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What controls the occurrence of inland earthquakes after the 2011 Tohoku-Oki earthquake?

OKADA, Tomomi[1*], YOSHIDA, Keisuke[1], SHIKASHO, Kenta[1], TAKAGI, Ryota[1], HASEGAWA, Akira[1], Group for the aftershock observations of the 2011 Tohoku-Oki earthquake[1]

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Shallow seismic activity in the crust of the overriding plate west of the source area changed significantly after the 2011 M9.0 Tohoku-Oki earthquake which ruptured the plate boundary east off northern Japan beneath the Pacific Ocean.

In order to understand the cause of the distinctive seismicity change of inland earthquakes, Okada et al. (2011) [1] precisely relocated earthquake hypocenters for several earthquake sequences following the Tohoku-Oki earthquake using the double-difference method. Hypocenter distributions were used to discriminate the fault plane from the auxiliary plane of the focal mechanisms for those earthquake sequences. Some of the plausible fault planes are not correlated the previously-known active faults around them. Some earthquake sequences were swarm-like and spatio-temporal migration of hypocenters of some earthquake sequences were observed.

We calculated Coulomb stress change on those fault planes caused by the Tohoku-Oki earthquake. In all cases, the estimated Coulomb stress changes at the plausible fault planes for those post-Tohoku-Oki sequences are positive. The positive Coulomb stress change is mainly due to the reduction of normal stress on the fault plane of the earthquake sequences caused by the large, low-angle thrust fault of the Tohoku-Oki earthquake. The present observations suggest the static stress transfer possibly triggered those post-Tohoku-Oki earthquake sequences.

We also estimated stress fields in inland areas of eastern Japan before and after the Tohoku-Oki earthquake by inverting focal mechanism data (Yoshida et al., 2011 [2]). Before the earthquake, sigma-1 axis was oriented EW in Tohoku but NW-SE in Kanto and Chubu regions. The stress fields changed after the earthquake in northern Tohoku and in southeastern Tohoku, where the orientations of the principal stresses seem to be approximately the same as the orientations of the static stress change associated with the earthquake. This indicates that differential stresses in these areas before the earthquake were very small. In Kanto and Chubu regions, principal axes of the stress perturbations caused by the M9 earthquake are almost parallel to the respective axes of the background stress field. This is probably the reason why conspicuous seismicity increase was observed there.

Okada et al. (2010) [3] estimated a detailed seismic velocity structure in the central part of NE Japan using data obtained from a dense temporary seismic network. They found distinct seismic low-velocity zone below the seismically active areas (the seismic belt) along the volcanic front and fore-arc region.

The post-Tohoku-Oki events were also relocated using the three-dimensional velocity structure. The post-Tohoku-Oki events also tend to be distributed above the edge of the seismic low-velocity zone in the lower crust. This seismic low-velocity zone in the lower crust corresponds to the high seismic attenuation zone (Shikasho et al. [2011] [4]). This suggests that inhomogeneous structure of viscoelastic structure and overpressured fluid distribution which appear as the seismic low-velocity / high attenuation in the lower crust are spatially related to the distribution of the post-megathrust events. Small background differential stress inferred from the stress change analyses could be due to the high fluid pressure. Spatio-temporal migration of hypocenters of some earthquake sequences can be interpreted as the result of fluid diffusion.

Not only the elastic stress transfer/change but also the inelastic deformation and/or fluid distribution are possibly important for understanding the interaction between the large subduction thrust ruptures and seismicity of inland earthquakes.

References: [1] T. Okada et al., Earth Planets Space, 63, 749 (2011). [2] K. Yoshida et al., Geophys. Res. Lett., 2011GL0049729, in press. [3] T. Okada et al., Earth Planets Space, 62, 347, (2010). [4] K. Shikasho et al., AGU Fall Meeting, S41A-2174, (2011).