Small-scale lower mantle heterogeneities as geochemical reservoirs

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Where are the major geochemical reservoirs in the lower mantle? There are few direct constraints because geochemical sampling has poor vertical resolution and the lower mantle seems seismologically featureless except at the core-mantle boundary (CMB). Geochemists appear comfortable apportioning uniform mantle reservoirs to the upper mantle and the lower mantle, which interact in limited ways involving mixing mediated by subducted lithospheric slabs and ascending plumes. This accomodates the geochemical constraints from Sr-Nd and Pb documenting long-term segregation of reservoirs approximately the size of the upper and lower mantle, and preserves undegassed regions of the mantle, possibly the lower mantle exclusively (Hofmann, 1997).

The seismological view is that some subducted lithospheric slabs get into the lower mantle, making the lower mantle weakly heterogeneous as compared to the upper mantle. Recent results reveal other small-scale heterogeneities in the lower mantle, 10s to 100s of kilometers in size and well away from the well-known seismic variability in the CMB vicinity. Hedlin *et al.* (1997) propose a haze-like population of small (~8 km) heterogeneities extending up to 1200 km above the CMB based on precursory seismic wave arrivals. Kaneshima and Helffrich (1998) found a 15–35 km body in the middle of the lower mantle using a related scattering method. Neither of the structures found are laterally uniform like pressure-mediated phase transformations, which cause the major seismic discontinuities in the mantle. What these observations all share is the possibility that the compact, seismically different areas are chemically different as well.

The object found by Kaneshima and Helffrich (1998) is 1600 km below the western Pacific at about 26N and 148E. Plate reconstructions put subduction at this position no earlier than 170 Ma. A thermal anomaly could not survive long enough to maintain the 4% lower seismic velocity difference relative to the mantle required by the observations, so this object seems compositionally different to its surroundings. A body this small, representing perhaps a parcel of undegassed mantle, could survive sampling by mantle plume upwellings for longer than the age of the Earth. Thus it is entirely plausible to attribute long-term segregation of the mantle's geochemical components to small, distinct bodies rather than to large homogeneous reservoirs.

References

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