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Tomographic Imaging of Seismic Velocity Structure Beneath the NE Japan Arc (Extended Abstract)

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Abstract : Precise estimation both for P- and S-wave velocity structures is essential for understanding the nature of the Earth's interior. We tried to estimate P- and S-wave velocity structures beneath the northeastern (NE) Japan arc by travel time tomography. We used 169,712 P-wave and 103,993 S-wave arrival times read from waveform data of 4338 events recorded at more than 200 seismic stations. Estimated Vp/Vs ratio is 1.69 on average in the upper crust, 1.75 in the lower crust and 1.77 in the uppermost mantle. These differences in Vp/Vs ratio among layers are probably caused by the differences in material composing each layer. Our results clearly show low-velocity areas for both P- and S-waves in the crust beneath active volcanoes. In the uppermost mantle, low-velocity areas spread extensively along the volcanic front. The low-velocity areas beneath active volcanoes have smaller Vp/Vs ratio in the upper crust, while they have larger values in the lower crust and uppermost mantle. Inclined low-velocity zones for both P- and S-waves are seen in the mantle wedge in parallel with the subducted Pacific slab even for the area without active volcanoes.

Extended Abstract

The northeastern (NE) Japan arc has long been recognized as a typical subduction zone, where the Pacific plate is subducting beneath the North American/Okhotsk plate at a rate of ~10 cm/yr. Because of the plate subduction, earthquakes occur actively along the plate boundary, within the subducted Pacific plate and in the shallow portion of the overriding continental plate. So far many studies have been carried out to investigate the three-dimensional (3-D) seismic structure of this region.

Zhao *et al.* [1992] developed an updated tomography method that could handle complexly-shaped seismic velocity discontinuities such as the Moho and the slab boundary. Applying the method to first and later phase data from both shallow and intermediate-depth earthquakes, Zhao *et al.* [1992] obtained a detailed P- and S-wave velocity structures beneath NE Japan down to 200 km depth. Their result clearly showed that low velocity zones were distributed continuously along the volcanic front in the uppermost mantle and extended to the backarc side in the mantle wedge, generally in parallel to the subducted Pacific slab.

The number of seismic stations deployed in NE Japan has increased greatly in the last decade. In particular, many temporary stations were set up during the period from October 1997 to June 1999 in the central part of NE Japan as a part of the Joint Seismic Observation Project by Japanese university groups [Hasegawa and Hirata, 1999]. Data obtained by this dense seismic network facilitated to update the previous results of travel time tomography.

We estimated 3-D P- and S-wave velocity structures beneath NE Japan based on these data

[Nakajima *et al.*, 2001b]. Here, we describe an outline of the obtained results.

In the tomography study, we used the method and computer programs developed by Zhao *et al.* [1992]. We used 169,712 P- and 103,993 S-wave arrival time data from shallow and intermediate-depth earthquakes located during the period from October 1997 to July 1999 by the seismic network of Tohoku University which covers NE Japan. We performed the inversions by setting grid nodes with a spacing of 0.25 degrees in NS and EW directions and 10-30 km in depths. In the tomographic inversions, we have taken into account the Conrad and the Moho discontinuities and the upper boundary of the subducted Pacific slab. Following Zhao *et al.* [1992], we adopted the depth distributions of the Conrad and the Moho discontinuities determined by Zhao *et al.* [1990] and that of the upper boundary of the subducted Pacific slab by Hasegawa *et al.* [1983]. However, for the central part of NE Japan, we used the Moho geometry determined recently by Nakajima *et al.* [2001a] from arrival time data of reflected and converted waves at the Moho.

The final results of the inversions were obtained after six iterations. The root-mean-square (rms) of arrival time residuals for the initial model was 0.267 s for P-wave and 0.593 s for S-wave. After the six iterations the rms residual is reduced to 0.214 s for P-wave and 0.437 s for S-wave. Figures 1(a) and (b) show P- and S-wave velocity perturbations we obtained, respectively. Vp/Vs images are shown in Figure 1(c). The obtained P- and S-wave images at each depth are very similar to each other. Slow anomalies are visible right beneath active volcanoes in the upper crust (10 km depth), while they spread over in wider areas of the lower crust (25 km depth). In the uppermost mantle (40 km depth), very slow anomalies are distributed continuously along the volcanic front both for P- and S-waves. The amplitude of slow Vs anomalies is greater than that of Vp anomalies.

We computed the Vp/Vs ratio down to a depth of 40 km from the obtained P- and S-wave velocity structures (Figure 1(c)). The average Vp/Vs ratio is 1.69 in the upper crust, 1.75 in the lower crust and 1.77 in the uppermost mantle. These differences in Vp/Vs ratio are probably caused by the lithological variations in depths. Vp/Vs ratio beneath active volcanoes has anomalous depth variations in contrast with those in other regions. We can see from Figure 1(c) that beneath active volcanoes, Vp/Vs ratio is small in the upper crust, while it is large in the lower crust and uppermost mantle. Extremely high Vp/Vs areas are extensively distributed along the volcanic front in the uppermost mantle. Materials under active volcanoes exhibit low-Vp, low-Vs and low Vp/Vs in the upper crust but low-Vp, low-Vs and high Vp/Vs in the lower crust and the uppermost mantle. The low-Vp, low-Vs and low Vp/Vs features in the upper crust beneath active volcanoes may suggest the existence of H_2O (rather than melts) right beneath active volcanoes, while the low-Vp, low-Vs and high Vp/Vs in the lower crust and the uppermost mantle are interpreted in terms of partial melting and/or H_2O, and they may indicate the presence of a vast amount of melts in the uppermost mantle [Nakajima *et al.*, 2001b]. These results suggest that partial melting zones may not appear in the upper crust beneath active volcanoes at least in a volume larger than the spatial resolution of the present inversions, while partial melting zones should exist in the lower crust and the uppermost mantle.

Vertical cross sections across active volcanoes clearly show that low-velocity zones are distributed almost in parallel to the subducted Pacific slab continuously from the deeper portion of the mantle wedge in the backarc side to the crust right beneath active volcanoes for both P- and S-wave images. In the cross section which does not pass through active volcanoes, similar low-velocity zones inclined to the backarc side are visible but they have smaller amplitudes than

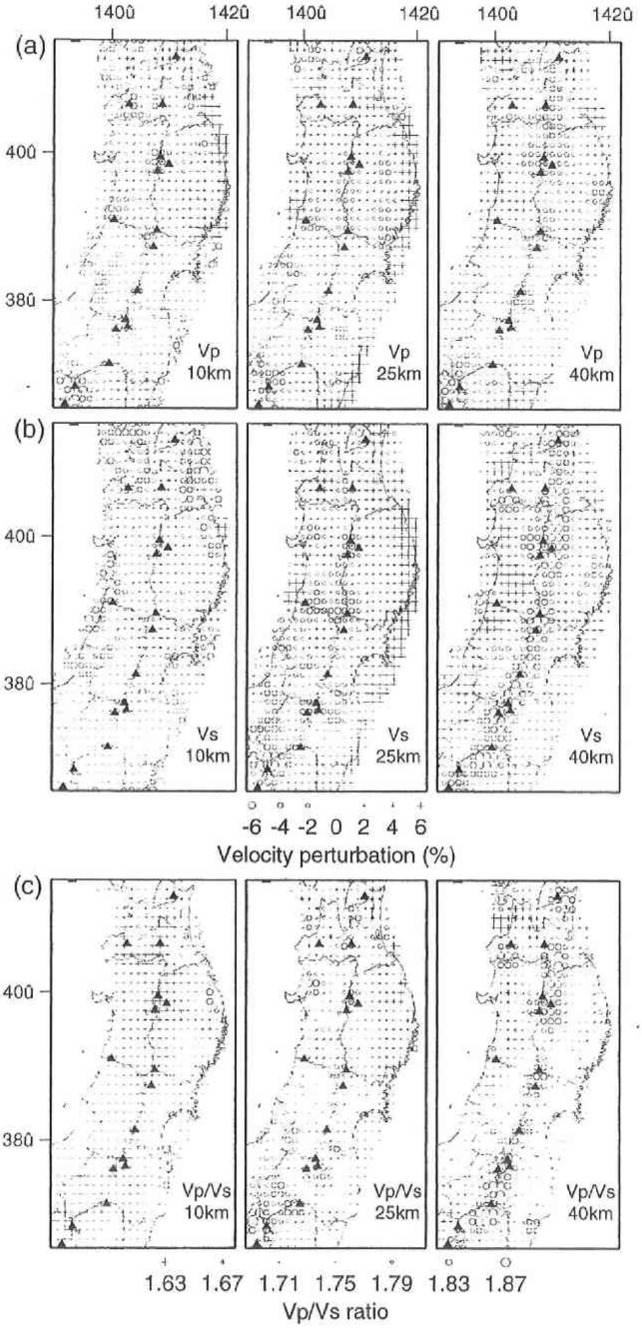

Fig. 1 (a) P- and (b) S-wave velocity perturbations and (c) Vp/Vs values obtained by the inversions. Circles and Crosses in (a) and (b) represent low- and high-velocities, respectively. Circles and crosses in (c) represent high and low Vp/Vs, respectively. Solid triangles denote active volcanoes. The depth of the layer is shown in the bottom right corner of each map.

those in the cross sections with active volcanoes. It is of note that the inclined low-velocity zones exist in the mantle wedge even for areas where active volcanoes do not appear at the surface, although they have slightly smaller amplitudes. We infer that these inclined low-velocity zones are images of the ascending flow of the mantle material from depth, that is, a portion of the secondary convection mechanically induced by the plate subduction.

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