

A global overview of isotopic heterogeneities in the oceanic mantle

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Studies on modern oceanic lithosphere and ophiolites have revealed high degrees of chemical and isotopic heterogeneity in the mantle, as well as isotopic contrasts between mantle and crust. These features cannot be explained just by simple extraction of partial melt but require considerably more complex petrogenetic processes. Here we present an overview of the present knowledge on isotopic heterogeneities of Sr, Nd, Hf and Os in oceanic peridotites (by reviewing data on modern abyssal peridotites and the Alpine-Apennine ophiolites), and discuss their significance in terms of i) length scale and extent of isotopic heterogeneities in the upper mantle and ii) isotopic mantle-crust relations at oceanic settings. Overall results show that mantle peridotites record significant isotopic heterogeneity, detectable on a wide range of length scales, much larger than observed in associated MORB. In addition, abyssal peridotites are on average more depleted than MORB. The high degree of isotopic heterogeneity is clear evidence for the inefficiency of mantle convection in homogenizing mantle rocks. It may be caused by i) variably old depletion events (partly unrelated to recent MORB production), ii) pyroxenite components in the mantle source, iii) recent pre- and/or post-melting metasomatism. Some abyssal peridotites have extremely depleted isotopic compositions, not seen in MORBs, and these have been interpreted as the evidence for old (1 to 2 Ga) refractory domains in the asthenospheric mantle or, alternatively, as evidence for recent incorporation of (also old) subcontinental lithospheric mantle, potentially through delamination during continental breakup. The first hypothesis has been corroborated by finding, in a few ridge segments (e.g. Gakkel Ridge) of correlations between chemical fertility indexes and isotopic (Os, Hf) ratios, and this has been inferred to result from recycling of old residual oceanic lithospheric mantle into the MORB source. However, no general consensus exists yet on the two proposed models. The difference in average isotopic depletion between peridotites and basalts has been also ascribed to the presence of pyroxenites, which have “enriched” isotopic signature relative to the peridotite component. Because of the lower solidus temperatures of such pyroxenites, they may be preferentially sampled by mid-ocean ridge basalts. The origin and composition of such small-scale lithological heterogeneities remain however still controversial and poorly constrained, due to the difficulty to link petrologic and geochemical studies with direct field observations, and to the scarcity of chemical and isotopic data on pyroxenites in ophiolitic and abyssal peridotites, i.e. the closest available “proxies” of the MORB mantle. Larger isotopic homogeneity observed in MORB relative to peridotites in single ridge segments clearly reflect their origin as aggregated melts which inevitably “smooth” and average mantle source heterogeneities. Overall, the questions about the origin and spatial distribution of chemical and isotopic heterogeneities are not resolved, and this calls for detailed field-based studies in spatially-controlled settings to shed light on the issue of small-scale mantle heterogeneities and the role of enriched (e.g. pyroxenites) and highly depleted domains in MORB melting.