A process-oriented view of the isotopic variability in oceanic basalts

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Oceanic basalts are partial melts of Earth's mantle. The generated melts evolve via melt mixing, reaction with wall rocks, fractional crystallization, and degassing before eruption on the surface. Because these processes variably influence the composition of the mantle-derived melts, none of the erupted lavas represent primary melts in equilibrium with the melting mantle.

By now, there is abundant evidence that mantle heterogeneity is of km scale or less [1], yet melts generated over 100s km wide regions travel over long vertical and lateral distances towards their localized eruption sites. It is thus inevitable that melts mix during extraction and further melt evolution in the shallow mantle or overlying crust. Although it is crucial to understand how these mixing processes affect the relation between mantle and basalt heterogeneity, few attempts have been made to understand the functional form of these mixing processes [cf. 2-4].

These studies show that the isotopic diversity of heterogeneous mantle sources is increasingly dampened by progressive melt mixing. Hence, erupted melts rarely reflect the entire range of isotope ratios of the different source materials; especially melts from incompatible element depleted materials have low preservation potential. It remains difficult, therefore, to accurately assess mantle depletion from basalts, but also to relate spatial patterns in surface lavas to the distribution of heterogeneous materials in the underlying mantle.

One strategy to better understand how isotopic heterogeneity is conveyed from source to melt is to compare the isotopic diversity of primitive melt inclusions with that of the erupted lavas. Our recent data on olivine-hosted melt inclusions in ocean island basalts (OIB) show that their isotopic variability is much larger than that of the erupted melts, at both the enriched and depleted end of the isotopic spectrum. Neodymium isotope ratios in some melt inclusions range to the highest values ever measured in mantle derived melts. Owing to the low preservation potential of such ultra-depleted melts, their occurrence suggests that highly depleted mantle is the volumetrically dominant component of some OIB sources. However, isotopically depleted compositions are deficient in more evolved lavas due to progressive mixing with enriched melts during melt evolution.

Although melt inclusions thus reveal greater isotopic variability than the erupted lavas, they still provide an incomplete account of the expected range of isotopic heterogeneity in most mantle sources. A better understanding of the functional form of melt mixing consequently requires developing mathematical models of melt mixing and comparison to the observed isotopic variability in melt inclusions and erupted melts.

[1] Stracke, A., 2012. Chem. Geol. 330-331, 274-299. [2] Stracke, A., Bourdon, B., 2009. Geochim. Cosmochim. Acta 73, 218-238. [3] Rudge, J.F., Maclennan, J., Stracke, A., 2013. Geochim. Cosmochim. Acta 114, 112-143. [4] Bo, T., Katz, R.F., Shorttle, O., Rudge, J.F., 2018. Geochem. Geophys. Geosys. 19, 4694-4721.