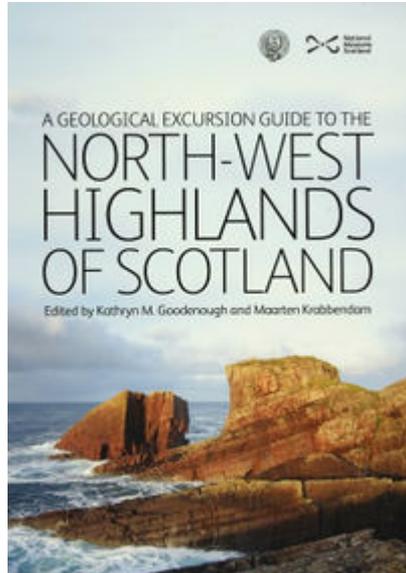


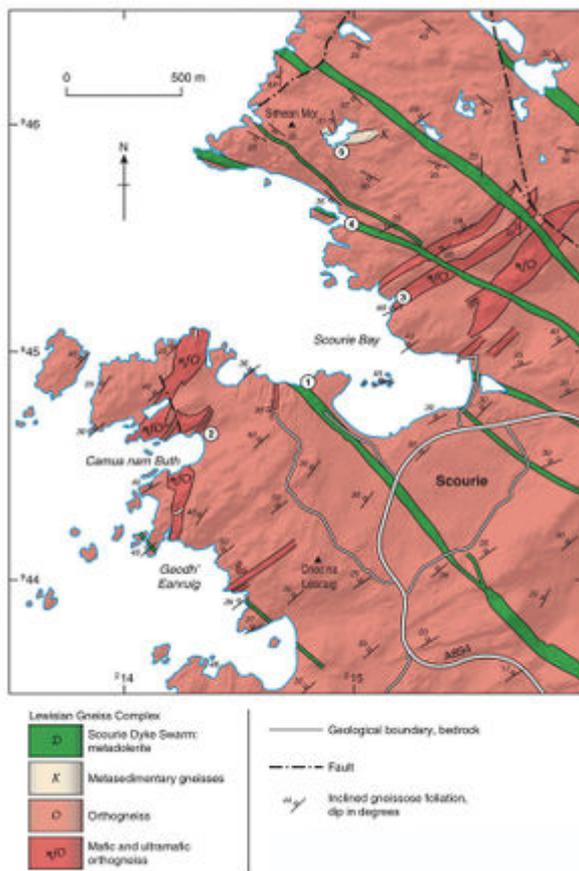
# Scourie Mòr, North-west Highlands - an excursion

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Simplified geological map of the Scourie area, after Mendum, et al. (2009), showing the localities described in Excursion 12.



View north across Camas nam Buth, Locality 12.2. The low hills on the north side of the bay are largely made up of mafic to ultramafic layered gneisses with sheets of felsic gneiss. (BGS photograph P706764, © NERC)



Outcrop of layered mafic-ultramafic gneiss on the north side of Camas nam Buth at Locality 12.2. These outcrops have suffered generally low strain, so that this layering is thought to be igneous in origin. (BGS photograph P593099, © NERC)



View of the outcrops at Geodh' Eanruig, with a prominent pink pegmatitic granite sheet in the foreground. This intrusion cuts the local mafic gneisses, but is in turn cut by

a Scourie Dyke. (BGS photograph P667680, © NERC)



The Scourie Dyke at Poll Eòrna. The figures on the beach are standing on the Scourie Dyke, which forms a weathered gully that is also traceable on the far headland. (BGS photograph P593100, © NERC)

**By Clark Friend**

**Excursion 12 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.**

<b>Purpose</b>	To study aspects of the Lewisian Gneiss Complex of the Assynt Terrane, including the classic Scourie Dyke.
<b>Aspects covered</b>	Granulite-facies felsic and mafic gneisses, Scourie Dykes.
<b>Maps</b>	OS: 1:50,000 Landranger sheet 9 Cape Wrath; 1:25,000 Explorer sheet 445 Foinaven, Arkle, Kylesku and Scourie. BGS: 1:50,000 Sheet 107, Glencoul.
<b>Terrain</b>	This excursion incorporates a number of stops around Scourie Bay, mostly involving short walks over some rough and rocky ground.
<b>Time</b>	The whole excursion is likely to occupy most of a day.
<b>Access</b>	There are no known problems with access to these sites, but please ensure that all gates are closed and that dogs are kept on leads.

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## Locality 12.1 Scourie Graveyard. [NC 148 448]

Turn off the A894 at a minor junction in Scourie village, on the south side of the bay, and park just before the graveyard. Go through the gate in the north-west wall of the graveyard and walk onto the gneiss outcrops north of the main beach, Port an Tagail. These outcrops include one of the classic examples of a Scourie Dyke ([See image](#)). Because the dykes in the Scourie area are relatively little deformed, an estimate of the amount of crustal extension that this segment of continental crust underwent may be made here. This locality is best visited at low tide, but outcrops can be reached at any tide state.

The gneisses on the headland of Meallan an Tiodhlacaidh [NC 149 449] are typical tonalitic, granulite-facies gneisses that have suffered intense ductile strain, reflected by a strong compositional banding comprising finely interbanded orthopyroxene-bearing tonalitic layers and thin, discontinuous, plagioclase-rich leucocratic layers. Because the gneisses are essentially unretrogressed, these events appear to be pre-or syn-granulite facies metamorphism and prior to dyke emplacement. No distinct lithological boundaries are evident in the gneisses, due to extensive granulite-facies recrystallisation and ductile deformation. Scattered throughout the gneisses are numerous small, dark green to black, lens-shaped, hornblendite pods up to ~1m across. These are contained within the structure and larger pods preserve the process of break-up, demonstrating stages in the formation of the smaller hornblendite pods that appear to be derived from larger mafic-ultramafic bodies. In a few places orthopyroxene is patchily absent from the quartzo-feldspathic gneisses owing to a greater degree of late hydrous retrogression.

Several Scourie dykes in the vicinity are relatively little deformed, pre-serving discordant relations with structures in the host gneisses. Between Port an Tagail and Meallan an Tiodhlacaidh are two sub-parallel dykes, both trending roughly ESE. The southern, larger, dyke belongs to the ophitic-textured, quartz-bearing, microgabbroic type (Tarney and Weaver, 1987) and is one of the most studied in the suite. Whilst little deformed, both dykes have been variably sheared and hydrated to amphibole-bearing assemblages  $\pm$  garnet demonstrating that they were subject to amphibolite-facies (Laxfordian) metamorphism (e.g. O'Hara, 1961a). The thinner dyke (c.0.75m) is exposed on the rock platform c.50m north of the thicker dyke, and has a contact displaced by numerous small faults that appear to be related to joints in the host gneisses. On the basis of the textures, most of these faults do not appear to go through the dyke and displace it. These joints could be interpreted to have been active during dyke emplacement indicating a brittle regime. However, there is still debate as to whether the dykes were emplaced into hot or cold rocks. The whole of this dyke has been hydrated and no remnants of igneous minerals occur, though small, granular aggregates of plagioclase appear to retain a texture resembling igneous domains in a microgabbro. Small (<5mm) garnet porphyroblasts are present amongst dark greenish amphibole and plagioclase ( $\pm$  quartz).

The thicker dyke is sub-vertical, c.55m thick, and forms a distinct gully on the shoreline north of the graveyard. This dyke has a Rb-Sr whole rock isochron age of  $2390 \pm 20$  Ma (Chapman, 1979). It is asymmetrically zoned across its width and shows several different internal responses to later deformation and metamorphism, which in part depend upon distance from the margin of the dyke. At its northern contact a zone of about 1-2m of variably foliated and sheared amphibolite occurs with small, rounded garnet porphyroblasts, resembling the thinner dyke, and probably representing a chilled margin. A transition zone follows from the foliated margin through a zone of decreasing strain into areas that are essentially undeformed. Within this zone, thin (c.1-2mm), cross-cutting, discontinuous garnet veinlets can be found. These veinlets appear to be late, as they cross the weak shear fabric. Traversing southwards, the shear foliation continues to decrease in intensity and a relict, ophitic igneous texture becomes apparent with relict igneous ortho- and clinopyroxene, mainly replaced by amphibole and some biotite. Towards the centre of the dyke, the amount of amphibole

decreases and garnet coronas between plagioclase and pyroxenes give the rock a pinkish colour. This zone extends towards the southern contact where there is a thin zone of foliated, amphibolised material against the host gneiss.

The gneisses on the southern contact are typically more mafic than on the north side, and spectacular coronitic garnets including reaction relations with ortho- and clinopyroxene can be found. The state of the tide will dictate how far north-west along the contact can be reached.

## **Locality 12.2 Scourie Mòr [NC 144 446] to Geodh' Eanruig. [NC 143 443]**

Drive back to the A894, turn south and take the next turning on the right at [NC 153 440] towards Scouriemore, and park close to the primary school. Walk up the Scouriemore road to its end, and just before the last house, turn left and go out through a gate onto open moorland. Walk towards the low hills on the north side of the bay of Camas nam Buth [NC 143 447].

The outcrops in the area immediately west of the road are fairly typical felsic gneisses of the Assynt Terrane. These gneisses are broadly tonalitic or dioritic in composition and are typically dark grey-brown when fresh. They are commonly banded, with layers of felsic gneiss alternating with more mafic gneiss, frequently foliated and in some places lineated, though outcrop-scale fold structures are uncommon. Orthopyroxene, commonly associated with garnet, is extensive and provides evidence for granulite-facies metamorphic conditions. The lithological layering is mostly foliation-parallel and any original relations between the slightly different acid lithologies have largely been obliterated due to extensive recrystallisation during high strain under granulite-facies conditions. Syn-granulite facies deformation appears to have occurred in a ductile environment because orthopyroxene commonly defines a lineation and, together with discontinuous quartz ribbons, is found parallel to the banding and foliation.

On the low hills around [NC 143 447] are outcrops of layered mafic-ultramafic gneisses. These are part of a large mafic-ultramafic body (hundreds of metres across) that outcrops on the north side of Camas nam Buth (Figs 80, 81), and is part of a suite of similar bodies scattered around Scourie Bay. Some of these mafic-ultramafic bodies outline map-scale folds. The ultramafic bodies display a variety of lithologies that are commonly inter-layered, grading from pure dunite through clinopyroxene- and/or orthopyroxene-rich varieties into spinel-lherzolites and peridotites. Common mineral assemblages at Scourie Mòr are opx-cpx-olivine in the peridotites and opx-cpx-pargasite  $\pm$  spinel  $\pm$  olivine in the pyroxenites. The mafic rocks are generally more homogeneous, commonly with two pyroxenes + plagioclase + garnet with accessory spinel, sulphides and FeTi oxides. There are some layers in which prominent garnet porphyroblasts, up to 5cm diameter, have grown; good examples can be seen at [NC 1436 4470]. These normally have plagioclase-rich, symplectic decompression coronas around them that, where the garnets are small, completely replace them. The decompression symplectites vary according to the FeO:MgO ratio of the rock and have been used to constrain a *PT* path (Savage and Sills, 1980; Rollinson 1981). That these delicate granulite-facies textures survive demonstrates the general lack of later, hydrous deformation.

Along the north shore of Camas nam Buth, where overall strain appears to have been relatively low, sheets and sub-parallel masses of felsic gneiss are interleaved with some of the ultramafic/mafic rocks, and veins of felsic material intrude the more mafic gneisses, clearly cross-cutting the mineral layering. This relationship is consistent with similar instances on the north side of Scourie Bay (e.g. Friend and Kinny, 1995), but does not fit with dating studies from the area. An early Sm/Nd study of Scourie Mòr peridotites gave an age of  $2670 \pm 110$  Ma (Whitehouse, 1989), and this emplacement age for the mafic-ultramafic bodies has been supported by Re-Os studies which suggested that

emplacement occurred at  $2687 \pm 15$  Ma (Burton et al., 2000). These dates apparently conflict with 2960–3030 Ma U-Pb ages for the protoliths of the felsic gneisses (Friend and Kinny 1995; Kinny and Friend 1997). Possible explanations for this include: (a) the felsic gneisses are indeed older, and the apparently cross-cutting sheets are rheomorphic veins formed when the magmas were emplaced at c.2687 Ma; or (b) the mafic-ultramafic bodies are older, but their isotopic systems have been disturbed during their long and complex history. At Camas nam Buth the mafic-ultramafic bodies have been shown to represent fragmented layered complexes, through extensive geochemistry that demonstrated cryptic layering and established a consistent geochemical way up, which could be traced over two sets of fold hinges (Sills et al., 1982). It is now accepted that the ultramafic and mafic rocks have suffered the same metamorphic history as the gneisses, but the survival of any remnants of the primary igneous minerals is still debated. From the head of Camas nam Buth, pick up a rough path that winds along the south side of the bay just above the shoreline. Continue SSW, over a low col between two rocky knolls, towards Geodh' Eanruig [NC 142 442]. Here, mafic-ultramafic gneisses similar to those at Camas nam Buth can be seen, including some pyroxene-rich varieties with large garnet porphyroblasts. Also in this area are examples of cross-cutting, broadly ESE-trending, narrow Scourie Dykes as at [NC 1412 4418], mostly with microgabbroic texture and essentially undeformed but amphibolitised. The area is cut by hydrous shear zones, many of which coincide with the margins of parts of the dykes. As these shears and associated metamorphism affect the Scourie Dykes, they are of presumed Laxfordian age. The gneisses at Geodh' Eanruig [NC 142 442] are cut by a largely undeformed sheet of pegmatitic granite ([P667680](#)), with spectacular crystals of pink alkali feldspar, showing graphic texture on a very coarse scale. With some searching, it is possible to find outcrops in which a Scourie Dyke cuts across this pegmatite (e.g. [NC 1415 4418]), and the pegmatite is thus considered to be Inverian in age. From Geodh' Eanruig, return eastwards across moorland to the road.

## **Locality 12.3 First Inlet. [NC 152 453]**

Drive back onto the A894 and turn north; just beyond the caravan site, at [NC 1550 4460], turn left and park before the pier. From the pier, climb a steep path up the slope to the north and then follow a field wall in a north-west direction until it abruptly turns north [NC 1535 4520]. If the path appears very overgrown or parking is difficult, it is also possible to park at the public toilets on the main road through Scourie and follow the minor road that turns into a track through a farm at [NC 1570 4510], then walk west through the fields beyond the farm to reach the same point.

Continue north along the wall to cross a small stream and then descend steeply to the beach at First Inlet. This locality can be visited at any state of the tide, but is better with low water.

Layered ultramafic and mafic bodies, which have been interpreted to belong to the same supracrustal suite exposed on Scourie Mòr, are contained in granulite-facies gneisses and form a distinct ridge in the middle of the inlet. The clear peridotite-pyroxenite layering appears to outline the nose of a fold that possibly links south to those on Scourie Mòr. On the north side of the inlet, boulders often obscure the relationships with mafic rocks that contain spectacular decompression textures. Good examples can be found in the loose blocks and there is a very complex prograde and retro-grade metamorphic history preserved in these textures. On a gross scale the ultramafic body appears to be concordant within the gneisses. However, the internal layering is cross-cut by sheets and veins of tonalite that have bluish quartz on fresh surfaces and carry orthopyroxene with the same linear fabric as the gneisses outside. Zircons from one sheet have a maximum age of ~2960 Ma, which matches the age of a gneiss sample from the ridge above the bay to the north, and is interpreted as the igneous age of the sheet, not the age of an inherited component (Friend and Kinny, 1995).

On the south side of the inlet, a prominent, thin layer of pyroxene + quartz + magnetite (+ minor garnet) rock is interpreted as an ironstone and thus considered to represent sedimentary material (Barnicoat and O'Hara, 1979). This unit contains manganiferous pigeonitic pyroxene from which exsolution lamellae compositions suggest temperatures of at least 1000°C were attained.

If time permits, in the next inlet to the north-west ('Second Inlet') good exposures of the relationships between ultramafic and gabbroic lithologies are seen, again with intercalated gneiss sheets. Thin, rusty, brown-weathering sulphide bands that are garnetiferous may be sedimentary in origin.

## **Locality 12.4 Poll Eòrna. [NC 150 456]**

Climb out of First Inlet on the north side and then head north between two knolls to the foot of a prominent rise. Turn north-west along a grassy gully (in fact the trace of a Scourie Dyke) to a small raised beach that slopes down to the present beach ([P593100](#)). The rocky beach is eroded into a c.35m-thick WNW-ESE Scourie Dyke that emerges on the shore at [NC 149 456]. Best visited at low tide, this dyke dips c.80° northwards and can be seen to continue on the same strike across the bay to the north-west where it occurs in a marked notch through the headland of Creag a' Mhàil. It is considered to be the type Scourie Dyke, first described by Teall (1885) and later by O'Hara (1961b), and cuts granulite-facies quartzo-feldspathic gneisses that can be examined along either contact.

The felsic gneisses contain, and appear to break up, layers and lenses of mafic to ultramafic gneisses, which are locally interlayered with brownish-weathering, biotite-rich rocks interpreted to be of metasedimentary origin (O'Hara, 1960, 1961b). These latter rocks probably represent a continuum with those recognised on Sìthean Mòr [NC 150 460] about 350m to the north. The host gneisses demonstrate a variable degree of retrogression and associated shear fabric development. In some places on the dyke contact discordances are still preserved, but most frequently there are sections where a completely new amphibolite-facies fabric parallel to the dyke margin has developed.

Whilst the Scourie Dyke is essentially undeformed on a large scale, it has suffered much internal deformation and metamorphism, assumed to be Laxfordian, and is now amphibolitised. The centre still preserves a relict ophitic texture, with variably amphibolitised pyroxene still visible.

The dyke is cut by many amphibolite-facies shear zones that have two dominant directions; sub-parallel to the margins of the dyke, and at a high angle across the dyke. Inspection of these shears suggests that they are linked and the new fabrics indicate a dominantly dextral sense of movement. The NE-SW shear zones cause a marked dextral displacement by some 2m of the contact on the north side of the beach, interpreted as consistent with development by simple shear deformation (Ramsay and Graham, 1970). The shear zones become much wider in the gneisses outside the dyke and two main hypotheses have been debated. Were there two shearing episodes? Was the dyke emplaced towards the end of the shearing event? As at Scourie Graveyard 1-2mm straight to highly irregular veinlets of garnet cross-cut the late shear foliation in the dyke. Some of the straight veins may be developed in conjugate sets with SE and SSE directions, whilst the more irregular ones have random orientations. Obviously all of this metamorphism and deformation is post-shearing and clearly indicates that the metamorphic history of the Assynt Terrane is not as straightforward as it might appear.

## **Locality 12.5 Sìthean Mòr. [NC 150 461]**

From the beach, ascend steeply northwards following the eastern side of a small stream up to a

lochán and pass round to the north shore.

Here brown-weathering granulite-facies gneisses are interlayered with garnetiferous metabasic rocks, interpreted as a sediment-lava supracrustal succession. The most abundant lithologies are quartz-plagioclase-garnet-biotite gneisses. These rocks commonly appear in the field as rusty brown weathering gneisses, probably because of a small but significant sulphide content. These rocks are described as being traversed by slightly paler-coloured Laxfordian shear zones (Beach, 1973) in which small blades of kyanite occur. Monazites from these rocks have been dated by Zhu *et al.* (1997), who found evidence for two episodes of granulite-facies meta-morphism at *c.*2760 Ma and *c.*2526 Ma, followed by Laxfordian metamorphism at 1750 Ma, during which the kyanite formed.

From here, retrace your steps back to the vehicles.

## References

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

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