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Seismic imaging of the 2011 Iwaki earthquake area: Effect of Pacific slab dehydration on the rupture nucleation

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The 2011 Iwaki earthquake (M7.0) occurred on 11 April 2011 and it was a crustal earthquake with normal faulting along the Idosawa fault. Such a large earthquake was not expected at this fault before the Iwaki earthquake took place. In order to understand the generation mechanism of this earthquake, we need to study the detailed 3-D crustal and upper-mantle structure of the earthquake source area.

Tong et al. (2012) determined 3-D tomographic images of the crust and upper mantle in and around the source area of the Iwaki earthquake. Their results show that the Iwaki earthquake and its aftershocks mainly occurred in a boundary zone with strong variations in seismic velocity and Poisson's ratio, and prominent low-velocity anomalies are revealed in the lower crust and upper mantle under the Iwaki source area, which may reflect fluids released from dehydration of the subducting Pacific slab. Many previous studies have found that crustal fluids played an important role in the nucleation of large crustal earthquakes in the Japan Islands (e.g., Zhao et al., 1996, 2010; Wang and Zhao, 2006a, b; Cheng et al., 2011; Gupta et al., 2011; Padhy et al., 2011). It was suggested that the 2011 Iwaki earthquake was generated by a similar mechanism (Tong et al., 2012).

In this study, we selected 6912 earthquakes which occurred during a period from Jun. 2002 to Nov. 2012, which is over 1 year longer than the study of Tong et al. (2012. These earthquakes were recorded by the combined seismic network in Japan, and carefully selected based on the following criteria: (1) all the events ($M>1.5$) were recorded by more than 30 seismic stations; (2) to keep a uniform distribution of hypocenter locations and avoid the event clustering, we divide the study area into small blocks, and selected only one event in each block that was recorded by the maximal number of stations; (3) the uncertainty in the hypocentral location is < 4.0 km. As a result, 6912 events were selected that were recorded by 139 seismic stations in the study area. Different from Tong et al. (2012), we removed the offshore earthquakes which occurred over 20 km away from the Pacific coastline, because those events are located outside the seismic network and so they have poor hypocentral locations. Finally we used 163585 P-wave arrival times and 150182 S-wave arrival times from 5099 earthquakes recorded by 139 seismic stations. We have applied the tomographic method of Zhao et al. (1992) to our data set. The horizontal grid interval is 0.08 deg. in the Iwaki earthquake area and 0.15 deg. in the surrounding region. The final root-mean-square travel-time residual is 0.171 s for the P-wave data and 0.342 s for the S-wave data.

The obtained tomographic images are generally similar to those by Tong et al. (2012), while our present results have a better resolution and reliability. Prominent low-velocity anomalies are revealed in the crust and the upper-mantle wedge under the volcanic front, which reflect the arc-magma related hot anomalies. Fine low-velocity anomalies are also revealed very clearly in the lower crust and upper mantle under the Iwaki hypocenter as well as beneath the active Futaba fault which is located right beside the Fukushima Nuclear Power Plant (FNPP). We consider that these low-velocity anomalies reflect fluids from the dehydration of the subducting Pacific slab. The great 2011 Tohoku-oki earthquake (Mw 9.0) induced static stress change in the overriding Okhotsk plate, resulting in significant increase of seismicity in the Iwaki source area after the Tohoku-oki mainshock. Our results support the suggestion of Tong et al. (2012) that the Iwaki earthquake was triggered by the ascending fluids from the Pacific slab dehydration and the crustal stress variation induced by the Tohoku-oki mainshock. The similar structures in both the Idosawa and Futaba fault zones suggest that the security of the FNPP site should be strengthened to withstand a potential large earthquake in the future.

Keywords: Seismic tomography, The 2011 Iwaki earthquake, Crustal fluid