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Multiple magmatic lineages in calcalkaline spatially and temporally related granitoid suites: the example of the Arrochar and Garabal Hill-Glen Fyne intrusions of Scotland

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The Garabal Hill, Glen Fyne and Arrochar intrusions (ca 425 Ma) contain biotite- and hornblende-bearing I-type rocks, and are situated within the south-western Grampian Highlands of Scotland. They intrude Dalradian metasedimentary rocks of the Southern Highland Group. The Arrochar complex is composed of porphyritic gabbro, enclosing a small central mass of granodiorite. Minor bodies of quartz monzodiorite occur adjacent to the granodiorite and in small isolated outcrops within the main intrusion. Very small, irregular-shaped outcrops of diorite and gabbro are present both within the intrusion and the surrounding schists. Ultramafic rocks form dyke-like bodies adjacent to minor faults within the intrusion. Many small, satellitic diorite bodies crop out parallel to the long axis of the main Arrochar intrusion. The Garabal Hill complex lies roughly parallel with and $\sim$ 7 km to the north of Arrochar, adjacent to the Garabal Fault. All the rock-types at Arrochar also occur at Garabal Hill. The main rock-type in the Glen Fyne intrusion is a K-feldspar-phyric granite. A distinctive quartz monzodiorite occurs as a narrow southwest to southeast crescent within the intrusion. Minor bodies of pegmatite, leucogranite and granophyre are present at the highest topographic levels. The main granitoid rock masses in this area all contain igneous-textured, microgranular enclaves (typically $<$ 10 cm across and mainly rounded in shape) that are generally more mafic than their host rocks.

Geochemical data, portrayed on Harker plots suggest that all these intrusive bodies could be related by some fairly simple processes such as crystal fractionation. The coexistence of mafic (gabbroic to dioritic) and felsic (granodioritic to granitic) rock

types also suggests a possible role for magma mingling and mixing. In such models, the mafic to intermediate enclaves are commonly interpreted as intermediates in the mixing process – hybridised remnants of the mafic end member in the series. Here we pose the questions: are these simple models viable and what end members may have been involved in producing the magma series?

Backed up by detailed petrographic study of all the rock types, we have carried out geochemical and isotope (Rb-Sr and Sm-Nd) analyses of a large number of rocks from the area. These data are used to show that, far from being simple, the magmas must have been derived from several different source materials within the mantle and at least two crustal reservoirs as well. Additionally, we show that the enclave suite of the Glen Fyne granite does not form part of the host magmatic lineage. The enclaves represent a group of accessory hybrid magmas produced by mixing between a mantle-derived mafic end member (similar to some rocks of the Arrochar intrusion) and a granitic magma similar to the more felsic rocks of the Glen Fyne intrusion. The main trends for the Arrochar and Glen Fyne intrusions are also characterised by mixing between mafic and more felsic end members. Contrary to what might be expected in high-K calcalkaline series, it seems that the high K content in the magmas is derived from the mantle end member rather than directly from the crust. This could be a general feature in such suites. Finally, there is significant isotopic variation among the felsic Glen Fyne rocks. It seems likely that a good deal of the geochemical variation in all these magmas was either inherited directly from the protoliths (in the mantle and crust) or was produced by magma mixing. There is little evidence for crystal fractionation, though it probably occurred locally, to produce some of the most felsic magmas.