Clatteringshaws Dam Quarry

[NX 548 754]

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Introduction

The Fleet pluton

The Cairnsmore of Fleet pluton (nowadays usually called the Fleet pluton) is one of three large and several small granitic bodies in the Southern Uplands of Scotland that comprise the Galloway Suite. The pluton lies within a broad zone of ductile shear, the Moniaive Shear zone, that affects Llandovery age sedimentary rocks of the Gala Group (Phillips *et al.,* 1995a). Weak to moderately developed pre-full crystallization fabrics, transitional into high-temperature fabrics within the pluton and shear-fabrics within the contact aureole (Barnes *et al.,* 1995), argue the case for emplacement during the final stages of sinistral movement within the shear zone. The Orlock Bridge Fault, close to the NW margin of the pluton, is a late brittle structure that developed on the NW edge of the shear zone.

Most of the plutons of the Galloway Suite have similar mineralogical and compositional characteristics but the Fleet pluton is distinctly different. This uniqueness, coupled with its young age, has important implications for the petrogenesis of the relatively late Caledonian granites and the reconstruction of their plate tectonic environment. The pluton has two main granite facies, first established by Gardiner and Reynolds (1936), namely biotite granite and biotite-muscovite granite. The distribution of these facies was mapped by Parslow (1968) who further subdivided the biotite-muscovite granite facies into fine- and coarse-grained varieties, separated by a mappable sharp internal contact (Figure 8.31). Parslow (1971) also mapped the modal mineralogy and major oxide composition, and showed that some key parameters are concentrically zoned. The internal and external contacts were modelled from gravity anomalies, which suggest that the pluton continues to a depth of at least 11 km beneath the present surface (Parslow and Randall, 1973). In a regional study of the pluton and its environs Cook (1976) confirmed the general structure of the pluton and argued that extensive base metal mineralization in the south-western aureole is related to a shallow roof zone, in agreement with the sug gestion from gravity anomalies of a western extension of the granite and a subsurface cupola (Parslow and Randall, 1973).

In a regional context the Fleet pluton is petrologically and geochemically unique (Stephens and Halliday, 1984). It has many of the characteristics of S-type granites (Chappell and White, 1974), indicating derivation of the magmas from a metasedimentary source, unlike the other late Caledonian granites in Scotland, which are all I-type and derived from meta-igneous sources (Stephens and Halliday, 1984). Isotopic compositions are generally similar to the Lower Palaeozoic host rocks suggesting that such a pro-tolith may have provided a significant proportion of the granitic magmas from which the Fleet pluton crystallized (Halliday *et al.,* 1980).

The pluton has been dated by various methods. A U-Pb determination on zircon separates gave 390 ± 6 Ma (Pidgeon and Aftalion, 1978) within error of an Rb-Sr whole rock isochron age of 392 ± 2 Ma (Halliday *et al.,* 1980). A new unpublished zircon age is apparently similar (J. A. Evans, quoted by Barnes and Fettes, 1996). As the local metamorphic grade was low, these results establish the emplacement of this pluton at around 392 Ma, clearly Early Devonian, and the youngest reliably dated Caledonian pluton of mainland Scotland.

These data establish this pluton as somewhat anomalous in its context as a late Caledonian granite emplaced north of the Solway-Shannon line, which is usually taken as the line of the Iapetus Suture. Looking farther afield, the Fleet pluton is seen to have far stronger geochemical affinities with the plutons emplaced south of this line, that is those of the English Lake District and SE Ireland. It has been suggested that the source of the Fleet magmas was the same as those of the Lake District plutons (Stephens and Halliday, 1984) with the implication that magma genesis occurred after closure of the Iapetus Ocean and during underthrusting of the Southern Uplands by the leading edge of the southerly continent, and

this is supported by more recent Pb isotope data (Thirlwall, 1989).

The importance of this pluton is its unique age and composition for a northerly late Caledonian granite, and its affinity with its southerly equivalents. The pluton is likely to provide important constraints on the timing and structure of the end-Iapetus closure and collision events. Two GCR sites have been selected, one to represent the more primitive outer portions (Clatteringshaws Dam Quarry) and one to represent the more evolved central facies (Lea Larks).

Clatteringshaws Dam Quarry GCR site

The quarry and road cuttings at Clatteringshaws Dam (Barnes and Fettes, 1996) provide accessible and representative exposures of the marginal biotite granite facies of the pluton, which here is injected with aplite and pegmatite veins. The outer contact of the pluton with the metasedimentary rocks is also well exposed.

Description

The contact zone of the pluton is traversed by the road cuttings at Clatteringshaws Dam. Here the hornfelsed Silurian greywackes can be seen to dip northwards away from the pluton at about 40°, which is typical of that predicted by the gravity anomaly study (Parslow and Randall, 1973). The small quarry at Clatteringshaws Dam was cut in grey coarse-grained biotite granites, the outer facies of the zoned Fleet pluton, about 100 m from the outer contact (Figure 8.31).

This outer granite consists dominantly of alkali feldspar (microcline) and quartz. The alkali feldspars form quite large crystals (up to 5 cm) and are microperthitic; plagioclase is much less abundant and forms small crystals. Quartz forms large pools of strained polycrystalline aggregates. There is some biotite, usually chloritized, and some secondary muscovite replacing the alkali feldspars, but very few opaque minerals. The rock has a marked fabric with a strongly developed mortar texture in which strings of granulated quartz and mica develop around large 'islands' of alkali feldspar. This fabric gives the rock a foliation, obvious in the field, which can be traced throughout the pluton suggesting a relationship to its mode of emplacement. At this locality the foliation has a similar orientation to the foliation in the local hornfelsed country rocks.

Veins of aplite and pegmatite are common in both the quarry and the road cutting. The aplitic rocks are highly leucocratic bodies composed dominantly of alkali feldspar, plagioclase and quartz with minor chloritized biotite and accessory garnet. Analyses of these garnets show them to be unusually manganiferous (Macleod, 1992) and it is noteworthy that Tilley described similarly spessartine-rich garnets from garnet-rich lenticles within the Fleet aureole in his discussion of the paper by Gardiner and Reynolds (1936). The pegmatites are characterized by large alkali feldspars and quartz with some muscovite.

Interpretation

Studies of the composition of the pluton (Stephens and Halliday, 1979; Halliday *et al.,* 1980; Stephens and Halliday, 1984) showed that it is the most evolved of all the Galloway Suite plutons in terms of major oxide composition and Sr isotopes. Despite being relatively evolved, the granites at Clatteringshaws Dam are among the least evolved of the pluton, with about 69% SiO_2 (in contrast to the much more evolved granite facies at the Lea Larks GCR site with 76% SiO_2). Like most of the rocks in the pluton the granites here are corundum normative, reflecting the peraluminous composition and the dominance of micas among the mafic minerals. However, at this locality the abundance of normative corundum is low, at less than 1%. This granite also has the least evolved isotopic compositions of this pluton, with a $^{87}Sr/^{86}Sr$ initial ratio of 0.7062 (Halliday *et* ed., 1980) and ■Nd at this locality of –2.4 (Halliday, 1984). The oxygen isotope values for the whole pluton (including this site) are highly evolved, with $\delta^{18}O$ around 11‰, indicative of a source with a major sedimentary component (Halliday *et al.,* 1980). A lead isotope study (Thirlwall, 1989) showed that the Fleet pluton is enriched in $^{207}Pb/^{204}Pb$, a signature more typical of Lake District granites such as Skiddaw than the Scottish late Caledonian granites.

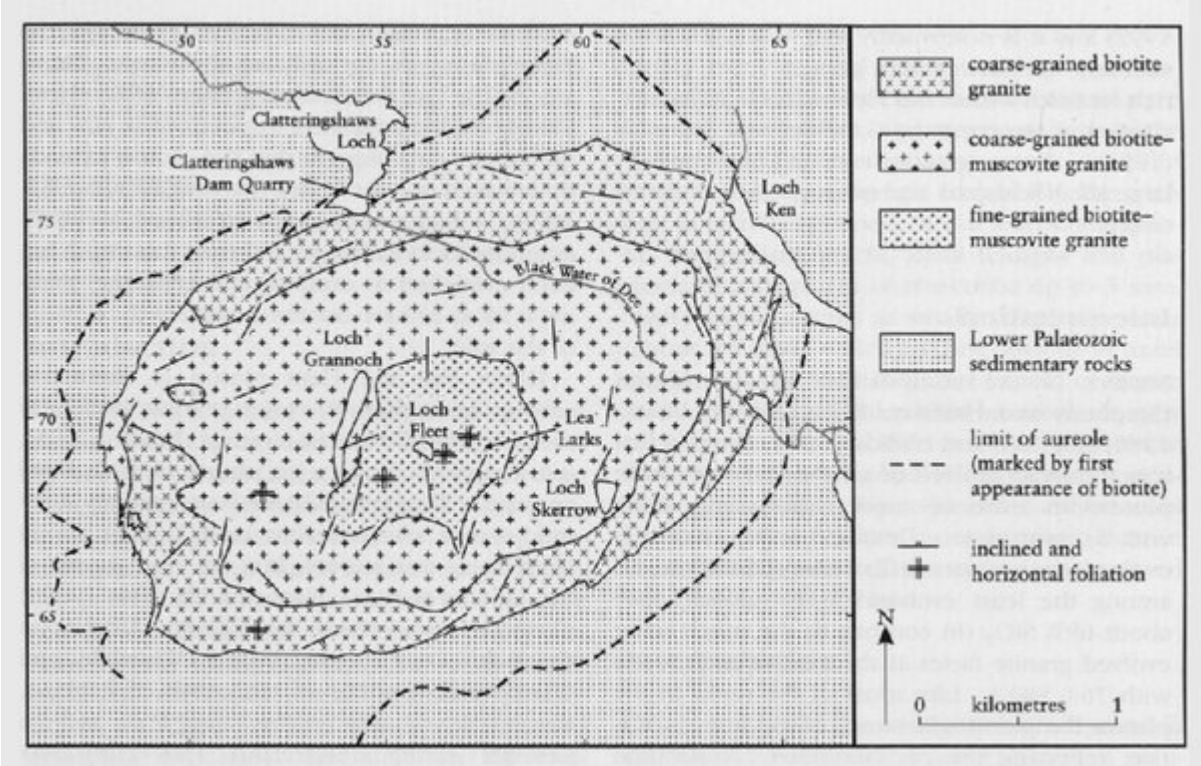
In a regional survey of the Scottish late Caledonian granites, Stephens and Halliday (1984) found that the Fleet pluton, and to a lesser extent the Criffel pluton, do not fit neatly into their classification (see Chapter 8: Introduction) and they were omitted. Most of the late Caledonian plutons are I-type granites, whereas Fleet has many of the important characteristics of an S-type granite (Chappell and White, 1974) indicating that a major part of its protolith was metasedimentary. This conclusion is supported by the Sr and oxygen isotopic data, which are also consistent with derivation of the magmas in large part from the local Silurian metasedimentary rocks. These data establish the Fleet pluton as the only wholly S-type pluton among the late Caledonian granites of Scotland. Clearly the magmas were not derived *in situ* and the gravity data suggest that the pluton extends downwards at least 11 km (Parslow and Randall, 1973). A thickness of Lower Palaeozoic metasedimentary rocks rather greater than this depth has been modelled to underlie this area, and melting is likely to have occurred towards the bottom of this pile.

Given that the Fleet pluton is distinctive among more than 50 major granitic bodies in the Scottish Caledonian terranes (Brown, 1991), it is important to place the pluton in its regional context. Two-mica Caledonian granites with mild S-type characteristics and lacking zircon inheritance are known, but not from north of the Iapetus Suture. Plutons with many similar characteristics include the Skiddaw Granite in the Lake District, the buried Weardale and Wensleydale granites of the north of England, the Foxdale Granite on the Isle of Man, and the Leinster Granite of SE Ireland. This strong association with plutons on the other side of the Iapetus Suture led Stephens (1988) to suggest that they had a common, rather young, immature sedimentary source and that they shared an end-closure tectonic environment in which the same source rocks became available on either side of the suture. This implies underthrusting of the southerly continent beneath the leading edge of the northern continent, i.e. beneath the Fleet pluton, and this is consistent with the geophysical interpretations of Beamish and Smythe (1986).

Conclusions

The Fleet granite pluton is unique among all the late Caledonian granites of Scotland, as a consequence of the change in source of magmas near the leading edge of the northern (Laurentian) continental landmass. Geochemical evidence strongly suggests an origin of the magma in rocks similar to those that currently host the pluton, but the pluton's rather greater affinity with those in the English Lake District points to a more southerly source. These associations have important tectonic implications for the events that followed closure of the Iapetus Ocean and the collision of the continents either side of the Iapetus Suture. The site is thus of major national importance for the conclusions that have arisen from mineralogical and geochemical studies of the rocks present.

References



(Figure 8.31) Map of the Fleet pluton, adapted from Parslow (1968), showing the locations of the Clatteringshaws Dam Quarry and Lea Larks GCR sites.