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Comparing geochemical and geophysical mantle evolution models

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The mantle is Earth's largest reservoir of mass and heat. Its thermochemical budget is fundamental to the understanding of our planet, from plate tectonics to habitability. Observational constraints on mantle dynamics, rheology and composition come from geophysical observations, geochemical measurements of mantle-derived melts, and circulation models built on first principles. An integration of findings from these separate disciplines has been lacking, especially between geophysics and geochemistry.

Here we investigate mantle evolution through a comparison of (1) model results from the (geophysical) three-dimensional mantle convection code TERRA[1] and (2) model results from a purely geochemical inversion of the global multi-isotope dataset for oceanic basalts (Sr-Nd-Hf-Pb). Both models quantify mantle evolution through time: chemical depletion through melt extraction and re-enrichment through crustal recycling. They however do so through fundamentally distinct approaches. In TERRA, active particles track chemical information throughout mantle circulation, while our geochemical inversion uses a *Monte Carlo* approach to match natural isotope observations through variable extents and timings of melting and re-enrichment of a model mantle source.

To make model comparisons possible, we restrict our investigation of TERRA results to the particles present under modelled ridges and plumes, which correspond to the mantle investigated through our geochemical inversion of natural basalts. We find a good agreement between the two models, revealing a greater extent of secular melt depletion (mass%) in the plume mantle (TERRA: 4.8%, Geochem.: 6.5%) compared to the sub-ridge mantle (TERRA: 3.6%, Geochem.: 5.6%). In both models, the excess melt-depletion of the plume mantle tends to be either fully compensated or exceeded by incorporation of chemically enriched recycled crustal material. The magnitude of these fluxes is highly dependent on the presence or absence of a deep primitive layer, and on the presence of garnet during melt depletion in the geochemical model.

This work is a rare example of a quantitative, multi-disciplinary approach comparing fundamentally distinct models of mantle evolution. Our early results suggest this method can be particularly useful to test the robustness of a hypothesis (e.g. plumes are more enriched than ridges) while identifying the key underlying assumptions.

[1] Baumgardner (1985). Journal of Statistical Physics, 39(5-6), 501-511.