Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.5465

Joint Seismological-Geodynamical Assessment of Lower Mantle Temperature and Composition Variations

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Uncorrelated seismic P- and S-wave velocity (V_P and V_S) variations in the Earth's mantle are indicative of non-thermal heterogeneity, such as variations in phase and/or composition. Seismic tomography reveals a discrepancy between V_P and V_S below ~2200 km, which has been used to argue for the existence of large-scale heterogeneity in chemical composition. Nevertheless, some uncertainties remain regarding the relative resolving power of V_P and V_S tomography models, and purely thermal models (i.e., without chemical heterogeneity) have not been entirely excluded. Here we use a singular value decomposition of two mutually consistent V_P and V_S models to construct a "tomographic filter" and apply it to the outcomes of mantle convection models for both purely thermal and thermal-chemical layering scenarios. This is the first time such a procedure has been performed with both a V_P and V_S model. A filtered lower mantle model with only temperature variations does not yield a large low V_S anomaly, and is inconsistent with seismic observations. By contrast, the filtered model predicted using both composition and temperature variations results in a slow V_S anomaly and a neutral V_P anomaly, which provides a good correspondence with observations. A dense (Fe-rich), high bulk modulus, and low shear modulus may explain the seismic observations and provide for geodynamical stability against entrainment by mantle convection. Such dense "chemical piles" or other structures have been attributed to the accumulation of basaltic crust, core-mantle interactions, cumulates of a basal magma ocean, and/or residues of early differentiation.