The geodynamical origin of lowermost mantle structure

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Large regions of the lowermost mantle exhibit low seismic-wave speeds. These Large Low Shear-Velocity Provinces (LLSVPs) are interpreted as thermal structures by some and thermochemical structures by others. As thermal structures, their formation is a consequence of plume clustering, which is partially controlled by subduction history. As thermochemical structures, they may be remnants of a primitive reservoir or accumulations of recycled heterogeneity over time. The appeal of the latter interpretation is that we have experimental and observational evidence that subducted oceanic crust will have a greater density than the ambient mantle, causing it to accumulate at the base of the mantle. In contrast, reasons for a primitive mantle reservoir to have the excess density required to survive 4.5 Gyrs of convective mixing are plausible but poorly constrained, typically invoking a process of iron-enrichment.

Here we explore primitive material and recycled crust as possible origins for LLSVPs by comparing models with primordial heterogeneity and those where heterogeneity is produced by oceanic crust formation and recycling. We use existing simulations of convection in an incompressible mantle with force-balanced plates and new high resolution compressible models with phase changes and a yield stress rheology. For comparison, we tomographically filter our geodynamic models to the same spatial resolution as S40RTS. Our results show that models incorporating moderate excess crustal density or a primitive mantle reservoir both account for LLSVPs found in S40RTS similarly well.