Global tomographic images of 45 hotspots

DAPENG ZHAO

Geodynamics Research Center, Ehime University, Matsuyama 790, Japan (zhao@sci.ehime-u.ac.jp)

Hotspots are centers of massive volcanism not linked to plate boundaries, and they are commonly explained by mantle plumes. The mantle plume hypothesis is now widely accepted to explain hotspot volcanoes, but direct evidence for actual plumes is weak, and seismic images are available for only a few hotspots. In this work, we used a new global tomography model (Zhao, 2001, 2003) to make whole-mantle images under 45 major hotspots on Earth.

Slow anomalies are revealed in the mantle under most of the hotspots. Plume-like, continuous slow anomalies in the entire mantle are visible under Hawaii, Iceland, Jan Mayen, Cobb, Eifel, Louisville, Canary, Cape Verde, Kerguelen, Tibesti, Tahiti and other five hotspots in South Pacific, suggesting that mantle plumes, if any, under those hotspots originate from the core-mantle boundary (CMB).

The slow anomalies under those hotspots usually do not show a vertical pillar shape, which suggests that plumes are not fixed in the mantle but can be deflected by the mantle flow. As a consequence, hotspots are not fixed but can wander on the Earth's surface, as evidenced by recent paleomagnetic and numeric modeling studies. In many cases, slow anomalies under the hotspots are complex around the transition zone.

A thin low-velocity layer is visible right beneath the 660 km discontinuity under some hotspots, which may reflect ponding of plume material in the top part of the lower mantle. Under a few other hotspots, slow anomalies spread laterally just above the 660 km discontinuity.

The variety of behaviors of the slow anomalies under hotspots reflects strong lateral variations in temperature and viscosity of the mantle, which controls the generation and ascending of mantle plumes as well as the flow pattern of mantle convection.

References

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Seismic imaging of mantle plumes and subducting slabs

DAPENG ZHAO

Geodynamics Research Center, Ehime University, Matsuyama 790, Japan (zhao@sci.ehime-u.ac.jp)

Mantle plumes and subducting slabs are studied by using a new model of whole mantle tomography that is determined with a novel approach (Zhao, 2001, 2003). Strong and wide high-velocity anomalies are visible in the transition zone depths under the subduction regions, suggesting that most of the slab materials are stagnant in the transition zone before finally collapsing down to the lower mantle.

Very slow anomalies exist in the upper mantle right beneath the active volcanoes in Eastern China, right above the stagnant Pacific slab in the transition zone, suggesting that the origin of the intraplate volcanism in East Asia is closely related to the Pacific plate subduction process, such as deep slab dehydration and convection circulation in the mantle wedge.

Plume-like slow anomalies are clearly visible under the major hotspot regions in most parts of the mantle, in particular, under Hawaii, Iceland, South Pacific and Africa. The slow anomalies under South Pacific and

Africa have lateral extensions of over 1000 km and exist in the entire mantle, representing two superplumes. The slow anomalies under hotspots usually do not show a straight pillar shape, but exhibit winding images, suggesting that plumes are not fixed in the mantle but can be deflected by the mantle flow. As a consequence, hotspots are not really fixed but can wander on the Earth's surface.

Wider and more prominent slow anomalies are visible at the core-mantle boundary (CMB) than most of the lower mantle, and there is a good correlation between the distribution of slow anomalies at the CMB and that of hotspots on the surface, suggesting that most of the strong mantle plumes under the hotspots originate from the CMB. However, there may be some small-scaled, weak plumes originating from the transition zone or mid mantle depths.