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Geophysical and geochemical evidence for deep temperature variations beneath mid-ocean ridges

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Mantle temperature and composition together control density and viscosity and therefore the rate and scale of mantle convection and the thermal evolution of the Earth. We present the first comprehensive global comparison of seismic velocity, axial depth, and basalt composition along mid-ocean ridges to test whether the observations are most consistent with variations in mantle composition or mantle temperature. To compare to the seismic models, we have assembled a new global data set of major- and trace-element concentrations for 16,694 MORB samples from the published data archived in PetDB and GeoRoc as well as unpublished analyses. We first identified the individual segments of the global ridge system, using shipboard and satellite bathymetry in GeoMapApp, on the basis of first- and higher-order segmentation features. The resulting catalogue contains the geographic position, axial ridge depth, and spreading rate for 771 ridge segments spanning 60,864 km, including back-arc spreading centers. For ridge segments containing MORB samples from at least 3 unique locations, the major-element compositions were corrected for low-pressure fractionation to MgO = 8 wt. %. This resulted in fractionation-corrected composition estimates for 246 ridge segments.

The seismic models and ridge observations are strongly correlated. The correlation between axial ridge depth and shear velocity is largest for mantle depths 300-400 km and remains >0.6 to $\sim$600 km. We show that the correlation between the three data sets requires 250-degree variation in temperature beneath ridges extending to depths >400 km and cannot be reconciled with variations in composition at nearly constant temperature. High temperatures are mostly associated with upwelling mantle plumes, whereas cold downwellings are less often sampled by mid-ocean ridges. This finding addresses outstanding questions regarding the cause of along-ridge variations in axial depth and chemistry, and it provides calibration for the temperature sensitivity of shear velocity, allowing estimates of mantle temperature from tomographic models.