Seismic structure around the SSE event source in northeastern Japan forearc deduced by an airgun-ocean bottom survey

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Various kinds of slips have been observed along the plate boundary (PB) in the Japan Trench subduction zone. The 2011 Tohoku-oki earthquake ruptured the large area of PB fault along the Japan Trench, and a huge slip (> 40 m) happened at 37.5–38.5N in the Miyagi-oki region. Prior to the Tohoku-oki earthquake, slow slip events (SSE) also happened in 2008 and 2011 at 37.7–38.7N (Ito et al., 2012). Faults hosting slow slip events are often characterized by low seismic velocity anomalies (e.g., Obara and Kodaira, 2009). Although it is expected that the distribution of the interplate low velocity material can be identified by strong seismic reflectivity of the interface, a detail structure in the Miyagi-oki SSE source area remains unknown. To clarify a structural characteristic near the PB, which would provide useful information to understand the occurrence mechanism of SSE, we made an airgun-OBS (Ocean Bottom Seismometer) survey in the SSE source area.

The survey was carried out in 2014. Survey lines with 180 km length were slightly oblique to the Japan Trench axis and overwrapped the SSE source area at the southern section. We deployed 17 and 20 OBSs along each line with 10 and 8 km intervals. An airgun array with a total volume of 100 liter was shot with 50 m intervals along those lines.

To obtain a seismic velocity structure beneath each line, we performed a tomographic inversion using first arrival traveltimes (Fujie et al., 2013). Results of checkerboard resolution test indicated that velocity anomalies with > ~ 15 km and ~ 4 km in horizontal and vertical sizes can be resolved down to ~ 25 km in depth. To investigate spatial distribution of reflectors with their intensities, we applied a traveltime mapping method (Fujie et al., 2006) to observed reflected arrivals. This method directly projects picked arrival times of observed reflection signals onto corresponding reflection points in a depth-distance domain.

The P-wave velocity (Vp) model estimated by the tomographic inversion showed distinct variation of Vp in the overriding plate; high Vp of > ~ 4 km equivalent to the island arc crust material was estimated to the south of 39 N, whereas low Vp of < ~ 3 km/s corresponding to unconsolidated sedimentary layer distributed in the northern part of the survey line. On the reflection mapping images, the PB was imaged as a continuous reflector at depths from 8 km to 14 km, where Vp is ~ 5 km/s. This reflector is more distinctive beneath the island arc crust than that beneath the sedimentary layer. Since the Vps of the island arc upper crust and the oceanic layer 2 may not be different significantly, the distinctive reflections from the PB suggest the existence of a low Vp channel layer along the PB. The spatial extent of high-Vp overriding crust and the highly reflective PB, identified to the south of 39N, almost coincides with the SSE source location estimated by Ito et al. (2012). Therefore, our survey results suggest that the Miyagi-oki SSE source area is characterized by the presence of low-Vp channel layer along the PB beneath the high Vp overriding crust.

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