Structural heterogeneity of the upper slab boundary and the generation of large thrust earthquakes

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http://www.epsu.jp/jmoo2005/

In order to clarify the generating mechanism of large thrust earthquakes in the forearc region of subduction zones, it is necessary to determine the detailed structure of the main thrust zone between the subducting oceanic plate and the overlying continental plate. So far 3-D seismic structure of the crust and upper mantle has been well determined under the land areas of Northeast Japan. However, the structure of the forearc region under the Pacific Ocean has been less known because earthquakes in the forearc region are not located accurately due to the lack of seismic stations. Umino et al. (1995) detected sP phase from seismograms of earthquakes under the Pacific Ocean recorded by land seismic stations and used the sP phase to relocate the sub-oceanic events accurately because the sP phase is very sensitive to the focal depth. In this study, we first detect sP depth phases from Hi-net seismograms of the earthquakes under NE Japan forearc beneath the Pacific Ocean, then use the sP phase and P and S first arrivals to relocate the sub-oceanic events. Then we combine P and S wave data from earthquakes beneath both the land and Pacific Ocean to determine 3-D P and S velocity structures under the entire NE Japan arc from the trench to the Japan Sea coast. We used 166,835 P and 97,724 S wave arrival times from 4536 local earthquakes under the land area and 2845 sP depth phase from 385 events beneath the Pacific Ocean. The method of Zhao et al.(1992) is used to conduct tomographic inversions. Our inversion results confirmed the main features delineated by the previous studies for the land areas and revealed some new features of structural heterogeneity beneath the forearc region. The cold subducting Pacific slab and the hot mantle-wedge low-velocity anomalies are clearly imaged. Strong lateral heterogeneities are revealed on the upper boundary of the Pacific slab under the forearc region, which show a good correlation with the spatial distribution of the large interplate earthquakes. Widespread slow anomalies are visible in the forearc mantle above the subducting Pacific slab, which may reflect the serpentinization of the forearc mantle associated with the dehydration process of the subducting slab. Our present results indicate that fluids from the slab dehydration and lateral heterogeneity on the slab boundary can certainly affect the nucleation of large interplate earthquakes in the forearc region.

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