The crust and uppermost mantle structure across the central part of the NE Japan Arc revealed from the 2019 onshore seismic refraction/wide-angle reflection profiling - II

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In 2019, an extensive onshore-offshore seismic expedition was undertaken from the Yamato bank to the Japan Trench across the central part of the NE Japan arc (Sato et al., 2020a, b). The onshore seismic line of this expedition was of 150-km length, laid out from the Shonai Plain on the coast of the Sea of Japan to the eastern margin of the Kitakami Mountains on the Pacific coast, crossing the Dewa Hills, Shinjo Basin, Ou Backbone Range and Kitakami River Valley from west to east. On this profile, 1,667 receivers were set to record 24 large energy shots generated by explosives and 4 vibroseis trucks.

Following the previous analyses by Sato et al. (2020a, b), Iwasaki et al. (2021a, 2021b) and Kurashimo et al. (2021), we continued to construct the whole crust and the uppermost mantle based on the asymptotic ray theory. In the modelling for the crooked part of the onshore profile, "the distance correction" was applied to correct the systematic travel-time shifts arising from the ray-tracing calculation under the simple 2D assumption. The structure of lower crust and uppermost mantle were modelled from the first arrivals and later phases at far offsets (>50-60 km). To extract structural information for weak wide-angle reflections from the deeper crust, we applied the stacking method to the original seismic records, where neighboring 3-7 seismic traces within 300-400-m offset difference are summed up with an apparent velocity of around 10 km/s. Travel-time analysis was done both for the original and stacked seismic sections.

The obtained model at the present stage, which is mainly constrained from the travel-time data, has the following features.

(1) The uppermost part of the crust is composed of 4 layers of Vp= 1.6-2.0, 1.8-3.5, 3.7-5.0 and 4.5-5.5 km/s, respectively, representing sedimentary and volcaniclastic rocks. Their geometry shows significant change along the profile line, well correlated with fault and caldera systems developed under successive tectonic processes in the NE Japan arc since Miocene.
(2) The crystalline part of the upper crust has a velocity of 5.8-6.1 km/s, which was underlain by the middle crust with Vp of 6.4-6.5 km/s. The thicknesses of the upper and middle crusts are 5-9 and 5-7 km, respectively.
(3) The Moho depth is around 30-32 km, beneath which the upper mantle velocity is estimated to be about 7.7 km/s.
(4) The lower crust, situated in a depth range of 15-30~32 km, has a velocity of 6.5-7.1 km/s. This part is separated into 3 layers by boundaries at depths of 19~21 and 24~26km. Generally, the lower crust is considered to be of reflective, but this property may have regional difference both in horizontal and vertical directions.
(5) Beneath the Moho, we found two velocity discontinuities at depths of about 38 and 46 km. The uppermost part of the mantle down to the 46-km boundary is also reflective.

(6) Crustal earthquakes occurring under our surveyed area are concentrated within the upper/middle crust beneath the middle and eastern parts of our profile, while, in its western part, they are located at deeper depths. Low frequency earthquakes recognized under the Shinjo Basin show narrow and linear distribution extending from 15 to 40-km depth. It is interesting that its lower depth limit is situated around the velocity discontinuity at 38-km depth in the uppermost mantle detected by the present analysis (see (5)).

In the present model, however, there remain some unsolved problems. Considering the evolution and deformation processes in our surveyed area, the uppermost crust including its crystalline part is expected to have structural variation along the profile. Seismic activity in the surveyed area also suggests such variation. In our model, in contrast, the 5.8-6.1 km/s layer corresponding to the crystalline crust is quite uniform except in the easternmost part of the profile. This disagreement requires the careful reliability checks both for our travel-time data and modelling process, especially for the western part of the profile. Also, seismic velocities in deeper parts may not be well constrained only from the travel-time data. For these points, our seismic data are being intensively reevaluated both from travel-analysis and amplitude calculation by synthetic seismograms.

Keywords: crust and uppermost mantle structure, Northeast Japan Arc, Controlled source seismic expedition, backarc spreading, evolution and deformation of island arc crust, active margin

