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Change in seismicity rate around major active faults due to the 2011 off the Pacific coast of Tohoku Earthquake

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Significant changes in seismicity rate are observed around major late Quaternary active fault zones in Tohoku and Central Japan due to the 2011 off the Pacific coast of Tohoku Earthquake with a magnitude (M) of 9.0 on the Japan Meteorological Agency scale (MJMA). Changes in seismicity around fault zones in Central Japan are basically well explained by the static changes in the Coulomb Failure Function (dCFF) due to the mainshock. However, increases in seismicity rate around some fault zones (e.g., thrust fault zones in Tohoku region) are inconsistent with dCFF imparted by the giant earthquake and calculated on the major fault zones. In these regions, changes in both hypocentral locations and focal mechanisms are observed. This implies that the stress field in the crust is originally heterogeneous in space.

Occurrences of large earthquakes concentrate on a time interval, several years before and 10 years after an occurrence of a large (giant) interplate earthquake along the Japan Trench (Shimazaki, 1978). For example, Rikuu earthquake (M 7.2) occurred two and half months after the 1896 Meiji Sanriku earthquake. Swarm activity was observed in the Rikuu earthquake source region after the Meiji Sanriku earthquake (Imamura, 1913). It is important to examine changes in seismicity rate in order to infer an effect on large earthquakes occurring on major fault zones.

In this study, we investigated changes in seismicity rate around about 100 major active fault zones, which are selected by the Headquarters for Earthquake Research Promotion, by extracting earthquakes which occurred within 5-km distance from a fault plane from March 11, 2010 to November 11, 2011, and calculating changes in seismicity rate. We also examined the consistency with dCFF due to the mainshock and afterslip (Earthquake Research Committee, 2011). We used the unified JMA catalog from March 11, 2010 to February 28, 2011 and PDE catalog provided by JMA from March 1, 2011 to November 11, 2011.

Seismicity rate increased more than 10 times for 11 fault zones (i.e., the Sakai Toge/Kamiya (Main), Kita-Izu, Mahiru-Sanchi Toen, Nagamachi-Rifusen, Yokote-Bonchi Toen, Nagai-Bonchi Seien, Takada-Heiya Toen, Tokamachi (West), Muika-machi (South), Inohana fault zones, and Gofukuji fault).

Among these, The Sakai Toge/Kamiya (Main), Kita-Izu fault zones, and Gofukuji fault are consistent with the increases in dCFF. However, increases in seismicity rate are inconsistent with dCFF calculated for the Mahiru-Sanchi Toen, Yokote-Bonchi Toen, and Inohana fault zones. The dCFF are small for the Inohana fault zone. For the Mahiru-Sanchi Toen and Yokote-Bonchi Toen fault zones, seismicity rates increased regardless of decreases in dCFF. Focal mechanisms of earthquakes which occurred after the mainshock are dominantly strike-slip even though the thrust-type is dominant before the mainshock. The distribution is complementary with the distribution of earthquakes which occurred before the mainshock. Thrust type of earthquakes in Tohoku region such as the aftershock area of the 2008 Iwate-Miyagi earthquake (MJMA 7.2) drastically decreased after March 11, and this is well explained by the extension in the E-W direction due to the mainshock.

The increases in seismicity rate for the other fault zones are apparent. Swarm activities have been observed after the mainshock near the Nagamachi-Rifusen and Nagai-Bonchi Seien fault zones. Changes in seismicity rate around the Tokamachi, Muikamachi, and Takada-Heiya Toen fault zones are contaminated by the occurrence of the MJMA 6.7 earthquake on March 12.

It is reported that the increases in seismicity rate by dynamic stress changes due to the passage of seismic waves. Other factors such as pore pressure changes due to the fluid migration will also change seismicity rate. Declustered catalog may be more appropriate in order to estimate the change in background seismicity rate.

Keywords: The 2011 off the Pacific coast of Tohoku Earthquake, Change in seismicity, major late Quaternary active faults, static changes in the Coulomb Failure Function