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Do zinc isotopes tell the deep carbon story?

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Zinc isotopes in primitive magmatic rocks are increasingly used to investigate the origins of mantle heterogeneity. Of special interest are the high $d^{66}Zn$ values obtained for several OIBs and continental alkali basalts, and this signature hints at recycled carbon-bearing oceanic crust (including marine carbonate sediment) in their mantle sources. In contrast, other studies argue that large zinc isotope fractionation results from the peridotite melting process, based on correlations between the degree of partial melting and $d^{66}Zn$ of basaltic to komatiitic lavas. To further explore the utility of zinc isotopes in the study of deep volatile cycles, we investigate the $d^{66}Zn$ of kimberlites and lamproites from the Kalahari craton in southern Africa. These rocks formed by H_2O-CO_2 fluxed partial melting of metasomatized peridotite at >180 km depths, and their contrasting Sr-Nd-Hf isotopic compositions indicate distinct sources near the lithosphere–asthenosphere boundary. Both magma types contain notable amounts of magmatic carbonates with mantle-like $d^{13}C$ values.

In keeping with the discrete Sr-Nd-Hf isotope groupings, the kimberlites and lamproites have different $d^{66}Zn$ compositions, with median values of 0.33 ±0.07‰ (n=22) and 0.25 ±0.06‰ (n=18), respectively. They have low zinc concentrations (64 ±35 and 51 ±29 ppm), more similar to MORBs (64 ±25 ppm) than to OIBs (120 ±40 ppm). Given that the degree of partial melting is equally low for kimberlites and lamproites (<1%), our study provides evidence for significant zinc isotope heterogeneity in the deep upper mantle. Modeling shows that the kimberlite and lamproite zinc systematics fit with near-solidus melting of asthenospheric and refractory cratonic peridotites, respectively. The minor alkali-metasomatic components required to explain the petrology of lamproites do not influence the zinc systematics of carbonated mantle melts, probably owed to the compatible nature of zinc in mineralogically exotic metasomes. Although the origins of kimberlites and OIBs are frequently compared because of their apparent link to LLSVPs in the lower mantle, our dataset for African kimberlites lacks the anomalously high $d^{66}Zn$ values reported for OIBs (up to 0.4‰). This suggests that recycled carbon plays no important role in the formation of carbonated melts within the asthenosphere, in agreement with their mantle-like $d^{13}C$ compositions.