# GLEN MORE

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## Introduction

The Ratagain pluton is distinctive among the late Caledonian intrusions of Scotland in having compositional features transitional between the alkaline intrusions of Assynt and the NW Foreland (see Chapter 7) and the more common metaluminous calc-alkaline intrusions of the Argyll and Northern Highlands Suite. In this sense it forms a link between these very different but near-contemporaneous periods of magmatism. The pluton shows considerable petrological variety in a small area (*c.* 17 km²), and also has some notable compositional characteristics, having among the highest known Sr and Ba abundances for such rock types anywhere. The presence of mafic (meladiorite) bodies and a degree of mingling between mafic masses and felsic magmas are well displayed, in common with several other plutons lying between the Great Glen Fault and the Moine Thrust. It is one of the few plutons in Scotland that hosts gold-bearing veins.

The pluton was first described by the Geological Survey (Peach *et al.*, 1910), and a detailed petrological account was presented by Nicholls (1951a, 1951b). An extension to the intrusion was recognized by Dhonau (1964), and the main pluton was characterized geochemically and isotopically by Halliday *et al.* (1984) and Hutton *et al.* (1993). A new map of the pluton, taking advantage of many new exposures associated with local forestry activities, has revised the various petrological facies and their distribution (Hutton *et al.*, 1993). Emplacement of the pluton in relation to movements on regional faults systems was the subject of a further study by Hutton and McErlean (1991).

The pluton was emplaced at 425 ± 3 Ma (U-Pb baddelyite age from the pyroxene-mica diorite facies; Rogers and Dunning, 1991). A Rb-Sr mineral-whole rock isochron age of 415 ± 5 Ma (Turnell, 1985) is now regarded as too young and is taken to reflect the fairly rapid cooling history of the complex. These data indicate that the pluton was emplaced more-or-less contemporaneously with late members of the Assynt alkaline suite such as the Ben Loyal syenite (van Breemen *et al.*, 1979a; Halliday *et al.*, 1987).

In recent years this pluton has contributed to the debate over the role of subduction in the origin of the Caledonian granites, the compositions of some components having been correlated with those of shoshonitic lavas, which tend to be associated with the deepest parts of subduction zones (Thompson and Fowler, 1986).

The Glen More GCR site contains all the important members of the pluton, as well as, at Braeside, the only outcrops of an olivine-gabbro component. The site includes the hillside of Moyle Wood in which various relationships between earlier and later members of the pluton are well displayed. Good examples of the small mafic bodies previously described as ‘appinites' are well exposed in the Glen More river.

## Description

The Ratagain pluton comprises principally diorites and quartz-monzonites (Figure8.5). The diorites tend to occupy the low ground around Glen More and the valley sides of Moyle Wood. These are cut by later quartz-monzonites which form the hill of Druim Sgurr nan Cabar, above the Bealach Ratagain, and its easterly slopes down to Loch Duich. Overall, the pluton has shallow-dipping walls, where they can be mapped, but the main internal contact between the diorite and the quartz-monzonite is rather steep. In the Glen More region, the present topographical surface appears to be nearly parallel to the roof of the diorite.

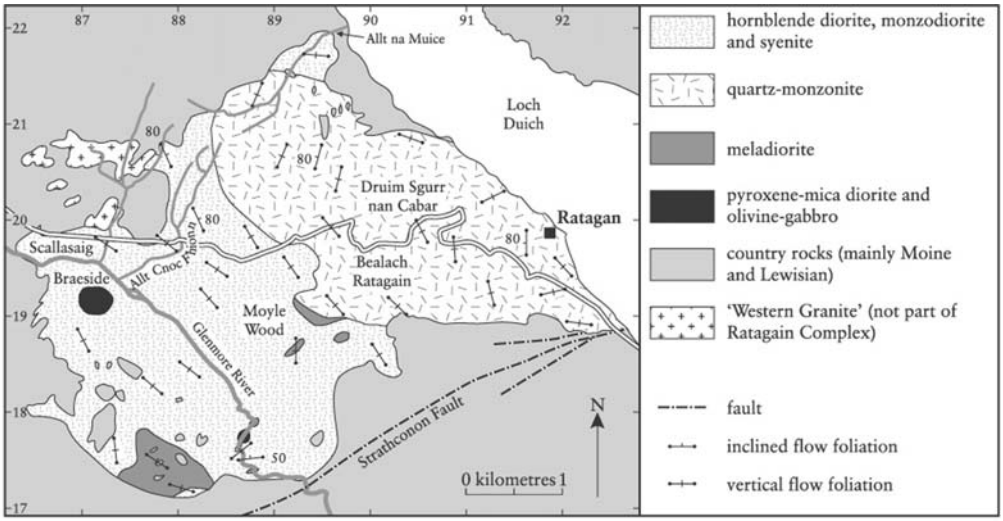


*Figure 8.5: Map of the Ratagain pluton, adapted from Hutton et al. (1993).*

The main diorite mass is highly xenolithic with abundant mafic-rich enclaves and some metasedimentary inclusions, all of which are well exposed in the Glen More river and in some tributaries such as the Allt Cnoc Fhionn. The diorites are usually medium grained with hornblende, biotite and plagioclase as the principal minerals, with accessory titanite and minor celestine. Compared with other diorites in the late Caledonian suites, these display considerable textural and mineralogical heterogeneity. One poor exposure of considerable petrogenetic importance in southern Glen More at Braeside is of pyroxene-mica diorite associated with olivine-gabbro (Figure 8.5).

Included within the diorite are large rafts of metasedimentary rock as well as mafic bodies originally described as ‘appinites' (Figure 8.6). However these ‘appinites' contrast strongly with the type appinites of Appin in Argyll in which amphibole is generally idiomorphic (see the Ardsheal Hill and Peninsula GCR site report). Amphibole is only rarely idiomorphic in the Ratagain rocks and biotite is more abundant than in the type appinites; hence the term meladiorite is preferred. These rocks are best displayed in forestry road cuttings in Glen More and in the woods to the NE. Some of the meladiorite masses may have been intruded in a solid state as pipe-like bodies facilitated by felsic magma. This is suggested by an exposure in a small quarry within Moyle Wood, where pillow-like meladiorite masses are vertically aligned within a monzonitic matrix. While most of these meladiorite bodies have igneous textures at least one example in the Glen More river is banded with layers containing abundant titanite poikilitically enclosed within large alkali feldspars. Petrographical and geochemical evidence indicates that some of these mafic masses may be the result of interaction between diorite and local calcareous metasedimentary rocks, as originally suggested byNicholls (1951a).

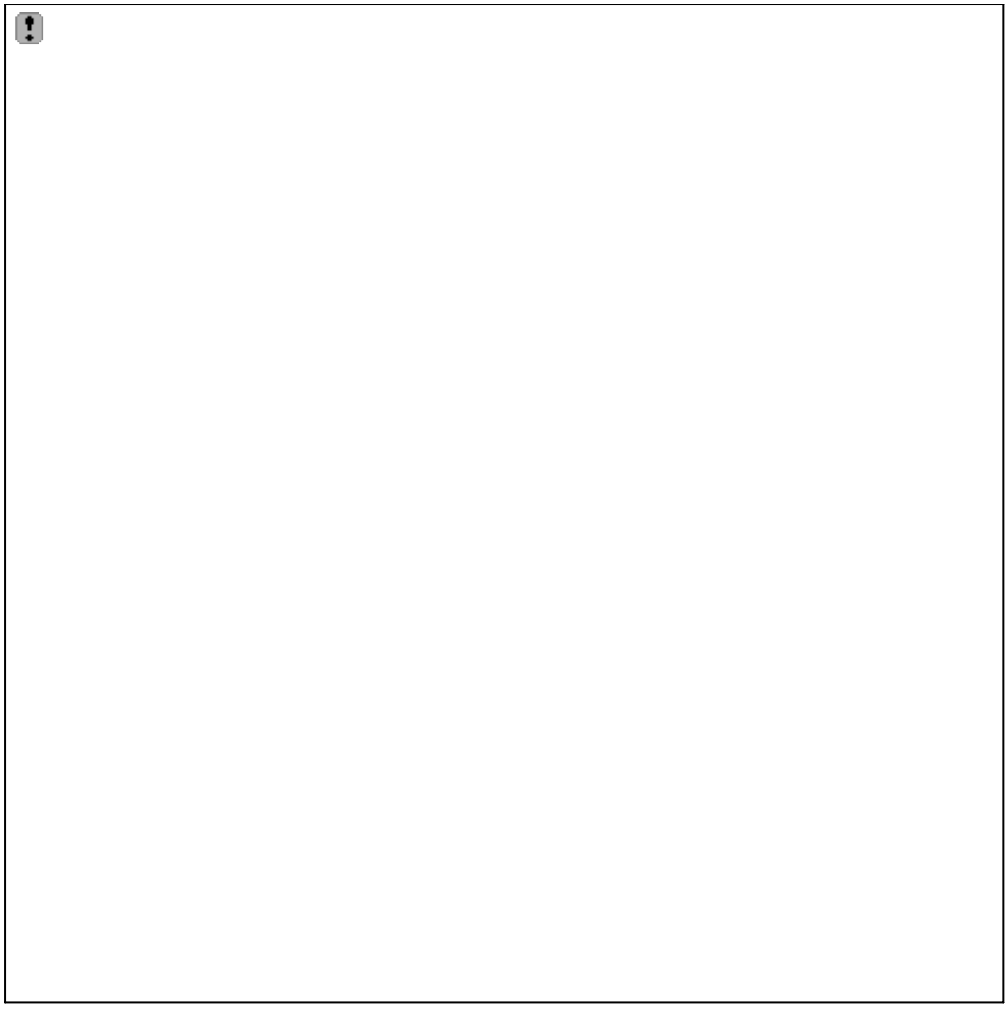

*Figure 8.6: Net-veined meladiorite ('appinite') from the Ratagain pluton. (Photo: W.E. Stephens.)*

The pink- or buff-coloured quartz-monzonites were intruded late (Figure8.5), and it is difficult to find sharp contacts with the earlier diorites, most being transitional over about 200 m. An approximate boundary zone can be traced in the cuttings of the Glenelg–Ratagain road and in the forestry tracks in the northern parts of Moyle Wood. Away from the contact, veins of felsic monzonites intrude brittle fractures in the diorites. The quartz-monzonite adjacent to the contact is rich in mafic minerals, bearing conspicuous hornblende-rich aggregates, and containing large meladiorite inclusions (up to 0.5 m) in places. Farther into the quartz-monzonites, i.e. towards the interior of the pluton, the abundance of quartz appears to increase, although this has not been quantified.

As discussed later, much has been made of the syenitic rocks within the Ratagain pluton (e.g. Thompson and Fowler, 1986). The petrological map of Nicholls (1951a) shows extensive outcrops of syenite in the Glen More and Moyle Wood areas of this GCR site. Exposures of syenitic rocks can indeed be found, for instance at the junction of the Allt Cnoc Fhionn and the main road, but all are small (metres scale) and enclosed within the more evolved diorites. Thus the syenite is regarded as a local facies rather than as a major member of this pluton (Hutton *et al.*, 1993). Nicholls' petrological map also indicates outcrops of 'Western Granite' to the NE of the Glen More river at Scallasaig, which were interpreted as the earliest member of the pluton (Nicholls, 1951a). Mapping by Hutton *et al.* (1993) and associated geochemical studies have shown that this granite is not part of the main Ratagain pluton.

## Interpretation

Strongly alkaline granites (*sensu lato*) are unusual and are normally associated with extensional tectonic environments, yet the contemporaneous alkaline syenitic rocks of Assynt

(some 100 km to the north of Ratagain) are clearly associated with regional movements on the Moine Thrust, so precluding an extensional origin (see Chapter 7).Thompson and Fowler (1986) highlighted the similarity of the Ratagain syenites with those of Glen Dessarry, Loch Borralan and Loch Ailsh and argued that they were derived from deep asthenospheric mantle sources in a subduction-related setting. However, most recent studies have shown the syenites to be a relatively insignificant facies of the Ratagain pluton and hence they cannot be representative of the mass as a whole (Hutton *et al*., 1993). An isotopic study of the whole pluton by Halliday *et al*. (1984) established that both mantle and crustal sources were involved in the genesis of the magmas, but detected no subduction-related characteristics.

Compositionally the whole pluton has some most unusual features for a late Caledonian granitic intrusion. As well as unusually high levels of alkalis, especially $Na_2O$, the trace elements Sr (1000–5000 ppm), Ba (1000–6000 ppm), and Ce (representing the light rare earth elements, 70–400 ppm) are extremely high. These enrichments are not closely correlated, with higher Sr tending to be found in the diorites and Ba being enriched in the monzonites. The origin of this extreme enrichment in incompatible trace elements is still not resolved (Hutton *et al*., 1993). Such trace element characteristics in intermediate magmas are uncommon in typical subduction regimes, but are known from post-subduction and ridge-subduction systems (Saunders *et al*., 1987).

The variety of igneous rocks in the pluton is greatest in the Glen More area, virtually spanning the whole range. Olivine-gabbros and pyroxene-mica diorites near the outer contact at Braeside have quenched magmatic textures and thus provide evidence of potential parental basic magmas to at least some facies within the pluton (Hutton *et al*., 1993). The more basic rock types at Ratagain, including the pyroxene-mica diorite and meladiorite have unambiguous mantle isotopic signatures, which vary sufficiently to suggest that the mantle sources were heterogeneous. The more evolved rock types, including the quartz-monzonites and some diorites, have isotopic signatures that indicate interaction with crustal sources, though not the local metasedimentary rocks (Halliday *et al*., 1984). The syenitic rocks, which Thompson and Fowler (1986) regarded as K-rich shoshonites with a mantle origin, are in fact more sodic than potassic and are probably local variants of the diorites.

Nicholls (1951a) explained the variety of rocks in the pluton in terms of the co-existence of a calc-alkaline magma of ‘Newer Granite' affinity and an alkaline magma of Assynt and Ben Loyal affinity, which underwent extensive hybridization, both at depth and after emplacement. Field evidence in Moyle Wood and in the road cuttings suggests that some hybridization has occurred between the diorites and the quartz-monzonites, and it is likely that the quartz-monzonites have also undergone some fractional crystallization.

A further unusual feature of this pluton in the context of the late Caledonian granitic suites is the rather oxidized condition of the magmas, with the presence of sulphates (celestine and baryte) in the igneous rocks. This condition in monzonites is known to favour the occurrence of gold (Cameron and Hattori, 1987), and indeed small amounts of gold mineralization have been described from late veins in the pluton (Alderton, 1986, 1988).

## Conclusions

The Glen More GCR site contains all the major facies of the Ratagain pluton, as well as providing constraints on some of the important field relationships between these members. This single, rather small intrusion is important for its unusual transitional alkaline composition and its implications for the plate tectonic environment of the NW Highlands during late Caledonian times. It has been constructed from magmas derived from a wide range of mantle and crustal sources and could be important in providing a better understanding of the relationships between thrust tectonics and the tapping of magmas from their source regions. The pluton is most unusual, not just in the Caledonian rocks of Britain, but worldwide, in having extreme enrichments of the trace elements Sr and Ba. There is no close analogue anywhere in the world and further studies will contribute to an understanding of this rare type of geochemical enrichment.

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