# Persistence of large-scale heterogeneity in the Earth's mantle

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Seismic imaging of subducted slabs in the lower mantle has been taken as evidence for efficient mantle mixing. However, cosmochemical constraints point to a lower-mantle composition that has Mg/Si lower than upper-mantle pyrolite. Also, geochemical signatures of magmatic rocks witness the long-term persistence of primordial mantle reservoirs. Here, I discuss numerical-model predictions to establish geodynamic mechanisms for sustaining large-scale heterogeneity, even in the presence of whole-mantle convection. Mantle flow is controlled by rock density and viscosity. Intrinsic variations in density, such as due to variable basalt or iron content, can induce partial layering in the mantle. Partial layering is sustained as small-scale heterogeneity is "un-mixed" due to mid-scale convection across low-viscosity layers, e.g. in the transition zone or near the core-mantle boundary [1]. On the other hand, lateral variations in intrinsic rock viscosity, such as due to variable Mg/Si, can strongly affect the timescales of mantle mixing. In an end-member case, intrinsically strong rocks may remain unmixed through the age of the Earth, and persist as large-scale domains in the mid-mantle due to focusing of deformation along weak conveyor belts [2]. That large-scale lateral heterogeneity and/or layering persists in the presence of whole-mantle convection can explain the stagnation of some slabs, as well as the deflection of some plumes, in the mid-mantle. These findings indeed motivate new seismic and geochemical studies for rigorous tests of geodynamic-model predictions.

[1] Ballmer, Schmerr, Nakagawa, and Ritsema (2015), *Science Advances* 1, e1500815.

[2] Ballmer, Houser, Hernlund, Wentzcovitch, and Hirose (2017), *Nature Geoscience* 10, 236-240.