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Controls on the Zr Stable Isotope Composition and Variability of Earth's Upper Mantle

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Recent studies have shown that Zr stable isotope compositions vary in terrestrial igneous systems, both at the mineral and bulk-rock scales [e.g., 1, 2]. Nevertheless, the mechanism(s) driving this variability and the petrogenetic significance of fractionated compositions remain poorly understood. Critically, the Zr stable isotope composition and variability of mantle peridotites has not been directly studied, nor have the potential isotopic effects induced by mantle partial melting and/or refertilization been explored.

Orogenic peridotite massifs preserve an unparalleled record of the petrologic and geochemical development of the subcontinental lithospheric mantle (SCLM) [3], and are key to our understanding of the chemical and isotopic composition of the Earth. The Beni Bousera peridotite massif in the Betic-Rif belt, western Mediterranean, preserves an outstanding record of the petrologic processes that shape the SCLM. Correlations between major and trace elements, as well as variable modal abundances of Ol-Cpx-Opx, have been ascribed to variable degrees of melt extraction and/or re-fertilization *via* melt–rock reactions [4]. Clinopyroxene, the main phase consumed during partial melting of fertile lherzolites, is also the main reservoir of Zr in mantle peridotites. Therefore, reactions that consume or produce Cpx are likely to have an influence in the Zr isotope systematics of variably depleted upper mantle.

We find the Zr isotopic compositions of Beni Bousera peridotites, expressed as $\delta^{94/90}Zr_{NIST}$ [1], to span a range >0.7‰ and exhibit correlations with petrologic indicators of melt depletion and re-fertilization. Whereas the isotopic composition of fertile peridotites resemble those of komatiites and MORB [5], refractory harzburguites are isotopically heavier. We show that: 1) preferential Cpx removal during melting explains the Zr isotope composition of MORB; 2) Opx is an 'isotopically heavy' phase for Zr; and 3) isotope fractionation during peridotite melt depletion induces Zr isotope heterogeneity in the mantle.

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