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The origin of radiogenic isotope variability in granites: intracrustal recycling and/or juvenile crust production?

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Radiogenic isotope data determined at the crystal and sub-crystal scale has led to the recognition that isotope variability is commonplace in igneous rocks of intermediate to acidic composition. This evidence has often been considered as the smoking gun supporting the involvement of mantle-derived magmas in the genesis of many granites; with the implication that crustal growth is reflected in the genesis of felsic rocks exhibiting inter- and intra-crystalline isotopic diversity. Such interpretations overlook two important realities. Firstly, that granites and rhyolites, tap source rock volumes that are very unlikely to have been isotopically homogeneous. Therefore, some aspects of the isotopic variability recorded in granites may represent mixing between magmas produced by partial melting of isotopically diverse domains of the source. Secondly, typical source rocks also exhibit isotopic diversity at the mineral-scale that either may homogenize during the pre-anatectic metamorphic event, melting and magma extraction, or be transferred to the granite. The isotopic variability of the source may be a primary feature, such as in the case of εHf diversity among detrital zircons in metasediments, or be acquired by the source through time, as the result of isotopic ingrowth. When isotopic equilibrium between melt and crustal residue is not attained, the composition of the melt will be dependent on the isotopic compositions of the reactant phases, the stoichiometry of the melting reaction as well as on the amount of accessory phases that dissolve into the melt. In such situations, an individual source is able generating melts with different isotopic composition.

Here, I report two case studies. In the first one, the εHf range recorded by magmatic and inherited zircon in the S-type Peninsula pluton (South Africa) is investigated as a function of sample size. At all scales, the εHf variability in the magmatic zircon fraction (ca. 8 εHf units) matches well that portrayed by the time evolved inherited zircon population, suggesting that the εHf heterogeneity of magmatic zircon is inherited from the source. The model proposed involves dissolution at the emplacement level of detrital zircons within small magma volumes and crystallization of new zircon from these magma domains, prior to complete hafnium isotopic homogenization. In the second case, the extreme mineral-scale initial Sr isotope variability characterizing the Elba Island granitic complex (Italy) is explained by mixing between magma batches produced by disequilibrium melting of individual crustal sources. These batches represent discrete melting events taking place as the isotherms advance through the source: the earlier magmas represent lower-temperature melts while magmas developed later formed at higher-temperature.

The prime implication of these studies is that isotope variations in granitoids do not necessarily call for the involvement of a mantle-derived component. Substantial isotopic variation is to be expected in felsic magmas produced solely by reworking of crustal material, with no net crustal growth. Isotopic variability, generated during crustal anatexis, can survive magma segregation and ascent indicating the lack of pluton-wide homogenization occurring at the emplacement level.