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The effect of variable mantle composition on melt generation and extraction at mid-ocean ridges

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Most models for melting beneath mid-ocean ridges assume a relatively homogeneous peridotitic mantle, especially with respect to major elements. Mantle heterogeneities as observed by variation in isotopic composition are not thought to effect melt generation or extraction significantly. Here I present evidence to the contrary.

We analyzed basalts from the East Pacific Rise between 6^{o}N and 18^{o}N for trace element content and isotopic composition. The EPR basalts are relatively homogeneous in composition, especially on the scale of an individual ridge segment. The variability along the northern EPR can be explained by three components: a depleted one, an enriched one and a component similar to recycled gabbro. Our high-resolution sampling indicates that on a segment-scale two “local” components are needed to explain the chemical variability within the individual ridge segments and two adjacent segments are chemically and isotopically discontinuous and have, at most, one “local” component in common. These segment-scale “local” components are a combination of the three end members. The coincidence of change in source composition at ridge discontinuities indicates that source composition can influence segmentation and that there is little melt transport across a transform fault plane.

A study of abyssal peridotites from the Gakkel Ridge provides an example where mantle composition controls the amount of crust generated. The samples we analyzed range to extremely radiogenic isotopic composition; i.e. the most radiogenic in Nd and Hf-isotopic composition of the ocean basins with ε_{Nd} up to 27.4 and ε_{Hf} up to 291! This data confirms the ultra depleted nature of the Gakkel Ridge mantle [1] and its highly heterogeneous nature [2]. Since the Hf and Nd system is expected to behave similar during melting, melt can be added back in the peridotite until the Hf and Nd model age coincide. These calculations show that depleted Gakkel Ridge peridotites have very little melt extracted from them ($<$1%) and have model ages that ranges from 2.4Ga to future ages with most between 600Ma and 1.2 Ga.

Previous it has been shown that a strongly depleted mantle (ReLish) such as observed at Gakkel can be a ubiquitous part of the asthenosphere [3]. ReLish is expected to yield little melt during ascent under the ridge. In a heterogeneous mantle containing ReLish crustal thickness is not only related to degree of melting but also to the fraction of mantle that yields melt. Normal or thin oceanic crust ($<$6km thickness) with evidence for melting in the garnet stability field can be explained if a significant proportion of the asthenosphere is extremely depleted. The observation of existence of such a depleted mantle at the Gakkel Ridge as well as the Hf-Nd isotope variation in MORB shows that such a heterogeneous mantle is common. Thus our estimates of the asthenospheric mantle based on the composition of MORB alone will underestimate its depleted character.

[1] Stracke, A, *et al.*, Earth Plan. Sci. Lett, **308**, 359-368 (2011).

[2] Liu, C.Z., *et al.*, Nature, 452, 311-315 (2008).

[3] Salters, V.J.M., et al., Geochem. Geophys. Geosys. 12, Q08001.