Serpentinized peridotite revealed by Seismic Tomography within forearc mantle wedge regions

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Serpentinized peridotite is detected seismologically by mapping Poisson's ratio within subduction zones, because serpentinite has a higher Poisson's ratio than other rocks in the crust and upper mantle. We determine three-dimensional P and S wave velocity models using an iterative nonlinear travel time tomography technique beneath the Kanto-Tokai district of central Japan and then construct a three-dimensional map of Poisson's ratio. We select 18,805 hypocenters and adopt 413,808 P-wave and 200,575 S-wave arrival time data from the catalog of the National Research Institute for Earth Science and Disaster prevention (NIED). Arrival time data picked by NIED are classified into four ranks, A-D, according to the picking accuracy. Respective errors of arrival times for A, B, C and D are less than 0.1 s, from 0.1 s to 0.3 s, from 0.3 s to 1.0 s, and greater than 1.0 s [Ukawa et al., 1984]. We use only data that are ranked A or B by NIED for both P-waves and S-waves to determine precise structures.

The modeling space includes the ranges of 32.8^o-37.3^{o}N, 136.8^o-141.3^{o}E, and depths of 0-450 km. All earthquake hypocenters and seismic stations used in this study are located inside the modeling space. We assume three-dimensional grid nets in the modeling space. We also use a small grid interval to reveal a fine structure of 0.1^{o}x 0.1^{o}x 8 km for depths of 0-40 km, 0.1^{o}x 0.1^{o}x 10 km for depths of 40-200 km, 0.1^{o}x 0.1^{o}x 25 km for depths of 200-400 km, and 0.1^{o}x 0.1^{o}x 50 km for depths greater than 400 km. The estimated unknown parameters are 18,805 x 4 source parameters, 106 x 2 station corrections and 31,192 velocity perturbations for P-waves and 28,792 for S-waves. Travel time residuals are reduced from 0.432 s to 0.389 s for P-waves and from 0.761 s to 0.678 s for S-waves after inversion.

In our results, at depths of 30-50 km, high Poisson's ratio regions are located around the descending Philippine Sea slab beneath the Kanto (around 36^{o}N, 139^o-140^{o}E) and Tokai districts (35^o-35.5^{o}N, 137^o-138^{o}E). Pressure and temperature conditions alone cannot explain the high Poisson's ratio anomaly because both pressure and temperature dependencies of the Poisson's ratio are small for most rocks [Christensen, 1996]. The anomalies cannot be attributed to free water in the rocks because the Poisson's ratios of rocks with free water are not very high [Watanabe, 1993]. Moreover, olivine and talc with H_2O fluid generated by dehydration reaction from serpentinite do not show very high Poisson's ratios [Sato and Ito, 2002]. We attribute the high Poisson's ratio anomalies to hydrated mantle peridotite, serpentinite, that is generated with peridotite in the mantle wedge, along with H_2O produced by the descending oceanic slabs. These anomalies are located along the upper boundary of the descending Philippine Sea plate. And the source regions of the great interplate earthquakes (1923 Kanto earthquake and anticipated Tokai earthquake) are located immediately shallower part of the plate boundary.

Geologically, serpentinite bodies are observed in the northwestern Kanto mountains [e.g. Hirauchi, 2006] just above the high Poison's ratio region at depths of 30-50 km obtained in our tomography. Between the high Poisson's ratio region and the earth surface, we find a tube-shaped high Poisson's ratio anomalies from the depth of 30 km to the earth surface where the serpentinite bodies are located in the northwestern Kanto mountains. It suggests that the serpentinites were generated in the mantle wedge region with subduction of the Philippine Sea plate and then transported to the earth surface.