Extreme mantle heterogeneity preserved in Earth's oceanic crust

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Earth's oceanic crust, produced by melting of the upper mantle where it upwells beneath mid-ocean ridges, provides a geographically widespread elemental and isotopic 'sample' of Earth's mantle, preserving key information on planetary differentiation. The problem remains that mixing and reaction during melt ascent act to homogenise the chemical variations that Mid-Ocean-Ridge-Basalts (MORB) acquire. Primitive minerals in MORB and their trapped melt inclusions point to substantial heterogeneity in the mantle source, implying that the lower oceanic crust is also heterogeneous. This study presents radiogenic (Pb, Nd and Os) and stable isotope (Fe, Zn) data for primitive crystals in MORB, and gabbroic minerals from the lower oceanic crust.

Primitive minerals hosted by MORB glass, from the FAMOUS segment on the mid Atlantic ridge, yield Pb, Nd and Os isotope compositions indicating the presence of an extremely depleted mantle source (εNd ≈ +12; $^{206}Pb/^{204}Pb \approx 17.40$; $^{187}Os/^{188}Os \approx 0.12$), not evident in the host glass. While Fe and Zn stable isotopes for the same minerals yield compositions closer to those of the depleted mantle ($\delta^{56}Fe \approx +0.02$; $\delta^{66}Zn \approx +0.15$) than typical MORB. Melt inclusions indicate that these phases must have crystallised in the lower oceanic crust. The radiogenic isotope composition of minerals from lower crustal gabbros and troctolites, from the Atlantis Bank, south the SW Indian ridge, indicate an even greater heterogeneity than that seen in primitive minerals in MORB, while Fe and Zn isotopes reflect both source variations and the effects of fractional crystallisation.

Overall, these results indicate that primitive minerals in MORB and the lower oceanic crust, preserve a record of depletion and enrichment that is largelly erased in erupted MORB glass, moreover this signal is biased towards the composition of more fusible rock types [1]. Offsets in the stable isotope composition of MORB, relative to mantle rocks largelly reflect these different sources, rather than processes such as partial melting or redox/polymerization in magmas.

[1] Salters & Dick (2002) Nature, 418 67-72.