Mantle composition, structure and distribution of radiogenic power: Paradigms of the Earth's interior

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Mantle-derived materials, whether they be extracted liquids (e.g., basalts) or residues (e.g., peridotite) of partial melting, provide insights into the constitution of the planet's interior. Geochemical studies of these materials require a multicomponent mantle with long-lived heterogeneities. Regardless of their physical manifestation, the existence of multiple distinct mantle sources has important consequences for mass balance and paradigms of modern mantle structure.

Presented here is a compositional model of the modern mantle as projected through the analysis of a global suite of mid-ocean ridge basalts (MORB) and ocean island basalts (OIB). The abundances of heat-producing K, Th and U in multiple OIB sources are estimated based on bivariate linear regression analyses and inverse modeling of accumulated fractional melting. Our results predict a mean of 140 – 180 ng/g Th in the OIB source region, whereas global MORB implicate an average of ~24 ng/g Th in the upper mantle source of these materials. In conjunction with compositional and geoneutrino studies of the continental crust, the mantle sources characterized here produce too much radiogenic heat to support a bulk silicate Earth (BSE) formed from simple enstatite chondrite or non-chondritic Earth models.

According to our preferred model, the OIB source region is responsible for contributing 7 TW to the planet's total surface heat flux, with another 7 TW and 6 TW of power generated by the continental crust and MORB source, respectively. We assert that the OIB source comprises a significant amount of recycled crust and constitutes ~20% of the mantle by mass without bias for how a two-component mantle may be manifested physically. A tertiary mantle source, such as an early enriched reservoir (EER), would contain even higher concentrations of radioactive elements than the OIB source described here, suggesting an even greater rate of radiogenic heat generation in the planet's interior than the model presented here.