地球内部の multi-scale イメージとダイナミクス

Multi-scale images and dynamics of the Earth interior

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The distribution of both earthquakes and seismic stations on Earth is nonuniform. Earthquakes occur mainly in the plate boundary regions; intermediate-depth and deep-focus earthquakes occur only in subduction zones. Seismic stations are installed mainly in a few developed countries on the land areas. In the broad oceanic regions and the African and South American continents, there are few permanent stations. This nonuniform nature of the distribution of the seismic sources and stations requires a multi-scale approach to seismic imaging. Regions covered densely by stations or seismicity can be imaged with a high resolution, while poorly instrumented regions can only be imaged roughly by global or large-scale regional tomography. This situation will last for quite a long time. A thorough understanding of the structure and dynamics of the Earth's deep interior will only be achieved by a combination of more effective seismic imaging techniques and dense coverage of global seismic networks, particularly in the oceans.

In this presentation we review the state-of-the-art multi-scale seismic images of the Earth interior and discuss our current understanding of the deep Earth dynamics, focusing on the subducting slabs and upwelling mantle plumes. Applications of the well-established local and teleseismic tomography methods to subduction zones have resulted in clear images of subducting slabs and magma chambers in the mantle wedge beneath active arc volcanoes, indicating that geodynamic systems associated with arc magmatism and back-arc spreading are related to deep processes, such as convective circulation in the mantle wedge and dehydration reactions of the subducting slab. Evidence also shows that arc magma and slab dehydration may also contribute to the generation of various types of earthquakes in subduction zones. Most of the slab materials are stagnant in the mantle transition zone before finally collapsing down to the core-mantle boundary as a result of large gravitational instability from phase transitions. Because most hotspots are located in poorly instrumented continental and oceanic regions, 3-D crust and upper mantle structure is determined for only a few hotspots such as Iceland, Yellowstone and Eifel which are covered by seismic networks. Plume-like low-velocity anomalies are revealed in the upper mantle under those hotspots. Global tomographic studies for deep mantle plumes have just started, but promising results have been obtained on the detection of deep mantle plumes under major hotspots such as Hawaii, Iceland, Kerguelen, Afar, and those in South Pacific, though more efforts are needed to image the conduits of the lower-mantle plumes. Both the seismological and mineral physics studies indicate that water has played an important role in the dynamic processes and evolutions of the Earth.