Mantle heterogeneity preserved in the lower oceanic crust

SARAH LAMBART[1]*, JANNE M. KOORNNEEF[2], MARC-ALBAN MILLET[3], GARETH R. DAVIES[4], MATTHEW COOK[5], C. JOHAN LISSENBERG[6]

[1]Geology and Geophysics, Univ. of Utah, Salt Lake City, UT 84112, USA (sarah.lambart@utah.edu)
[2]Vrije Univ. Amsterdam, Faculty of Science, Amsterdam, The Netherlands (j.m.koornneef@vu.nl)
[3]Cardiff Univ., School of Earth and Ocean Sciences, Cardiff, UK (milletm@cardiff.ac.uk)
[4]Vrije Univ. Amsterdam, Faculty of Science, Amsterdam, The Netherlands (g.r.davies@vu.nl)
[6]Cardiff Univ., School of Earth and Ocean Sciences, Cardiff, UK (matthewcook245@googlemail.com)
[6]Cardiff Univ., School of Earth and Ocean Sciences, Cardiff, UK (LissenbergCJ@cardiff.ac.uk)

Radiogenic isotope signatures of mid-ocean ridge basalts (MORB) have been used for decades to map mantle composition, defining the depleted mantle end member. However, MORB homogenize via magma mixing prior to eruption and, hence, may not capture the full chemical variability of their mantle source. Here we show that substantial mantle heterogenity is preserved in the lower crust, providing strong evidence that the limited isotopic variability recorded in MORB is a consequence of crustal-level mixing of melts from a highly heterogeneous source.

We performed high spatial resolution Sr-Nd isotope analyses on clinopyroxene and plagioclase from lower crustal gabbros drilled on a depleted ridge segment of the northern Mid-Atlantic Ridge. These primitive cumulate minerals record nearly the full heterogeneity observed along the northern Mid-Atlantic Ridge, including hotspots. Furthermore, we find that isotopic heterogeneity occurs down to the sample scale, with plagioclase and clinopyroxene from individual samples commonly not in isotopic equilibrium.

We demonstrate that MORB and cumulate mineral data can be reconciled with high magnitude, small length scale heterogeneity throughout the North Atlantic upper mantle. Modelling indicates that North Atlantic data can be reproduced by melting a depleted peridotite source containing 3.2% to 8.5% of enriched recycled crustal material and a restricted range of potential temperatures (1245°C-1367°C). Furthermore, the data require that magma mixing during melt transport and extraction from the mantle is limited, and that the isotopic homogeneity of MORB on a regional scale is instead the result of extensive mixing at shallower pressure in the crust.