



The preservation of primordial heterogeneity in the Earth's mantle due to composition-dependent rheology

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Mantle convection simulations and seismic tomography models suggest that although thermochemical piles may persist in the lowermost part of the lower mantle, whole-mantle convection has efficiently mixed most of the mantle over time scales shorter than the age of the Earth. This inferred efficient mixing, however, is contradicted by abundant ^{182}W and noble gas isotope anomalies in modern ocean-island basalts which provide evidence for the survival of primordial heterogeneity somewhere in the Earth's mantle. In an attempt to reconcile these opposing geochemical and geophysical views, recent geodynamic models have presented a new mantle convection regime in which primordial, silica-enriched heterogeneity can persist in the mantle for longer than the age of the Earth (Ballmer et al., 2017). However, those models employed both a simplified rheology and tectonic style, and were also solved in a simplified Cartesian geometry.

In this contribution, we explore 2D spherical-annulus models of mantle convection with composition dependent rheology using the code StagYY. We find that heterogeneity preservation is dependent on the viscosity and density contrasts that exist between the primordial material and the rest of the mantle. The density of the primordial material in the lower mantle and its depth dependence strongly affect the style of heterogeneity preservation, with the regime described by Ballmer et al. (2017) being recreated for moderately enhanced densities and bulk-moduli in the primordial material. Additionally, the intrinsic viscosity contrast controls both the time it takes for the initial mantle overturn to occur, as well as the timescale of preservation for primordial heterogeneity. The effects of composition on mantle viscosity can indeed reconcile the survival of primordial domains in the presence of billions of years of whole-mantle convection and stirring.

Reference

Ballmer, M., C. Houser, J. Hernlund, R. Wentzcovitch, and K. Hirose (2017), Persistence of strong silica-enriched domains in the Earth's lower mantle, *Nature Geoscience*, 10(3), 236-240, doi:10.1038/ngeo2898.