Three-dimensional seismic velocity structure in the off-Miyagi and off-Fukushima forearc region

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The Japan Trench is a plate convergent zone where the Pacific Plate is subducting below the NE Japan arc. The off-Miyagi region and the off-Fukushima region show different characteristics of the interplate seismic activity. In the off Miyagi region, the large earthquakes with thrust mechanisms have occurred at intervals of about 40 years. In the off-Fukushima region, few large interplate earthquakes have occurred while the background microseismicity is high.

In order to clarify whether there are some differences in the seismic velocity structures between the off-Miyagi and the off-Fukushima regions, corresponding to the differences in the seismic activity, we estimated a 3D seismic velocity structure in the off-Miyagi and off-Fukushima forearc region by using the double-difference tomography method [Zhang and Thurber, 2006]. To obtain the detail structure of the seismogenic zone around plate boundary, we jointly use travel time data obtained by on-land seismic network and ocean bottom observations.

In our results, Most of the relocated hypocenters are along a landward dipping plane. Since the hypocenters of the repeating small earthquakes and small to middle earthquakes with thrust-type focal mechanisms are aligned along this plane, we conclude that this plane indicates the location of the plate boundary. Beneath the plate boundary, the subducting oceanic crust was imaged as the landward dipping low velocity layer, overlain by a zone of high velocity corresponding to the mantle wedge of the overriding plate. In general, the oceanic crust is characterized by its high Vp/Vs, however, the oceanic crust around the focal area of Miyagi-Oki earthquake shows significantly smaller Vp/Vs value.

In the mantle wedge, there are some velocity variations. Comparing spatial extents of the rupture areas of the 1978 and 2005 earthquakes [Yamanaka and Kikuchi, 2004; Yaginuma, 2006] and the velocity variation in the mantle wedge, we found that the location of high Vp, high Vs and low Vp/Vs anomaly corresponds to the rupture areas of the large interplate earthquakes. The high velocity and low Vp/Vs feature is indicative of less serpentinized state of the mantle wedge, and this may be the reason why M7 earthquakes repeatedly occurred in off-Miyagi region. On the contrary to the case in the rupture area of 1978 and 2005 earthquakes, we found high Vp/Vs anomaly in the mantle wedge above the rupture area of the 1936 Miyagi-Oki earthquake estimated by Yamanaka and Kikuchi (2004). Recent studies on the 1936 Miyagi-Oki earthquake [e.g. Umino et al., 2006] indicate that the actual location of the 1936 earthquake could be located more to the north compare to that estimated by Yamanaka and Kikuchi (2004). We consider that the high Vp/Vs anomaly found by this study support these results of the recent studies.

In the off-Fukushima forearc region, we found the low velocity anomaly both in the mantle wedge and the oceanic crust. The strike of the velocity anomaly zone is SE-NW. This strike direction is almost parallel to the strike direction of the fracture zones, which lie on the Pacific plate [Nakanishi et al. 1992]. At the toe of the low velocity forearc mantle, where the mantle is pinched out between the island arc Moho and subducting oceanic crust, high Vp/Vs area is found, suggesting the occurrence of serpentinization of mantle. This high Vp/Vs area is corresponding to the low backslip area revealed by GPS study [Iinuma et al. 2007]. Previous airgun-OBS experiment studies also indicated that there is a low Vp (~7.5 km/s) area at the tip of the mantle wedge in the off-Fukushima [Miura et al., 2003], while the Vp of the mantle wedge in the off-Miyagi is high (~8.0 km/s) [Miura et al., 2005]. We think that the existence of the serpentinized mantle limits the spatial extent of the interplate seismogenic zone in the off-Fukushima region, where large earthquakes rarely occur.