Scourie Bay

[NC 148 448], [NC 146 461]–[NC 149 453]

C.R.L. Friend

Introduction

This GCR site comprises two localities on the north and south sides of Scourie Bay that include the type locality for the mafic and ultramafic Scourie Dyke Suite, which Peach *et al.* (1907) first recognized as crucial in interpreting the history of the Lewisian Gneiss Complex. Sutton and Watson (1951) subsequently used the dykes as a time-marker, separating the Scourian structural and metamorphic components of the Lewisian Gneiss Complex that were unaffected by significant Proterozoic deformation, from the Laxfordian components that had been partially to totally reworked under amphibolite-facies metamorphic conditions. They demonstrated that the evolution of gneiss complexes could be mapped and investigated through the use of regional dyke-swarms as deformational markers.

Sutton and Watson considered the Scourie dykes to belong to a single swarm, but it is clear from field relationships that there is more than one generation of emplacement (Peach *et al.,* 1907). Bridgewater *et al.* (1995) documented the main Proterozoic mafic dyke-swarms in the Labrador, Greenland and Baltic basement cratons, and showed that not only do they vary in age from 2500 Ma to 1900 Ma, but they also differ geochemically. On the basis of petrology and geochemistry, Tarney (1973) and Tarney and Weaver (1987b) divided the Scourie Dyke Suite into four distinct types; bronzite picrites, norites, olivine-gabbros and quartz-dolerites, with the latter being by far the most abundant. Many dykes in the Scourie area are relatively little deformed by Proterozoic and subsequent events, and as a consequence in many places they still preserve discordant relationships with the structures in the host felsic and mafic gneisses.

On the north side of Scourie Bay, the thick quartz-dolerite intrusion is exposed on the beach at Poll Eòrna and in the crags of Creag a' Mhail and is considered to be the type Scourie dyke. C.T. Clough mapped the area for the Geological Survey in 1887. However, Teall (1885) had earlier described the petrography of the dyke in detail, with further work carried out by O'Hara (1961b). A second important quartz-dolerite dyke (the 'graveyard' dyke of O'Hara, 1961b) is exposed on the south side of Scourie Bay. Both dykes cross-cut the mainly granulite-facies banded felsic and mafic gneisses (Figure 3.4).

Description

The GCR site on the north side of Scourie Bay includes the coastal section at Poll Eòrna and the rocky promontories of Creag a' Mhail and Sgeir Fhiaclach. Inland, rocky exposures with intervening grassy areas extend up to *c.* 75 m above OD in the north-west part, but the ground becomes lower to the south-east. On the south side of Scourie Bay a *c.* 500 m-long coastal section and its immediate hinterland area lie just north-west of Scourie graveyard.

The type example of a Scourie dyke, at Poll Eòrna, is about 35 m wide, trends ESE, and dips at *c.* 65°–80° to the NNE. The dyke passes offshore but reappears along strike to the WNW where it occurs in a marked notch cutting through the headland of Creag a' Wail (Figure 3.6). The host rocks are typical granulite-facies felsic gneisses whose overall banding normally dips 35°–50° to the south-west.

The southern contact and much of the northern contact of the dyke are sheared and amphibolitized, and in these areas the dyke is made up of hornblende and plagioclase, with a marked shear fabric indicating a dextral sense of movement along the margins. On the south-east side of Poll &ma the dyke is cut by many shear zones which have two dominant directions, sub-parallel to the margins of the dyke and at a high angle across the dyke, causing a marked dextral displacement of the contact by some 2 m on the north side of the beach. The foliation within the dyke can be clearly seen to curve into the shear zone on both sides (Beach, 1978). The host gneisses demonstrate a variable degree of shear-related fabric development along the contact. In places, structures discordant to the dyke margin are still

preserved, but sections where a new amphibolite-facies fabric parallel to the dyke margin has developed are more common. Unsheared contacts may be seen on the Poll Eòrna beach.

The core of the dyke preserves a relict ophitic igneous texture, with pyroxenes showing varying degrees of replacement by amphibole. Garnets were developed at different stages of the metamorphism; they appear within the finer-grained marginal facies of the dyke but are not seen in the sheared rocks (O'Hara, 1961b). In places very thin (1–2mm) planar to highly irregular veins of garnet cross-cut the fabrics. Some of the planar veins form conjugate sets with south-east and SSE trends, whereas the more-irregular veins appear to have random orientations.

The part of the GCR site on the southern side of Scourie Bay contains two sub-parallel Scourie dykes. The larger dyke, the 'graveyard' dyke of O'Hara (1961b), is a subvertical quartz-dolerite, *c.* 50 m wide, that trends roughly ESE. Just to the north, is a much thinner (*c.* 0.75 m wide), vertical, satellite dyke that displays particularly good cross-cutting relationships with the structures in the surrounding felsic gneisses (Figure 3.7). The main dyke is variably affected by later deformation and metamorphism, in part dependent upon distance from its margin. Both dykes have been hydrated and metamorphosed under amphibolite-facies conditions to varying degrees and contain garnet + amphibole-bearing assemblages.

The thicker 'graveyard' dyke is zoned across its width from north to south. Adjacent to its northern contact is a 1–2m zone of variably foliated and sheared amphibolite with small, rounded garnet porphyroblasts. Towards the centre of the dyke the foliation becomes weaker, and a relict, ophitic igneous texture becomes apparent. Relict orthopyroxene and clinopyroxene, now mainly replaced by amphibole and some biotite, are present. Within this transition zone, thin (*c.* 1–2 mm), cross-cutting, discontinuous garnet veinlets can be found. Near the centre of the dyke the amount of amphibole decreases, and garnet coronas between plagioclase and pyroxenes give the rock a pinkish colour. This relatively undeformed zone extends towards the southern contact where there is a thin zone of amphibolitized material against the host felsic gneisses.

The contact of the thinner dyke is displaced by numerous small faults (Figure 3.7). The faults appear to be related to joints in the host gneisses but do not go entirely through the dyke and displace it; hence, they may be interpreted to have controlled the geometry of dyke intrusion rather than being later features. No remnants of igneous minerals remain in the dyke, which is now amphibolite, although some small, granular aggregates of plagioclase retain a texture resembling that of a dolerite. Small garnet porphyroblasts (less than 5 mm) are present amongst dark-greenish amphibole and plagioclase (± quartz). This mineralogy replicates that seen at the northern contact of the thicker dyke.

An ultramafic dyke of the Scourie Dyke Suite crops out just north of the GCR site on the beach at the head of Scourie Bay [NC 155 447] (O'Hara, 1961a). Its mineralogy and texture can be readily compared with those in the dolerite dykes.

The felsic gneisses throughout the Scourie Bay GCR site are typically tonalitic in composition and preserve extensive orthopyroxene as evidence for granulite-facies conditions. In shear zones they are retrogressed to amphibole-and biotite-bearing gneisses with development of a new foliation. In a few exposures around the headland of Meallan an Tiodhlacaidh [NC 149 449], north of Scourie graveyard, orthopyroxene is absent, owing to a greater general degree of retrogression under amphibolite-facies conditions. On the beach around Meallan an Tiodhlacaidh the gneissic banding is more attenuated with thin tonalitic layers interbanded with discontinuous, plagioclase-rich layers. This attenuation appears to be related to the granulite-facies conditions, as the gneisses are not retrogressed, and were patently deformed prior to the intrusion of the metadolerite dykes. No distinct lithological units can be discerned in the gneisses, largely due to extensive granulite-facies recrystallization and ductile deformation.

Contained within the foliation and banding, and generally scattered throughout the gneisses, are numerous small, dark-green to black hornblendite pods up to about 1 m in diameter. Even though pre-dyke strain at this site is high compared with, for example, Camas nam Buth, only about 0.5 km to the WSW (see Scourie Mor GCR site report, this chapter), these pods are interpreted to be derived from larger mafic–ultramafic bodies, in common with other parts of the area. In one or two places larger pods show possible transitional stages of this fragmentation.

On the north side of Scourie Bay, the host felsic gneisses contain, and appear to break up, layers and lenses of mafic to ultramafic gneisses that are associated with brownish-weathering, biotite-rich gneissose semipelite, interpreted to be of metasedimentary origin (O'Hara, 1960, 1961b). These rocks are similar to those described in the Sìthean Mòr GCR site report (this chapter), about 300 m to the north.

Interpretation

The dykes of the Scourie Dyke Suite within this GCR site were emplaced following the granulite-fades metamorphism of the host gneisses. There is still some debate as to whether the dykes were emplaced into hot, cold or warm country rocks, but it is clear from the field relationships that the host gneisses behaved in a relatively brittle manner (e.g. (Figure 3.7)). Whilst the region as a whole has essentially behaved as a stable block during later events, the dykes demonstrate that the area has suffered localized and variable Proterozoic amphibolite-facies metamorphism, particularly along zones of high strain. The dykes preserve a history of fluid ingress and metamorphic retrogression and alteration, dependent partly on their thickness and the extent to which they have been dissected by shears. The site demonstrates the way that Laxfordian strain is partitioned into narrow shear-zones, in part controlled by lithological discontinuities.

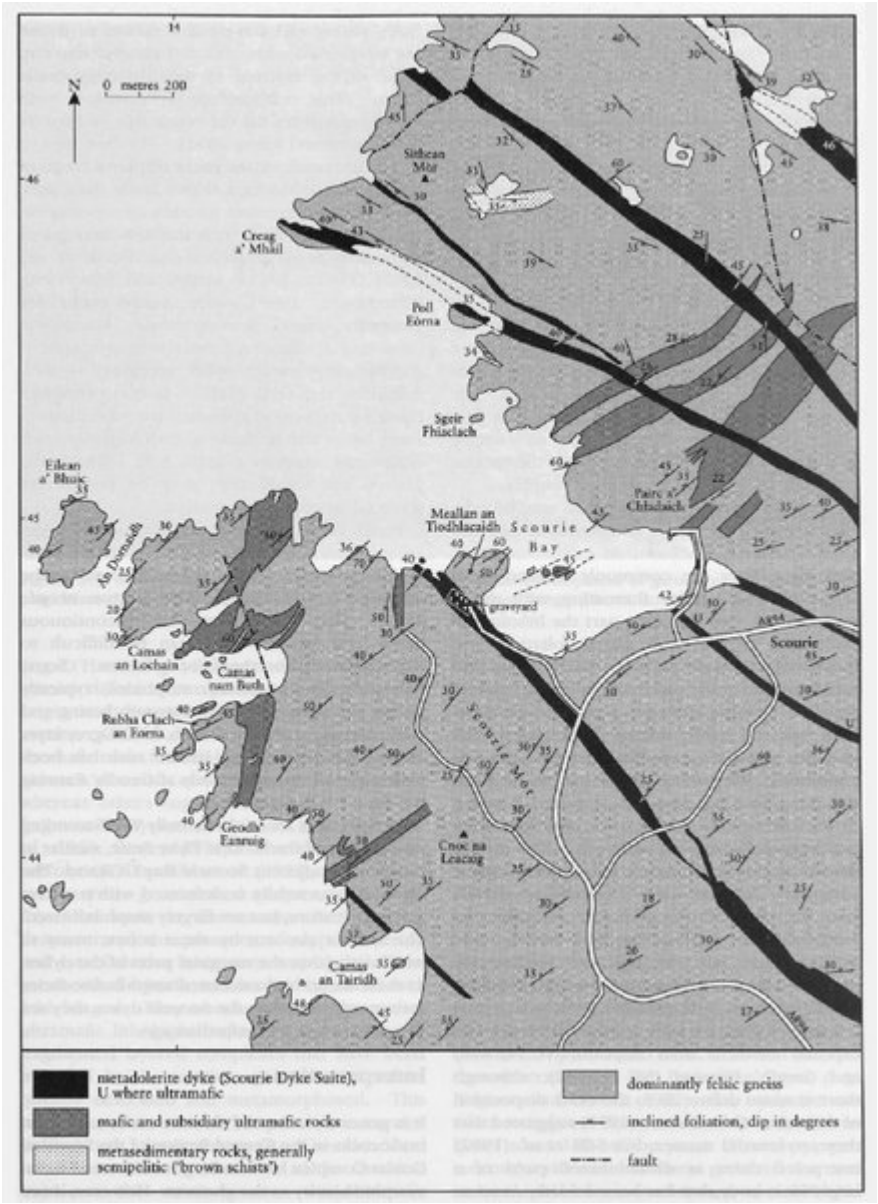
The dykes at this site have been studied by a variety of dating techniques. Chapman (1979) presented Rb-Sr data for three dykes from the Scourie region, including the two main dykes at Scourie Bay, and derived a combined isochron age of 2390 ± 20 Ma. Waters *et al.* (1990) carried out Sm-Nd, Rb-Sr and U-Pb isotope studies on a variety of Scourie dykes. A sample from the Poll Eòrna dyke, which retains some primary igneous mineralogy, gave a mineral isochron age of 1982 ± 44 Ma, whereas the moderately amphibolitized 'graveyard' dyke gave an isochron age of 1758 ± 7 Ma based on the metamorphic minerals. This latter age was considered to represent the timing of metamorphic recrystallization during the Laxfordian event. However, a two-point Rb-Sr age of 2027 ± 11 Ma was also obtained for the 'graveyard' dyke, and Waters *et al.* (1990) thus interpreted both dykes to have been emplaced at *c.* 2000 Ma.

It is clear from wider studies in the North Atlantic cratons that several different mafic dyke-swarms were intruded into Archaean basement terrains during the Palaeoproterozoic. Bridgewater *et al.* (1995) showed that their ages ranged from 2500 Ma to 1900 Ma with high-Mg basic dykes intruded between 2500 Ma and 2200 Ma, and tholeiitic swarms intruded at 2200 Ma in southern Greenland and Labrador. These swarms were emplaced largely under tensional conditions with localized sinistral shearing. However, the thick dykes of the younger (*c.* 2000 Ma) Kangamiut Dyke Swarm are composed of Fe-enriched hornblende-bearing tholeiites. They are found widely in southern and central Greenland, and were emplaced into the craton at the time of continental break-up. The dykes were subsequently spectacularly deformed and metamorphosed by the Nagssugtoqidian Orogen between 1870 Ma and 1750 Ma (van Gool *et al.,* 2002). The later *c.* 1835 Ma Avayalik Dyke Swarm in the northern part of the Nain Province in Labrador appears to have been emplaced synchronous with tectonometamorphic orogenic activity in the Torngat Orogen and emplacement of calc-alkaline plutons (Bridgewater *et al.,* 1995).

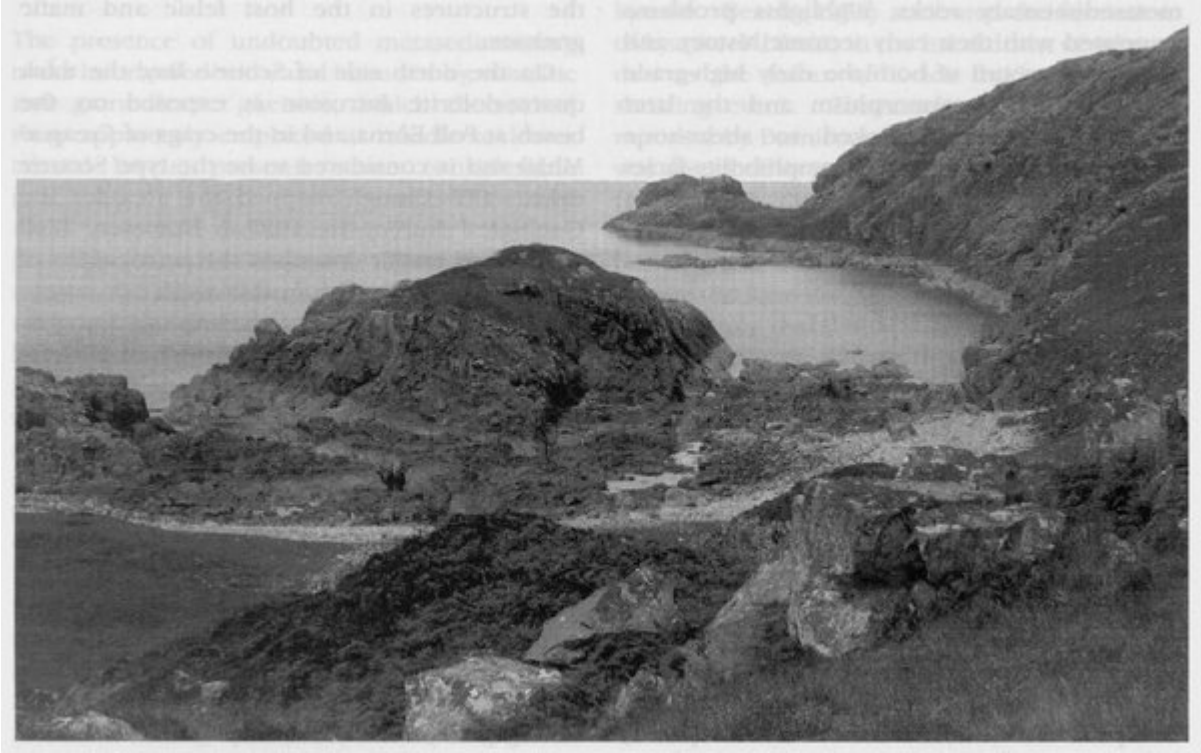
Conclusions

The Scourie Bay GCR site contains two excellent examples of metadolerite dykes of the Scourie Dyke Suite, with the Poll Eòrna dyke considered to be the type locality. Cross-cutting relationships between the quartz-dolerite dykes and their host Badcallian granulite-facies felsic and mafic gneisses are well preserved. The dykes contain remnants of igneous mineralogy in their central parts, but towards the margins they are more strongly foliated and retrograded to amphibolite. The varied geometry of the dykes, internal and external shear-zones, and the amphibolite-facies retrogression is well displayed at the GCR site. Most of this deformation and metamorphism occurred during the Laxfordian reworking, dated here at *c.* 1750 Ma. Following deformation, renewed growth of clinopyroxene and garnet occurred, generating very narrow discordant veinlets. The complex metamorphic history is best understood by combining data from the dykes and the host felsic gneisses. The site is of international importance, as the Scourie Dyke Suite forms part of a more-widespread and long-lasting Palaeoproterozoic metadolerite dyke intrusion event that occurred in Archaean basement areas of Labrador, Greeenland and Scandinavia. The Scourie Bay locality is excellent for teaching purposes and suitable for further studies.

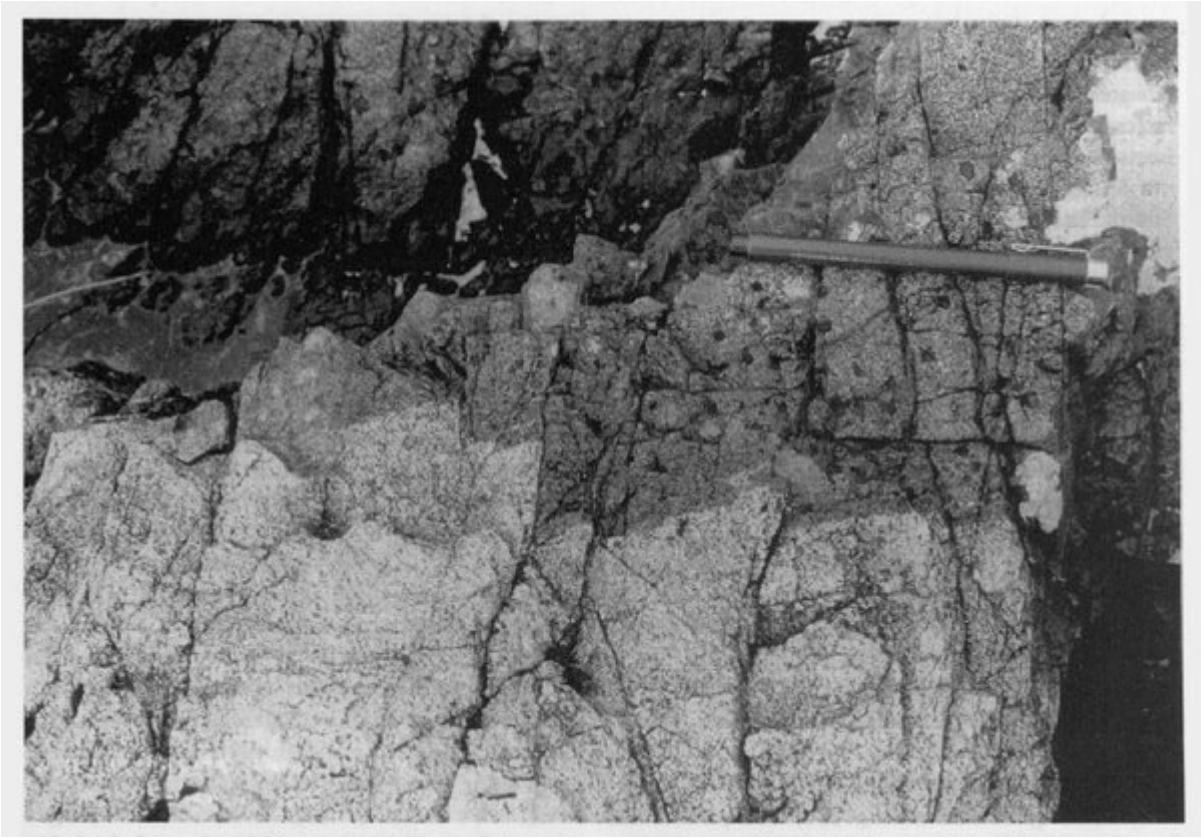
References



(Figure 3.4) Map of the Scourie area, including the areas covered by the Scourie Mor, Scourie Bay and Sìthean Mòr GCR sites. Based on the Geological Survey 1:10 560 sheets Sutherland 30 (1913), 39 (1912), and O'Hara (1961a).



(Figure 3.6) Poll Eorna and Creag a' Mhail, Scourie Bay. The notch in the distant promontory, the small bay in the middle distance, and the notch in the foreground, are all formed along the line of the type example of a Scourie dyke. (Photo: British Geological Survey, No. P001655, reproduced with the permission of the Director, British Geological Survey, © NERC.)



(Figure 3.7) Small satellite Scourie dyke showing cross-cutting relationship with the gneisses, about 150 m NNW of the gate at Scourie graveyard, Scourie Bay. The dyke is amphibolitized and has small, rounded garnet porphyroblasts. It also has a steep contact displaced by several minor faults, which seem to be related to early joints in the gneisses. The pen is 15 cm long. (Photo: C.R.L. Friend.)