Reconciling the compositions of ridge basalts and peridotites

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Mid-ocean ridge basalts and peridotites constrain the composition of the oceanic mantle and the processes it undergoes. Despite decades of work on basalts and peridotites recovered from ridges, the degree to which these two rock types are co-genetic remains the subject of debate. Using a global compilation of abyssal peridotite bulk rock and mineral compositions (major elements, trace elements, and isotopes), I show that the mantle source is best represented by a heterogeneous mantle consisting of lherzolite, harzburgite, and pyroxenite, which combined represent the counterpart to basalts.

Evidence for the harzburgitic component in the source mantle comes from the long-lived radiogenic isotopes (Nd, Sr, Hf, Os, Pb). Basalts and peridotites have overlapping compositions, with similar averages, but peridotites extend to more depleted isotopic compositions than basalts. For example, some peridotites have Os model ages up to 2 Ga and unradiogenic Pb. The different shape of the isotope distributions suggests that peridotites preserve a record of prior depletion events, which are under-sampled in basalts. Isotopic depletion requires accompanying infertile major and trace element compositions, indicating the presence of harzburgitic domains in the source mantle. Globally, ultra-refractory harzburgites, defined as containing <1 wt% Al_2O_3, correspond to ~10% of residual peridotites recovered at ridges. These harzburgites may have been too refractory to contribute to melt generation, particularly when they occur in regions – such as the Fifteen Twenty Fracture Zone – that lack a significant crustal layer.

At the other end of the spectrum, pyroxenites represent 5% of recovered ultramafic samples. These pyroxenites, which cover a large compositional range from silica-enriched to silica-poor, have been interpreted as the products of recent melt crystallization and not as direct pieces of recycled oceanic crust. Experimental data predict a much higher degree of melting for primary pyroxenites at ridges compared to peridotites. Thus, a subset of abyssal pyroxenites may represent recycled crust that has undergone recent melting and possible reaction with the host peridotite. Hence, consideration of the full spectrum of material recovered at ridges suggests that the source material for basalts is represented among abyssal ultramafic samples.