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Apparent crustal growth due to disequilibration crustal melting: evidence from the Lu-Hf isotope system in zircon

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The combined U-Pb-Hf analysis of zircon is a powerful, widely-used tool for studying the evolution of the continental crust through time. It allows for estimates of the proportions of new, primitive crust relative to the recycled, older continental crust for separate time slices from the Hadean through to the present. Though the general concept appears clear and straight forward, in reality there are many problems.

This study will focus on the possibility that many crustal melts do not reflect the isotopic composition of their source. Most granitic rocks contain inherited zircon in their zircon population commonly preserved as cores overgrown by newly crystallized rims. The Hf isotope composition of the rims usually represents that of the magma, which is either a mixture between mantle magma and crustal components or of pure crustal origin. Even in the latter case, the 176Hf/177Hf of the melt, as reflected by the zircon rim composition, will be more radiogenic than that of their average crustal source, as unradiogenic Hf is stored in the inherited cores. The effect will increase with the percentage of inherited, non-dissolved zircon and with the time since last isotope equilibration of the crustal source. This is because new 176Hf formed from Lu-decay usually readily enters the melt, as Lu is incorporated in phases other than zircon that are reactants in the melting process, while only a fraction of the Hf stored in zircon will be dissolved. Assuming a time span of 0.5 to 1.5 Ga since the last isotopic equilibration and dissolution of only 30 to 60% of protolith zircon in the melt, the Hf isotope composition of the melt will be about 3 to 24 epsilon Hf(t) (t= time of melting) units lower than that of the source. This relates to an overestimation of the T-DM(Hf) model age of 0.14 to 1.3 Ga. Using different examples from the recent literature, inherited zircon cores have at time of granite generation a mean epsilon Hf(t) of about -3 ± 3 to -22 ± 20, which is in average about 6-20 epsilon Hf units and 0.33 to 1.1 Ga (T-DM) lower than that of their magmatic rims. This correlates well with the mean U-Pb age of the cores, which are about 0.46 to 1.5 Ga older than that of their rims. Notably is also that the overall isotopic variation of the inherited cores is about 5-40times higher than that in the magmatic rims (e.g., ±0.7 epsilon Hf units).

As a consequence, estimation of the average crustal residence time (e.g. T-DM ages) based on the composition of the magmatic zircon will be too young and will thus usually overestimate the contribution of juvenile magmas to the system. Although granite magmas probably do not fully equilibrate with their sources, the data imply that crustal melting stimulates isotopic and chemical homogenisation of the crust.