Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SSS36-01 Room:303 Time:May 21 15:45-16:00

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), Muikamachi (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

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SSS36-02 Room:303 Time:May 21 16:00-16:15

The modified ETAS analysis on earthquake swarms induced by the Tohoku earthquake

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The ETAS model provides a good estimate of earthquake intensity when the underlying mechanism is uniform, or stationary. Any diversions of it from the data hence imply seismicity anomalies involved temporally into the focal region. Activation and quiescence caused by stress changes from outside are one of such anomalies. Relatively long-lasting changes can be treated by the ETAS model with one or a few change-points; in which framework all or part of ETAS parameters are estimated separately and independently across those change-points. This method, however, has troubles when changes occur gradually over time or kicks in for a short period of time, or appears repeatedly. For such cases, alongside the change-point framework, we consider the following more flexible form of misfit functions q(t)'s which estimate the misfits of the ETAS model from data.

We here adopt two forms of misfit functions. Both of them are to be estimated as the best modifications of the ETAS model to data, evaluated at each occurrence time of event. Because of this large parameterized nature, we use the Bayesian smoothing method to estimate them. The first misfit function modifies the overall reference ETAS intensity itself;

lambda'(t)=lambda(t)$*$q(t). (model1)

Any large diversions of q(t) from unity reveals misfit of the ETAS model and hence suggests anomalies in seismicity. The second misfit function re-estimate the background component of the ETAS intensity: mu, which is originally constant, as a time-varying function mu(t) in the form

mu'(t)=mu$*$q(t), (model2)

so that the estimated function let us follow the change in the background seismicity which is most susceptible to certain causes among the ETAS parameters. We check the characteristics of these functions with simulated data first, then applied them to some of inland earthquake clusters triggered by the Tohoku Earthquake as well as the data sets with swarm events, to which the normal ETAS model poorly fits. The data sets include earthquakes on Nagano-Niigata prefecture boundary (M6.7), eastern Shizuoka (M6.4), Fukushima Hamadori (M7.0) and swarm events in north-west of Lake Inawashiro.

Keywords: Touhoku earthquake, ETAS model, swarm, Bayesian smoothing, misfit

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SSS36-03 Room:303 Time:May 21 16:15-16:30

Normal-faulting seismic sequences in Ibaraki and Fukushima Prefectures triggered by the Mw9.0 Tohoku-oki Earthquake

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The 2011 M9.0 Tohoku-Oki Earthquake triggered widespread seismicity throughout the Japanese island arc including Hokkaido and Kyushu regions. In particular, a significant increase in the shallow seismicity was observed in the minutes following the main-shock along the Pacific coast of NE Japan, notably the northern part of Ibaraki Prefecture and the southern part of Fukushima Prefecture. The most striking feature of the induced seismicity is that the focal mechanisms reveal normal faulting with a T-axis orientated in a roughly E-W direction. Several large magnitude events including the maximum 7.0 earthquake have occurred during the sequence. It is very important to understand why such intensive earthquake swarm activity associated with large magnitude events was triggered therein.

We have, therefore, conducted a series of temporary seismic observations through a dense deployment of about 60 portable stations after outbreak of the intensive seismic swarm. We manually picked P- and S-wave arrival times of earthquakes using waveforms retrieved from the dense seismic network. We determined high-resolution three dimensional velocity structures applying the double-difference tomography method [Zhang and Thurber, 2003] to the datasets.

At the northern part of the Ibaraki prefecture, depth-sections of hypocenters show an earthquake alignment dipping westwards at 40 to 50-degree at depths shallower than 10 km. On the other hand, hypocenters at the south-east part of the Fukushima prefecture show diffused pattern, consisting of many small seismic clusters. Most of hypocenters appear to be located along velocity boundaries between high- and low- velocity bodies. Note that a low velocity body is clearly imaged beneath the hypocenter of the largest M7.0 event (2011/04/11) in this seismic sequence.

Keywords: triggered seismicity, velocity structure, earthquake

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SSS36-04 Room:303 Time:May 21 16:30-16:45

Characters of induced earthquakes with normal faulting in southern Abukuma based on a temporal aftershock observation

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A lot of inland earthquakes with normal faulting were induced to southern Abukuma region by the 2011 off the Pacific coast of Tohoku Earthquake (Mw9.0). We carried out temporary seismic observation in the region to examine the characteristics of induced earthquakes with normal faulting. As results of tomographic inversion analysis, high P-wave velocity anomaly corresponds well with the surface distribution of the metamorphic rocks, whereas low velocity predominates in the granitic rocks. The hypocenters distribute mainly in the low velocity zone, therefore the occurrence of the induced earthquakes may be controlled by the geological structure. Extreme high seismicity is observed in the western side of Itozawa fault, along which surface rupture appeared at the earthquake (M7.0) on April 11th, in contrast with low seismicity in the eastern side. The dip of the seismicity boundary is nearly vertical at shallow depth than 10 km, changing to 60W at the deeper depth. On the contrast low angle (35 SW) seismic plane dips in the western part of the Yunodake fault. Therefore the deeper part of the Itozawa fault and the Yunodake is possible to convergent. Focal mechanisms suggest that normal faulting is dominant in Abukuma area, while the direction of T-axes is variable. The fact suggests that the principal stress sigma-2 is nearly equal to sigma-3, and both orientations are horizontal. The induced earthquakes may be occurred at the existing weak plane which is perpendicular to the local orientation of sigma-3.

Keywords: The 2011 Tohoku-Oki earthquake, Induced earthquake, Normal fault, Aftershock observation, Crustal structure

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Fault length and the past millennium activity of the Fujigawa-kako Fault Zone

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The Fujikawa-kako fault zone, striking NNW-SSE, is located in the western side of the Mountain Fuji. This fault zone is the inland extension of the Nankai Trough, and is considered as a source fault of the Tokai large earthquake which has been altered for more than three decades in central Japan. To understand the seismic potentials for the Fujikawa-kako Fault Zone, quantitative assessment of recent activity is vital.

Previous studies reported that the Fujikawa-kako fault zone is about ˜26 km and the most recent seismic event may occurred before 1,500 years based on the drilling and trench data without direct fault evidence (Yamasaki et al., 2002; The Headquarters for Earthquake Research Promotion, 2010). However, our group has reported that the total length of the fault zone is up to ˜35 km and the most recent seismic faulting event may occur in the recent 1,500 years based on field investigations, trench excavations, and radio carbon dating ages which were carried out during the past decade.

In this study, geological and geomorphological investigations are conducted to identify the tectonic topography and characterize the recent faulting activity of the northern segment of the fault zone. Based on the interpretation of aerial photos and 3D perspective views analyzed using Digital Elevation Model (DEM) data, and field investigations, we have obtained following new findings: 1) distinct fault scarps are recognized in the northern area from Shibakawa to the Omuro volcano; ii) the total fault length is up to 36 km; iii) the AD 896 Jogan lava flow was displaced 2-4 m in vertical along the fault scarp. Trench excavations and fault outcrops, volcanic ash sequence analysis as well 14C dating results also show that the recent seismic faulting event probably occurred in the past millennium. Based on the historical records, it is inferred that the latest fault event occurred along the Fujikawa fault zone is related to one of the three large earthquakes of ˜M8: AD 1096 Eichou, AD 1707 Houei, and AD 1854 Ansei Tokai earthquakes, which all occurred in the Tokai region around the study area. In this presentation, we will report our recent results including field investigations and dating ages and discuss the fault length and recent activity of large earthquakes.

References cited:

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Keywords: Fujigawa-kako Fault Zone, Tokai Earthquake, Jougan lava, Eichou Earthquake, Ansei-Tokai Earthquake, Hoei Earthquake