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The nature and dynamics of deep mantle thermo-chemical reservoirs

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During the past decade, increasing seismological evidences have credited the existence of large scale thermo-chemical heterogeneities in the lowermost ($>$ 2000 km) mantle. However, the origin and nature of chemical anomalies is still debated. Two end-members hypothesis, the subduction and stacking of MORB, and the survival of primitive reservoirs of dense material, are usually advocated.

Slabs sinking in the deep mantle have been detected by seismic tomography. Furthermore, numerical models of thermo-chemical convection that include the production and recycling of oceanic crust have shown that MORB can segregate in stable pools at the bottom of the mantle. Our recent models, which include self-consistent mineralogy and spherical geometry, pointed out that the exact shape of these reservoirs is very sensitive to the composition of MORB in major oxides. It is important to note that high-pressure MORB are seismically faster than the average pyrolitic mantle. Thus, to explain the large low shear-wave velocity provinces observed at the bottom of the mantle, reservoirs of recycled MORB should be hotter than average.

The presence of a primitive undegassed reservoir located in the deep mantle is needed to explain the geochemistry of ocean island basalt, in particular the low values of the ^{4}He/^{3}He ratio. Primitive reservoirs may result from early partial differentiation of the Earth's mantle, or the recycling on an early crust. Experimental and numerical models of thermo-chemical convection that consider the evolution of an initial layer of dense material (including our recent models in 3D-Cartesian geometry), indicate that reservoirs of primitive material can survive convection for periods of time larger than the age of the Earth. Assuming that primitive reservoirs are enriched in iron and silicate, as suggested by probabilistic tomography and by enstatite chondrite models of Earth's composition, the amplitude and RMS of seismic velocity anomalies predicted by our 3D-Cartesian models are consistent with those observed by seismic tomography.

Very likely, thus, the seismic velocity and density anomalies observed in the deep mantle originate from a combination of thermal anomalies and two (or more) sources of chemical heterogeneities. In addition, the post-perovskite may play a significant role. In cold regions ($e.g.$, slab graveyards) perovskite may transform to post-perovskite at relatively shallow depths, whereas in hot regions ($e.g.$, plume sources) it may not transform at all. We continue our exploration of the model space of thermo-chemical convection, including models with primitive reservoirs in spherical geometry, and models that combine two sources of chemical heterogeneity, $i.e.$ recycled MORB and primitive reservoirs.