海洋地域下のマントル構造： ホットスポットとマントルプルーム

Mantle structure under Oceans: Hotspots and Mantle plumes

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At present there are still few seismic stations available in oceanic regions. Hence the mantle structure under oceans is poorly determined, which has prevented us from understanding many important geological phenomena on Earth, such as hotspots and mantle plumes. The mantle plume hypothesis was proposed thirty years ago by Wilson (1963) and Morgan (1971) to explain hotspot volcanoes such as Hawaii and Iceland. A mantle plume is a buoyant mass of material in the mantle that rises because of its buoyancy. On reaching the base of the lithosphere, plume heads may reach diameters of 500 to 3000 km, while plume tails are typically 100 to 300 km in diameter. Hotspots are the surface manifestation of mantle plumes and are focused zones of melting. They are characterized by high heat flow, active volcanism, variable topographic highs depending on plume depth, and hotspot tracks with the age of magmatism and deformation increasing with distance from a hotspot (Condie, 2001).

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, for the first time, we present whole-mantle tomographic images under 56 major hotspots on Earth using a new global tomography model (Zhao, 2001, 2003). 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.

With the availability of more and more ocean bottom seismometers and the improvement of seismic imaging techniques, seismologists will be able to image the mantle plumes better, greatly advancing our understanding of the deep Earth dynamics.