Gruinard River

[NG 980 886]–[NG 964 841]

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Introduction

The importance of this large and rather remote site, inland from Gruinard Bay, is that it exposes the transition between the Central and Southern regions of the mainland Lewisian Gneiss Complex. The tripartite division of the mainland outcrop into Northern, Central and Southern regions was first made by Peach *et al.* (1907) and was re-emphasized by Sutton and Watson (1951). The Central Region was viewed as a 'Scourian' block, metamorphosed under granulite-facies conditions, cut by undeformed mafic dykes of the Scourie Dyke Suite, and only locally affected by Laxfordian metamorphism and deformation, whereas the Northern and Southern regions were effectively regarded as Laxfordian orogenic belts in which the Scourian rocks together with the Scourie dykes had been thoroughly reworked.

Unlike the northern margin of the Central Region, which is separated from the Northern Region by a major shear-zone (the Laxford Shear Zone; see Tarbet to Rubha Ruadh GCR site report, this chapter), the southern margin is a transitional zone extending over several kilometres and can be adequately studied only in the good exposures south of the Gruinard River. In the northern part of the site, near the Gruinard River, Badcallian gneisses form a large-scale agmatite complex, in which blocks of amphibolite and older gneiss occur as rafts in leucotonalitic ('trondhjemitic) gneiss. Farther south, the gneisses are progressively deformed by NW-trending folds, and an accompanying foliation is developed that becomes more intense to the south-west. Scourie dykes in this part of the area are undeformed and show strong discordance in places, indicating an Inverian age for the NW-trending structures. This part of the site marks the north-east margin of a wide zone of Inverian reworking that extends southwards to the southern limit of the mainland Lewisian outcrop, a distance of about 40 km, with only a few small enclaves (such as that of An Ruadh Mheallan in the Diabaig GCR site) revealing the pre-Inverian structure. Towards the south-west boundary of the Gruinard River GCR site, and beyond, towards Fionn Loch, the Scourie dykes are progressively affected by Laxfordian deformation, which also imposes a new foliation in the gneisses.

The site also contains the enigmatic and stratigraphically important 'Gruinard assemblage' of amphibolite and siliceous schist, regarded by some as the equivalent of the Loch Maree Group, but whose relationships with the Inverian foliation and Scourie dykes suggest an older age.

The area was first mapped by W. Gunn and B.N. Peach in 1891 for the Geological Survey, and was described in the resulting memoir by Peach *et al.* (1907). It was remapped and described by Crane (1973, 1978) and Davies (1977). The agmatite complex in the northern part of the area, which represents a zone of very low Laxfordian strain, has attracted particular interest (Davies, 1977). Detailed geochemical studies have been carried out by Rollinson (1987), Rollinson and Fowler (1987), Fowler and Plant (1987) and Whitehouse *et al.* (1996). More recently, abundant U-Pb and Sm-Nd dating studies have investigated the evolution of the gneisses in the area (Whitehouse *et al.,* 1997a; Corfu *et al.,* 1998; Love *et al.,* 2004).

Description

The Gruinard River GCR site extends south-west of the Gruinard River in a roughly kilometre-wide strip for some 3.5 km to include the rocky outcrops that make up Creag-mheall Beag [NG 9745 8615] (348 m above OD) and cross the Uisge Toll a' Mhadaidh. It then dog-legs some 4 km to the south to include the steep north-western craggy and grassy slopes of Beinn a' Chàisgein that rise from 200 m above OD to *c.* 625 m. The description below focuses on the north-east part of the site where the gneisses show the effects of Inverian deformation and folding but are largely unaffected by the Laxfordian reworking (Figure 3.16).

Typical Badcallian gneisses are exposed on Creag Fiaraich, immediately west of the Gruinard River at [NG 980 880]. Here the country rocks are grey, coarse-grained, tonalitic ('trondhjemitic) and granodioritic gneisses, typically biotite-bearing (Rollinson and Fowler, 1987). The foliation has a general NNE trend, but is very variable in detail. These felsic gneisses contain many inclusions of both mafic and ultramafic material and tonalitic gneisses, which vary in size from a few centimetres to several hundred metres (Figure 3.17). The mafic and ultramafic inclusions are mainly composed of amphibolite, but metaperidotite and meta-pyroxenite are also found (Davies, 1977). Banded, biotite-rich tonalitic gneisses are also found at a few localities as inclusions within the felsic gneisses (Rollinson and Fowler, 1987). These relationships are considered to represent a large agmatite complex, showing a complete gradation from large bodies of amphibolite and tonalite with leucotonalite veins through to leucotonalitic gneiss with dispersed blocks of amphibolite and tonalite (Rollinson and Fowler, 1987). All the major rock-types in this area show indications of relict granulite-facies metamorphism (Field, 1978; Rollinson and Fowler, 1987), although there appears to have been a general retrogression to amphibolite facies prior to the intrusion of the Scourie Dyke Suite.

South of Creag Fiaraich, about 1 km from the Gruinard River, large-scale Inverian folds with steep NW-trending axial surfaces affect the steep, N-trending Badcallian gneissose banding. The folding is shown by the outcrop pattern of the bands of agmatitic gneiss (Figure 3.16) that can be traced southwards across the site. Good examples are seen on Creag-mheall Beag, around Lochan Dubh, and north of Loch a' Mhadaidh Mor (Corfu *et al.,* 1998). Smaller-scale folds ranging from a few centimetres to several metres in amplitude, with steeply plunging axes and a variably developed axial-planar foliation are also seen. On the NW-trending limbs of the tighter folds, the gneissic banding is attenuated and transposed into a new finer-grained Inverian fabric defined by the amphibolite-facies mineralogy.

The gneisses are cut by numerous Scourie dykes with varying orientations (Figure 3.16). Crane (1978) recognized three periods of dyke intrusion, based on cross-cutting relationships. All the dykes exhibit amphibolite-facies metamorphic assemblages. The oldest dykes are metapicritic, now composed mainly of pale-green amphibole, chlorite and recrystallized plagioclase. These are cross-cut by the dominant members of the Scourie Dyke Suite; metadolerites or metagabbros, formerly termed 'epidiorites,' that are now metamorphosed to amphibolite or hornblende schist. Some of the dykes exhibit evidence of multiple intrusion, and in places igneous layering is recorded (e.g. at [NG 986 866], east of Creag-mheall Beag). Dykes of the third set are again metadolerites but clearly cross-cut members of the second set, for example, the thin E–W-trending dyke that crosses the Uisge Toll a' Mhadaidh, south of Creag-mheall Beag (Figure 3.16). The general dyke pattern in this area is largely unaffected by later deformation, and is dramatically different from that seen in the Laxfordian areas farther south, such as around Gairloch and Diabaig, where the mafic dykes are generally sub-parallel to one another and strike north-westwards. Here, the trend varies from north-west to west and the margins are commonly highly irregular (Figure 3.16). Several of the large metadolerites form complex branching networks. A good example with several branches 100 m or more in thickness lies immediately south of Lochan Giubhais [NG 978 872] (Figure 3.16).

The dykes are typically undeformed, with chilled margins, and exhibit clearly discordant relationships to both the Badcallian and Inverian foliations. Although in some parts of the area there is a crude concordance between the NW-trending dykes and the Inverian foliation, local discordance is nearly always present. Some dykes exhibit narrow marginal shear-zones and, in places, thin dykes are crossed by a sigmoidal foliation. There are also a few narrow cataclastic zones, which cut and displace the dykes.

A rather enigmatic group of rocks, described in detail by W Gunn (in Peach *et al.,* 1907) and termed the 'Gruinard assemblage' for the purpose of this account, forms a broad, WNW-trending band south-west of the Loch a' Mhadaidh Mor (Figure 3.16). It is cut and displaced by a NNW-trending crush belt at the Uisge Toll a' Mhadaidh but can be traced for a further 3 km to the southeast. The main rock-type is amphibolite, which encloses bands of quartz-schist, and various types of hornblende schist containing quartz, biotite, chlorite, epidote and garnet in varying proportions. These rocks are cut by a Scourie dyke of the second (metadoleritic) set, which is clearly later than the banding in the 'Gruinard assemblage'. The assemblage appears from its outcrop pattern to be discordant to the overall banding in the felsic gneisses, and is interpreted as post-Badcallian in age.

Interpretation

The Badcallian felsic and mafic gneisses in the northern part of the site have been studied intensively, since they represent an area of relatively low Laxfordian strain in which some of the intrusive relationships of the gneisses have been preserved. Rollinson and Fowler (1987) studied the agmatitic gneiss complex, which they concluded was formed by the intrusion of leucotonalitic and granodioritic magmas into older tonalitic gneisses and amphibolites. These rocks were then subsequently metamorphosed under granulite-facies conditions, before being retrogressed to amphibolite facies. On the basis of geochemical data, Rollinson (1987) and Rollinson and Fowler (1987) suggested that the amphibolites were derived from a complex mantle source, possibly representing fragments of ocean crust. The tonalitic and leucotonalitic magmas were derived by partial melting of a basaltic source that may be represented by the amphibolites.

Whitehouse *et al.* (1996) also studied the geochemistry and Sm-Nd isotopic systematics of rocks from the Gruinard Bay area, and concluded that the older amphibolites were formed at *c.* 2940 Ma, with the leucotonalitic magmas forming at *c.* 2800 Ma by melting of a basaltic parent, possibly equivalent to the most light REE-enriched components of the amphibolite suite. The *c.* 2800 Ma age for the leucotonalitic gneisses was supported by U-Pb dating of zircons, which yielded ages in the range 2850–2750 Ma (Whitehouse *et al.,* 1997a). Slightly younger U-Pb TIMS zircon dates for the leucotonalites of *c.* 2730 Ma have been obtained by Corfu *et al.* (1998), who also obtained dates in the range 2825–2790 Ma for the amphibolites. Corfu *et al.* suggested that the 2730 Ma dates represent a period of metamorphism and magmatism, but Love *et al.* (2004) have used U-Pb SHRIMP dates on zircons from Gruinard Bay gneisses to argue that granulite-facies metamorphism occurred at 2730 Ma, and that the leucotonalitic gneisses were formed significantly earlier at *c.* 2850 Ma. Many of the above authors also noted that there is no geochronological evidence in this area for a metamorphic event at 2490 Ma (Inverian) as near Scourie (see Badcall and Scourie Mor GCR site reports, this chapter).

A regional study of the sense of shear in narrow shear-zones throughout the Southern Region by Park *et al.* (1987), found that zones in the northern part of this GCR site fall into two distinct groups; those with NNW trends showing a dextral sense, and those with WNW trends showing a sinistral sense. These narrow shear-zones thus appear to form a conjugate set indicating north-east–south-west compression. They are the only signs of Laxfordian deformation in the northern part of the site, but towards the south-west the Scourie dykes become foliated and the Laxfordian foliation becomes more pervasive and intense. The dykes become thoroughly deformed around Fionn Loch several kilometres to the south-west.

Gunn (in Peach *et al.,* 1907) was unable to reach a firm conclusion on the origin of the 'Gruinard assemblage' of amphibolite and siliceous schists. He pointed out that, although some of the rock types are similar to the metasedimentary rocks and basic meta-igneous rocks of the Loch Maree Group to the south, they could also be explained by quartz veining and shearing of the amphibolite. The 'Gruinard assemblage' appears to cross-cut the Badcallian banding and is itself cross-cut by a Scourie dyke which is clearly later than the banding and dominant foliation, regarded by Crane (1973) as Inverian in age. The dominant foliation apparently grades into the Inverian foliation outwith the assemblage. Crane (1978) referred to these rocks as the 'Gruinard metasedimentary rocks and basite', and regarded them as equivalent to the Loch Maree Group. However, if they are indeed correlatives of the Loch Maree Group, they should be post-Inverian and their foliation should be Laxfordian, not Inverian. This apparent paradox highlights the problems presented by strict reliance on the use of the Scourie dykes as stratigraphical markers, particularly in view of their large range of likely emplacement ages (*c.* 2400–2000 Ma). Consequently, for the present, the stratigraphical significance of the 'Gruinard assemblage' remains uncertain.

Conclusions

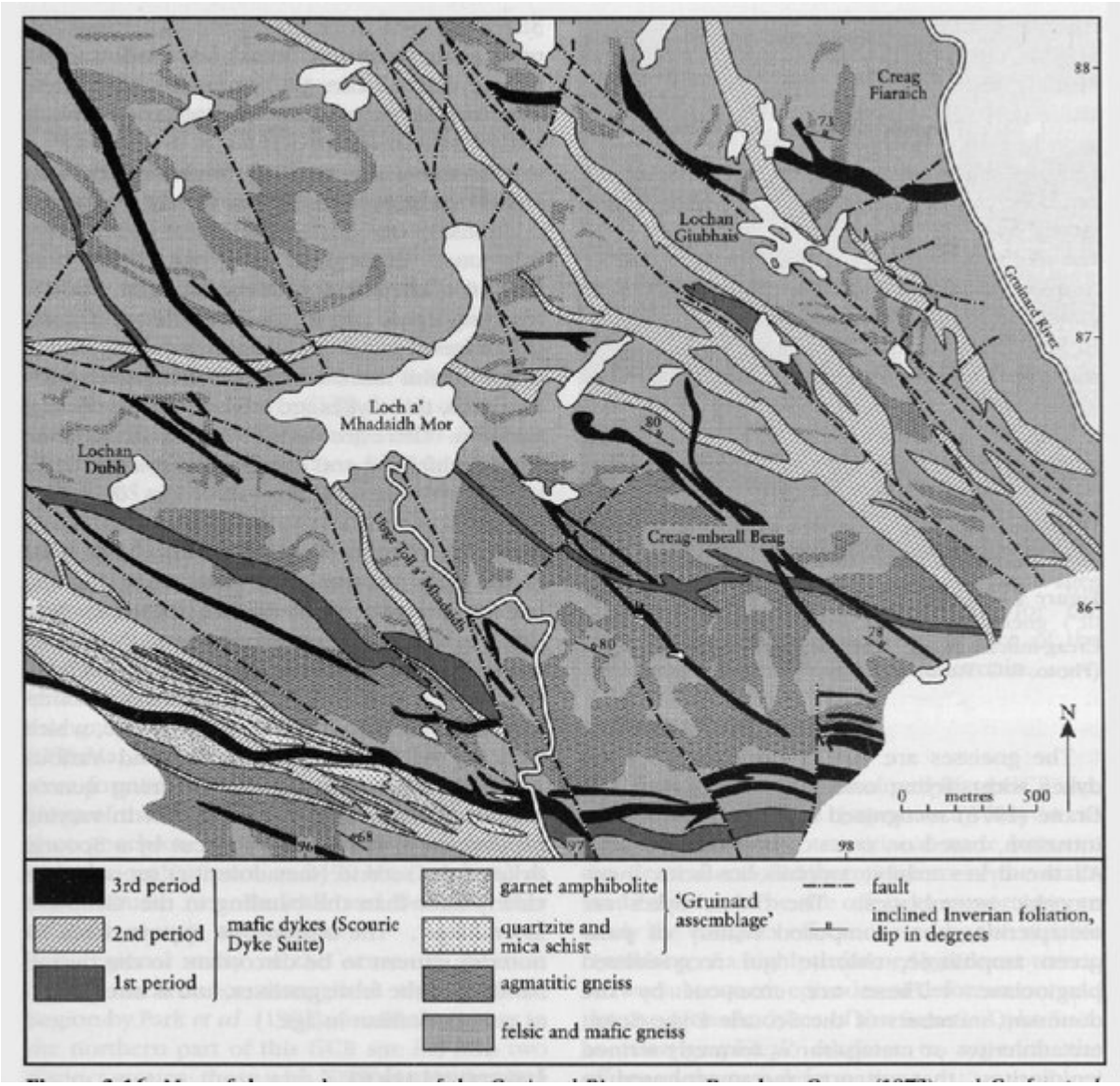
The significance of the Gruinard River GCR site, which is of national importance, lies in its position within the transitional zone between the Central and Southern regions of the mainland Lewisian. The site offers an opportunity to study the complex effects caused by the variable reworking of a highly deformed gneissose terrain in two subsequent episodes of deformation, and the use of mafic dykes of the Scourie Dyke Suite as 'stratigraphical' markers to separate the effects of the two deformations.

The original intrusive relationships of the gneisses can be clearly studied in the northern part of the site, which has not been significantly affected by Inverian or Laxfordian deformation. Farther south however, the site contains the north-east

margin of a wide zone of Inverian deformation and reworking that extends for at least 40 km to the south-west, and the relationships between the Badcallian and Inverian structures are clearly evident. Because of the absence of pervasive Laxfordian deformation, the site is also an excellent area for studying the complex outcrop patterns, mutually cross-cutting relationships, and marginal shearing of the three generations of Scourie dykes recognized in this part of the Lewisian Gneiss Complex.

Another important feature of the site is the presence of the stratigraphically important 'Gruinard assemblage', thought by Crane (1978) to be equivalent in age to the Loch Maree supracrustal sequence, but whose relationships to the Inverian foliation and Scourie dykes suggest an older age. Despite its moderately remote location, this is the most accessible locality where these important rocks can be studied.

References



(Figure 3.16) Map of the northern part of the Gruinard River area. Based on Crane (1973) and Corfu et al. (1998).

(Figure 3.17) Tonalitic and granodioritic ('trondhjemitic') gneiss containing abundant mafic enclaves, Creag-mheall Beag. The map case is 33 cm deep. (Photo: R.G. Park.)