3-D velocity structure in the Backbone Range of Tohoku bounded by active faults by a seismic tomography with spatial correlation

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The Tohoku arc is located in the northeastern Honshu, Japan. The Ou Backbone Range runs through the Tohoku arc in the N-S direction. There were several large in-land earthquakes corresponding to the active faults (Hasegawa, 1997). In the middle part of the arc, the active reverse Uwandaira and Sen'ya faults bind the Backbone Range. The purpose of the present study is to understand the relation among deep structure of active faults, 3-D velocity structures, and the microseismicity near the active faults.

From October 1997 to June 1999, Japanese university research groups carried out intensive seismic observation campaigns for both active and passive experiments in the central part of the Tohoku arc. We also conducted a dense seismic array observation of microearthquakes using off-line seismic stations in and around the Ou Backbone Range bounded by the active faults. We obtained 33,993 P- and 18,483 S-wave traveltime data from 706 natural sources and 40 blasts. We used these data and 2,803 P-wave traveltime data from 10 explosive shots in 1997 obtained by the RGES (RGES, 1999) for traveltime inversion.

We used a travel time inversion method with spatial correlation of velocities (Matsubata et al., 2001). We assumed as many grid nodes in a small interval as possible to increase freedom, simultaneously introduced correlation among velocities at surrounding grid nodes to stabilize solution. This is the method that can make the best use of data.

The minimum characteristic length of structure resolved from the data is 20 km in the area of the dense seismic observation and 60 km around the Ou Backbone Range in the upper crust. That in the lower crust is 40 km beneath the area in and around the Ou Backbone Range. The RMS of P-wave travel time residuals is 0.343 s before the inversion and is reduced to 0.186 s after 19 iterations. That of S-wave is 0.441 s and reduced to 0.280 s.

In the uppermost crust, the inversion gives 4-8 % low velocities beneath the low land, basins, plains, and active volcanoes. The interior of the Kitakami massif has 2-5 % higher velocities than the average velocity. In the lower crust, the inversion gives 2-4 % higher velocities than the average velocity beneath the Kitakami Low Land, 4-8 % low velocity anomaly at the southern end of the Kitakami Mountainous region, and a low velocity zone beneath the Ou Backbone Range and the west of the range.

Beneath the area bounded by the active faults, the inversion gives 5-10 % low P- and S-wave velocities beneath the Kitakami Low Land at the surface. We also observe a 6-8 % low P-wave velocity zone and a 2-6 % high P-wave velocity zone as compared to the average velocity beneath the Ou Backbone Range. The interior of the Ou Backbone Range has 4-8 % higher S-wave velocities than the average.

The microearthquakes made some clusters both spatially and temporally. Focal mechanism of events beneath the joint of the Sen'ya and Kawafune faults is thrust type compressed in east-west direction. Considering vertical alignment, those events beneath the Uwandaira fault zone are under down dip compression at depths of 5.5-7.5 km. That of events beneath the Uwandaira fault zone at a depth of around 10 km is thrust compressed in east-west direction. A P-axis acting to the fault zones is in the direction of east-west, however, T-axis is not constant.

The low velocity zone beneath the Ou Backbone Range corresponds to the electrically conductive zone derived from a magnetotelluric study. In spite of low velocity, the values of Vp/Vs ratio in this zone are small. One of the elements of this low velocity can be considered as the existence of aqueous. Takei (2002) solved the relationship between a ratio of the fractional changes in Vs and Vp, the bulk modulus, and aspect ratio. Applying our results, liquid volume fraction can be about 0.3-5 %. The low velocity zone extends about 18 km from north to south with a width of about 10 km in E-W direction and a thickness of about 8 km.