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A common source for strongly silica-undersaturated magmas: New insights from Zn-Fe isotopes of kimberlites

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Kimberlites contain distinct asthenospheric and lithospheric mantle components, but disentangling their relative importance is a challenging yet important goal in understanding potential temporal and spatial variations in the kimberlite sources. We analyzed the Zn-Fe isotope compositions of 56 globally distributed kimberlites previously well characterized for their bulk-rock major-trace and radiogenic isotope compositions. Unlike lithophile trace element isotopes, Zn and Fe should be less affected by complex cryptic metasomatic processes that affect the lithospheric mantle. The Zn-Fe isotopes of kimberlites in this study (δ^{66}Zn = 0.21-0.52‰; δ^{56}Fe = 0.02-0.28‰) define a strong positive correlation (R^2=0.87) from isotopically light compositions akin to cratonic peridotites to anomalously heavy compositions that are similar to those of melilitites and nephelinites globally. The Zn-Fe isotope compositions of kimberlites exhibit good correlations with whole rock Fe-Ti-Zn contents, Fe/Ti ratios, and, to a lesser extent, Sr-Nd isotopes. The correlation coefficients between δ^{66}Zn-δ^{56}Fe and incompatible trace element abundances decline with increasing incompatibility. These variations are best explained by mixing between compositionally similar primary kimberlite melts and cratonic mantle peridotites. Plots of Zn and Fe isotopes versus proxies of the degree of partial melting in mantle-derived magmas ranging from komatiites and picrites to nephelinites and melilitites show a progressive increase in δ^{66}Zn and δ^{56}Fe with decreasing extent of melting, so the relatively heavy Zn-Fe isotopes of primary kimberlite melt could be caused by low-degree partial melting of the asthenosphere. The similarities of trace elements and isotopes between primary kimberlite magmas and nephelinites and melilitites reveal that these strongly silica-undersaturated magmas tap a common and fusible mantle source with PREMA-like (Prevalent Mantle) characteristics. Partial melting of the common source under different melting conditions can produce the spectrum of mantle melts from kimberlitic to basaltic melts without necessarily invoking the compositional variations in the mantle source.