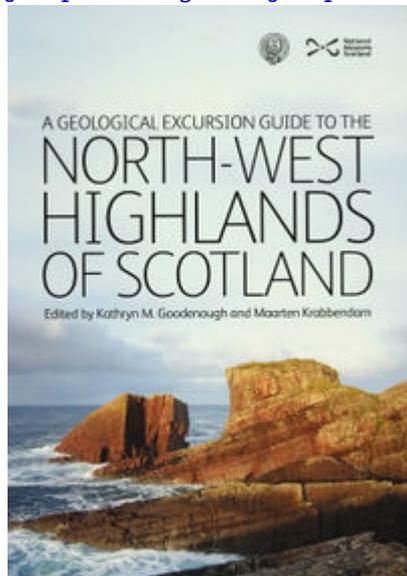


Cam Loch, Ledmore and the Loch Borralan Pluton, North-west Highlands - an excursion

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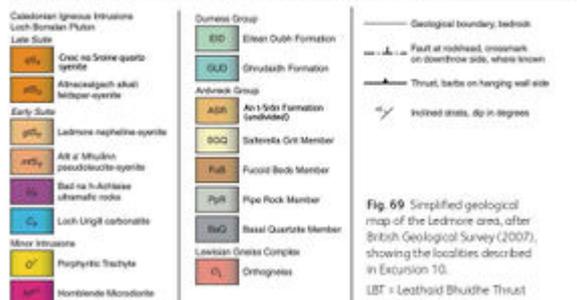
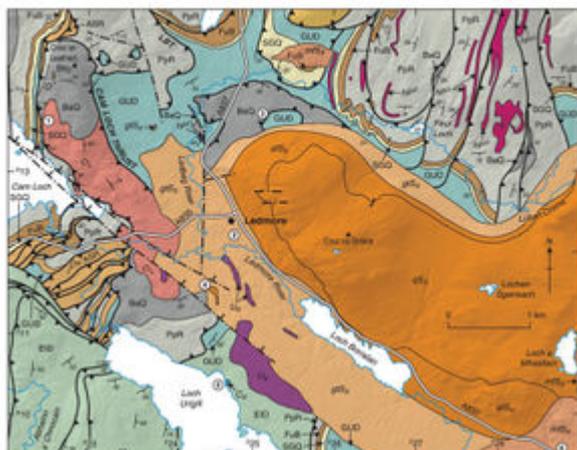


Fig. 69 Simplified geological map of the Ledmore area, after British Geological Survey (2007), showing the localities described in Excursion 10. LBT = Leathaid Bhuidhe Thrust

Simplified geological map of the Ledmore area, after British Geological Survey (2007), showing the localities described in Excursion 10. LBT = Leathaid Bhuidhe Thrust



The overturned, steeply dipping unconformity between Lewisian gneiss and Basal Quartzite Member in the Cam Loch Klippe. The geologist's hand is resting on Lewisian gneisses, but immediately to his left is the weathered-out unconformity, with Basal Quartzite out-crops further left. (BGS photograph P693882, © NERC)



Red Porphyritic Trachyte dyke, cutting Basal Quartzite Member in the Cam Loch Klippe. (BGS photograph P693883, © NERC)



View east from Cnoc an Leathaid Bhig. The low, dark hill slightly right of centre in the image is Cnoc na Stròine, formed of quartz-syenites of the late suite of the Loch Borralan Pluton. The early suite syenites outcrop in the poorly exposed lower ground around Loch Borralan on the right of the photograph. Some of the main thrusts in the area are indicated (BMT= Ben More Thrust). At a large scale these thrusts are

cross-cut by the Loch Borrallan Pluton; poor exposure obscures the detailed relations between the early suite syenites and the thrusts. (BGS photograph P693885-P693889, © NERC)



'Borolanite' in Ledmore Marble Quarry (Locality 10.3), with the characteristic spotted appearance due to the presence of white pseudoleucites. (BGS photograph P531474, © NERC)



Pegmatitic syenite in the Bad na h-Achlaise excavation, Locality 10.4. (BGS photograph P530690, © NERC)

By Kathryn Goodenough and Ian Parsons

Excursion 10 from: Goodenough, Kathryn M. and Krabbendam, Maartin (Editors) [A geological excursion guide to the North-west Highlands of Scotland](#). Edinburgh : Edinburgh Geological Society in association with NMS Enterprises Limited, 2011.

Purpose	To study the Loch Borrallan Pluton and its contact relationships with the structures of the Moine Thrust Zone.
Aspects covered	The Cam Loch Klippe, syenites of the Loch Borrallan Pluton, contact relationships of the pluton, and the Loch Urigill carbonatite.
Maps	OS: 1:50,000 Landranger sheet 15 Loch Assynt; 1:25,000 Explorer sheet 439 Coigach and Summer Isles. BGS: 1:50,000 special sheet, Assynt.
Terrain	The excursion comprises a series of stops linked by short drives. The longest walking distance at any stop is about 5km, mostly on paths and tracks, although some rough and boggy ground is covered, particularly around Cam Loch and Loch Urigill.

- Time** The whole excursion will take a full day, but most of the localities can be visited separately.
- Access** Localities 10.1, 10.2, 10.4, 10.5 and 10.6 should have no problems with access at most times of the year; for Locality 10.3 (Ledmore Marble Quarry) the quarry manager (Tel: 01854 666241) should be contacted before visiting. Hard hats and high visibility jackets will be required, and all instructions from the quarry manager should be followed.
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Introduction

At [NC 324 125] outcrops of coarse-grained syenite are seen in the river and the track. These are typical outcrops of the S3 phase of the Loch Ailsh Pluton. A little distance further up the river, at [NC 326 127], a large area of rock outcrop forms a waterfall, which provides excellent exposures of a variety of different facies of the Loch Ailsh syenites. Here, coarse-grained pyroxene-rich syenites are heavily veined by, and in places enclosed within, grey-pink leucosyenites ([P506429](#)). The pyroxene syenites contain abundant several cm across and have sharply defined margins. There are at least two generations of later leuco-syenite veins or sheets, which have sharp boundaries with the host pyroxene-rich syenites. These later intrusions include red syenite veins and later, grey leucosyenites that are related to the S3 syenites. Late-stage shear zones run through all the rocks, indicating deformation subsequent to the intrusion of the syenites.

Locality 10.1 Cam Loch Klippe. [NC 230 121] to [NC 224 140]

The first stop is a walk over the Cam Loch Klippe, which will take 3-4 hours and involves some steep and rough ground. This klippe comprises two fairly significant thrusts (the Cam Loch and Leathaid Bhuidhe thrusts) that carry Lewisian gneiss and Eriboll Formation over rocks of the Sole Thrust sheet ([See image](#)). It is not certain how these thrusts relate to other thrusts to the east, although it has been suggested in the past that the Cam Loch Thrust can be equated to the Ben More Thrust.

Park on the A835 about 1.5km west of Ledmore Junction, at [NC 234 122], where there is a small car-park with a footpath signpost saying 'Loch-inver 19km. Follow the path round the eastern side of the Cam Loch. At the easternmost tip of the loch [NC 233 126], quartzites of the Pipe Rock Member are exposed near the shore, with Lewisian gneisses slightly higher up the slope to the north. The Cam Loch Thrust lies in the unexposed ground in between these outcrops, and has carried the gneiss over the quartzite. Follow the path along the north-eastern side of the loch for approximately a kilometre. Just after a gate in a deer fence, the path runs over an exposure of Lewisian gneiss; at

this point you are above the Cam Loch Thrust, which here dips eastward fairly steeply.

Follow the path along the loch shore until it ascends a low ridge at [NC 222 135], and then walk up that ridge towards the cliffs that form the eastern side of Cnoc an Leathaid Bhig. The Cam Loch Thrust runs at the base of these cliffs, carrying Lewisian gneisses over Durness Group dolostones in the Sole Thrust Sheet, but the thrust itself is not exposed here. Scramble up steep slopes to a rowan tree growing out of a fallen boulder at [NC 224 137]. Here, the rocks above the thrust belong to the Basal Quartzite Member, and dip beneath the Lewisian gneisses ([P693882](#)); the rocks of the thrust sheet here are inverted by a major anticline. The steeply-dipping unconformity can be seen in the cliffs about 20m south-east of the rowan tree.

Continue northwards along the foot of the cliffs and ascend a broad heathery gully. At the top of this gully [NC 2244 1384], a conspicuous fine-grained red dyke, about 1m thick and striking roughly NNE-SSW, cuts the Basal Quartzite Member ([P693883](#)). This dyke is a member of the Porphyritic Trachyte Swarm, and is among the later intrusions in the area. It has similar mineralogy and chemistry to the syenites of the late suite of the Loch Borralan Pluton. Several smaller dykes of this swarm occur around the Cam Loch Klippe.

Continue upwards to the summit of Cnoc an Leathaid Bhig, which is an excellent viewpoint. To the east, the hill of Cnoc na Stròine is formed of quartz syenites of the late suite of the Loch Borralan Pluton; the topography of the hill reflects the stock-like nature of this late suite intrusion ([See image](#)). To the north-east, darker-coloured Torridon Group rocks form klippen of the Ben More Thrust Sheet on the hills of Beinn an Fhuarain and Beinn nan Cnaimhseag, in front of the quartzites of the Breabag Dome and Conival. Beyond Breabag darker-coloured rocks are seen above the Ben More Thrust on Sgonnan Mòr. To the north-west, the double unconformity is clearly visible on Canisp, with the distinctive profile of Suilven to the west. Directly to the north, the hill of Cnoc an Leathaid Bhuidhe consists of Pipe Rock that has been thrust over Durness Group dolostones. To the south, the green fields around Elphin indicate the presence of dolostone in the Sole Thrust Sheet.

Locality 10.2 Loch Borralan syenites at Ledmore. [NC 247 120]

Drive to the hamlet of Ledmore, turning off on a track on the right (east) just before the road junction, and park near the end of the track at [NC 247 121]. Walk down to the river, where there are scattered outcrops of the Ledmore nepheline-syenites ('ledmorites'). These medium-grained, purple-grey melanite-pyroxene nepheline-syenites make up a major part of the early, undersaturated suite of the Loch Borralan Pluton. In places the syenites are cut by sheets of white aegirine-aplite.

Slightly downriver, at [NC 246 120], there is a rather rotten exposure of pyroxene-rich syenite with many leucocratic veins. Pyroxenites have been recorded at this locality in the past, but are no longer exposed. However, geophysical methods and borehole drilling have indicated that these ultra-mafic rocks extend over a wide area on the south-western side of the intrusion.

Locality 10.3 Ledmore Marble Quarry. [NC 252 137]

From Ledmore, turn left at Ledmore Junction and drive along the road for a little over 1km to the entrance to the Ledmore Marble Quarry. Access per-mission to visit this quarry should be confirmed with the quarry manager (Tel: 01854 666241); hard hats and high-visibility jackets may be required.

This quarry cuts through a thrust that has carried Basal Quartzite Member over dolostones of the Ghrudaidh Formation, and which may be tentatively correlated with the Cam Loch Thrust. The

cross-bedded quartz arenites are exposed in a low cliff just to the left of the quarry entrance. In the main body of the quarry, Ghrudaidh Formation dolostones of the Sole Thrust Sheet have been intruded and metamorphosed by coarse-grained, irregular sheets of melanite-biotite-pseudoleucite nepheline-syenite ('boro-lanite'). The 'borolanites' are recognisable by their distinctive texture, with white pseudoleucite 'spots' in a dark grey matrix ([P531474](#)). The dolo-stones have been melted, metamorphosed and metasomatised by the intrusive sheets, producing a variety of interesting patterns in the rock faces. Of particular interest are cross-cutting carbonate sheets, which have been shown to have formed through melting of the local dolostones, in the presence of high temperatures and a fluid flux. These are the best available exposures of the contacts of the Loch Borrallan Pluton with the country rocks, but unfortunately the quarry exposures at the time of writing do not provide clear evidence of the relationship between the intrusive rocks and the thrust. However, the field relationships of the area in general indicate that the late suite of the Loch Borrallan Pluton does indeed cut, and therefore post-date, thrusts in this area.

Locality 10.4 Bad na h'Achlaise. [NC 245 115]

Return to the vehicles and drive eastwards, carrying straight on at Ledmore Junction, to park at the bridge over the Ledmore River at [NC 254 116]. Walk south over the bridge, go through the gate into the forestry plantation and follow the track uphill for about 800m, until it descends slightly to a stream which passes underneath the track through a conspicuous culvert (large pipe). This area is known as Bad na h'Achlaise, and contains some small but very important outcrops of the Loch Borrallan intrusion.

Just before reaching the stream, on the south side of the track [NC 2462 1139], there is a small quarry, much of it cut in drift. On the left, at the entrance, there is a substantial pile of large, angular fragments of various types of nepheline-syenite. They are not erratic blocks and appear to have been broken from an exposure during road or quarry construction.

Most blocks are grey, medium grained, meso-to leuco-cratic nepheline-syenite (alkali feldspars 1-5mm), but there are also pink variants which locally occur as veins cutting the grey varieties. There are mafic inclusions with sharp margins, some of which are foliated or layered, and locally veined by nepheline-syenite. In addition, there are diffuse, mafic patches in the syenites. Drilling work south and south-east of Bad na h'Achlaise has shown that rocks of these types are abundant under the now forested Mointeach na Totaig, although there are no exposures.

In the back left corner of the quarry there are exposures of jointed, fine-grained more melanocratic syenite similar in appearance to the Ledmore nepheline-syenites. This type is also cut by pink, leucocratic syenite veins.

Leave the forestry track at the culvert [NC 2458 1140] and walk down the right (east) bank of the stream. On a steep grassy bank overlooking the forest, which is about 150m ahead, there is a small exposure of pink nepheline-syenite [NC 2455 1150]. Immediately after the brow in front there is an outcrop of rusty-weathering, carbonated biotite pyroxenite [NC 2455 1152].

During the 1980s, the Nature Conservancy Council opened up a series of excavations running along the top of the slope to the west of the stream, to investigate the relationships between the igneous rocks and the rocks of the Cam Loch Klippe (Parsons and McKirdy, 1983). These exposures are becoming overgrown, but are still worthy of investigation. The smallest of the new exposures, some 12m west of the stream in Bad na h'Achlaise at [NC 2453 1151], consists of pyroxenite cut by an inclined sheet of nepheline-syenite. The pyroxenite is soft and highly weathered, but can be seen to be cut by cm-thick syenite veins.

Some 40m due west at [NC 24485 11506] a larger excavation, with a number of large loose blocks, revealed extremely coarse grained pegmatitic nepheline-syenite and some finer leucocratic variants (Parsons and McKirdy, 1983, loc. 2). At the top of the exposure there is a southward-inclined sheet of zoned pegmatite with striking euhedral, dark grey feldspars up to 20 centimetres in length ([P530690](#)). The host rock is finer-grained, more mafic, pink nepheline-syenite.

Continue west for 60m along a conspicuous excavated terrace to a large (20m long) excavated exposure at [NC 24411 11514 to NC 24432 11513] (Parsons and McKirdy, 1983, loc. 3). This is an important exposure which shows unequivocally that igneous rocks of the Loch Borralan Pluton were intruded into the Basal Quartzite Member, considered to be part of the Cam Loch Klippe. Since intrusions belonging to this pluton also cut rocks of the Sole Thrust sheet in Ledmore Marble Quarry, it is clear that the pluton cuts across the Cam Loch Thrust. It also shows that the pyroxenites are intrusive rocks, not metasomatic skarn rocks at the contact of intrusion with dolomite.

The pyroxenite occurs at the extreme west of the exposure, near the base. It is now more restricted in exposure than shown by Parsons and McKirdy (1983), and is very soft, but has clearly been injected into quartzite. The quartzite is fenitised, with rosettes of pale blue amphibole. The main face of the exposure is now cleaner than in 1983, and a number of pink syenite veins, typically around 30cm wide, are visible, forming a network in quartzite. There is a 10cm vug in the quartzite close to one of these veins, lined by euhedral quartz. The eastern end of the exposure is entirely pink, fine to coarse grained nepheline-syenite, with tight angular jointing.

Locality 10.5 The Loch Urigill carbonatite. [NC 247 104]

Return to the forest road above Bad na h'Achlaise and follow it westwards until a Y-junction; take the left-hand (uphill) fork and continue to the end of the track. From here a path continues downhill to the shores of Loch Urigill. Do not cross the deer fence, but follow it round the east side of the small bay to [NC 247 104]. The carbonatite exposure, the only known example of this rock-type in the British Isles, lies in an excavated hollow (Young *et al.*, 1994). The carbonatite outcrops are dark grey on weathered surfaces, but fresh surfaces are white, crystalline and coarse-grained. These are sövites (calcite-carbonatites), with xenoliths of nepheline-syenite and pyroxenite from the Loch Borralan intrusion. Also found in the area, chiefly as blocks, are phlogopite sövites, which have an orange weathered colour due to the presence of plates of phlogopite within the calcite matrix of the rock. One of the sövite outcrops shows layering, brought out by the mineral chondrodite, and brecciated carbonatites are also present. The carbonatite was actually intruded into dolostones of the Durness Group, and is not an integral part of the Loch Borralan Pluton, but it is considered to be associated with it.

Locality 10.6 Allt a'Mhuillin Quarry. [NC 287 096]

Return to the cars; drive south-east along the A837, past the Altnacealgach Motel, to where the road crosses the Allt a'Mhuillin stream at [NC 287 096]. Park at the roadside, and walk through tussocky grass just to the west of the forest, to reach the prominent quarry at [NC 287 097].

This quarry is the type locality for the Allt a'Mhuillin pseudoleucite-syenite ('borolanite'), part of the early suite of the Loch Borralan Pluton. These rocks are melanite-biotite-pyroxene nepheline-syenites which contain white spots that are pseudomorphs after leucite, now made up of an aggregate of K-feldspar, white mica and nepheline. These pseudoleucites show varying degrees of flattening, from near-spherical to highly flattened white streaks, but other minerals in the rock appear euhedral. The pseudo-leucite-syenites contain numerous xenoliths of darker-coloured rock

types, including a more mafic melanite-pyroxene-biotite syenite. Many fresh samples can be found among the fallen blocks that litter the quarry floor.

The pseudoleucite-syenites in the quarry are cut by a set of undeformed pegmatite veins that contain an unusual mineral assemblage: feldspar, nepheline, biotite, melanite, magnetite, titanite, allanite, zeolite and blue cancrinite. Later shear zones cut all the rock-types.

The earliest workers interpreted the relationships in this quarry as proof that the intrusion of the Loch Borralan Pluton must have overlapped movements on the Ben More Thrust, with the 'borolanites' being deformed by thrusting prior to the intrusion of the pegmatites. The flattening of the pseudoleucites has been interpreted as of igneous origin (Elliott and Johnson, 1980) or as a tectonic fabric (Searle, *et al.*, 2010), with different implications for the relative timing of intrusion and thrusting. This contro-versy has not yet been fully resolved; it is most likely that intrusion of the rocks of the early suite was broadly contemporaneous with thrusting, and that the late suite syenites were intruded after thrust movement had ceased (Woolley, 1970; Goodenough *et al.*, 2011).

References

At all times follow: [The Scottish Access Code](#) and [Code of conduct for geological field work](#)

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