P-wave velocity structure beneath landward slope of the Japan trench revealed by controlled sources and ocean bottom seismometers

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The Japan Trench is a plate convergent zone where the Pacific Plate is subducting below the northeastern Japan island. Associated with the plate convergence, many earthquakes occur beneath landward slopes of the Japan Trench. It is suggested that a large earthquake will occur in the near future. In the region off Miyagi, earthquakes with magnitude greater than 7 occurred repeatedly with a time interval of approximately 40 years. In the region off Ibaragi and Fukushima adjacent the off-Miyagi region, a series of 5 large earthquakes with a magnitude greater than 7 occurred in 1938. However, no other large earthquakes have occurred in historic times in this area. The difference of the seismic features should be related to the regionally difference of coupling between the landward plate and the Pacific plate. To consider the seismic activities of these regions, it is useful to obtain detailed P-wave velocity structures to the plate boundary.

An intensive seismic refraction/reflection survey using ocean bottom seismometers (OBSs), land stations and controlled sources in sea and land was carried out in 2004 (Shinohara et al., 2007). Beneath the trench parallel profile, an island arc Moho exists at 18-24 km depth and P-wave velocity of the uppermost mantle is estimated to be 7.9-8.1 km/s. Furthermore, the depth to the plate boundary was estimated to be about 29-34 km by using travel times of reflected waves. It is suggested that a shape of the plate boundary between the landward plate and the subducting oceanic plate influences the rupture of the interplate earthquakes. In addition, the asperity areas of the Off-Miyagi earthquakes correspond to the region with a relative slow Pn velocity (7.9 km/s).

A seismic experiment was conducted in the autumn of 2006 in the region off Fukushima and Ibaragi (Okubo et al., 2007). One of the objectives is to obtain precise Pn velocity in the landward mantle. A length of the profile parallel to the trench is 250km and we deployed 26 OBSs at an interval of 10km on the profile. We used airguns and explosives as controlled seismic sources. Total size of airguns was 100 liters and the charge size of explosives was 40kg or 60kg. Two dimensional velocity models was estimated by a 2-D ray tracing method. An island arc Moho exists at depths of 18-23km. P-wave velocity of the uppermost mantle is approximately 8 km/s. However Pn velocity above the asperity of the 1938 earthquakes is estimated to decrease to 7.6 km/s. Furthermore, the depth to the plate boundary was estimated to be about 30km by using travel times of reflected waves.

Yamamoto et al. (2006) reports that P-wave velocity in the mantle wedge beneath the region off Sanriku has P-wave velocity of approximately 7.5 km/s by a seismic tomography method using OBSs, whereas Pn velocity is estimated to be 8.0 km/s from this study. Since a seismic ray of Pn from a controlled source generally penetrates a few km into a mantle, a Pn velocity represents a P-wave velocity of the uppermost mantle. Therefore, there is a possibility that this inconsistency arises from a heterogeneity for vertical direction in the mantle wedge. A spatial spread of asperities of large earthquakes may be related to a shape of the plate boundary and a heterogeneity of a seismic velocity for a vertical direction in the mantle wedge.