Deep seismic structure beneath the Japanese Islands
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Seismic imaging of the subducting plates and arc magmatism

The upper surfaces of the Pacific and Philippine Sea plates subducting beneath the Japanese Islands have been precisely estimated based on high-resolution imaging of 3D seismic velocity structures and distributions of earthquakes relocated with the new 3D velocity model (Hirose et al., 2008; Nakajima et al., 2009a). The updated model of the Philippine Sea plate suggests that the plate is subducting to depths of 140-150 km in central Japan without a gap between Kanto and Tokai areas. The model further defined an area of a slab-slab contact beneath Kanto, where the bottom of the Philippine Sea plate is in contact with the upper surface of the underlying Pacific plate (Uchida et al., 2009; Nakajima et al., 2009a). The slab-slab contact has large effects on the genesis of intraslab earthquakes and volcanoes beneath Kanto and central Japan, as a result of the delay of thermal recovery of the Pacific slab due to the overlying Philippine Sea plate.

Seismic tomography studies further revealed the existence of an inclined low-velocity and high-attenuation zone at the core of the mantle wedge of NE Japan (e.g., Nakajima et al., 2001; Hasegawa and Nakajima, 2004). An important point to be noticed is that amplitudes of seismic velocity in the inclined low-velocity zone vary along the arc, with larger velocity reductions in areas where Quaternary volcanoes are formed at the surface. These results suggest that volcanism beneath the Japanese Islands may be controlled by an upwelling flow in the upper mantle (Nakajima and Hasegawa, 2007).

Internal structure of the slab and its relation to intraslab earthquakes

Tsuji et al. (2008) and Nakajima et al. (2009b) revealed that the depth extent of the low-velocity (hydrated) oceanic crust varies along the arc. The low-velocity oceanic crust is subducting to depths of 120-150 km beneath Kanto, which is 40-70 km deep compared to NE Japan. Such a deeper preservation of the low-velocity oceanic crust can be explained by lower-temperature conditions in the Pacific slab as a result of the subduction of the Philippine Sea slab immediately above it. These observations suggest that phase changes of crustal materials accompanied by large velocity changes are controlled principally by temperatures, not by pressures. They also find spatial correspondence between intensive seismicity in the oceanic crust and the disappearance depth of the low-velocity oceanic crust, showing a close relation between breakdown of hydrous minerals and seismicity in the crust.

Heterogeneous structures in subducting slabs are also closely related to the occurrence of large (M>7) earthquakes. For the 1993 Kushiro-oki earthquake (M7.8) and an intraslab earthquake (M7.1) that occurred off Miyagi, one month after the Mw9.0 Tohoku earthquake, a distinct low-velocity anomaly is observed along the distribution of aftershocks (Nakajima et al., 2009c, 2011). Angles between the aftershock alignment and the dip of the slab surface are ~60° for the both earthquakes. These observations imply that large intraslab earthquakes occur as a result of reactivation of pre-existing hydrated faults that formed at the outer-trench slope.

References