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

SSS25-P01 Room:Convention Hall Time:May 21 18:15-19:30

Crustal deformation before and after the Tohoku-oki earthquake in the central part of the Tohoku district by GPS data

Hideki Fukuda[1], Yusaku Ohta[2*], Seiichi Shimada[3], Akiko Hasemi[1], Kenji Tachibana[2], Tomotsugu Demachi[2], Satoshi Miura[4], Teruyuki Kato[4]

[1]Guraduate School of Science and Engineering,Yamagata University, [2]Graduate School of Science, Tohoku University, [3]National Research Institute for Earth Science and Disaster Prevention, [4]Earthquake Research Institute, University of Tokyo

The Yamagata-bonchi fault zone runs along the western margin of the Yamagata basin. This fault zone is separated into northern and southern parts around Sagae city. The first objective of this study is to investigate the difference in the strain field between the Yamagata-bonchi fault zone and the surrounding area. The difference of strain distribution between the northern and southern parts of the Yamagata-bonchi fault zone was also investigated.

Ohzono et al. (2012) estimated the coseismic heterogeneous property of crustal response to stress disturbance of step function using GPS data from the Tohoku district. Their result showed that crustal deformation in the strain concentration zone along the backbone range was small compared to the theoretical coseismic crustal deformation associated with the 2011 Tohoku-oki earthquake. They indicated that the difference resulted from the structure of the lower crust in the strain concentration zone. The second objective of this study is to investigate the strain distribution character in the middle of the Tohoku district where Ohzono et al. (2012) indicated a heterogeneous crust .

We used 54 GEONET stations, 4 Yamagata University stations, and 11 Tohoku University stations. The number of total stations is 69. The analysis period was January, 2008 to December, 2012. Analysis softwares were GAMIT/GLOBK ver. 10.4 (Herring et al., 2011). We calculated each day coordinate value of 69 stations using ITRF2005 as a reference.

We calculated each site displacement rate during 1, July, 2008 to 1, March, 2011 to estimate the strain distribution before the Tohoku-oki earthquake. We considered the annual variation and half annual variation to estimate the strain displacement for this period. We estimated the strain distribution using the method of Shen et al. (1996). The result showed contraction in the east-west direction caused by subduction of the Pacific plate. The southern part of Yamagata Prefecture containing the Yamagata-bonchi fault zone was contracted in the northeast-southwest direction. This direction is the same as that of a compression axis of microearthquakes in the southern part of Yamagata bonchi fault zone obtained by Furusawa et al. (2008). There is a little strain concentration in the Yamagata- bonchi fault zone compared to the surrounding area, but no difference between the northern and southern parts of the fault zone. We obtained coseismic strain distribution using displacement from 3-9, May, 2011 to 18-20, April, 2011. The result showed $1.5*10^{-5}$ extension in the east-west direction in the Yamagata-bonchi fault zone. We also estimated the strain distribution after the Tohoku-oki earthquake. The prominent results were as follows. The back-arc area was the extensional strain field. A coastal area on the Pacific Ocean side was a contraction field, and there was an extensional field on the east side of the backbone range. The area along the backbone range was a contraction area. We calculated the strain distribution assuming a single rectangular after slip area on the plate boundary, referring to the Geospatial Information Authority of Japan (2012) and compared the calculation and observed strain distribution. We found that strain distribution could be explained by after slip except in the area along the backbone range that was an extensional field in the calculated result. Ohzono et al. (2012) suggested that backbone range is smaller contraction compared with surrounding region by coseismic displacement. Our result also show the characteristic strain anomaly distribution in postseismic stage. This anomaly may be caused by some elastic constant variation of upper crust and/or rheological heterogeneity of lower crust or upper mantle.

Keywords: Tohoku-oki earthquake, Crustal deformation, GPS, Yamagata-bonchi fault zone

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Crustal movement of the Nagano-ken Hokubu earthquake and seismotectonics of the Sakae-Tsunan-Matsunoyama district

Yuka Ito[1*], Akira Takeuchi[2]

[1]Grad. Sch. Sci. Eng., Univ. Toyama, [2]Grad. Res. Sci. Eng., Univ. Toyama

Just after the Mw9.0 off the Pacific coast of Tohoku Earthquake (Tohoku Earthquake), the Mw6.7 Nagano-ken Hokubu Earthquake (Sakae Earthquake, hereafter) occurred on the boundary between Nagano and Niigata prefectures, on March 12th in 2011. This area is located within the Shinanogawa Seismic Belt (Ohmori, 1907) and Niigata-Kobe Tectonic zone (Sagiya et al., 2000), where the maximum shortening occurs in an E-W trend.

By analyzing the GEONET GPS data, Geospatial Information Authority of Japan (GSI) announced that, the Matsuno-yama site (0244) in Niigata Prefecture was displaced northeastward by 39.3 cm, and that the Nagano-sakae site (0982) was displaced northward by 4.2 cm.

In order to reveal and understand temporal change in displacement field at and around the time of those earthquakes, and also to examine the characteristics of the source fault of the Sakae Earthquake, this study analyzed the GEONET GPS data by utilizing both GAMIT software (ver.10.42) and RTD software (ver.3.5).

As a result, this study revealed that at the moment when the Sakae earthquake occurred, the Matsuno-yama (0244) was displaced by 35.6 cm northward and 20.2 cm eastward while the Nagano-sakae (0982) was displaced by 7.7 cm northward and no displacement was recorded both eastward and westward. The Sakae Earthquake did cause a large displacement to around the epicenter area, while the post-seismic crustal movement of the Tohoku Earthquake has progressed remarkably after the Sakae Earthquake.

The ground surface deformation due to shear and tensile faults were also analyzed with DCSTN software (Okada, 1992). The result showed that, a reverse faulting with an upward dip-slip in a northwest direction could account for the coseismic displacement field of the Sakae Earthquake. However, such a fault slip is not enough to account for all the displacement at the GEONET sites.

This implies that any other movements than the faulting might affect the displacements of GPS permanent stations. One of such possibilities is tilting of sedimentary layers due to dome-like upheaval. The dome structure around this area is an anticline with a short axis, which is characterized by the intersection of the eastern margin of Northern Fossa Magna and the western margin of central uplift belt. So this study presents a 2-dimensional fault model for the main shock, which can explain displacements at Matsuno-yama and Nagano-sakae sites and geological structure in the study area. Coseismic growth of the fold structure might imply that the basement faulting made the sedimentary cover to be deformed.

After analyzing an after-slip deformation of the Sakae Earthquake, this study is able to present the following two possibilities. The first is that the source fault of the main shock was also reactivated to slip also after the main shock. The second is that, to the south of the Sakae source fault, another strike-slip fault was also activated to generate Mw5.6 event on April 12, 2011.

Keywords: Nagano-ken Hokubu earthquake, Niigata-Kobe Tectonic zone, Northern Fossa Magna, GEONET, faults, dome

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The March 12, 2011, Northern Nagano Prefecture earthquake - a normal fault event?

Atsushi Nozu[1]*

[1]Port and Airport Research Institute

The March 12, 2011, Northern Nagano Prefecture, Japan, earthquake (M6.7), which occurred one day after the Tohoku earthquake, caused significant damage to Sakae village. The aftershock distribution for the initial 24 hours suggests a NE-dipping fault plane, while the CMT solutions from NIED and JMA suggest a reverse-fault event on a NW-dipping or a SE-dipping fault plane. Possible solution for this conflict was investigated. As a result, the possibility of the earthquake being a normal fault event was suggested.

Aftershock distributions for large earthquakes have often been used for the determination of the fault plane. For example, it was based on the aftershock distribution that the 1994 Northridge earthquake was assigned to a south-dipping fault plane, although the nearby 1971 San Fernando earthquake had a north-dipping fault plane. Although some earthquakes have ambiguous aftershock distribution, the aftershock distribution for the initial 24 hours for this particular earthquake (Figure) is much clearer than for the 2004 Mid Niigata Prefecture earthquake (Kato et al., 2005, GRL) or the 2007 Chuetsu-oki, Niigata, earthquake (Kato et al., 2008, EPS). Therefore, it is easy to conclude from the aftershock distribution that the earthquake had a NE-dipping fault plane.

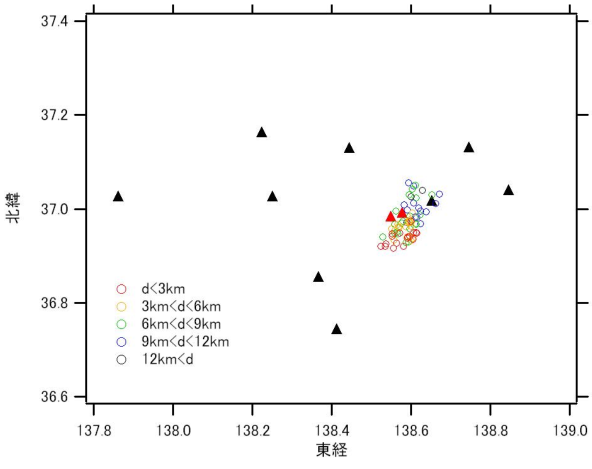
However, the CMT solutions from NIED and JMA suggest a NW-dipping or a SE-dipping fault plane. There have to be some explanation for this conflict.

The author tried to solve this conflict as follows. The strike and dip angles were fixed based on the aftershock distribution and the rake angle was varied to investigate its effect on the SH and SV radiation coefficients. The result indicates that, if the rake angle is assumed to be minus 120 degrees, then the resultant radiation pattern for the far field becomes similar to those associated with a reverse-fault event on a NW-dipping or a SE-dipping fault plane. Thus, even if we assume a NE-dipping fault plane, the far field radiation pattern, from which the CMT solution is obtained, can be explained. In this way, we can solve the conflict between the aftershock distribution and the CMT solution.

By the way, the above solution requires a negative rake angle, which corresponds to a normal fault event. If we can assume that the earthquake is a normal fault event, it is advantageous for explaining other data associated with the same earthquake. For example, for the two strong motion stations just above the fault (Sakae town office and K-NET Tsunan), the initial P waves were negative (tension). It is easier to explain this polarity with a normal fault event. Finally, this earthquake might have been triggered by the great Tohoku event (Okada et al., 2011, EPS). If it is true that the earthquake was triggered by the Tohoku event, it is natural to assume that the earthquake was a normal fault event, because the incremental stress induced by the Tohoku event was mainly a tensile one in the NE-SW direction.

Acknowledgment: The author used the K-NET and SK-net strong motion data.

Keywords: the 2011 Northern Nagano Prefecture earthquake, aftershock distribution, CMT solution, normal fault, radiation pattern, triggered earthquake



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A stress estimation using calcite twin piezometer of fault rock derived from the Ryoke belt along MTL, SW Japan

Nobuaki Tanaka[1*], Koichiro Fujimoto[1], Norio Shigematsu[2]

[1]Tokyo Gakugei University, [2]AIST

Stress is important to understand the strength of the crust and the generation of large earthquakes. Despite considerable research, there is still no consensus on the stress of major tectonic faults. In this study, we measured deformation twin density (mm^(-1)) in the calcite grain in the fault rocks along the Median Tectonic Line (MTL) and evaluated differential stress (MPa) of them.

AIST drilled a borehole penetrating the MTL for predicting Tonaikai-Nankai Earthquake at Matsusaka-Iitaka, Mie prefecture (total depth 600m). It crosses MTL at the depth of 473.9m. Hangingwall of the MTL consists of the Ryoke-derived tonalitic rocks and footwall of the MTL consists of the Sanbagawa metamorphic rocks.

The fault rocks in the hangingwall experienced the four kinds of tectonic stresses within the brittle regime (Shigematsu et al., 2010). The fault rocks contain a large number of calcite veins (Tanaka et al., 2012). So far, calcite twin piezometer has applied only to the rocks purely composed of calcite. Sakaguchi et al. (2011) found a strong correlation between differential stress and twin density for the sand stone containing calcite grains; D=6.0729^(-3) x (delta d)^1.7543 (D: twin density, delta d: differential stress).

At the depth of 353.4m, the twin density is 118.7 +/- 87.8 /mm (n=63) and differential stress is 155MPa $<$ delta d $<$ 456MPa.

Keywords: calcite, twin, stress, Ryoke belt, Median Tectonic Line, fault rock