

Constraints on mantle dynamics from global seismic imaging

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Over the last four decades, global seismic tomography has produced progressively sharper images of the earth's deep mantle. Intriguing features, such as the presence of two antipodal large low shear velocity provinces (LLSVPs) beneath the Pacific basin and Africa, were revealed early on, as was evidence for the penetration of slabs into the lower mantle. Other surprises have followed. While it is now well established that global material circulation extends across the whole mantle, improved seismic resolution has shown that slabs spread horizontally not only at the base of the upper mantle but also around 1000 km depth.

With the advent of full waveform inversion (FWI) combined with accurate seismic wavefield predictions, the existence of conduits of hot material - akin to fat mantle plumes - extending from the core-mantle boundary to the upper mantle beneath major hotspots has been revealed. However, the morphology of these plumes in the lower mantle is different from what is expected in a purely thermally-driven convective system. Also, most of these plumes, like slabs, deflect horizontally - or "pond" - around 1000 km depth, and subsequently meander across the upper mantle. On the other hand, evidence for meso-scale convection with horizontal scales of ~1000 km has been found across major ocean basins. All this suggests the presence of a more vigorous circulation across the top third of the mantle, but no clear physical explanation for a change in rheology at the base of the extended transition zone has yet been agreed upon. Interestingly, most, if not all fat plumes have their base within the perimeter of the LLSVPs, calling into question whether the LLSVPs are unbroken piles of compositionally different, denser material of primordial origin, or rather, bundles of distinct mantle plumes.

I will review these recent findings with a focus on the south and central Atlantic ocean, where recent higher resolution FWI has allowed us to highlight some of these features and relate them to trace isotope geochemistry of mid-plate volcanoes in the region (Munch, Romanowicz, Mukhopadhyay and Rudolph, PNAS, 2024).