Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SCG68-10 Room:303 Time:May 23 16:45-17:00

Change in the stress field in the inland area of NE Japan after the 2011 Tohoku-Oki earthquake

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We have reported that the principal stress orientations changed after the 2011 Tohoku-Oki earthquake even in the inland areas far from the source area (Yoshida et al., 2012). A typical example of such areas with changed stress orientations is central Akita Prefecture. We investigated amply the stress field in the inland area of Tohoku to further confirm the above results and to know in detail the areas where the principal stress orientations changed after the 2011 Tohoku-Oki earthquake. In order to considerably increase focal mechanism data, we picked P-wave initial-motion polarity data from original seismic waveform records observed at many temporary seismic stations that are deployed in this area both before and after the Tohoku-Oki earthquake. Then we determined focal mechanisms of those events. The number of well-determined focal mechanisms is 2835 and 4291 before and after the 2011 Tohoku-oki earthquake, respectively. These numbers almost doubled the previous dataset. First, we estimated the spatial variation of the stress fields in NE Japan before and after the Tohoku-Oki earthquake in each 50 km spaced grid by applying the stress tensor inversion method. The results show that the estimated principal stress orientations significantly changed after the earthquake in three regions; northeast Miyagi Prefecture, central Akita Prefecture and southeast Tohoku near Iwaki city. The estimated orientations correspond to those of the static stress change caused by the coseismic slip of the Tohoku-Oki earthquake.

Then, we estimated again the stress fields in those regions before and after the Tohoku-Oki earthquake in more detail. We relocated hypocenters using the double-difference location method in the three regions, and applied the stress tensor inversion method to those data by subdividing the regions. Although the change in the stress fields near Iwaki city was not significant due to the existence of the depth variations of stress fields, the stress fields changed significantly in NE Miyagi Prefecture and central Akita Prefecture. This suggests that the stress magnitudes in NE Japan are very low because the static stress changes are only about 1-3 MPa of differential stress. Another possibility is that the stress fields in NE Japan are spatially very heterogeneous with the scale $<$ 10 km.

To confirm whether the stress magnitude has such a low value, we investigated the effect of the tidal stress on earthquake rate. Tidal stresses were calculated including both the solid earth and ocean loading to focal mechanisms estimated above. The phase distribution exhibits a strong influence of tidal shear stress increments in NE Japan both before and after the Tohoku-Oki earthquake. Statistical test shows that it is significant (Schuster, 1897). Using the formula by Dieterich (1987), which was obtained through numerical simulations based on rate- and state-dependent friction law, we estimated the effective normal stress from the phase distribution. Assuming a = 0.004-0.01, the effective normal stress is estimated as 1.0-2.5 MPa. This value is roughly consistent with the value estimated using the change of the stress field after the 2011 Tohoku-oki earthquake.

Keywords: stress field, static stress change, focal mechanisim, tidal triggering, stress magnitude, frictional strength