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Isotopic heterogeneity in granites: melting or mixing?

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An ability to constrain models of granite magma formation is essential in investigating processes of crustal growth and evolution. Pb, Sr, Nd, Hf and O isotopic compositions of bulk rock samples and mineral phases have been important in the development of such petrogenetic models, yet it is now clear that these isotope systems can behave in a more complex manner during partial melting and crystallisation than is often assumed.

In a recent study, Iles et al. [1] examined a set of diverse granite samples from the Lachlan Fold Belt of southeastern Australia. They found that low temperature I- and S-type granites preserve linear variations on Harker diagrams and negligible covariation between O and Hf isotopes in magmatic zircon, which are inconsistent with assimilation or simple mixing hypotheses. Yet in these samples, differences between bulk rock and zircon ε_{Hf} compositions are commonplace, and are best explained by isotopic disequilibrium between the melt and the restite assemblage. $\Delta\varepsilon_{Hf}^{bulk\text{-}zircon}$ values measured in I-type granites (0.4-2.5) can be explained largely by disequilibrium amphibole dehydration melting of meta-igneous protoliths that have aged in the crust for 0.5-1.0 billion years prior to melting. For S-type magmatism the data and models suggest greater levels of complexity. The majority of S-type melting scenarios modelled (muscovite and/or biotite dehydration melting) predict negative $\Delta\varepsilon_{Hf}^{source\text{-}melt}$ values, and although samples from one of the studied suites are consistent with this view ($\Delta\varepsilon_{Hf}^{bulk\text{-}zircon}$ values -0.4 to -0.9), most actually record positive values (+0.2-1.1). A recently proposed hypothesis in which magmatic zircon acquires its Hf isotope composition both from the melt and from the inherited zircon population (Villaros et al. 2012, Farina et al. 2014) can explain why measured $\Delta\varepsilon Hf^{bulk\text{-}zircon}$ values could become positive in such rocks.

The results of our study of KB32 (from the Jillamatong granodiorite) do not support partial dissolution and re-precipitation of inherited zircons as a mechanism to explain isotope compositions in magmatic zircon. If such a process does occur, it is a subordinate aspect of magmatic zircon growth, and the impact on the isotopic composition of the grains is not sufficiently pronounced to be detected. Instead, the variation observed is more likely to be inherited from the granite source region.

Our research suggests that, for restite-bearing granites, the magmatic zircons do not accurately represent the protolith composition. Rather, the bulk-rock compositions of mafic granite samples might provide a better image of the source.

References:

[1] Iles K et al. (2015) In: *The 8th Hutton Symposium on Granites and Related Rocks*: PT.003

[2] Villaros A et al. (2012) Contributions to Mineralogy and Petrology 163: 243-257

[3] Farina F et al. (2014) Contributions to Mineralogy and Petrology 168: 1065