Active-source seismic study with a dense linear OBS array off Nemuro, the southern Kuril subduction zone

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The Kuril Trench subduction zone, the northwestern Pacific, is known as one of the most active seismogenic zone having super cycle M9-class earthquakes. For the coming event, an occurrence of ‘slip to the trench’ like the 2011 Tohoku-oki earthquake occurs, which is related to the crustal structural heterogeneity, is essential for the tsunami disaster mitigation. Thus, a comparison of the interplate structure between Kuril and Japan trench M9 source regions helps to consider what happens in the next event. The normal faulting of the incoming plate before subduction relates to control a frictional property of the plate boundary because the faulting makes the plate surface rough and transports fluid captured by crust and mantle hydration into the plate boundary. Whereas, the frontal structure in the hanging wall side of the plate boundary, especially the location of the backstop against the trench, also assumes an important role in the occurrence of ‘slip to the trench.’ From these backgrounds, this study aims to understand relationships between these interplate fault properties and plate subduction through an active-source seismic study around the super cycle source area.

In 2019, a seismic survey was conducted off Nemuro Peninsula, Hokkaido, in the southern Kuril Trench, by the R/V Kairei and Yokosuka of JAMSTEC. We set one refraction/reflection line (KT209) and three reflection lines (KT150, KT169, KT187), and each line run from the land slope to the outer rise area of the incoming Pacific Plate. Along KT209 with a length of 208 km, 80 of ocean bottom seismometers (OBSs) were deployed every 2 km (67 sites on the land slope and 13 on the incoming plate). An airgun array with a total volume of 7,800 cu.in. was used as a controlled source and shoot every 200 m. During the refraction survey, a reflection data was also collected by a 444-ch hydrophone streamer cable with a group interval of 12.5 m.

The obtained record sections of OBSs show clear fast arrivals of refracted P-wave which can be correctly traced to an offset distance of 40 km at least (200 km in maximum). 23,889 of first arrivals were preliminary picked with a pick uncertainty of ±50 msec, and their apparent velocities increase from ~2 km/s to ~8 km/s by increasing offset distances. Several later phases thought as wide-angle reflections were also observed and are under investigation.

To obtain a P-wave velocity (Vp) structure, we applied a 2D tomographic inversion method for traveltimes of first arrivals (Fujie et al., 2006). For the inverse analysis, we prepared four starting models to investigate a dependency of the analysis on an initial model; an original model by smoothing the layered structure constructed at the neighbor refraction line (Nakanishi et al., 2004), and others by editing Vp in the island arc crust and the incoming plate from the original model. Then, we started the inverse analysis from these models.

As a preliminary result, root-mean-square traveltime residuals (T_{RMS}) of final models were decreased from 500.3–973.1 msec to 45.7–47.6 msec, and normalized T_{RMS} by pick uncertainty (χ^2, < 1 indicates good data reproducibility) were converged to 0.84–0.91. A checker-board resolution test (CRT) with a checker board size of 8 km ×4 km (horizontal ×vertical) for every final model shows that the current traveltime data can resolve the structure with depths down to ~8 km from the sea bottom. The rays also distribute around depths corresponding to the oceanic mantle but the CRT are less recovered because traveltime data of deeper arrivals is insufficient. Although all models commonly show the low Vp (< ~3 km/s) zone on the plate boundary from the trench axis to ~30 km landward, Vp in the deeper crust certainly differs between models. To obtain more objective result through the inverse analysis, we will investigate to dependency of initial models more in detail by the Monte Calro approach.

Keywords: Seismic survey, Incoming Pacific plate, Island arc crust, Subduction zone earthquake