Excursion 4 The Central Intrusion

Highlights

(Excursion 4A) Exposures in the Central Intrusion close to the road to Harris and to the west and south of the Long Loch include excellent examples of layered troctolite, apparent erosion of troctolite by 'debris flows' crowded with peridotite 'cobbles' and 'pebbles', and blocks of layered troctolite and feldspathic peridotite ranging in size from a metre to many tens of metres in breccias with highly disturbed feldspathic peridotite matrices. Further south, unusual feldspar and olivine growth structures occur in the Central Intrusion and also in the Western Layered Intrusion, which may be visited in the latter part of the day. The excursion may be extended (Excursion 4B) by continuing to Harris Bay (a long walk), where layering in gabbros extends to within a few metres of the contact with microgranite and where the complicated contact between the Western Layered Intrusion and the Western Granite is excellently exposed in sea cliffs.

Follow the Kilmory road from Kinloch for 3 km then take the south fork towards Harris (Figure 33).

Excursion 4A

Locality 4.1 Harris road near Kilmory fork – quarry shows sandstone baked by dolerite plug [NG 3696 0016]

A small roadstone quarry on the south side of the road exposes a dolerite plug with adjoining bleached, fractured and baked sandstone. The alteration is typical of that encountered next to the dolerite and gabbro plugs found throughout northern Rum. From this locality the distinctive, localised grey scree derived from fragmented sandstone next to a substantial gabbro plug may be seen on the western slopes of Mullach Mòr, about 2 km to the north-north-east (at [NG 376 012]). Another 400 m along the road a contact between peridotite and baked sandstone is exposed in a stream bed above a bridge [NG 3672 0000], but the degree of alteration appears much less than that found adjacent to gabbro or dolerite plugs.

Locality 4.2 Bridge south of Long Loch – evidence for Long Loch Fault in riverside exposures [NM 3639 9944]

The Long Loch Fault follows the course of the Kilmory River at the bridge, and fractured, sheared and crushed peridotite, microgranite, sandstone and gneiss are exposed in the river bed hereabouts. The latest movement on the fault post-dates the central complex, but the fault is thought to have had significant pre-central complex movement. Thermally altered gneiss (pyroxene hornfels) crops out in sparse exposures in a low, east-facing scarp about 100 m west of the bridge. Continue along the road to a shallow east–west valley through peridotite [NM 3617 9919].

Locality 4.3 North of Harris road – layering in troctolite deformed by 'dropstones' [NM 3615 9929]

Blocks of troctolite are enclosed in feldspathic peridotite about 150 m to the north of the road. Distortion of the layering around the blocks resembles that seen where dropstones have impacted into bedded sedimentary rocks (Figure 34).

South of the road a low, 'whaleback' ridge extends north–south for about 500 m on the west side of the Long Loch. Westward-dipping (30–40º) layered troctolites are magnificently exposed on flat, glaciated surfaces along much of the length of the ridge. They are interpreted to be within a 'megablock' that spalled off the adjoining Eastern Layered Intrusion, subsiding into magma rising along feeders located on the early Long Loch Fault.

Locality 4.4 'Whaleback' west of Long Loch – depositional and erosional sedimentary structures in troctolite [NM 3620 9908]

Troctolite seen on the glaciated slabs contain slump, scour, 'flame', and graded-bedding structures resembling those found in clastic sedimentary rocks (Figure 35). The upper surface of the layered structures appears to have been eroded by a 'debris avalanche' of peridotite laden with rounded pebble- and cobble-sized peridotite fragments which also show some size-grading (Figure 36).

Locality 4.5 'Whaleback' – layering in troctolite, transgressed by underlying peridotite [NM 3623 9893]

Particularly good three-dimensional examples of the layering occur in a low cliff on the east side of the ridge (Figure 37). At this locality, the troctolite is underlain by brown peridotite which has finger-like protrusions extending upwards into the layered rocks (cf. Locality 6.2). Towards the south end of the ridge, the peridotite that underlies layered troctolite at Locality 4.5 cross-cuts and locally replaces troctolite.

Continue to the south end of the Long Loch [NM 3627 9810] (but note that the stream at [NM 3628 9853] may be difficult to cross after heavy rain), cross the dam and continue a further 200 m to the south-south-east.

Locality 4.6 South of Long Loch – layered troctolite/peridotite blocks in deformed layered peridotite [NM 3635 9792]

The layered peridotites exposed in small cliffs and scarps are extremely deformed around large blocks of troctolite and layered peridotite that have collapsed into them. In some instances the blocks, which range from metres to tens of metres in size, are themselves layered, and individual blocks may preserve a record of magmatic sedimentation, slumping, corrosion and replacement (Figure 38). The blocks are thought to have avalanched off the edge of the Eastern Layered Intrusion during emplacement of the Central Intrusion, deforming the poorly consolidated feldspathic peridotite cumulates. About 150 m to the south, across a small stream, steeply dipping layered troctolite exposed in an elongate (north–south) knoll is another example of one of these megablocks.

Cross the 50 m-wide, steep-sided valley marking the course of the Long Loch Fault (Figure 39) and walk uphill for 300 m in a westerly direction, until the outlet of a lochan is reached at [NM 3588 9782]. This traverse crosses part of the Central Intrusion characterised by approximately north–south zones of peridotite breccias (Donaldson, 1975), commonly crowded with blocks of peridotite and troctolite, some of which are layered (Figure 40). This traverse crosses part of the complex feeder zone to the Layered Centre of the Rum Central Complex (Figure 43).

Locality 4.7 Loch an Dornabac – poikilo-macro-spherulitic structures in peridotite of Central Intrusion [NM 3569 9769]

These structures are on a shelf about 200 m to the south-west of the lochan. Here, spectacular bunches of radiating, bifurcating rays of plagioclase crystals occur in feldspathic peridotite (Figure 41). The feldspars are up to 40 cm in length and enclose innumerable small olivine crystals. These are the type examples of *poikilo-macro-spherulitic* structures (Donaldson *et al.*, 1973) and have grown *in situ*, possibly from a hydrous feldspathic peridotite magma. About 50 m to the east-north-east, olivine lamination in peridotite is deformed around peridotite inclusions.

Locality 4.8 North of Loch an Dornabac – small-scale layering in peridotite of Western Layered Intrusion [NM 3576 9800]

South-east-dipping, finely layered peridotite belonging to the Ard Mheall member (Figure 33) at the top of the Western Layered Intrusion forms the cliffs 300 m north-north-east of Locality 4.6. The contact with the Central Intrusion is exposed a short distance to the north on the north-north-west-trending ridge.

To regain the Harris road (at about [NM 3527 9810]), walk 500 m west-north-west across wet peaty ground with scattered peridotite exposures. At this point, either (A) return to Kinloch along the road (*c*. 5 km) or (B) continue south through the

Western Layered Intrusion towards its outer contact with the Western Granite at Harris.

Locality 4.9 Road east of Ard Nev – dense, black picrite dyke intruding peridotite [NM 353 984]

Following option 'A', walking towards Kinloch, there are several shallow abandoned quarries in crumbling peridotite on the east side of the track. Loose blocks of a dense, matt-black picrite come from a badly weathered picrite dyke. The highly magnesian picrite contains an abundance of forsteritic olivines (Fo93); (McClurg, 1982; Upton *et al.*, 2002).

Locality 4.10 Roadside north-east of Ard Nev – baked microgranite and (nearby) altered dolerite, near peridotite [NM 3540 9870]

Farther along the road, baked microgranite (the Western Granite) is exposed in contact with peridotite. Off the road some 70 m to the west a thick, north-west-trending dolerite dyke intrudes the microgranite. This dyke, which forms a low ridge, has also been altered by the nearby peridotite. Continue along the road to Kinloch.

If proceeding towards Harris (option 'B', (Figure 44)) and (Figure 45), follow the road south for about 200 m, then contour around the hillside for a further 200 m, passing derelict eagle cages on the way.

Locality 4.11 East of Ard Mheall – harrisitic structures in peridotite, some showing erosional features [NM 3502 9772]

Excellent harrisitic structures (Harker, 1908; Donaldson, 1974, 1976; O'Driscoll *et al.*, 2007a) occur in layered peridotites of the Ard Mheall member (Western Layered Intrusion), exposed in a series of low, west-facing crags (Figure 42). Elongate olivine crystals in the peridotite appear to have grown upwards for 5–20 cm from a substrate of granular olivine. In places, dark, platy olivine crystals are arranged in an imbricate manner, suggesting they have been broken from the tips of harrisitic structures and redistributed by magmatic currents (Figure 42), (Figure 43). Walk downhill to the road and continue south for 2 km. Exposures are few and the ground is largely drift covered.

Excursion 4B

Locality 4.12 North of Harris Bay – roadside exposures of harrisitic structures [NM 341 963] (Figure 44)

Roadside exposures in crags at the transition between the gabbroic Harris Bay member and the overlying peridotites of the Ard Mheall member contain excellent examples of harrisitic structures (Wadsworth, 1961).

Locality 4.13 Harris – spectacular layering in gabbros north of bridge [NM 3377 9602]

On the approach to Harris, strongly contrasting, flat-lying, feldspathic and mafic layering occurs in gabbro on the east side of the Glen Duian Burn, close to the bridge. Continue to Harris Lodge [NM 3366 9574], and cross the flat ground south to the low cliffs about 100 m south-south-west of the mausoleum.

Locality 4.14 West end, Harris Bay – contact of layered gabbro (with harrisite) and microgranite [NM 3350 9560]

To the south-south-west of the mausoleum, the layered rocks are separated from microgranite by a thin zone of gabbro, and basic and acid hybrid rocks. There is a limited development of intrusion breccia and some intricate felsic net-veining of the gabbro (Greenwood, 1987). Flat-lying harrisitic layers (Figure 46) crop out to within a metre or so of the contact zone; some layers appear to bifurcate. Numerous hornfelsed basaltic dykes cut the microgranite, and dykes and sheets

are common in the microgranite exposed in the sea cliffs to the north-west (Figure 47). It is difficult to verify that the dykes are truncated by the mafic rocks, since most appear to die out close to the contact, but the dykes are commonly cut by thin felsic veins in the contact zone. Microgranite at and near the contact has a dull, matt-grey appearance, contrasting with the usual cream-white colour elsewhere in the Western Granite. Thin section examination shows that the rock has been extensively recrystallised; fingerprint textures are present in the plagioclase phenocrysts and aggregates of hypersthene, augite and opaque minerals pseudomorph the original mafic minerals.

Locality 4.15 Cove west of Harris Bay – contact between gabbro and hybridised microgranite [NM 3348 9565]

West of the mausoleum a path leads down to a cove where the contact zone is exposed (Figure 48)a, (Figure 48)b. Cliffs on the west of the cove expose grey microgranite cut by numerous sheets and dykes of dolerite and basalt striking approximately parallel to the coast (i.e. north-west). The microgranite is in contact with a felsic hybrid rock characterised by an acicular development of mafic minerals. Near the west end of a small cliff next to the path on the north side of the cove, the felsic hybrid is in fairly well-defined contact with contaminated (silicified) gabbro characterised by a patchy pegmatitic crystallisation. A few metres east of the contact the silicified gabbro contains xenoliths of layered gabbroic rock. Faint layering occurs in gabbroic rocks at the eastern end of this face and a thick band of gabbro, similar to that in the xenoliths in the contaminated gabbro, crops out at path level.

The contact between layered gabbros of the Harris Bay Member and microgranite belonging to the Western Granite is also extremely well exposed at the east end of Harris Bay. To reach this locality from the mausoleum, cross the Glen Duian burn near the shore (or go upstream and use the road bridge [Locality 4.13] if the river is high), and continue east, either along the layered gabbro benches on the rocky foreshore or walk along the low cliffs, on the magnificent late-glacial storm beaches at the back of the bay. There is a bridge over the Abhainn Rangail at [NM 3450 9555], although it is normally possible to cross the river close to the shore. The contact is exposed on a promontory about 350 m to the south and is most easily approached over the grass-covered storm beach. Note that here, and elsewhere, the boulders and cobbles in these beach deposits consist largely of microgranite and (Torridonian) sandstone. Gabbro and peridotite are virtually absent, presumably having disintegrated under the turbulent conditions when the beaches formed.

Locality 4.16 Harris Bay – shelves eroded in well-layered gabbro [NM 373 958]

Slabs and cliffs on this part of the coast and for some hundreds of metres to the east, provide the best exposures of the gabbroic rocks of the Harris Bay member, including good examples of harrisitic structures (cf. Donaldson *et al.*, 1973; (Figure 7), (Figure 46).

Locality 4.17 East end Harris Bay – intrusion breccia at gabbro/microgranite contact [NM 3405 9505]

Gabbro with flat-lying layering occupies most of the promontory, but a small area of baked, bleached microgranite crops out on the south side. The gabbro and microgranite are separated by a zone of intrusion breccia several metres in width, consisting of angular and subangular blocks of basalt, dolerite, gabbro and rare peridotite, from 0.5 to 2 m in diameter, in a felsic matrix which is continuous with the microgranite (Figure 49), (Figure 50). The breccia appears to be in steep contact with the layered gabbros and transgresses the layering. Felsic net-veining is widespread and extends for several metres into the mafic rocks where it forms flat-lying sheets and zones conformable with the layering (Figure 50). Within the breccia zone there are trains of even-textured basaltic fragments which represent dykes in various stages of disintegration, and in one instance a dyke in microgranite may be followed into a train of blocks (Figure 49). A few fragments of dolerite have rounded, lobate, fine-grained selvedges against the felsic matrix, suggesting that there was limited co-existence of mafic and felsic magmas.

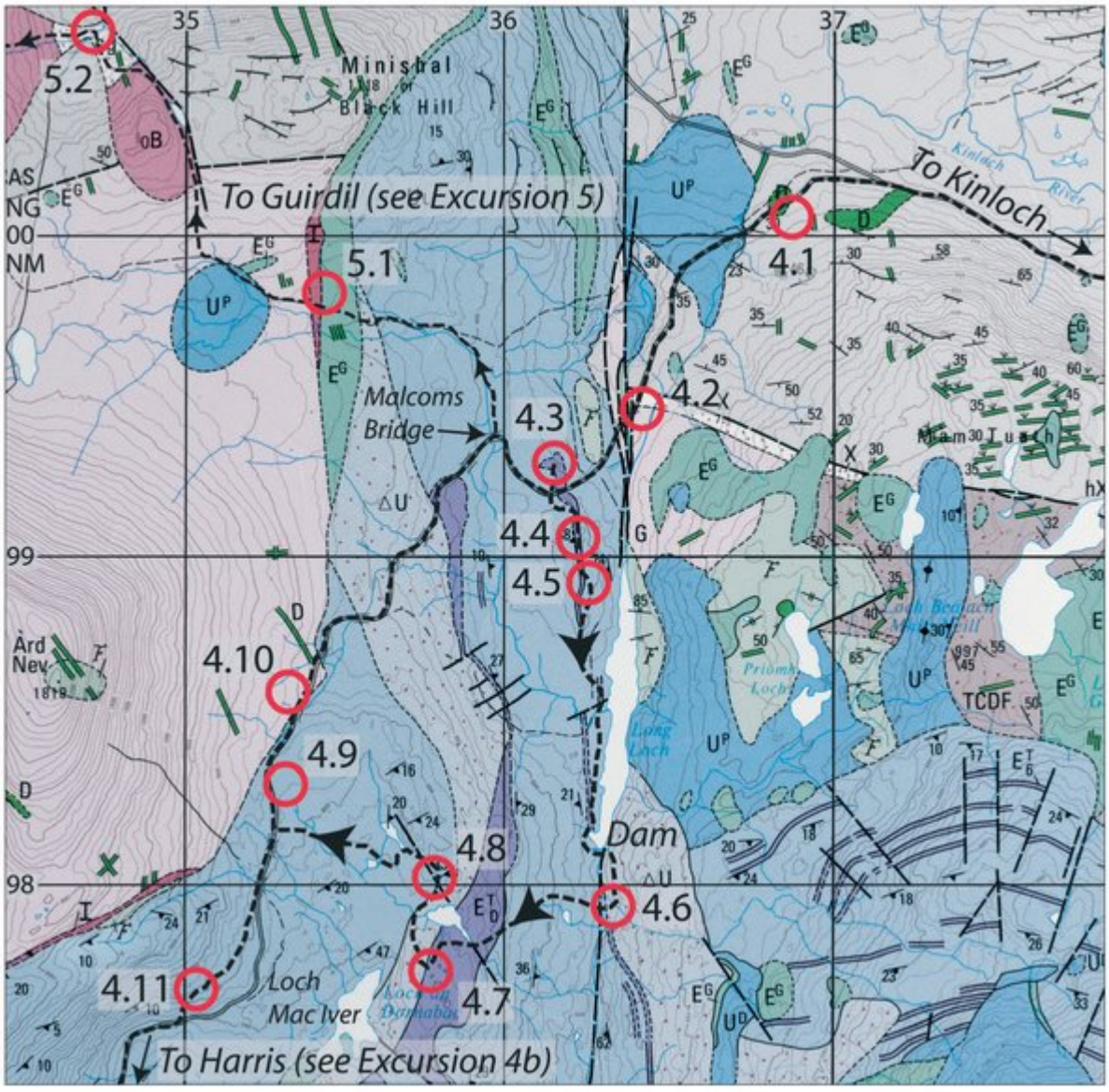
From the rocks of the Harris Bay localities it is clear that the emplacement of hot, mafic material into earlier granitic rocks resulted in generation of rheomorphic silicic magma, with the formation of intrusion breccias and felsic net-veining, a

phenomenon that is common throughout the central complexes of the Palaeogene volcanic districts (e.g. Blake *et al.*, 1965). Return to the Abhainn Rangail bridge and walk upstream for 150 m.

Locality 4.18 Abhainn Rangail – peridotite breccia in Central Intrusion, with chromite seams [NM 3450 9557]

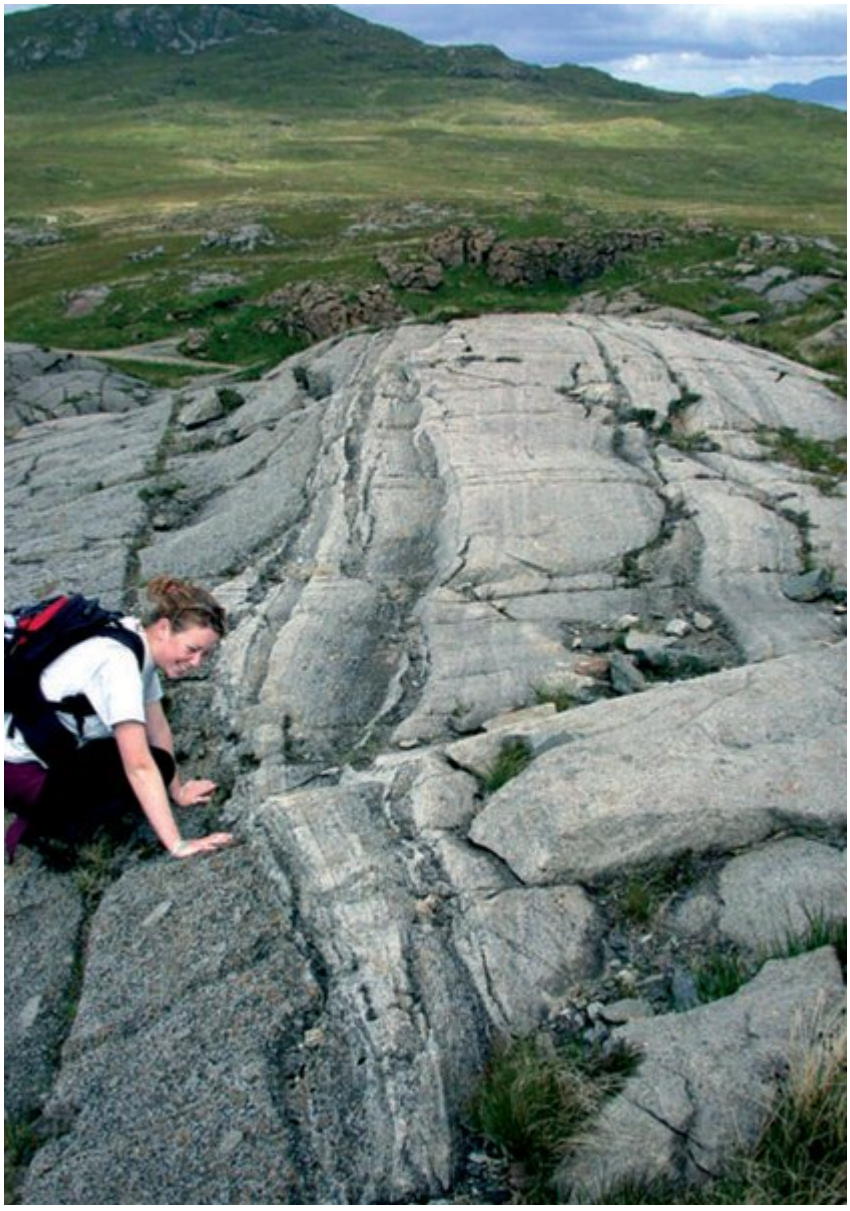
At the junction of the Abhainn Rangail with the Allt Lag Sleitir, which enters from the north-west, ultrabasic breccias belonging to the Central Intrusion crop out in the stream bed (Figure 40)a. The breccias consist of angular and subangular blocks of peridotite and feldspathic peridotite in a feldspathic peridotite matrix containing thin seams of black, lustrous chromite. They were interpreted by Wadsworth (1961) to have formed at fault-scarps in a magma chamber and by Donaldson (1975) to be intrusive breccias. Walk due north for 800 m to regain the road near Hugh's Brae [NM 345 964]. Return to Kinloch (*c*. 8 km), examining Localities 4.9 and 4.10 on the way (see above).

References

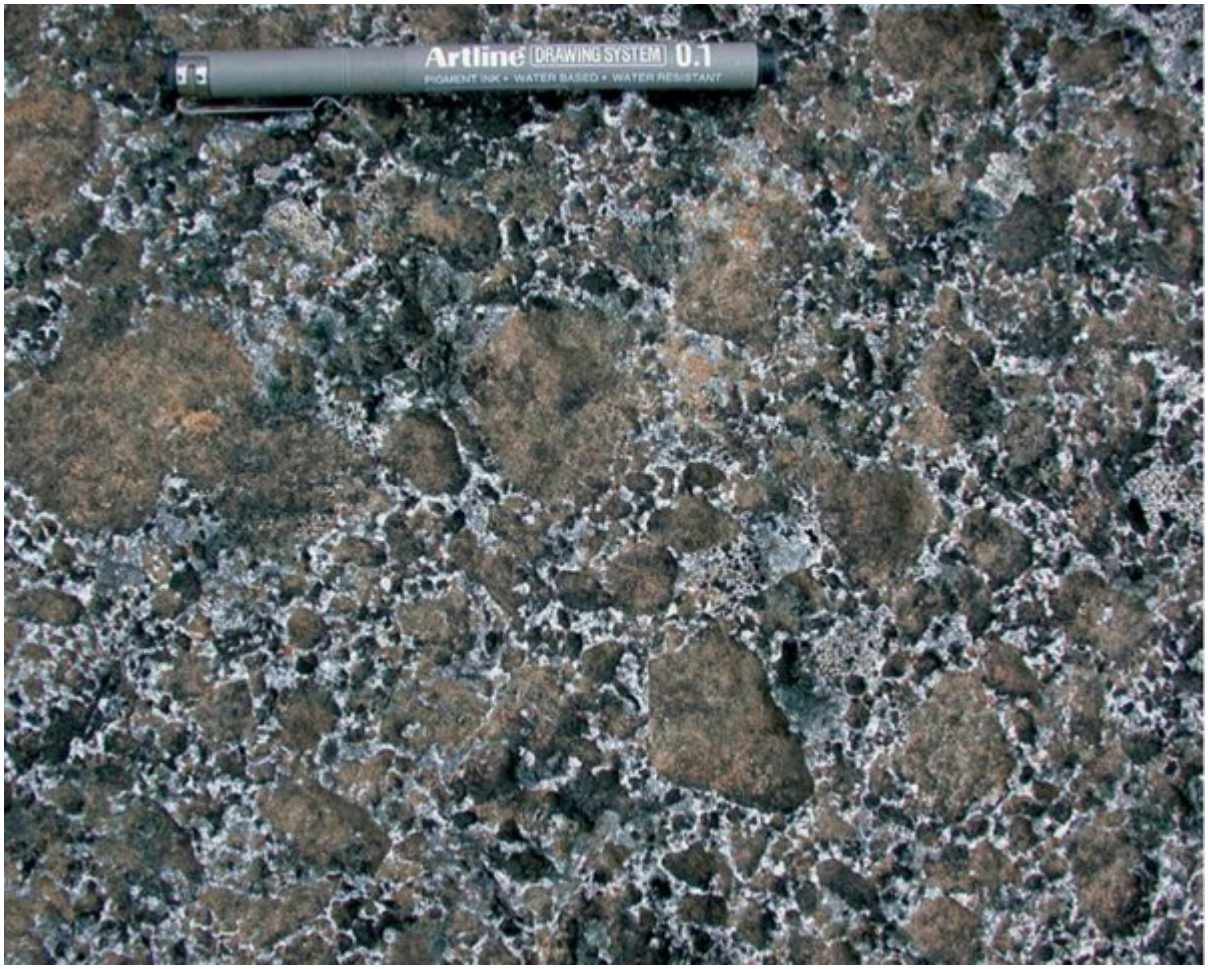


(Figure 33) Geological map of Excursion 4A, Central Rum, covering the northern end of the Central Intrusion and adjoining layered areas of the Eastern Layered Intrusion and Western Layered Intrusion ((Key) ; based on SNH 1:20,000 solid geology map; © SNH).

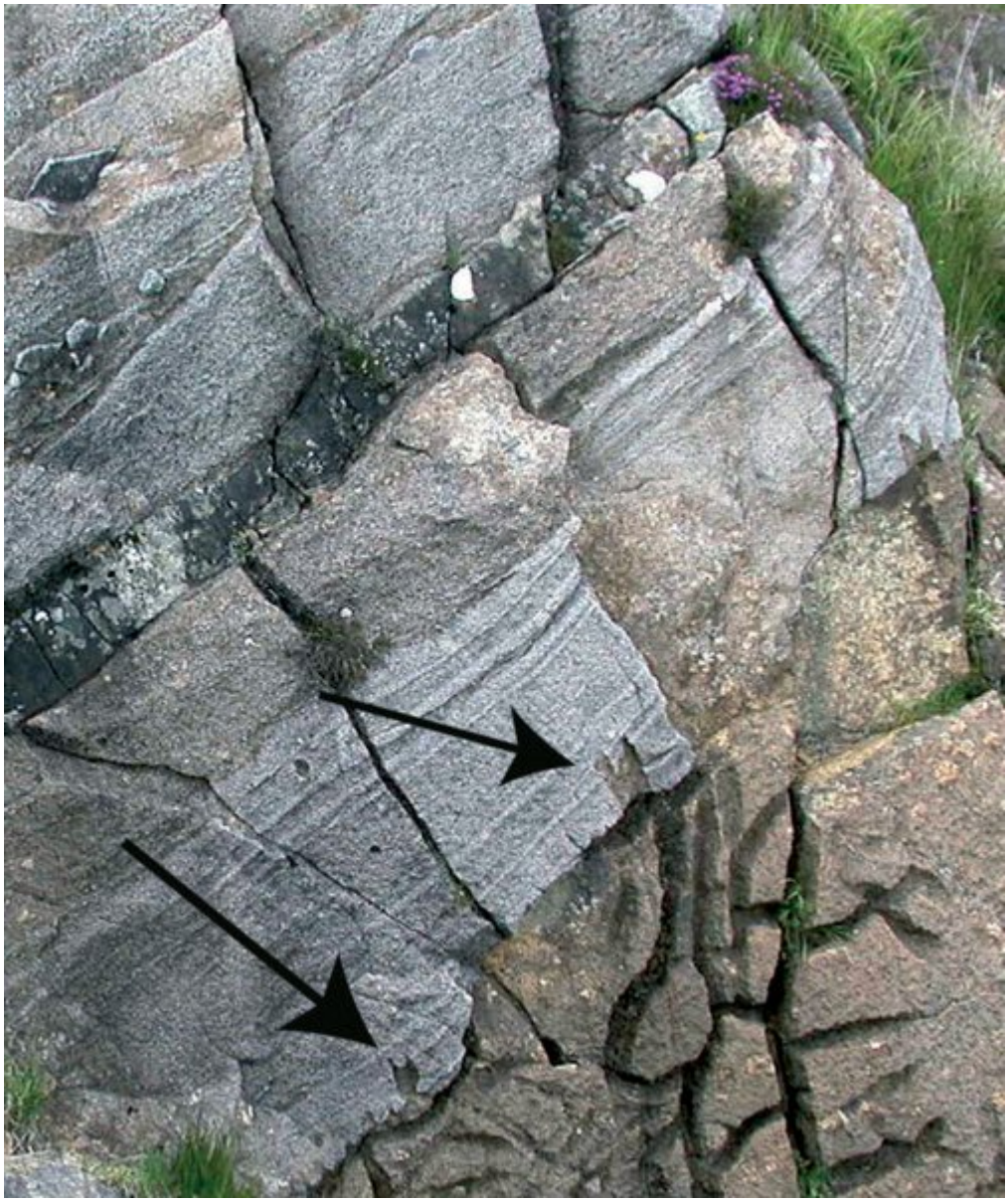
(Figure 34) Peridotite blocks ('dropstones') with deformed layering (impact structures?) in layered troctolite of the Central Intrusion. Scale: pen 13 cm. Locality 4.3.



(Figure 35) Layered troctolite in the Central Intrusion. Locality 4.4, 'whaleback' ridge west of Long Loch.



(Figure 36) Detail of the peridotite 'cobble' avalanche deposit as in (Figure 35). Locality 4.4. Central Intrusion. Scale: pen c.15 cm.

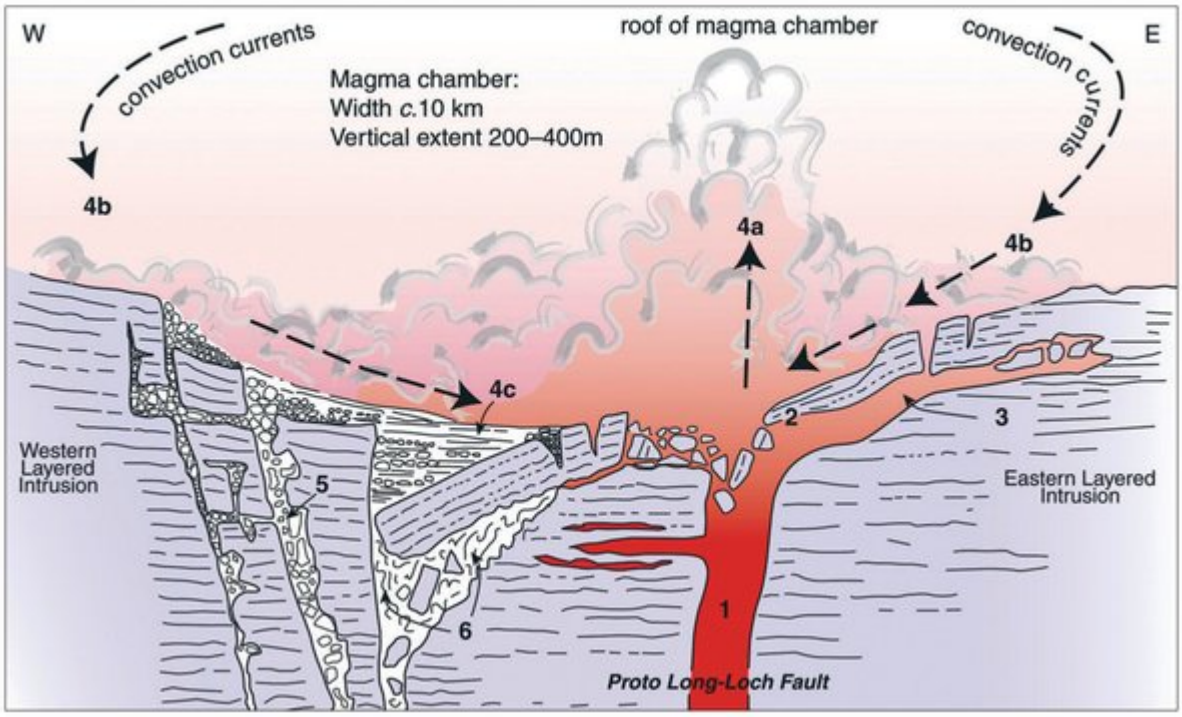


(Figure 37) Graded and slumped layered troctolite cut by thin basalt sheets at the east side of the 'whaleback' ridge. Note how the brown peridotite at the base of the section cuts across the layering and sends irregular finger-like projections into the overlying troctolite (see arrows).n Locality 4.5 Central Intrusion, 'whaleback' west of Long Loch. Rock-face is c.2–5m high.

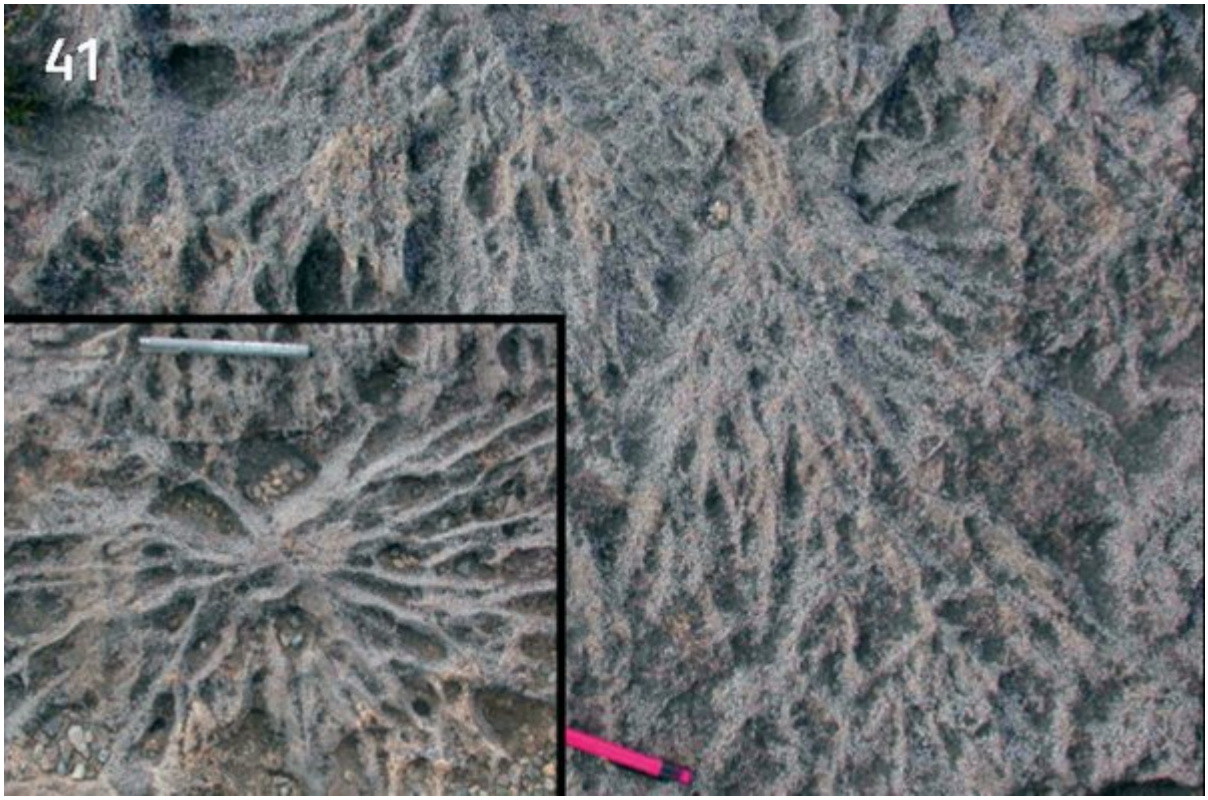
(Figure 38) Large triangular block of layered troctolite and peridotite enclosed in disturbed troctolite draped over the top. Locality 4.6, about 120 m south-south-east of Long Loch. Central Intrusion. Scale: hammer shaft at left centre 30 cm.

(Figure 39) Pronounced, narrow trench eroded along the course of the Long Loch Fault. (Near Locality 4.6.) Looking south. Central Intrusion, south of the Long Loch.

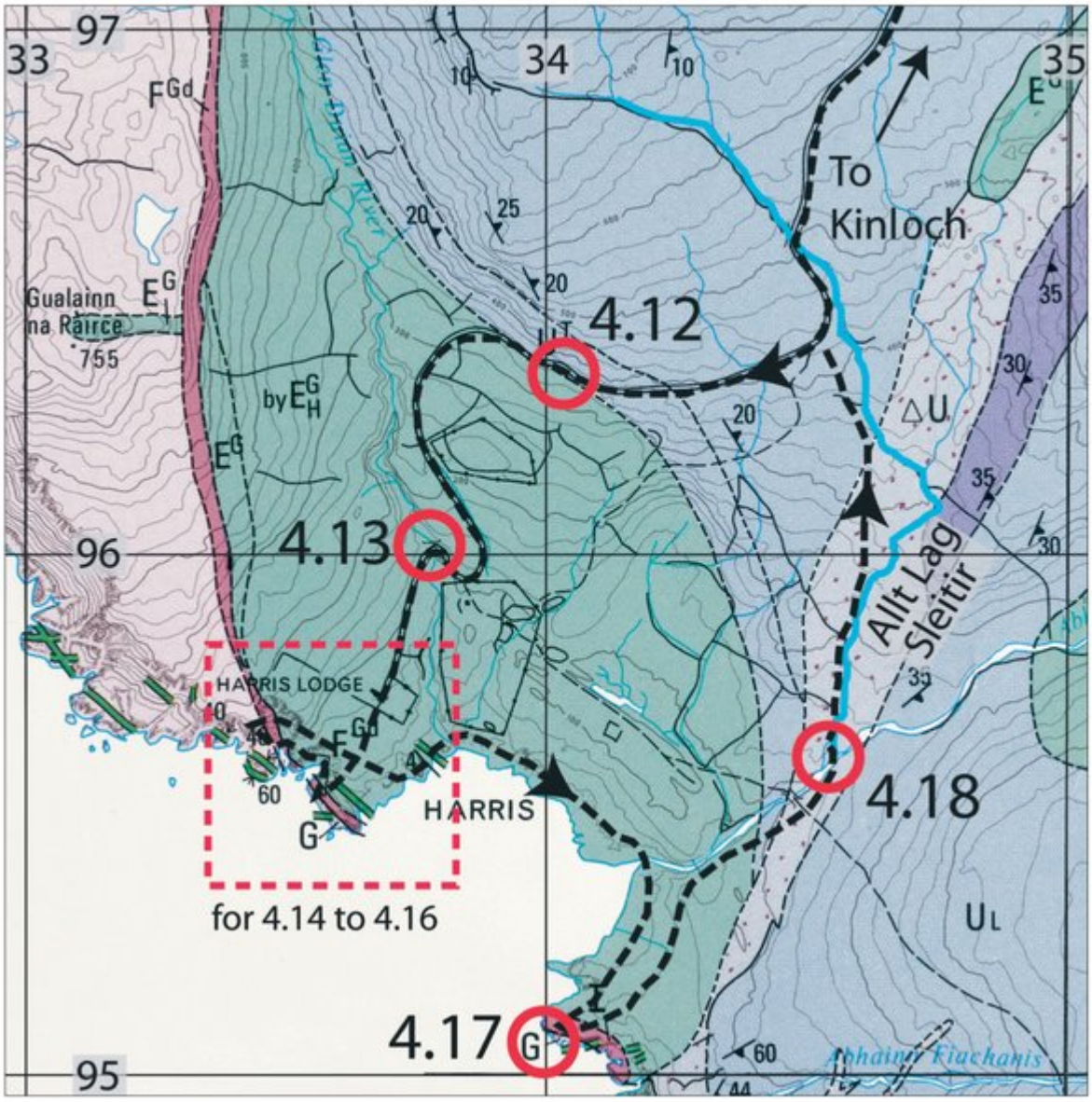
(Figure 40) a. Portion of ultrabasic intrusion breccia (conduit fill) in the Central Intrusion, Abhainn Rangail. Scale: hammer shaft 30 cm. Locality 4.18. b. Breccia of layered troctolite blocks in a feldspathic peridotite matrix (debris avalanche type), Central Intrusion, Harris track near Locality 4.7.



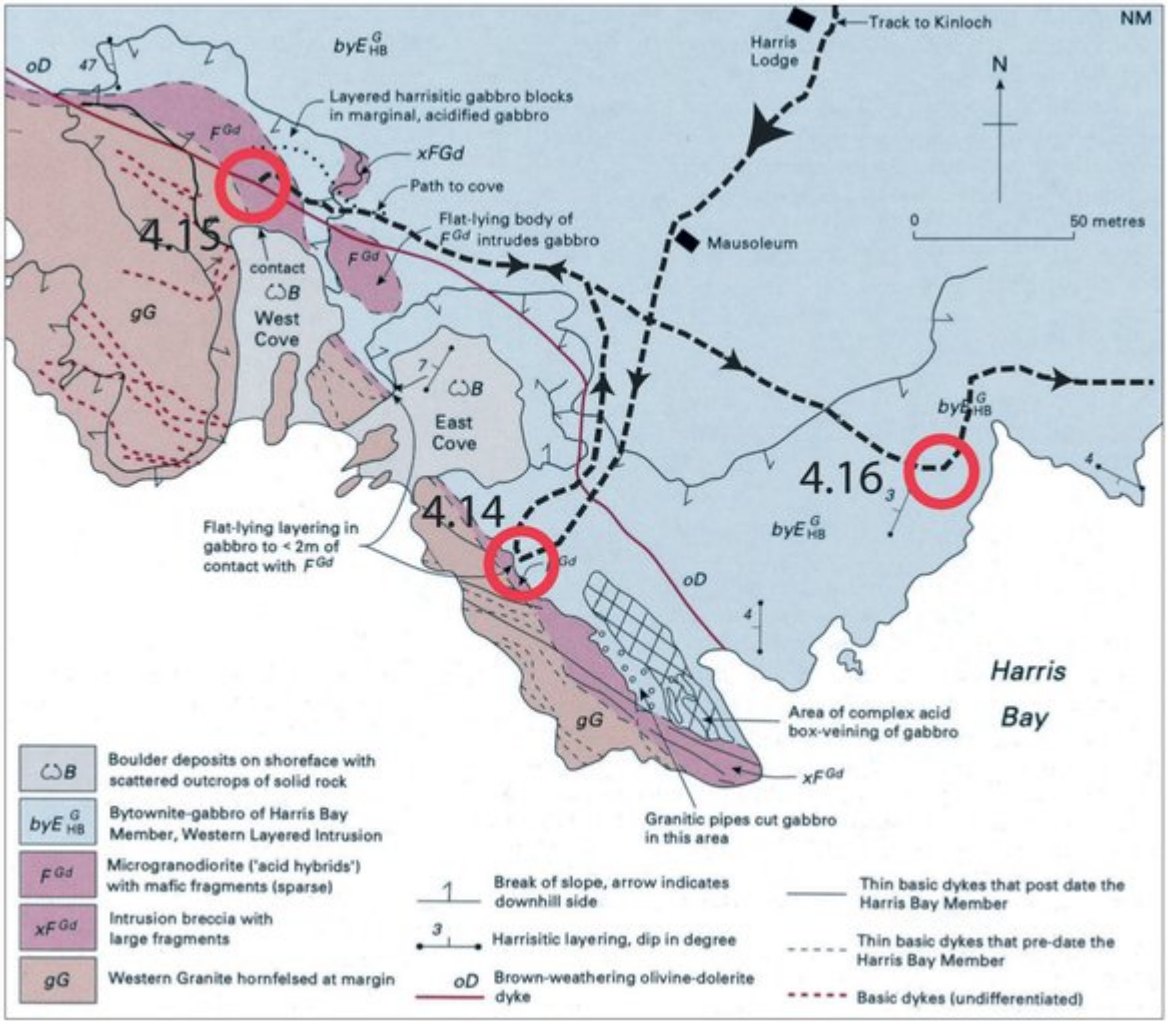
(Figure 43) Schematic representation of possible events leading to the formation of the Central Intrusion. Periodic replenishments of picritic magma (1) rejuvenated the magma chamber causing sliding and slumping (2) and intruded laterally into earlier cumulates (3). Magma fountaining into the chamber (4a) flows off the roof and down the sides as crystal-laden, gravity-driven currents (4b), dislodging crystal mushes as they move, then spread across the floor, reworking cumulate debris and depositing this material and primary crystals on the floor (4c). Movement on faults was accompanied by magma injection, thermal erosion of earlier rocks and their fragmentation to form breccia zones (5). Slides of coherent blocks of cumulate across partly liquefied cumulate led to spectacular slump mélanges (6). (Emeleus et al. [1996]. After Emeleus and Bell [2005].) (© NERC)



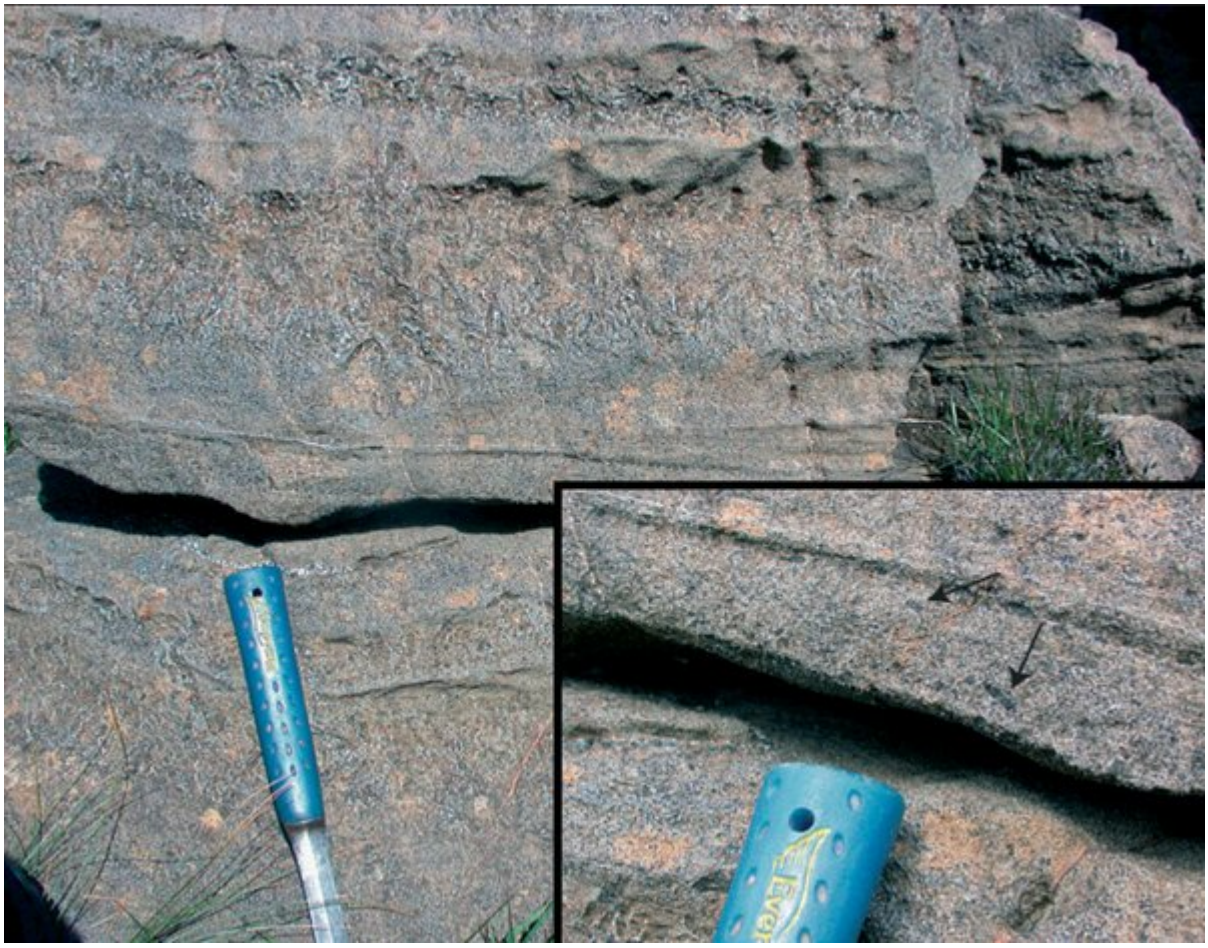
(Figure 41) Radiating rays of plagioclase in feldspathic peridotite ('poikilo-macro-spherulitic structures') in Central Intrusion east of Loch MacIver (Loch an Dornabac). [NM3569 9772], Locality 4.7. Scale: pen 13 cm. INSET: Close up of a poikilo-macro-spherulite.



(Figure 44) Geological map of the Harris Bay area, Excursion 4b. ((Key) ; based on SNH 1:20,000 solid geology map; © SNH.)



(Figure 45) Geological map of western Harris Bay, showing details of the contact between the Western Layered Intrusion and the Western Granite (after Emeleus, 1997 /© NERC) (Key).



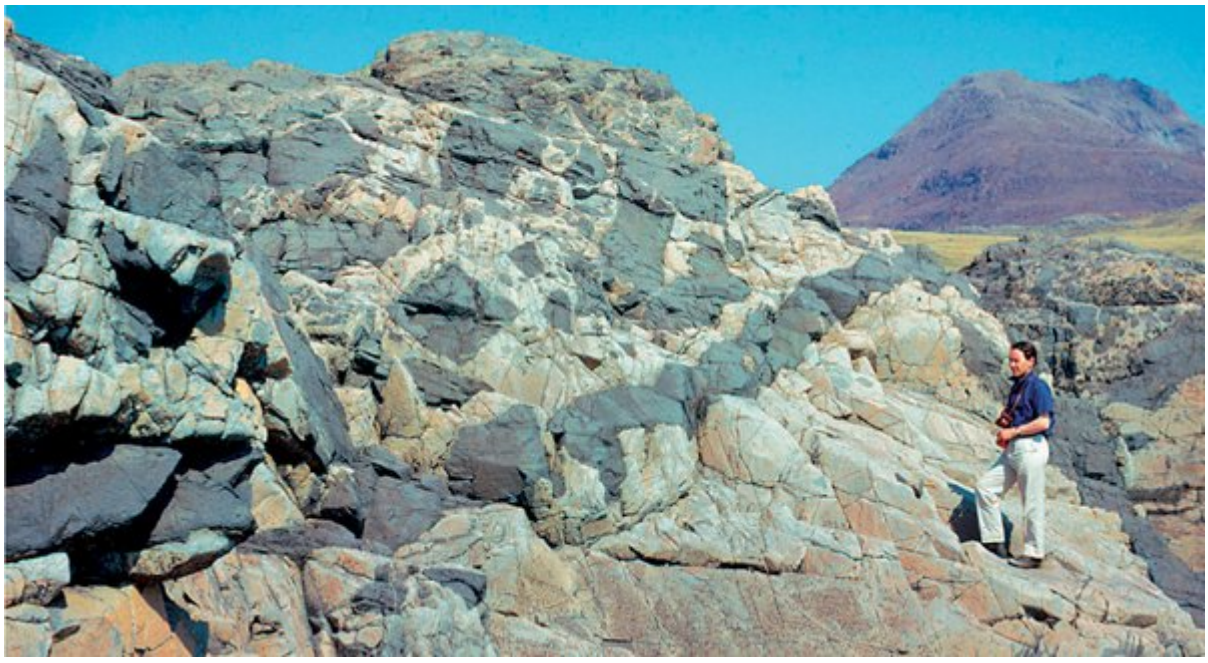
(Figure 42) Rhythmic harrisite and 'sedimentary' lay- ers in feldspathic peridotite. Sedimentary layers contain recycled harrisite crystals. Scale: hammer shaft c.15 cm. Locality 4.11, Western Layered Intrusion, east of Ard Mheall. INSET: Fragments of dark harrisite olivines that have been 'reworked' by sedimentary processes (see arrows).

(Figure 46) Layer of coarse-grained harrisitic olivine in bytownite gabbro of the Western Layered Intrusion, Harris Bay. Scale: hammer shaft c.35 cm.

(Figure 47) Sea-cliffs of granite intruded by numerous north-west-trending basaltic dykes and inclined sheets. Western Granite on the west side of Harris Bay. The shelf at the top of the cliffs is a pre- Late Devensian rock platform.

(Figure 48) a. Tongues of harrisitic gabbro in bytownite gabbro (Western Layered Intrusion) extending into hybrid granite zone to the left. Locality 4.15, Cove west of mausoleum, Harris Bay. b. Close-up of contact, about 8 m to left of person in (Figure 48)a. Scale: hammer c.30 cm. The contact is highly irregular in detail, with some intrusion breccia in places.

(Figure 7) Harrisitic olivines in the Central Intrusion. Individual crystals may reach over 60 cm in length. See text for details.



(Figure 49) Zone of intrusion breccia at the contact of the Western Granite with bytownite gabbro of the Western Layered Intrusion, Locality 4.17, East end of Harris Bay. The line of dark blocks is a dyke broken up in the remobilised acid (felsic) matrix. (Photo: Emeleus/BGS © NERC)

(Figure 50) Layered gabbro in the Western Layered Intrusion intruded by rheomorphic felsic veins derived from remobilisation of the earlier Western Granite in this area. The felsic magma has been channelled along planes of weakness provided by the layered structures. Locality 4.17, east side of Harris Bay. Scale: hammer shaft 30 cm.