Goldschmidt 2024 Abstract
https://doi.org/10.46247/gold2024.23651

Potassium isotope insights into the low-K/U mantle sources of oceanic island basalts

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Earth's K, U, and Th abundances profoundly impact its radiogenic heat production and dynamic evolution. Earth is depleted in the moderately volatile K relative to the refractory U and Th prior to or during its accretion; conventionally, its K abundance is extrapolated from the K/U ratio and U concentration [1,2]. However, Earth's mantle does not have a uniform K/U ratio; notably, the plume sources of ocean island basalts (OIB) have markedly lower ratios than the sources of mid-ocean ridge basalts (MORB) [3,4]. Constraining the cause of this difference is of first-order importance in establishing a representative K/U ratio for the mantle. Here, we analyzed stable potassium isotopic compositions (reported as $\delta^{41}K$, the permil deviation of the $^{41}K/^{39}K$ ratio from the NIST3141a standard) of 35 compositionally diverse French Polynesian OIB samples to identify the cause of low K/U ratios in their mantle sources. Our data reveal a substantial variation in $\delta^{41}K$, ranging from mantle-like to significantly higher values. The elevated $\delta^{41}K$ values do not correlate with radiogenic Pb isotopes and are inconsistent with the extremely low $\delta^{41}K$ values reported for eclogites, which are assumed to be remnants of subducted oceanic crust. By contrast, lavas from the Marquesas and Society islands (with high $^{87}Sr/^{86}Sr$ ratios) display broad positive correlations in $\delta^{41}K$ with U/K, La/K, and $1/K_2O$, trending from an ambient mantle composition to a low-K/U, high-$\delta^{41}K$ composition. These correlations suggest that the variation in K/U ratio is controlled primarily by K rather than U, and possibly reflects recycled sedimentary phases in the lower mantle.

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