Quoich Spillway

[NH 071 024]

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Introduction

The Quoich Spillway GCR site, situated at the eastern end of Loch Quoich, provides a *c.* 175 m-long continuously exposed section across the Quoich Granite Gneiss and adjacent Moine metasedimentary rocks. The rocks dip steeply to the ESE and lie at the eastern margin of the 'Steep Belt' on what is termed the 'Quoich Line' (Clifford, 1957; Johnstone *et al.,* 1969; Roberts and Harris, 1983). This structural feature marks a change from steeply dipping, tightly folded, dominantly Glenfinnan Group pelites, semipelites and psammites to the west, to more gently dipping, open to tightly folded, Loch Eil Group psammites to the east. The Quoich Granite Gneiss is part of the West Highland Granite Gneiss Suite, which outcrops over a wide area in Inverness-shire between Strontian in the south and Glen Affric and Fort Augustus in the north. The suite comprises six major granite gneiss bodies and numerous smaller sheets, mostly intruded close to the boundary between the Glenfinnan and Loch Eil groups (Johnstone *et al.,* 1969; Johnstone, 1975; see also Fassfern to Lochailort Road Cuttings GCR site report, this chapter). U-Pb zircon isotopic data indicate a *c.* 870 Ma, Neoproterozoic age for the granite gneiss suite (Friend *et al.,* 1997). The Quoich Spillway site enables evaluation of the geological setting of the West Highland Granite Gneiss Suite and its role in the early tectonothermal evolution of the Moine Supergroup.

The Quoich Dam area was mapped by A.L. Harris for the Geological Survey in 1961, but more-detailed work was undertaken by A.M. Roberts as part of a PhD study of the stratigraphical and structural significance of the Quoich Line (Roberts and Harris, 1983; Roberts, 1984).

Description

The spillway at the Loch Quoich Dam exposes Moine rocks of the Lower Garry Psammite and the Garry Banded formations separated by a sheet of Quoich Granite Gneiss (Figure 8.11). The bedding and foliation are steeply inclined to subvertical. The upper, western 100 m of the spillway expose mainly psammites and quartzites of the Lower Garry Psammite Formation. Roberts and Harris (1983) interpreted this unit as a transitional lithology marking the Glenfinnan Group-Loch Eil Group boundary, but here it is assigned to the Loch Eil Group (see 'Introduction', this chapter, and (Figure 8.3)). The rocks display a uniform, centimetre-scale lithological layering suggestive of high tectonic strain, although locally a few highly deformed cross-beds can still be discerned. Two sets of folds are apparent: an early set of small-scale, steeply plunging, tight to isoclinal folds, and a later set of gently plunging, tight, asymmetrical folds which verge to the west. These fold sets have been assigned, respectively, to D2 and D3 deformation phases in this part of the Moine outcrop (Roberts and Harris, 1983; Roberts and Barr, 1988). Biotite and muscovite define a penetrative schistosity which is axial planar to the D2 folds. A 1 m-thick migmatitic pelite separates these psammites from the Quoich Granite Gneiss, which crops out in the lower 75 m of exposure in the spillway (Figure 8.11)a,b. The Garry Banded Formation crops out to the south-east of the granite gneiss and comprises psammite and gneissose pelite inter-layered on a centimetre-scale. Within the pelitic layers, quartzofeldspathic migmatitic segregations and veins are common and some veins are isoclinally folded, possibly by D2 structures. Roberts and Harris (1983) again interpreted these rocks as transitional between the Glenfinnan Group and the Loch Eil Group. The Upper Garry Psammite Formation, which consists of more-typical Loch Eil Group psammites, outcrops *c.* 500 m farther east (Roberts and Harris, 1983; Roberts and Barr, 1988).

The Quoich Granite Gneiss is a pale-pink to grey, foliated, medium-grained rock composed mostly of K-feldspar, plagioclase (oligoclase) and quartz with subsidiary biotite. Minor muscovite, garnet, ilmenite, pyrite and epidote also occur. The ubiquitous coarse gneissic foliation is defined by discontinuous biotite foliae and lenticular migmatitic quartz-feldspar segregations (Figure 8.12). Mafic selvedges around the segregations suggest that these probably formed

in situ by partial melting. F2 and F3 folds both deform the gneissic foliation. Contacts with the Moine rocks are sharp and concordant with the foliation, and there is no discernable increase in tectonic strain associated with either contact. Two metasedimentary enclaves, composed of psammite and quartzite with concordant hornblende schist, occur within the granite gneiss near its eastern boundary. Both enclaves are deformed by F2 folds. The foliation is locally re-orientated in a number of NW-trending sinistral shear-zones, notably in the central part of the granite gneiss outcrop (Figure 8.12). Some of these shear zones contain pegmatitic veins which apparently formed by localized segregation coeval with the shearing (Barr, 1985).

Concordant to slightly discordant sheets of hornblende schist, up to 4 m thick, occur within the Moine rocks and the granite gneiss (Figure 8.11)b. The hornblende schists are interpreted as deformed and metamorphosed mafic intrusions and several xenoliths of granite gneiss are seen in one sheet. In Coir' an t-Seasgaich, *c.* 1200 m ENE of the spillway, markedly discordant amphibolite dykes are seen cutting bedding in the Lower Garry Psammite Formation. These occur in the low-strain hinge zone of a large-scale F3 fold (Figure 8.11). Where F2 folds deform the hornblende schists, an S2 axial-planar fabric is produced.

The grade of metamorphism is difficult to evaluate because of the lack of aluminosilicate indicator minerals, but the presence of migmatitic segregations and possibly, localized partial-melting suggests that middle- or upper-amphibolite-facies metamorphic conditions prevailed prior to D2 deformation. The presence of aligned hornblendes within the S2 fabric, and segregations within the later crosscutting shear-zones indicates that amphibolite-facies conditions persisted during and after D2 deformation (Barr, 1985).

Within the Lower Garry Psammite Formation in the spillway section, several undeformed, N-trending pegmatites cut F2 folds, but are deformed by late kink-bands. The pegmatites were probably emplaced at a late stage of the Caledonian Orogeny. In addition, several 1–2m-thick, NE-trending microdiorite sheets, here largely undeformed, cut discordantly across the Moine rocks, the granite gneiss, and the amphibolites. They are members of the Silurian-age late Caledonian Microdiorite Sub-suite (Smith, 1979). Although their original igneous mineralogy has partially recrystallized under greenschist- and/or epidote-amphibolite-facies conditions, relict igneous features are typically preserved in their central parts. The sheets normally have coarse-grained central zones and marginal more-foliated zones, with biotite developed.

Interpretation

The significance of the site lies in the excellent exposure of a member of the West Highland Granite Gneiss Suite, intruded into lithological units that straddle the transition from Glenfinnan Group to Loch Eil Group rocks (Roberts and Harris, 1983). The main outcrop of the Glenfinnan Group comprises migmatitic, gneissose semipelite, pelite and micaceous and feldspathic psammite. In contrast the Loch Eil Group consists mainly of psammite and subordinate quartzite. The general lack of migmatization in the Loch Eil Group psammites is attributed to its relatively quartz-rich composition. The Moine sedimentary rocks were probably deposited in a variety of marine sub-environments (Strachan *et al.,* 1988), although primary sedimentary structures are generally absent around the Quoich Spillway, probably reflecting the high tectonic strain and extensive recrystallization.

The origin of the West Highland Granite Gneiss Suite has been controversial. Bailey and Maufe (1916) interpreted the southernmost body, the Ardgour Granite Gneiss, as a deformed, pre-metamorphic intrusion. Harry (1954) and Dalziel (1966) subsequently concluded that the Ardgour body formed *in situ as* a result of K-metasomatism of Moine (Glenfinnan Group) sediments during high-grade metamorphism. On the basis of limited chemical data, Mercy (1963) suggested that the Ardgour Granite Gneiss could have been magmatic in origin. Gould (1966), on the basis of a larger geochemical database, concluded that it has a uniform granitic composition, distinct from that of the adjacent Moine metasediments. However, he accepted Dalziel's field and petrographic evidence and suggested intrusion of an Al-undersaturated magma in order to retain a metasedimentary component in the bulk gneiss. To explain the presence of granite gneiss in areas of apparent low metamorphic grade, Harris (in discussion of Winchester, 1974) suggested that it could be a slice of pre-existing granitic basement tectonically emplaced into the Moine.

Barr *et al.* (1985) re-investigated the granite gneiss occurrences in the North-west Highlands and concluded that they represent a series of deformed and metamorphosed intrusive granite sheets. This is consistent with the absence of

transitional metasedimentary rock–granite gneiss contacts, the overall homogeneity of the granite gneisses, and its appearance as a weakly deformed granite in low-strain zones within the larger bodies. The granite gneisses record all the deformation and metamorphic episodes apparent in the adjacent Moine rocks, and hence their igneous precursors must have been intruded either prior to or during D 1. The lack of any thermal aureole suggested to Barr *et al.* (1985) that the granites were intruded into Moine rocks that were already undergoing high-grade metamorphism, thus indicating a syn-D1 rather than pre-D1 origin. The major-element and limited trace-element geochemical data are consistent with an origin by partial melting of Moine metasediments at a deeper structural level. The emplacement of the granite gneiss suite may have been controlled by the lithological contrast between the Glenfinnan and Loch Eil groups. Alternatively it may reflect a deep lineament in the basement to the Moine succession. The location of the granite gneisses within the Moine succession, rather than at its base, and their homogeneous character compared to the Lewisianoid inliers, shows that they cannot represent pre-Moine basement. Furthermore, granite gneiss–metasedimentary rock contacts lack the very high ductile strains that generally accompany proven allochthonous basement slices in the Moine (cf. Rathbone and Harris, 1979).

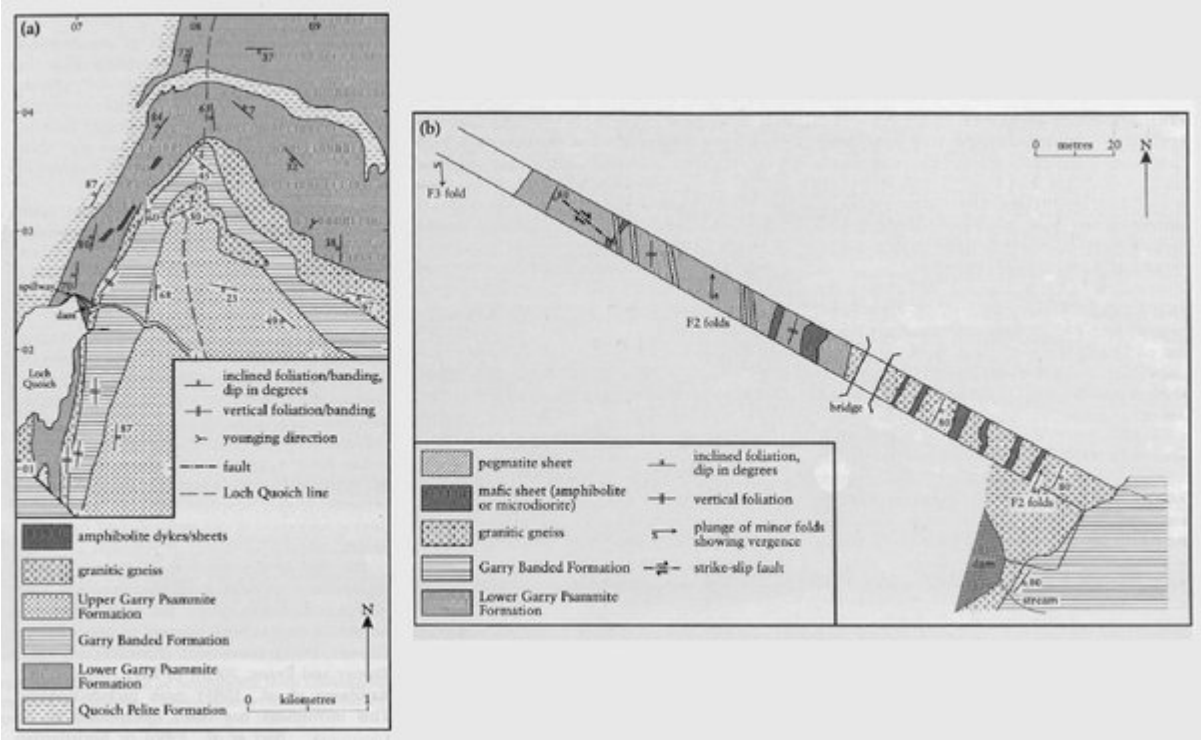
Isotopic data have consistently indicated a Neoproterozoic age for the high-grade tectono-thermal event, which resulted in formation of the granite gneiss suite (e.g. Brook *et* at, 1976; Piasecki and van Breemen, 1979a). Recent high-precision U-Pb SHRIMP and TIMS dating of single zircon grains from both the Ardgour and Fort Augustus granite gneisses indicated an age of *c.* 870 Ma (Friend *et al.,* 1997, Rogers *et al.,* 2001). This is currently regarded as the most reliable age of intrusion of the granite gneisses.

The age of D2 deformation in and around the granite gneiss is uncertain. D3 structures correspond to a phase of tight upright Caledonian folding, which resulted in the formation of the 'Steep Belt' (Roberts and Harris, 1983). The centimetre-scale lithological layering, notably flattened D3 fold style, and steep foliation attitude are characteristic structural features of the highly strained rocks within the 'Steep Belt'.

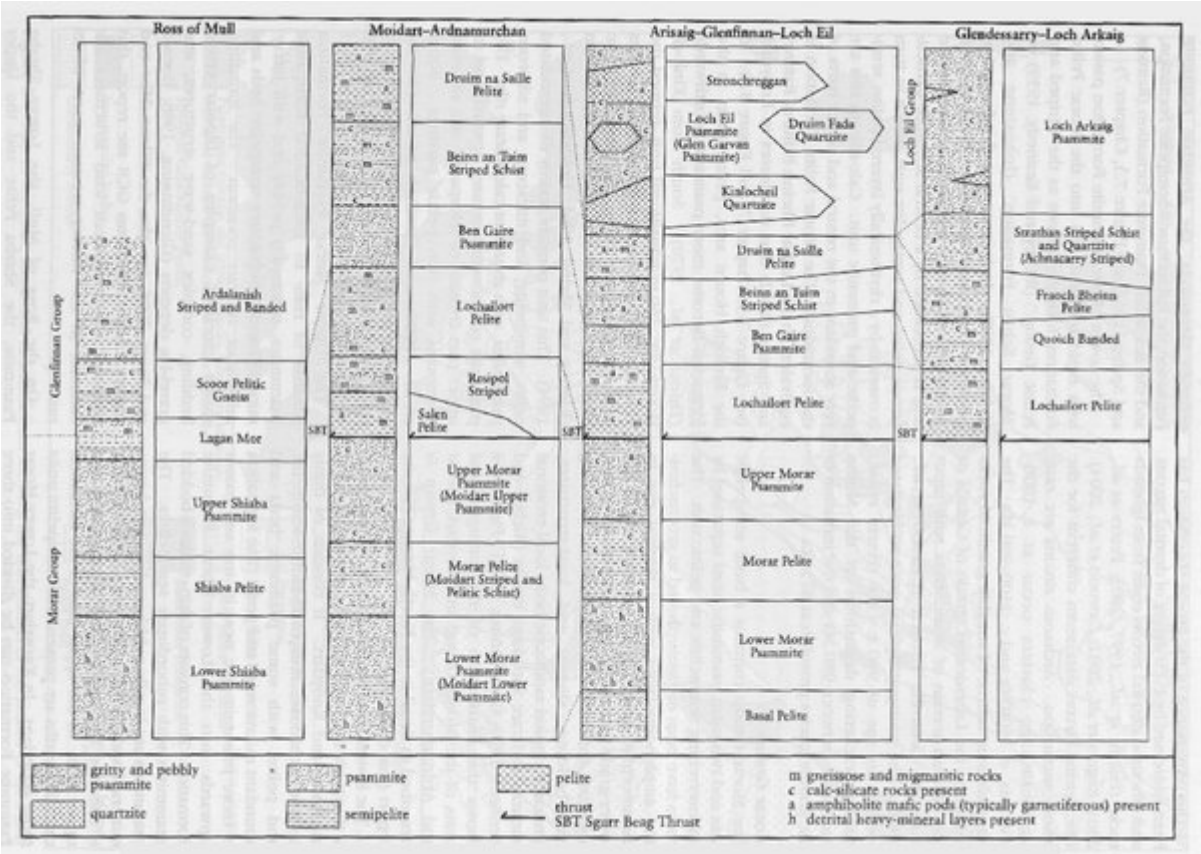
Conclusions

At the Quoich Spillway GCR site are excellent exposures of the Quoich Granite Gneiss, a member of the West Highland Granite Gneiss Suite, and its contacts with the host Moine metasedimentary rocks. The Quoich Granite Gneiss was intruded as a granite sheet into transitional psammite and semipelite units that straddle the Glenfinnan Group–Loch Ell Group boundary. U-Pb zircon isotopic dating indicates a Neoproterozoic age (*c.* 870 million years) for emplacement of the West Highland Granite Gneiss Suite, and clarification of its geological setting is crucial for understanding the early history of the Moine Supergroup. The contact relationships of the granite gneiss at the site are consistent with the view that it represents deformed and metamorphosed thick granite sheets, emplaced into the Moine rocks prior to or during earliest D1 deformation, accompanied by amphibolite-facies metamorphism and migmatization. The granite gneiss suite places important constraints on the age of deposition of the Moine Supergroup and the early D1 and D2 tectonothermal events; thus the Quoich Spillway GCR site is of international importance.

References



(Figure 8.11) (a) Map of the Quoich Spillway GCR site and surrounding area (after Roberts and Barr, 1988). (b) The local geological setting of the Quoich Spillway section (after Roberts and Barr, 1988).



(Figure 8.3) Tectonostratigraphy of the Moine succession within the Moine (South) area, showing the main formations.

(Figure 8.12) Typical aspect of the Quoich Granite Gneiss at the site, showing the gneissose foliation and migmatitic segregations deformed by a sinistral ductile shear-zone. The coin is 2.4 cm in diameter. (Photo: A.M. Roberts.)