Seismology and Plume Tectonics

Dapeng Zhao[1], Shigenori Maruyama[2]

[1] GRC, Ehime Univ, [2] Earth and Planetary Sci., Tokyo Institute of Technology

http://www.epsu.jp/jmoo2003/

During the past three decades, plate tectonics has proved to explain well the various geological phenomena and processes on the Earth's surface and in the upper mantle, but it does not explain the Earth's deeper structure and dynamics. Hence plate tectonics is considered to be a superficial phenomenon on the Earth less than 1/10 of Earth's radius. Plume tectonics (Maruyama, 1994) has provided a promising framework for our understanding of the deep processes of the Earth's interior, which insists that columnar plume flows dominate in major parts of deeper mantle, and two hot superplumes under South Pacific and Africa and and one cold superplume in Asia control the major tectonic events on Earth, such as thermal-material mantle convections, continental break-up, and convection patterns of outer core.

In this work we attempt to employ new pieces of seismological evidence to support the theory of plume tectonics. A new whole-mantle tomography model (Zhao, 2001, 2003) shows that strong and wide high-velocity anomalies exist in the transition zone depths under the subduction regions, which suggests 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 Wudalianchi and Changbai 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 one thousand kilometers 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, as evidenced by the recent paleomagnetic and numeric modeling studies (Steinberger, 2000; Tarduno and Cottrell, 1997). Other seismological studies using waveform modelings also suggested a lower mantle origin of plumes under those major hotspots and the deflection of plume conduits (e.g., Shen et al., 2002). Wider and more prominent slow anomalies, some of which contain ultra-low velocity zones (ULVZ) (Lay et al., 1998; Garnero, 2000), 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.

Maruyama, S., 1994. Plume tectonics. J. Geol. Soc. Japan 100, 24-49.

Zhao, D., 2001. Seismic structure and origin of hotspots and mantle plumes. Earth Planet. Sci. Lett. 192, 251-265.

Zhao, D., 2003. Global tomographic images of mantle plumes and subducting slabs: Insight into deep Earth dynamics. Phys. Earth Planet. Inter., in press.