Sìthean Mòr

[NC 150 460]

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Introduction

Rocks of undisputed original sedimentary origin constitute only a small proportion of the granulite-facies gneisses in the Central Region of the Lewisian Gneiss Complex. The most abundant metasedimentary rocks occur as inter-banded and lenticular small units of brownish-weathering gneissose to schistose semipelite and pelite that have been derived from aluminous siltstone and mudstone protoliths. A notable concentration of these pelitic rocks occurs on Sìthean Mòr; on the north side of Scourie Bay, where individual occurrences are up to *c.* 0.5 km long. These rocks and the adjacent orthogneisses have been the subject of detailed petrographical and geochemical studies (Beach, 1973, 1976; Okeke *et al.,* 1983; Barnicoat *et al.,* 1987). No calc-silicate rocks are noted on Sìthean Mòr, but Barooah (1970) has described calc-silicate rocks and possible meta-'arkose' from several localities south-east of Scourie. In addition, some unusual metasedimentary rock-types have been recorded in the Scourie area, such as a unit of banded-iron formation at Pairc a' Chladaich [NC 153 451].

The pelitic rocks have a relatively simple mineralogy when at granulite facies, but where they are cut by later shear-zones the mineral assemblages are retrogressed to amphibolite facies giving rise to a considerably more-complex mineralogy (Beach, 1973; Okeke *et al.,* 1983). Evidence for several significant mineral reactions is preserved, which was originally described by O'Hara (1961b). Subsequently, work by Barnicoat (1987) and Sills and Rollinson (1987) has elucidated a P–T path, tracking changes in pressure and temperature conditions for the metasedimentary rocks during both the original granulite-facies metamorphism and the later Laxfordian lower-grade shearing. These results link with work on the nearby banded-iron formation, which preserves evidence for very high-temperature metamorphic conditions (Barnicoat and O'Hara, 1979).

In the north-east part of the GCR site, a thick metadolerite dyke of the Scourie Dyke Suite cuts discordantly across the granulite-facies felsic gneisses and metasedimentary enclaves (Figure 3.4). The dyke shows evidence of localized deformation and metamorphism focused along narrow ENE-trending shear-zones, whose development is attributed to the Laxfordian event (see Scourie Bay GCR site report, this chapter).

Description

The Sìthean Mòr GCR site occupies a restricted area (*c.* 1km^2) of glacially scoured, rocky ground lying at between 75 m and 100 m above OD on the north side of Scourie Bay. It includes a small lochan beside which the metasedimentary rocks are well exposed at [NC 149 459]. The metasedimentary gneisses are coarsely foliated, light-to mid-brown-weathering, dark-grey rocks studded with dark-red garnets up to 1 cm across. They are interbanded with felsic and mafic banded gneisses that are essentially similar to, and contiguous with, the tonalitic, granodioritic, and more-mafic gneisses that occur in the Badcall and Scourie Bay GCR site areas. Both the metasedimentary and meta-igneous rocks show granulite-facies mineralogies and preserve extensive orthopyroxene, which is retrogressed to biotite + kyanite/sillimanite and to hornblende, respectively, in the hydrous shear-zones. The gneisses are cut by essentially undeformed but amphibolitized, ESE-trending mafic dykes of the Scourie Dyke Suite (see Scourie Bay GCR site report, this chapter). Several discrete ENE-trending shear-zones transect the gneisses in this area, and as they also cut the Scourie dykes, they are presumed to be Laxfordian (Palaeoproterozoic) in age.

Mineral assemblages in the granulite-facies metasedimentary rocks include orthopyroxene, garnet, antiperthitic plagioclase, quartz, and magnetite ± pyrite (Beach, 1973; Okeke *et al.,* 1983). Locally magnetite is the principal ferro-magnesian mineral. The orthopyroxene is relatively magnesian (En_{70}), and its modal composition shows an inverse relationship with quartz. It is comonly absent from the more quartz-rich rocks, in which garnet remains the stable phase.

Okeke *et al.* (1983) determined the major- and trace-element geochemistry of representative pelitic and semipelitic samples using XRF methods from the site area and from the Foindle area farther north. The two pelitic rocks from Sìthean Mòr have average SiO_2 values of 54.3%, Al_2O_3 values of 20.3%, and FeO + Fe_2O_3 values of 9.22%, confirming their iron-rich and aluminous nature. Average values for eight semipelitic rocks were 68.2% SiO_2, 16% Al_2O_3, and 3.6% FeO + Fe_2O_3. Zinc and barium both showed notably high values also. The metasedimentary rock analyses are distinct from those of the host tonalitic and granodioritic gneisses and accord with typical values for pelitic rocks (Okeke *et al.,* 1983).

The granulite-facies rocks commonly show little internal compositional banding, but this develops as the rocks become progressively foliated in the steeply dipping amphibolite-facies Laxfordian shear-zones. Beach (1973) carried out detailed petrographical work on both the granulite- and amphibolite-facies metasedimentary rocks and carried out electron microprobe analyses on some of the minerals. He noted that, as the rocks pass into the shear zones, orthopyroxene disappears, garnet abundance increases and biotite becomes the dominant mineral. In these sheared rocks, Beach (1973) recorded the presence of kyanite, spinel, corundum, staurolite, opaques, muscovite and epidote with minor accessory green spinet, dark-brown perovskite and apatite. He used the mineralogy to determine the likely sequence of metamorphic reactions that had occurred in the metasedimentary rocks during this retrograde alteration. He concluded that the shear zones had focused water-rich fluids and that metamorphic changes had occurred at temperatures of *c.* 600° C and pressures of *c.* 6 kbar.

Interpretation

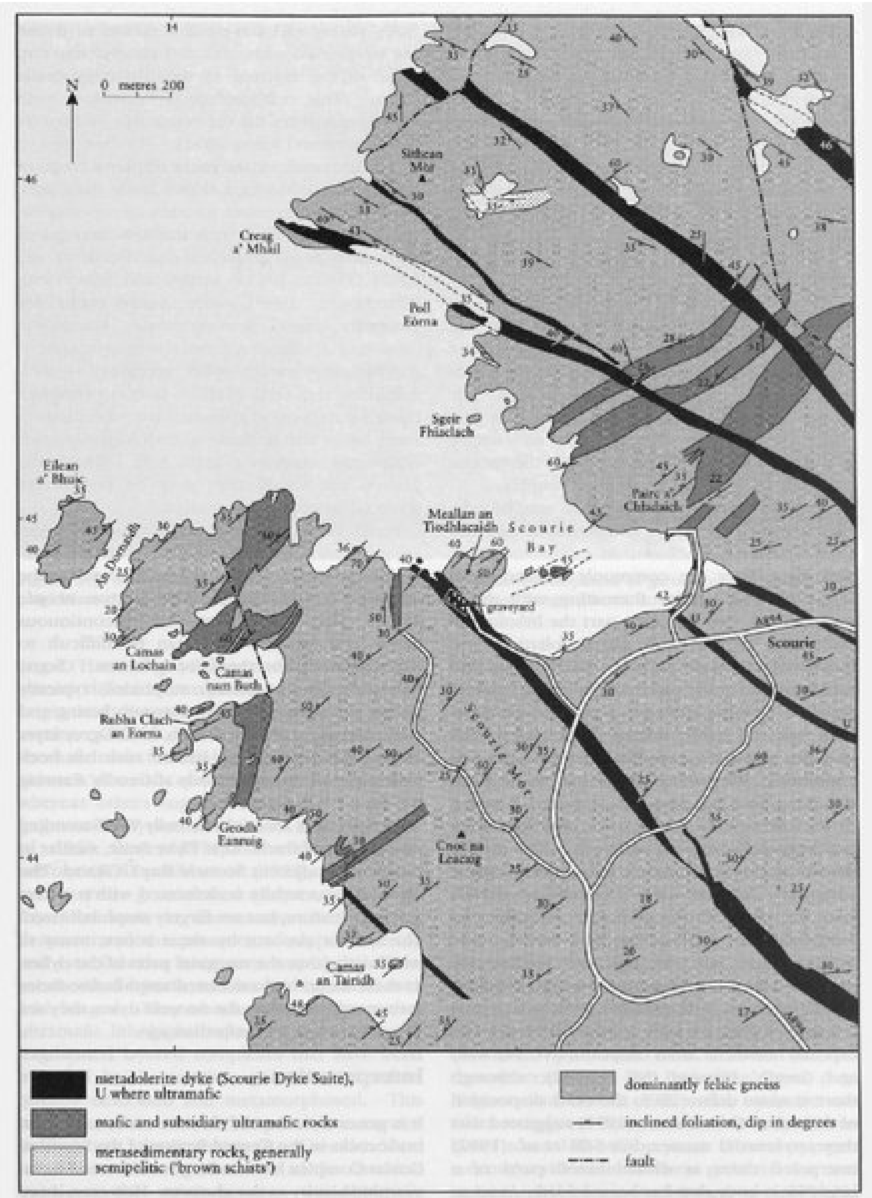
The presence of undoubted metasedimentary rocks interleaved with, and intruded by, tonalitic and granodiorite gneisses, which themselves were apparently emplaced at middle to lower crustal levels, presents some considerable problems. It is clear that the metasedimentary rocks were laid down on the Earth's surface, probably as marine deposits. Then they were transported down to some 25+ km, where they were intruded by the meta-igneous rocks, and a little later subject to granulite-facies metamorphism. Where they are associated with layered ultramafic rocks an argument can be made that the metasedimentary rocks were deposited on oceanic crust and the two units were subducted to mid- or lower crustal levels (Tarney and Weaver, 1987a). Where metasedimentary rocks occur as isolated lenses and accumulations amongst the felsic and mafic banded gneisses their original depositional environment is unclear, and evidence of subduction is lacking. It is tempting to view the metasedimentary rocks as having been deposited in a later Proterozoic basin and subsequently juxtaposed tectonically with the older Archaean elements, as in the Loch Maree and South Harris metasedimentary belts. However, this explanation is clearly untenable in the Central Region where the protoliths of the felsic and mafic gneisses were emplaced at *c.* 3000 Ma (Friend and Kinny, 1995; Kinny and Friend, 1997), and granulite-facies metamorphism occurred at *c.* 2700 Ma and *c.* 2490 Ma (Corfu *et al.,* 1994; Friend and Kinny, 1995). The corollary of this association of metasedimentary rocks and lower crustal intrusions is that plate-tectonic systems probably did not operate in the same way as at present. Crustal thicknesses, subduction patterns, heat flow, and depths of magma generation were probably different in Archaean times to those that prevailed in Proterozoic and Phanerozoic times.

The metasedimentary rocks of the Slthean Mor GCR site admirably display both granulite-and amphibolite-facies mineral assemblages. Beach (1973) documented the main mineralogical changes in the Laxfordian amphibolite-facies shear-zones as: orthopyroxene to biotite; garnet to biotite, aluminosilicate and epidote; and andesine and potash feldspar to a more albite-rich plagioclase. Kyanite and sillimanite both occur locally in the sheared rocks. Two explana tions have been put forward for the presence of kyanite. Beach (1973) attributed the formation of kyanite + biotite to the breakdown of garnet, due to the influx of K-rich fluid during the shearing event. Conversely, in the examples reported by Barnicoat *et al.* (1987), the kyanite was described as partly defining a flat-lying fabric (ascribed to the Badcallian event), which is cross-cut by a steeper fabric interpreted to have been formed during the Inverian event. If the kyanite did form during the Badcallian event, this would imply that it was stable under granulite-facies conditions. Clearly this has significant P–T implications, as the assemblage orthopyroxene + kyanite requires pressures of at least 12 kbar at 950° C. It is perhaps significant that detailed U-Pb SIMS ion-probe dating from a sheared gneissose pelite has shown that monazite inclusions within granulite-facies garnets are of Archaean age, whereas monazites within the kyanite and in the matrix are Proterozoic in age (Zhou *et al.,* 1997b).

Conclusions

The Sìthean Mòr GCR site contains some of the best-documented exposures of metasedimentary rocks within the granulite-facies tonalitic and granodioritic gneisses of the Central Region of the Lewisian Gneiss Complex. The metasedimentary rocks, which probably originated as aluminous siltstones and mudstones, lie in juxtaposition with gneissose meta-igneous rocks that were intruded at mid- to deep crustal levels. This highlights the problem as to how metasedimentary rocks could be transposed from the Earth's surface to moderate or deep crustal levels. The lack of associated mafic–ultramafic bodies, as found farther north in the Tarbet to Rubha Ruadh GCR site, seems to preclude the metasedimentary rocks from having been originally associated with oceanic crust. Although subduction processes were active in the Archaean, no structural evidence of such processes is preserved in these rocks. The metasedimentary rocks preserve mineral assemblages that reveal the pressure and temperature conditions of the early Archaean granulite-facies metamorphism. They also document some of the stages of hydrous metamorphism under amphibolite-facies conditions that took place during the generation of shear zones during the Palaeoproterozoic Laxfordian event. The site is nationally significant in that it demonstrates the unequivocal nature of the metasedimentary rocks, highlights problems associated with their early tectonic history, and provides a record of both the early high-grade granulite-facies metamorphism and the later partial retrogression linked to shear-zone formation under lower-grade amphibolite-facies conditions.

[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).