Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.18004

Zirconium isotopes reveal continental crust recycling into the mantle

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The recycling of the crust into the Earth's mantle plays a crucial role in shaping the chemical heterogeneities of the planet's interior. Zirconium is a refractory and immobile element in fluids and its stable isotopes can be fractionated during magmatic differentiation. Therefore, Zr isotopes have the potential to be used to trace crustal recycling in the mantle. Here we conducted a survey of Zr isotopic systematics in oceanic island basalt (OIB) lavas collected from a range of mantle end-members with distinct geochemical and geological characteristics.

While most OIB lavas exhibit homogeneous $\delta^{94/90}$Zr (the permil deviation from the IPGP-Zr standard) values, high ^{3}He/^{4}He, HIMU and EM1 mantle sources show $\delta^{94/90}$Zr values that are relatively indistinguishable within error from the bulk silicate Earth estimate (i.e., 0.041 ± 0.041‰ [1]). In contrast, Samoan EM2 lavas display higher $\delta^{94/90}$Zr values (up to 0.194 ± 0.019‰). Additionally, the $\delta^{94/90}$Zr values of the Samoan EM2 lavas display a co-variation with ^{87}Sr/^{86}Sr and ^{144}Nd/^{143}Nd ratios.

Our analyses indicate that the elevated $\delta^{94/90}$Zr signature observed in the Samoan EM2 lavas is not a result of zircon saturation, mantle melting or shallow assimilation. Instead, the $\delta^{94/90}$Zr-^{87}Sr/^{86}Sr and $\delta^{94/90}$Zr-^{144}Nd/^{143}Nd trends are consistent with binary mixing between a slightly depleted mantle with lower $\delta^{94/90}$Zr and a recycled component from the upper continental crust (UCC) with higher $\delta^{94/90}$Zr. We calculated the $\delta^{94/90}$Zr of the recycled UCC material to be 0.35‰, which falls within the $\delta^{94/90}$Zr range of intermediate-felsic continental rocks.

Based on the $\delta^{94/90}$Zr-^{87}Sr/^{86}Sr array formed by the EM2 lavas, we infer that a continental protolith from UCC is the most likely origin for the isotopic composition of the Samoan EM2 mantle. This study demonstrates the potential of Zr isotopes as a tool for tracing recycling in the Earth's mantle and provides insight into the composition of the planet's interior.

Reference:

[1] S. Tian *et al. (2021) Earth Planet. Sci. Lett* 572, 117086.