Please note that this is a very popular excursion, and that the outcrops should not be hammered.

Excursion 1A: The foreland succession of the Loch Assynt roadside

Locality 1.1 Lewisian outcrops, Loch Assynt. [NC 2125 2507]

Park in the lay-by [NC 212 251] alongside the A837 to Lochinver from Skiag Bridge (second lay-by on the left). From the lay-by, walk down to a small east-facing bay on the shore of Loch Assynt (Figure 11), adjacent to an island with two large Scots Pines and many dead trees. The bay [NC 2125 2507] contains a 9 m wide, ESE-trending ultramafic Scourie Dyke, intruded into Lewisian orthogneisses with a westward dipping foliation (Figure 12). The core of the dyke is a fairly fresh, olivine-rich metaclinopyroxene-norite (Tarney, 1973). The host rocks are chiefly pyroxene-bearing felsic gneisses, consisting of quartz, feldspar and hypersthene, with hornblende and biotite also present. Lenses, pods and bands of both mafic and ultramafic rock are common and are generally unfoliated.

Locality 1.2 Basal unconformity of the Torridon Group. [NC 2134 2516]

Return to the lay-by and examine the roadside cutting opposite the eastern entrance to the lay-by. Conglomerates and pebbly sandstones of the Diabaig Formation (Torridon Group) unconformably overlie highly weathered, pale green to cream Lewisian gneisses with some red staining. Two lithofacies are present in the Diabaig Formation; the first is a poorly lithified and poorly sorted, tabular-bedded, very coarse sandstone with a muddy matrix and matrix-supported pebbles composed principally of gneisses and vein quartz. The pebbles are rounded to sub-rounded and frequently preserve a desert varnish; wind-etched dreikanter pebbles are not uncommon.

The second lithofacies is better sorted and comprises very coarse sand to granule grade sediment with matrix-supported pebbles. Some beds have erosive bases and there is poorly developed inverse grading with concentrations of pebbles at bed tops. Parallel lamination is also evident at the top of some beds.

In both lithofacies the matrix is arkosic. Further evidence of terrestrial erosion comes from the presence of highly rounded, almost millet seed, sand grains within the matrix. Both facies are the product of alluvial fans interacting with

lacustrine environments, and palaeocurrent data suggests that the fans may have been confined within valleys (Stewart, 2002).

The unconformity at this locality represents an enormous amount of 'missing' time. The Lewisian gneisses here have protolith ages of about 3000 Ma (Kinny and Friend, 1997), and the Scourie Dykes were intruded around 2400–2000 Ma (Heaman and Tarney, 1989). In contrast, the sandstones of the Diabaig Formation were deposited at about 1000 Ma (Turnbull *et al.*, 1996). Thus, over 20% of Earth history is missing at the unconformity surface.

Locality 1.3 Relief on the basal Torridon Group unconformity. [NC 2175 2503]

Walk eastwards to the 'falling rocks' road sign. Beds of Diabaig Formation are truncated against a topographic high on the Lewisian gneiss erosion surface. There has been some minor faulting on the flanks of the high during compaction, but the relationship is to a large degree the original stratigraphical one. To the east, the Diabaig Formation is visible in the top of the road cut for around 100 m until it is thrown down on a normal fault [NC 2183 2499]. The Lewisian gneiss is highly weathered to at least 10 m beneath the unconformity. Beyond the small fault, the Diabaig Formation reaches its greatest thickness in this section and is at least 25 m thick – the variable thickness reflects the local derivation of sediment and the infilling of topographic hollows on the unconformity surface. Looking southwards across Loch Assynt, considerable topography can be seen on top of the Lewisian Gneiss Complex. Around Quinag, to the north of Loch Assynt, there is up to 400 m of relief on the unconformity (Stewart, 2002).

Locality 1.4 Base of the Applecross Formation. [NC 2194 2497]

Thirty metres before the end of the roadside safety barrier, the character of the road-cut changes and thick, trough cross-bedded sandstones of the Applecross Formation (Torridon Group) can be seen to conformably overlie the thinly bedded, poorly sorted, laminated granulestones of the Diabaig Formation (Figure 13). The lithology of the Applecross Formation will be examined at Locality

Locality 1.5 Glacial striae. [NC 2225 2489]

A small cutting by the road preserves well-developed glacial striae on the surface of ice-sculpted Applecross Formation sandstone (best seen on the southern side of the east end of the cutting). Striae are rarely seen on Torridon Group sediments, but here they have been protected from erosion by peat cover.

Locality 1.6 Typical outcrops of Applecross Formation. [NC 2248 2479]

Continuing eastwards, just beyond an old road sign and set back 20 m from the road next to a small holly is an easily accessible outcrop of typical Applecross Formation. The grain size varies from very coarse sand to granule and the clasts are angular to sub-angular; there is very little silt or clay, in common with most of the Applecross Formation.

Compositionally, the sediment contains a high proportion of terracotta-coloured feldspar and lithic clasts in addition to vein and polycrystalline quartz. Trough cross-bedding is common throughout, with sets varying from 10–20 cm. (Figure 14). On the upper surface of the outcrop, sets can be seen clearly in 3D with current directions towards 100°. The sediments were deposited by deep, perennial braided rivers that formed a very large-scale braidplain, with a mean current direction of 123° (Stewart, 2002).

Locality 1.7 The basal Cambrian unconformity. [NC 2273 2470]

The last outcrops of Applecross Formation by the road provide a good viewpoint north-westwards towards the summit of Spidean Coinich (764 m), one of the summits of Quinag. White, well-bedded quartz arenites of the Eriboll Formation dip east at 12–15° and overlie the sub-horizontal Applecross Formation with angular unconformity, the boundary descending to the road just beyond a small stream.

The slabs of Applecross Formation by the road again preserve friction cracks and good striae at 113°, indicating westward transport of ice along the valley axis.

Locality 1.8 The base of the Eriboll Formation. [NC 2291 2472]

The Applecross–Eriboll formation boundary is not exposed (though there are excellent exposures of this unconformity about 1.5 km from the road at [NC 220 257]). The first roadside outcrop of the lower member of the Eriboll Formation, the Basal Quartzite Member, is just past the stream culvert. These are very light grey-weathering, very coarse sandstones–granulestones, which have a high content of terracotta-coloured feldspars, enough to be classified as sub-arkoses despite the name of the member. Small-scale cross-bedding is evident.

Locality 1.9 Typical outcrops of the Basal Quartzite Member. [NC 2308 2453]

A large cutting within the Eriboll Formation lies 200 m farther eastwards. Much of the sedimentary detail is obscured by mineral-coated joint faces, including slickensides, but good exposures lie around 20 m before the end of the safety barrier, within the upper part of the Basal Quartzite Member. The sediment is generally finer than at the base, but there is still granule-grade material on the bounding surfaces. The proportion of feldspar has also decreased and the sediments here are true quartz arenites. Well-developed planar tabular cross-bedding forms 5–20 cm. sets. Bipolar current directions are evident (towards 290° and 055–110°) and, in places, well-developed herringbone cross-bedding is present. A small-scale duplex structure that shows floor and roof thrusts and several imbricate slices can also be seen within this outcrop.

The youngest beds in the cutting [NC 2313 2451] contain very faint, but clearly distinguishable, *Skolithos*'pipes', indicating that the Basal Quartzite–Pipe Rock Member boundary lies a few metres from the top of the exposed succession. In beds where *Skolithos* is ambiguously developed in vertical profile, this can often be verified by looking for the tell-tale dimples and corresponding warts on the bedding surfaces where the burrows pass through.

Locality 1.10 Classic outcrops of the Pipe Rock Member. [NC 2349 2440]

Twenty metres up the Kylesku road from Skiag Bridge lie some of the most photographed trace fossils in the United Kingdom. The matrix of the Pipe Rock Member is here stained red by diagenetic iron oxide, but the *Skolithos* burrows remain white as a result of differential early diagenesis (Figure 15). Somewhat masked by the red staining and the abundant *Skolithos* burrows, the Pipe Rock Member contains abundant large-scale planar tabular cross-bedding in sets of 0.5–1.5 m each set is divided by green mudstone seams from which sphaeromorph acritarch floras have been recovered. The *Skolithos* burrows are c.1 cm. wide with lengths of many tens of centimetres: precise maximum lengths are difficult to estimate since outcrop faces are not coincident with the burrow axes.

Locality 1.11 Outcrops of the Furoid Beds Member. [NC 2359 2423]

Return to the junction and continue eastwards along the lochside road towards Inchnadamph. The Pipe Rock Member is conformably overlain by the orange-brown Furoid Beds Member (An t-Sròn Formation) a short distance east along the roadcut, and typical lithofacies are exposed 10 m east of the brown tourist sign (Figure 16). Two lithofacies are present, the dominant one being dolomitic wavy bedded siltstones. *Skolithos* and *Palaeophycus* are common, but a diverse assemblage of other trace fossils is present, including *Planolites*, *Cruziana* and *Rusophycus*. Together these are characteristic of the *Cruziana* ichnofacies, which is indicative of a position above storm wave base but beneath fair weather wave base. It was the occurrence of abundant black burrows on bedding surfaces that early geologists mistook for fossil seaweeds, giving rise to the name of the member. The Furoid Beds Member is the earliest unit in the Cambrian succession to contain abundant body fossils as well as trace fossils, and trilobites that have been found in this member indicate a position within the *Bonnia–Olenellus* Biozone (late Early Cambrian to earliest Middle Cambrian).

The less abundant lithofacies comprises distinctive 10–30 cm. beds of dolomitic grainstones in which the dominant allochems are echinoderm fragments. McKie and Donovan (1992) identified eocrinoid fragments amongst the debris. The

grainstones are cross-bedded with E- to NE-directed palaeocurrents and are interpreted as storm event beds.

Locality 1.12 [NC 2372 2408] Outcrops of the Salterella Grit Member and Ghrudaidh Formation.

The Fucoïd Beds Member is conformably overlain by the Salterella Grit Member, which forms the upper part of the An t-Sròn Formation and marks a return to cross-bedded quartz arenite deposition. The roadside outcrop contains prominent *Skolithos* and less conspicuous examples of the body fossil *Salterella*. The latter is an organism of unknown affinity, but may be a primitive mollusc that produced an agglutinated rather than microcrystalline shell. In hand specimen, it appears as a cone a few millimetres long that produces dark, circular or v-shaped profiles depending on the section; very occasional 3D specimens are white or black, but the shell is frequently dissolved out leaving distinctive mouldic cavities. *Salterella* occurs from the upper part of the Pipe Rock Member through to the base of the Ghrudaidh Formation, but is particularly abundant in the eponymous member. The genus is stratigraphically restricted to the *Bonnia– Olenellus* Biozone. Other shell material is present as small fragments.

The Salterella Grit Member is conformably overlain by lead grey dolostones of the Ghrudaidh Formation (Durness Group), marking a major shift in depositional style on the Laurentian margin from clastic carbonate-dominated (Figure 17). In the roadside section the boundary is gradational over a metre or so, marked by a rubbly sandy dolostone. This is significantly different to the boundary exposed a few hundred metres away in the lowest horses of the Achmore Duplex (see Locality 1.14) where a low energy, dolomitic siltstone marks the boundary. The dolostones in the road cut are faintly mottled as a result of differential dolomitisation in burrow systems, and there are occasional quartz sands with intraclasts. Towards the top of the outcrop, irregular white vugs become common and represent pseudomorphed evaporite nodules, probably of anhydrite.

Locality 1.13 Vogesite sills and Sole Thrust. [NC 2382 2403]

Beyond the end of the lay-by, the top of a vogesite (hornblende lamprophyre) sill that intrudes the Ghrudaidh Formation is seen by a culvert. Ten metres farther east is a 5 m thick vogesite sill with a rubbly base, which has been interpreted as the floor thrust of the Achmore Duplex, and the lowest thrust (Sole Thrust) of the Moine Thrust Zone in this area.

Excursion 1B: The stratigraphy and structure of the Achmore Duplex and adjacent foreland

Park in the first car-park on the left [NC 234 248] on the road to Kylesku and Scourie from Skiag Bridge. From the lay-by, walk up the road to a gate on the right [NC 2349 2514] and then walk eastwards along a grassy track to a ford over a small stream [NC 2366 2509]. Proceed up the stream, which may be a dry bed or (very) wet. CAUTION: please do not hammer at any of the localities, this is a popular excursion and hammer scarring is becoming evident.

The Sole Thrust lies below the ford in the boggy ground, and most of the excursion is within a duplex developed beneath the Glencoul Thrust sheet. The stratigraphy of the horses within the duplex comprises the Fucoïd Beds and Salterella Grit members of the An t-Sròn Formation (Ardvreck Group) and the lower part of the Ghrudaidh Formation (Durness Group). The duplex is of large scale, with a vertical distance of around 150 m from floor thrust to roof thrust, but the local stratigraphy means that each individual horse is very thin, and the bounding thrusts are rarely separated by more than a few tens of metres.

Locality 1.14 Imbricates in the stream section west of Achmore Farm. [NC 2366 2509 to NC 2369 2528]

At the ford, where a grassy track crosses the small stream [NC 2366 2509], the Salterella Grit Member forms the base of a waterfall and is conformably overlain by the Ghrudaidh Formation. In contrast to the foreland section along the

lochside, the base of the Ghrudaidh Formation here comprises 2 m of dark grey dolomitic siltstone that is superficially similar to some parts of the Fucoïd Beds Member. This is overlain by typical buff grey weathering dolostones but, at the top of the second cascade, orange-weathering dolomitic siltstones of the Fucoïd Beds Member are thrust over the Ghrudaidh Formation to the left of the waterfall (all directions given looking upstream). The thrust plane is exposed and dips at 28° towards the north-east.

Continuing up the stream, the Fucoïd Beds – Salterella Grit – Ghrudaidh Formation succession is repeated by a number of small thrusts. Some horses do not contain all three units; for instance, the Fucoïd Beds Member is thrust over the Salterella Grit at [NC 2368 2518]. At a sharp left hand bend where the Salterella Grit Member crosses the stream [NC 2369 2518], the topographic expression of the duplex across the hillside becomes clearly visible. The bedding is steeply dipping, and ridges of Salterella Grit Member trend NW–SE. Behind some of the ridges are trenches that contain the Ghrudaidh Formation, evidenced by the vegetation and the presence of shake holes, together with scattered outcrops of the shaley base of the formation and the more typical overlying dolostones. Within the shaley base at [NC 2367 2520] is the key fossil locality from which Huselbee and Thomas (1998) described *Olenellus lapworthi* and *Salterella maccullochi*, indicating a *Bonnia–Olenellus* biozone (late Early Cambrian to earliest Middle Cambrian) age for the base of the Durness Group. Above each trench, a steep bank of Fucoïd Beds Member leads up to the next ridge of Salterella Grit Member. The stream flows along the trenches on the uphill side of the ridges, before cutting through the Salterella Grit and cascading down the steep banks.

Several more horses are crossed to a fence [NC 2369 2528], from where there is an excellent view across Loch Assynt to the 'double unconformity' (see Excursion 16). Above this point, the exposure becomes more sporadic.

Locality 1.15 [NC 2381 2558]

Follow the stream northwards to where it emerges from a small rising. Above this point the stream bed is dry, with occasional collapses into the underlying karst drainage. This is indicative of a change in the character of the duplex – above this point the horses are entirely composed of carbonates of the Durness Group, without the An t-Sròn Formation units seen at lower structural levels.

Locality 1.16 [NC 2363 2570]

From a short distance downstream of Locality 1.15, follow the last ridge of Salterella Grit Member north-westwards to another stream that offers a further section through the lower part of the duplex. On the way to this stream the highest point of the ridge offers an excellent viewpoint from which to survey the geology of Loch Assynt.

To the north-east, on Glas Bheinn (776 m), the Eriboll Formation sequence is repeated by a number of thrusts. The Glencoul Thrust occurs at the break in slope below the quartzite screes. To the south-west, the famous 'double unconformity' can be seen on the hill of Beinn Gharbh (539 m), with Lewisian gneisses overlain by Torridon Group units that are in turn overlain by quartz arenites of the Ardvreck Group (the latter intruded by sheets of Canisp Porphyry). To the west lies the foreland, with the dipslope of the Eriboll Formation unconformably overlying the arkoses of the Applecross Formation (Torridon Group) on Quinag.

At [NC 2363 2570], the ridge of Salterella Grit Member that has been followed across the moor crosses a second stream. The Fucoïd Beds Member is thrust over this unit and a short distance upstream, the carbonate-dominated duplex begins. Proceed downstream (all directions now refer to looking downstream).

The stream descends back through the imbricated sedimentary sequence, with the same topographic features as at Location 14, but with rather fewer exposures of Ghrudaidh Formation dolostones. Farther downstream, thick units of Fucoïd Beds Member with variable strike values and abrupt discontinuities in dip provide evidence for internal thrusts within this member. The reason for the contrast in stratigraphical composition of the horses in the first stream (Locality 1.14) with that seen here lies in the presence of a low angle lateral ramp, such that the older units are progressively cut out south-eastward between the two streams.

At the foot of a steep descent just above the road is a 5 m waterfall with a birch tree. The dip of the Fucoïd Beds Member in the waterfall is 52°, whereas a few metres lower down the valley, across a bounding thrust, the same unit has the gentle dips of the foreland. The Salterella Grit Member crops out by the culvert under the road, and between this and the last outcrop of Fucoïd Beds Member lies the floor thrust of the Achmore Duplex

– the Sole Thrust. This relationship is also seen slightly farther down the road [NC 2340 2546] and the Sole Thrust then lies a short distance above the road for several hundred metres down the hill. Good sedimentary structures are seen in the Salterella Grit Member in a small roadside quarry [NC 2340 2539]. Metre-scale planar tabular cross-bedding is well-exposed in the 3D outcrop, with laminae sharply defined by heavy minerals, though *Salterella* is scarce. Current directions are mainly directed towards the east and south-east. Topographically below and to the west of the quarry lies the foreland.

From the quarry, cross the road to rejoin the stream and follow it downstream. The same, foreland, Salterella Grit Member is seen across the deeply incised stream valley beneath a rowan tree, and directly below this lies an outcrop of foreland Fucoïd Beds Member. Farther downstream, close to the junction of the stream with Allt Sgiathaig, are outcrops of the Pipe Rock Member.

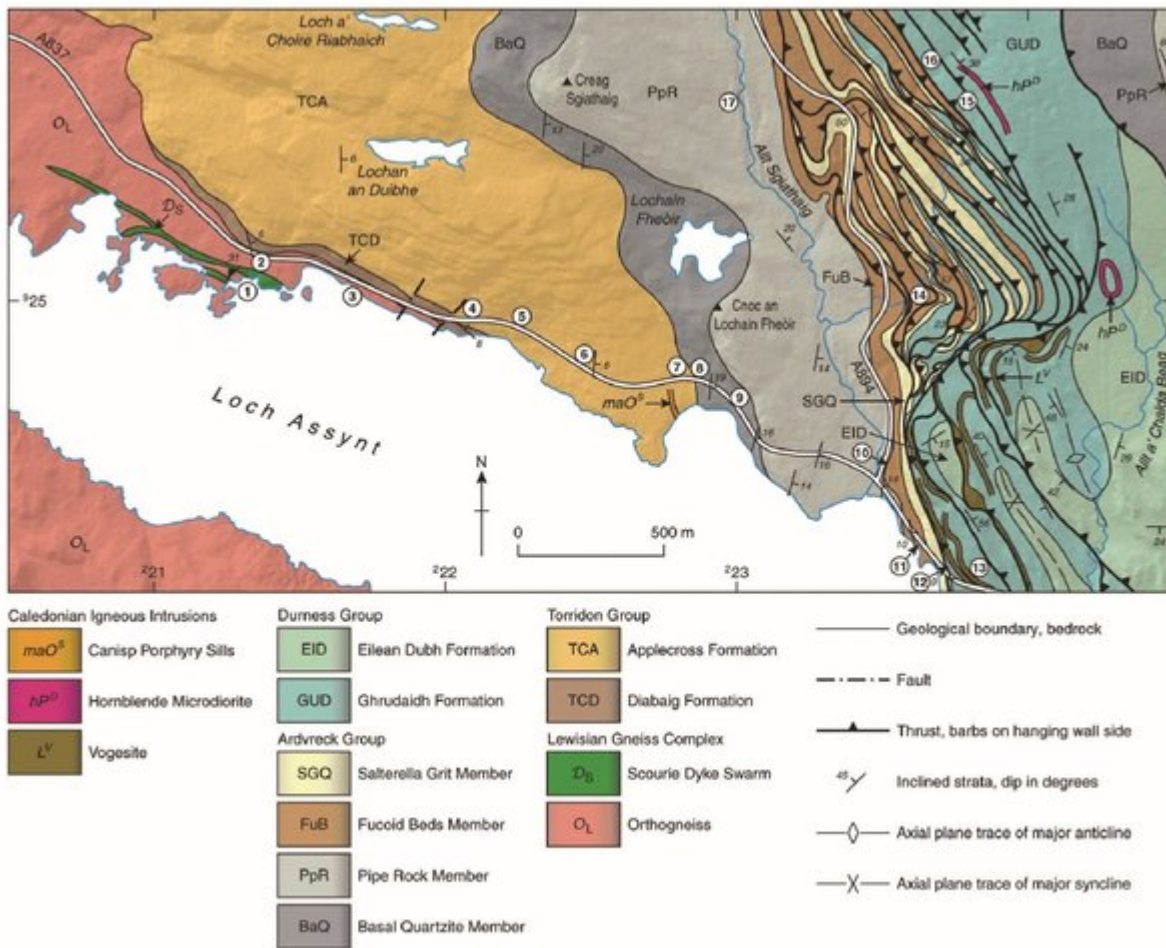
Locality 1.17 [NC 2310 2540]

From the stream junction, walk north-west up the Allt Sgiathaig across more or less continuously exposed Pipe Rock Member, passing one bedding surface [NC 2316 2533] with very well-developed *Monocraterion*—a burrow system similar to *Skolithos* but with a distinctive cone or 'trumpet' at the top of the burrow. Continue past a sharp bend and waterfall to where the stream flows over large bedding surfaces with a two-tiered cliff forming the east bank. On the west bank [NC 2305 2548] are bedding surfaces with fine calibre *Skolithos* and small *Monocraterion* (2–3 cm. tops with 0.5 cm. diameter burrows). The bedding has a maximum thickness of 20–40 cm. and is wedge-shaped at outcrop-scale. Wavy set boundaries indicate the presence of ripples on top of the dunes.

Recross to the east bank and climb to the top of the first tier of outcrop. The bedding surface contains densely packed *Skolithos* and occasional *Monocraterion*. Above this prominent surface are two further beds with *Skolithos*, but these are overlain by a 30 cm. bed and then a 5 m thick massive bed, first recognised by Peach *et al.* (1907), which forms the second tier (Figs 18, 19). This pale-weathering massive bed forms a distinctive marker horizon a short distance below the top of the Eriboll Formation, recognisable along much of the Cambro-Ordovician outcrop belt from Loch Eriboll in the north to the Isle of Skye, and represents a sequence boundary within the formation. Although most of the bed is structureless, the top surface contains planar lamination, ripple lamination and dewatering structures. The massive bed is overlain by a more heterolithic succession of interbedded sandstones and silty mudstones, representing the maximum flooding surface. The sandstones are planar-laminated and cross-bedded and contain red *Skolithos* in a red matrix. Several of the beds exhibit shearing of the *Skolithos* burrows (top to the NW). The 1.5 m heterolithic succession is overlain by typical Pipe Rock Member before outcrop is lost.

Walk down the bedding plane on the top of the massive bed to rejoin the Allt Sgiathiag and return to the lay-by, which is visible ahead. If time permits, it is worth driving northwards over the pass towards Kylesku, where a viewpoint at Newton (Locality 16.10) provides an excellent view down Loch Glencoul and context for the structural position of the Achmore Duplex beneath the Glencoul Thrust.

[References](#)



(Figure 11) Geological map of the Loch Assynt area, after British Geological Survey (2007), showing the localities described in Excursion 1.



(Figure 12) Outcrops of Lewisian gneiss on the shore of Loch Assynt at Locality 1.1. (BGS photograph P531871, © NERC)



(Figure 13) Massive, trough cross-bedded sandstones of the Applecross Formation overlying flaggy Diabaig Formation strata at Locality 1.4. (BGS photograph P506431, © NERC)



(Figure 14) Trough cross-bedded arkosic sandstones and granulestones of the Applecross Formation at [NC 2164 2539]. One metre rule for scale; note the convolute lamination in the lowest bed. (Photograph: © M. P. Smith)



(Figure 15) Distinctive surfaces of Pipe Rock Member at Skiag Bridge, Locality 1.10. (BGS photograph P531881, © NERC).



(Figure 16) Close-up of Furoid Beds Member at Skiag Bridge, Locality 1.11. (BGS photograph P531882, © NERC).



(Figure 17) White quartz arenites of the Salterella Grit Member overlain by grey dolostones of the Ghrudaidh Formation at Locality 1.12. This boundary is also the Ardvreck–Durness group boundary. (Photograph: © M. P. Smith)