Geochemistry of microgranular enclaves and host granodiorite from Oledo, Central Portugal

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The Iberian massif corresponds to the southwestern extension of the European Variscan Belt. The Ordovician magmatism is rare in the Central Iberian Zone of this massif. A medium-grained biotite granodiorite from Lower Ordovician of 479-480 Ma crops out at the Oledo-Idanha-a-Nova pluton. It intruded the Cambrian schist-metagreywacke complex, is deformed and contains fine-grained biotite tonalitic and biotite granodioritic microgranular enclaves, which are darker and richer in mafic minerals than the host granodiorite. The microgranular enclaves show rounded or ovoid shapes, some of them irregular, having sharp, occasionally crenulated and diffuse contacts. Microgranular enclaves and host biotite granodiorite are peraluminous (A/CNK=1.00 to 1.13) and contain quartz, K-feldspar, albite-labradorite, amphibole, biotite, sphene, allanite, zircon, monazite, apatite, ilmenite and magnetite. Variation diagrams of the rocks and their biotite, sphene, allanite and ilmenite show trends of fractionation from tonalitic enclaves to host granodiorite. The rare earth element (REE) patterns are sub-parallel. All REE contents decrease, the negative Eu anomaly increases and anorthite content of plagioclase decreases from tonalitic enclaves towards the host granodiorite. Biotite composition shows fractionation with decrease in deformation of host granodiorite. The least squares analysis of major elements and modelling of trace elements indicate that granodioritic enclaves and host biotite granodiorite were derived from the tonalitic magma by fractional crystallization of plagioclase, amphibole, biotite and ilmenite. The $(^{87}Sr/^{86}Sr)_{480}$ ratio (0.7050-0.7067), εNd_{480} (1.56-3.46) and $\delta^{18}O$ (6.00-8.92‰) values indicate that they are I-type granitic rocks and contain a mantle component. The decrease in $(^{87}Sr/^{86}Sr)_{480}$, irregular variation of εNd_{480} and increase in $\delta^{18}O$ from tonalitic enclaves to host biotite granodiorite suggest that another mechanism has also occurred, probably mixing with other magmas or are related to deformation.

An integrated in-situ O, U-Pb and Hf isotope approach to decipher the petrogenetic evolution of granites

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The combination of in-situ O, U-Pb and Hf isotope analyses of zircon provides very powerful constraints on the sources, ages and evolution of granitoid magmas. This robust zircon record has been accessed at the intra- and inter-grain scale by combining SEM imaging with SIMS ($\delta^{18}O$ and U-Pb) and LA-MC-ICP-MS (Lu-Hf) micro-analysis. The combined information has been used to constrain crystallisation and crustal residence ages, magma sources and relative mantle and crustal contributions of late Caledonian 'I-type' granites of the Scottish Grampian Highlands, which were emplaced between 430 and 400 Ma following the c. 470 Ma Grampian Orogeny. These comprise two main suites based on whole-rock geochemical and isotopic data. This study focuses on granites and diorites of the 420 Ma Lochnagar and the 425-400 Ma Etive plutons (U-Pb ages), representing the Cairngorm and Argyll suites respectively. In both plutons high-precision SIMS oxygen isotope analyses have enabled us to recognise statistically distinct zircon populations (e.g. Lochnagar diorite: population 1: 6.6±0.4‰ (2σ), population 2: 7.4±0.4‰ (2σ)) that indicate the entrainment and mixing of distinct mafic and felsic lower crustal source components. The absence of pure mantle zircon populations ($\delta^{18}O$ (Zrc) = 5.3±0.3‰) indicates that none of the granites and diorites contain an identifiable unmodified mantle component.

In-situ Hf isotope data also show a large spread in both plutons (Lochnagar: εHf = +4 to -4; Etive: εHf = -2 to -8 (±0.7-1.0 εHf (2σ)). This variation is caused by mixing of several felsic crustal components of differing residence ages in the range ~1.2 – 2.0 Ga.

Thus, this approach is able to distinguish several different mixing events and provides insights into the nature and ages of the sources involved. It also shows that formation of the 430-400 Ma Caledonian granites in Scotland is dominated by crustal recycling rather than crustal growth.