

Focal depth distribution of aftershocks of October 31, 2003, off-Fukushima earthquake (M6.8) estimated from sP phase

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A shallow large earthquake with a magnitude 6.8 occurred off the border between Miyagi and Fukushima Prefectures on October 31, 2003. Its aftershock area is located to the southeast of the asperity of the 1978 Miyagi Oki earthquake (M7.4). Focal mechanisms of the main shock and large aftershocks are low-angle thrust fault type. Many shallow aftershocks took place after the occurrence of the main shock and are located by the seismic network of Tohoku University. Since all the events occurred outside of the network, their hypocenters, especially focal depths, are not constrained well.

Distinct later phases were often observed in vertical component seismograms between direct P and S wave arrivals at epicentral distances of about 150 km or more for these aftershocks. We identified this later phase as to be sP phase, an upgoing S wave from the focus which is then reflected and converted to a P wave at the Earth's surface, diving into the Earth again, and finally arriving observation stations (Umino et al., 1995). Arrival time difference between this phase and the first P wave is very sensitive to focal depths of events, and is useful for accurate estimation of focal depths of events.

We checked 3 components of seismograms of the aftershocks which occurred during the period from 31 October to 4 November 2003. Distinctive sP phase was observed about 70% of those aftershocks. Arrival time differences between P and sP phases of aftershocks increase from ~5 seconds to ~9 seconds decreasing the longitudes of hypocenters. Therefore focal depths of the aftershocks increase from ~12 km to ~20 km. Distribution of aftershock focal depths dips at an extremely low angle of less than 10 degrees toward the west-northwest direction, the plate convergence direction of the subducting Pacific plate there.

Next we investigated focal depths of shallow earthquakes which occurred off Fukushima and Miyagi Prefectures before the 2003 M6.8 earthquake by using sP phases. Distribution of those earthquakes relocated by sP phases depicts the configuration of the upper plate boundary at shallower depths beneath the Pacific Ocean: the Pacific plate beneath the NE Japan arc subducts at an extremely low dip angle of less than ~10 degrees for the first descent to ~20 km depth and then gradually becomes a much steeper dip angle of ~30 degrees at depths deeper than ~30 km. The Pacific plate is slightly bent at the point where the dip angle of the plate changed from ~10 to ~30 degrees. Many large shallow earthquakes with magnitude 7 or greater took place at those bending points (Umino et al., 1995).

Focal mechanism of the M6.8 earthquake and obtained focal depth distributions of aftershocks and background events show that the M6.8 earthquake occurred at the boundary between the subducting Pacific plate and overriding plate. The M6.8 earthquake seems to have started at the bending point of the Pacific plate.

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