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Effects of mantle viscosity structure on the evolution and distribution of chemical heterogeneity

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A better understanding of the compositional structure of the Earth's mantle is needed to place the geochemical record of surface rocks into the context of Earth accretion and evolution. Cosmochemical constraints imply that lower-mantle rocks may be enriched in silicon relative to upper-mantle pyrolite, whereas geophysical observations tend to support whole-mantle convection and mixing. To resolve this discrepancy, it has been pointed out that subducted mid-ocean ridge basalts (MORBs) tend to segregate from harzburgites and be accumulated in the mantle transition zone (MTZ) and/or lower mantle. However, the key parameters that control MORB segregation and accumulation remain poorly constrained. Here, we use global-scale 2D thermochemical convection models to investigate the influences of plate and mantle rheology on the evolution and distribution of chemical heterogeneity. In particular, we focus on the accumulation of subducted MORB in a MTZ reservoir. Our results show that deep-rooted plumes as well as stagnant slabs deliver MORB to the MTZ to establish a MORB-reservoir at $\sim$1.5 Gyrs. Relatively low viscosities in the MTZ tend to facilitate the segregation of MORB from harzburgite, and accumulation of MORB in the MTZ. In turn, relatively high viscosities in the lower-mantle tend to suppress the entrainment of MORB by plumes that rise from the edges of recycled MORB piles, and related delivery of MORB to the MTZ. Finally, relatively high plate yield stresses tend to sustain the formation of large MORB piles in the deep mantle, but with little or no effect on MORB-enrichment in the MTZ reservoir. Our results suggest that the MORB-enriched MTZ reservoir may play an important role in regulating heat and material fluxes through the mantle.