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Investigating the presence of post-perovskite and large-scale chemical variations in Earth's lower mantle using tomographic-geodynamic model comparisons.

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Tomographic models of the Earth's mantle consistently image two large provinces of low shear-wave velocities (LLSVPs) in the lowermost mantle beneath Africa and the Pacific. Seismic studies also find an increase in the ratio of shear-wave velocity (Vs) to compressional-wave velocity (Vp) variations, accompanied by a significant negative correlation between shear-wave and bulk-sound velocity (Vc) variations, both of which are also observed in the recent SP12RTS model. The LLSVPs have consequently been suggested to represent intrinsically dense piles of thermochemical material. Alternatively, they have been interpreted as poorly imaged clusters of thermal plumes, with the deep mantle post-perovskite (pPv) phase invoked as explanation for the high Vs/Vp ratios and Vs-Vc anti-correlation. Geodynamical calculations of thermal plumes and thermochemical piles predict a fundamentally different style of mantle convection, interface topographies and CMB heat flow. However, to interpret tomographic images using these high-resolution models, the limited resolving power of seismic tomography has to be accounted for.

Here, we interpret the observed seismic characteristics of SP12RTS by comparing the velocity structures to synthetic tomography images derived from 3D mantle convection models. As in previous studies, geodynamic models are converted to seismic velocities using mineral physics constraints and subsequently convolved with the tomographic resolution operator. In contrast to these studies, where generally only the shear-wave velocity structure has been compared, we use both the Vs and Vp resolution operator of SP12RTS to allow direct comparisons of the resulting velocity ratios and correlations. We use geodynamic models with and without pPv and/or chemical variations to investigate the cause of the high Vs/Vp ratio and Vs-Vs anti-correlation. Although the tomographic filtering significantly affects the synthetic tomography images, we demonstrate that the patterns observed in the ratios and correlations of seismic velocities are robust features. Our tomographic-geodynamic model comparison suggests that the seismic characteristics of SP12RTS could be explained by the presence of post-perovskite, but it allows no discrimination between isochemical and thermochemical models of mantle convection.