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Using geochemical databases as inputs in geochemical models to validate geophysical mantle circulation models

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Global databases of mantle melts geochemistry are a valuable record of the Earth system, however multidisciplinary integrations of these data are lacking. We use a novel multidisciplinary approach to investigate how the parameter space of mantle convection affects present-day mantle composition.

We compare 22 numerical mantle circulation model (MCM) simulations against 24 variants of a geochemical inversion model (GIM) of the global radiogenic isotope dataset of mantle-derived lavas (1031 mid-oceanic ridge basalts from PetDB and 1615 oceanic island basalts from GEOROC). Both models are fully independent but able to output compositional parameters for the lower mantle sampled by upwelling mantle plumes and for the upper mantle sampled by mid-oceanic ridges.

MCM results suggest an excess degree of peridotite melt-depletion ΔF_d = +0.4±0.4 % and an excess amount of recycled crust Δf_{RC} = +2.7±3.1 % in plumes compared to ridges, while the GIM returns ΔF_d = +0.4±1.2 % and Δf_{RC} = +1.5±0.6 %. Models are thus in quantitative agreement but with opposite specificities to ΔF_d and Δf_{RC}. MCM runs agree best with the narrow geochemical Δf_{RC} for core-mantle boundary (CMB) temperatures of 3400-3800 K and a recycled crust buoyancy number of 0.44-0.66. A dense primordial layer at the CMB also leads to a better fit with geochemical results. Variants of our GIM agree with the narrow MCM ΔF_d value when early mantle differentiation occurs in the garnet stability field. We also find our GIM requires the formation of early compositional heterogeneities to fully explain the isotope range of mantle melts.

Our work shows the multidisciplinary integration of large geochemical datasets is possible. We however emphasize the need to correct isotopic data for the effects of non-magmatic processes (e.g. alteration) before extracting the mass-relevant parameters. Our quantitative, process-focused approach departs from the traditional paradigm of mixing mantle endmembers.