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Non-traditional stable isotopes in the mantle

DMITRI A IONOV

CNRS-UMR5243, Géosciences Montpellier, Université de Montpellier

Stable isotope data complement conventional geochemical tracers of mantle processes (major and trace elements, radiogenic isotopes), and provide alternative means to examine some aspects of mantle geochemistry that are hard to address with conventional methods. Among them are better detection of subducted crustal components (because stable isotopes fractionate more at low than at high temperatures), and insights into non-equilibrium processes, like diffusion-driven exchanges with metasomatic media in the mantle. This talk examines the methodology and prospects of the application of stable isotope data to mantle samples.

Stable isotope variations in the mantle can be ascribed to three groups of processes: (1) equilibrium mass-dependent fractionation, e.g., melting of the asthenosphere; (2) disequilibrium mass-dependent processes based on faster diffusion of lighter isotopes along chemical gradients in minerals, magmas, fluids or at their interfaces mainly via metasomatism of peridotites; (3) additions of subducted crustal materials. An essential task is obtaining estimates for specific isotope systems in the Bulk Silicate Earth (BSE). These estimates are constrained using the most fertile mantle peridotites that suffered no or little melt extraction before their integration into the lithospheric mantle from the asthenosphere, and no metasomatism. Yet, the most common mantle lherzolites in peridotite massifs and among mantle xenoliths suffered too much melt extraction and/or infiltration to be representative of the BSE. Generic terms “Earth’s mantle” or “normal mantle” are inappropriate in this context and one should seek instead to define the isotope composition of specific mantle reservoirs, based on tectonic settings and history, like “MORB-source” or “subduction-zone” mantle.

Modeling of equilibrium isotopic fractionation during mantle melting in comparison to natural peridotite, MORB, OIB and IAB data on well-studied isotope systems (Mg-Fe-Ca-Cr-Zn...) shows that aspects of the natural data can be matched by equilibrium isotope fractionation during partial melting of peridotite and pyroxenite sources. Yet, many other aspects suggest that kinetic isotope fractionation, or additions of recycled crustal material may be required. Intensely discussed topics include the use of Ca and Mg isotopes to trace recycling of carbonates and other sedimentary rocks to the sources of mantle magmas ranging from E-MORB to IAB.