Fluids and seismic low-velocity zones

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Recently, seismic velocity structure of the crust and mantle has been successfully estimated due to construction of dense seismograph networks and development of computers. In particular, seismic tomography method is one of the most useful tools to estimate velocity structures in the earth and has been developed by many researchers. For the northeastern (NE) Japan arc, seismic velocity structures by Zhao et al. [1992], including the pioneering works of Hasemi et al. [1984] and Obara et al. [1986], have provided good constraint on understanding heterogeneous structure in this arc. Recently, Nakajima et al. [2001a, b] imaged a more detailed structure both for P- and S-waves of the crust and uppermost mantle in this arc.

Tomographic study by Nakajima et al. [2001a, b] for NE Japan revealed that low-Vp, low-Vs and high Vp/Vs zones are continuously distributed beneath the Moho along the volcanic front. They are inclined toward the back arc side in the mantle wedge almost in parallel to the down dip direction of the subducted slab, which seems to correspond to the ascending mantle flow from the deeper portion of the back arc side. They interpreted that the low-Vp, low-Vs and high Vp/Vs are perhaps caused by partial melt. This shows the presence of vast melting zones in the uppermost mantle. In the lower crust, low-Vp, low-Vs and high Vp/Vs zones are not visible along the volcanic front but confined to the individual volcanic areas. The upper crust beneath active volcanoes, however, exhibit low-Vp, low-Vs and slightly low Vp/Vs rather than high Vp/Vs. These suggest that the melting materials distributed beneath the Moho along the volcanic front intrude the lower crustal levels beneath each active volcano and attain at those levels. Areas with low-Vp, low-Vs and slightly low Vp/Vs in the upper crust show the presence of H2O rather than melt, which suggests that melting areas with size greater than 10 km*10 km do not exist in the upper crust even beneath active volcanoes.

Deep low-frequency microearthquakes have been detected in the lower crust and uppermost mantle of NE Japan [Hasegawa et al., 1991]. They occur in the depth range of 25-40 km where rheological properties of rocks are ductile. Hasegawa and Yamamoto [1994] suggested that these events were generated by deep magmatic activity of mantle diapirs based on the observations that low-frequency events occurred in and around low velocity zones of Zhao et al. [1992]. Comparison with the tomographic images by Nakajima et al. [2001a, b] shows that most of them occurred at the edge of low-Vp, low-Vs and high Vp/Vs areas, that is, at the edge of partial melting areas.

Mid-crustal S-wave reflectors (bright spots) have been detected not only beneath active volcanoes but also in many other regions. Their anomalously large reflection coefficients indicate that their bodies are filled with fluids. Comparison with the tomographic images in NE Japan shows that many of them are located at mid-crustal levels and directly above low-Vp, low-Vs and high Vp/Vs zones. Recently, Ujikawa [2002] investigated the internal structure of three reflectors in NE Japan and concluded that the reflector bodies are not filled with melt but with H2O.This suggests that most of them are filled with H2O supplied from the partial melting zones directly below.

References:

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