SSS25-01 Room:302 Time:May 21 09:00-09:15

Local anomaly of crustal deformation associated with the 2011 Pacific coast off Tohoku earthquake in the Echigo plain

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Geospatial Information Authority of Japan constructed a dense GNSS array across the Echigo plain in the Niigata-Kobe tectonic zone in 2010. We conducted campaign GNSS measurements every fall. Strain distribution based on GNSS data acquired in 2010 and 2011 campaigns suggests that extensional strain of the 2011 Tohoku-oki earthquake is large in the Echigo plain, which is concordant with the analysis of Ohzono et al. (2013) using the GEONET data. Ozawa et al. (2013) pointed out local subsidence around active volcanoes of northeastern Japan using InSAR data and suggested that local deformation was attributed to soft medium beneath the volcanoes. We present detailed strain distribution measured by three GNSS campaigns and that calculated using finite element model (FEM) in and around the Echigo plain.

Strain and displacement distribution from October 2010 to October 2011 in a direction of N105^{o}E shows 6.2 ppm (15.4 cm in a 25-km-long baseline) of extension west of Niitsu hill and 3.8 ppm (6.2 cm in a 16-km-long baseline) of extension east of Niitsu hill, whereas the area east of the hill is close to the source area of the 2011 Tohoku-oki earthquake. It disagreed with our expectation that strain east of the hill should be larger than that west of the hill. Large strain west of the hill may be related with thick soft sediments layers in the Echigo plain. We made a FEM analysis with the rectangular fault model of Nishimura et al. (2011) and a heterogeneous elastic medium approximating the J-SHIS subsurface structure model developed by National Research Institute for Earth Science and Disaster Prevention. Calculated strain distribution shows EW extensional strain in a central part of the Echigo plain is about twice as large as that in the surrounding region. Calculated extensions are 6.1 and 3.4 ppm for western and eastern regions of Niitsu hill, respectively, which is concordant with the observation. It is generally difficult to distinguish heterogeneous strain distribution due to a fault mechanism and variable slip on the fault from that due to elastic heterogeneous medium using observed near-field deformation. However, a large slip of the 2011 Tohoku-oki earthquake far from the observation area enables us to distinguish them clearly. Our result suggests that incorporating inhomogeneous medium is important in the modeling of crustal deformation for not only the 2011 Tohoku-oki earthquake but also a general case.

Keywords: Crustal deformation, the 2011 Tohoku-oki earthquake, Finite Element Model, GNSS

Japan Geoscience Union Meeting 2013
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SSS25-02 Room:302 Time:May 21 09:15-09:30

Viscous relaxation after the Tohoku Oki Earthquake by heterogeneous rheological structure of the NE Japan

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Deployment of dense network of geodetic observations has illuminated the heterogeneous crustal deformation associated with the Mw 9.0 2011 Tohoku Oki earthquake. Ohzono et al. (2012) showed the heterogeneity of coseismic strain fields likely reflecting heterogeneity in rheological (viscoelastic) properties of the NE Japan lithosphere (Yabe et al., in prep). Moreover, viscoelastic relaxation after the earthquake that lasts longer than other mechanisms (e.g., afterslip and poro-elastic rebound) has also known to be affected by viscosity structures of the island arc-trench system such as elastic thickness variation, spatial and depth-dependent viscosity. Therefore, the viscosity structure of the NE Japan trench-arc system must be estimated in order to evaluate the viscous relaxation component accurately in the observed post-seismic deformation field. To this end, two-dimensional viscosity profiles of the northeastern (NE) Japan island arc-trench system were created using laboratory derived constitutive laws of various minerals. The calculated profiles based on temperature, pressure and water contents dependent rock rheology predict viscosities of the mantle wedge and oceanic mantle to be 10^{19} Pa s and 10^{20} Pa s, respectively. These values agree well with the recent estimate of the viscosities after the post-seismic deformation of the 2004 Sumatra earthquake (Mw 9.2). This indicates that the steady-state flow laws of rocks can be used to infer post seismic deformation field. However, our calculations reveal significant lateral variations in viscosities across the northeastern Japan arc: thick, high viscous lithosphere in the colder forearc and thin and low viscous lithosphere in the hotter volcanic front. Preliminary two-dimensional finite element modeling (FEM) on post-seismic deformation of the Tohoku Oki earthquake revealed that the incorporation of the lithosphere structures have significant effects to the stress relaxation process compared with widely used uniform layered model. In the presentation, we will furthermore examine stress relaxation process of the lithosphere from FEM modeling taking into account of temperature- and depth-dependent heterogeneous rheology.

References: [1] Muto, J. (2011) Tectonophysics, 503, 201-206. [2] Ohzono, M., Y. Yabe, T. Iinuma, Y. Ohta, S. Miura, K. Tachibana, T. Sato, and T. Demachi (2012) Earth Planets Space, 64, 1231-1238.

Keywords: Post-seismic deformation, Viscous relaxation, Rheology of crust and mantle, Tohoku Oki Earthquake, Northeastern Japan, Arc-trench system

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SSS25-03 Room:302 Time:May 21 09:30-09:45

Change in stress field by the 2011 Tohoku-Oki earthquake and fault strength-stress loading process for inland earthquake

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A clear temporal change in stress field was observed after the 2011 Tohoku-Oki earthquake in the upper plate beneath the Pacific Ocean (Hasegawa et al., 2012). The principal stress directions were reversed for areas with static stress change greater than 5-15 MPa, which indicates that those areas in the upper plate beneath the Pacific Ocean had differential stress magnitudes less than 5-15 MPa before the earthquake. Significant rotations of the principal stress axes after the earthquake were also observed for some areas of the inland, far from the source area of the Tohoku-Oki earthquake, suggesting that stress magnitudes for those areas before the earthquake were as small as ˜1 MPa (Yoshida et al., 2012). If the stress magnitudes have such small values, we need to reconsider the stress loading model for inland earthquakes.

A recent study on stress field in the inland of NE Japan based on many focal mechanism data shows that the arc and back-arc are characterized by spatially uniform margin normal compression, but the fore-arc has different stress orientations (Yoshida et al., this meeting). The Kitakami and Abukuma mountain ranges in the north and south have ?1 axis oriented nearly N-S and vertical, respectively. This indicates that the margin normal compression in the arc and back-arc is not caused mainly by the coupling with the Pacific plate beneath the Pacific Ocean but perhaps by the convergence of the Eurasia plate from the back-arc side.

These observations indicate that differential stress magnitudes causing inland earthquakes are small and so fault strengths are weak as well. The weak faults are probably caused by overpressured fluids. We propose a new stress loading model for inland earthquakes based on these observations.

Keywords: Stress, fault strength, stress loading process, inland earthquake, crustal fluids, Tohoku-Oki earthquake

Japan Geoscience Union Meeting 2013
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SSS25-04 Room:302 Time:May 21 09:45-10:00

Postseismic deformation following the 2008 Iwate-Miyagi Nairiku earthquake deduced from PS-InSAR time series analysis

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We detected the anomalous long-term crustal deformation after the 2008 Iwate-Miyagi Nairiku earthquake (hereafter IMEQ) deduced from PS-InSAR time series analysis based on the ALOS/PALSAR data. The anomalous crustal deformation caused by superposition of the long and short wavelength deformation.

The 2008 Iwate-Miyagi Nairiku earthquake occurred beneath the border between the Iwate and Miyagi prefectures at north-eastern Japan in 13 June 2008. Based on the long-term GPS time series (~1.5 years), Ohzono et al. (EPS, 2012) detected clear postseismic signal, which indicates wider-area crustal shortening between the focal area and the subsidence signal in the focal area. They conclude that this postseimsic signal is caused by viscoelastic relaxation process in the lower crust and/or upper mantle, and constructed a simple spherical 2-layerd (elastic and Maxwell viscoelatic layer) model. The viscoelastic model, however, could not explain the large GPS displacement near the focal area. In this study, we discuss the long-term crustal deformation after the IMEQ deduced from PS-InSAR time series analysis based on the ALOS/PALSAR InSAR data.

We applied StaMPS (Hooper et al., JGR, 2007) approach to the ALOS/PALSAR data obtained by the JAXA. In order to produce our interferograms, we processed a set of 14 descending orbit SAR images (Track 57, Frame 2830), acquired by the ALOS/PALSAR sensors from July 2008 to October 2010. In particular, SRTM4 Digital Elevation Model of the study area and precise orbital information were used for the interferograms generation. The master data image is acquired in June 3rd, 2009. The result based on our analysis clearly shows LOS (Line of Sight) change in and around the focal area. We found the clear LOS change in the footwall and hanging wall side of the focal area. In the footwall side, the LOS is extended which may be subsidence or displaced to the westward. It is clear evidence of the viscoelastic relaxation after the mainshock pointed by (Ohzono et al., EPS, 2011). The hanging wall side LOS change is characteristic. In the hanging wall side, we found the two large amount LOS shortening regions (around Ameta-mori and Mt. Takamatsu-dake). It is difficult to explain by the simple viscoelastic relaxation. We tried to explain the origin of these anomalous LOS changes. In the Ameta-mori region, it is possible to explain by the aseismic fault slip. In contrast, in Mt. Takamatsu-dake area, it may be caused by the volcanic process because of the shallow part (~3km) of this region clearly show the low seismic velocity compared with surrounding region (Okada et al., EPS, 2012).

Keywords: Inland earthquake, postseismic deformation, InSAR

Japan Geoscience Union Meeting 2013
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SSS25-05 Room:302 Time:May 21 10:00-10:15

Imaging the source regions of normal faulting sequences induced by the 2011 M9.0 Tohoku-Oki earthquake

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Intense swarm-like seismicity associated with shallow normal faulting was induced in Ibaraki and Fukushima prefectures, Japan, following the 2011 Tohoku-Oki earthquake. This seismicity shows a systematic spatiotemporal evolution, but little is known of the heterogeneity in crustal structure in this region, or its influence on the evolution of the seismicity. Here we elucidate a high-resolution model of crustal structure in this region, and determine precise hypocenter locations. Hypocenters in Ibaraki Prefecture reveal a planar earthquake alignment dipping SW at about 45-degree, whereas those in Fukushima Prefecture show a more complex distribution, consisting of conjugate sets of aligned small earthquakes. On the north of the hypocenter of the largest earthquake in the sequence (the M7.0 Iwaki earthquake), we imaged a high-velocity body at shallow depths that lacks aftershock seismicity. Based on fault source models, the large-slip region of the Iwaki earthquake is situated along a zone that roughly coincides with this high-velocity body. We delineated a separate low-velocity anomaly directly beneath the hypocenter of the Iwaki earthquake, indicating crustal fluids in this region. We hypothesize that strong crust underwent structural failure due to the infiltration of crustal fluids into the seismogenic zone from deeper levels, causing the Iwaki earthquake.

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SSS25-06 Room:302 Time:May 21 10:15-10:30

Spatial variation of the stress field and 3-D seismic velocity structure in the seismic belt of San-in district

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Spatial variations of the stress field and heterogeneous structures of the crust are important to clarify the earthquake occurrence mechanism. We used data from 50 temporary stations and 27 permanent stations in and around the seismic belt in the San-in district to look into a relation between the stress field, 3D seismic velocity structure seismicity and pore fluid pressures.

The stress field is estimated by a standard method of stress inversion using focal mechanisms. The estimated RMS of misfit angle is less than 10 degrees for each analysis area. This means that the estimated stress field can reproduce observed variations of slip directions. The azimuths of the maximum horizontal stress in the central part of the seismic belt are oriented in N120‘E-N130‘E, while in the other regions, they are oriented in almost N100‘E-N110‘E. This spatial change in the stress field in and around the seismic belt is consistent with the result by Kawanishi et al., (2009).

We also determined a 3D seismic velocity structure in the San-in district by using the program FMTOMO(Rawlinson et al., 2006) Grid intervals are 0.05‘ along the latitudinal and longitudinal directions, and 3 km in the vertical direction. As a result, we found that there are low velocity zones around the eastern Shimane Prefecture and the aftershock region of the 2000 Western Tottori. It seems that these low velocity zones extend to 13 km depth. We can see a relation between low velocity and the seismicity in this region. The low velocity zones are located boundary between low and high velocity zone. It seems that the seismicity in the eastern Shimane may be controlled by an upper crustal heterogeneity or fluid.

In order to clarify whether crustal fluid caused earthquake in the San-in district, we looked into the distribution of pore fluid pressure by using the results from the stress inversion and tomographic analyses. We assume that stress field is homogeneous within each region of the stress inversion and the friction coefficient on each fault is constant (0.6), as indicated by Byerlee’s law (Byerlee, 1978), then we can conclude that observed variation of focal mechanism is caused by variations in pore fluid pressures acting on faults. The result showed that there are results which have various fault strength. This is consistent with that crustal fluids in a low velocity zone in the San-in district is related to the seismicity in this region.

Keywords: focal mechanism, stress field, tomography

SSS25-07 Room:302 Time:May 21 10:30-10:45

Joint Inversion of Phase Velocity and Receiver Function for Estimation of Sedimentary Layers near the Tachikawa Fault

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Tachikawa fault is one of the most activity faults in the Tokyo metropolitan area and when large earthquake will occur by this fault in the near future, it is expected that large economic and human loss will happen around this area. However, three dimensional subsurface structural model is not clear still enough for the estimation of the strong ground motions in this area. In this study, we estimated the three dimensional subsurface structural model using the joint inversion of Rayleigh wave phase velocity and receiver functions.

To accomplish it, we first conducted the array observations of microtremors at eight sites around the Tachikawa fault. Rayleigh-wave phase velocity at periods from 0.5 to 5.0 seconds was estimated from a frequency-wave number spectral analysis of the microtremors. We next analyzed the earthquake records observed at 60 stations of the K-NET, KiK-NET and SK-net to derive a receiver function. We calculated the receiver functions from 20 to 50 seismic records obtained at each station.

Finally, we conducted the joint inversion of the phase velocity and the receiver function to a P and S-wave velocity profile based on the simulated annealing method. Based on numerical experiments, the inverted phase velocities and receiver function displayed good agreement with the observed ones. P-wave velocities ,S-wave velocities and thickness of individual layers are inverted very well, and the S-wave velocities of the inverted profile are 0.5, 0.9, 1.5, 2.7, and 3.2km/s.

Moreover, we constructed the three dimensional subsurface structural model in this area obtained from P-wave and S-wave velocity profiles of thick sediments at each station. The results indicate that a basement depth in those profiles at down-thrown side of the fault is larger than that at up-thrown side with a difference of about 1.8km.

Keywords: Tachikawa fault, joint inversion, receiver function, array microtremor exploration, Rayleigh wave phase velocity

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SSS25-08 Room:302 Time:May 21 11:00-11:15

Relationship between hypocentral distributions and seismic heterogeneous structures inferred from dense array data

Issei Doi[1*], Shunta Noda[2], Yoshihisa Iio[3], Shigeki Horiuchi[4], Shoji Sekiguchi[5]

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At present, we have not fully understood how earthquakes, especially crustal ones, are generated. However, elucidating generation process of earthquakes is very important for long-term forecasting and disaster reduction. To investigate the generation process of the mainshock and the swarm activity near the source, we conducted a three-dimensional travel time tomography in and around the source region of the 1984 western Nagano Prefecture earthquake, central Japan.

In western Nagano Prefecture, Ooida et al. (1989) pointed out that there was a high seismic activity in the hypocentral region of this earthquake even before the mainshock (at least from May, 1978, when Mt. Ontake erupted) and the activity is still high even now. We can also observe the swarm seismicity in the eastern part of the source region in recent years. In this region, Iio et al. (1999) have been conducting a dense seismic observation with 57 stations separating 1-4 km from each other. We used as much as about 215,096 P-wave and 183,917 S-wave travel time data from this network. The travel time errors were a few ms and a few decade ms for P and S arrival times, respectively.

In the tomographic inversion, we had three stages mentioned below. First, we determined the initial hypocenter locations and origin times with a fixed initial velocity structure. Next, we estimated the one-dimensional velocity profile as well as recalculated hypocenters and station corrections through a one-dimensional inversion. Lastly, we performed a three-dimensional seismic tomography to obtain three-dimensional velocity perturbations together with recalculated hypocenters and station corrections. Considering the errors of the estimated arrival times, horizontal grids were set with the interval of 1.5 km in the central part of the analysis area where many used hypocenters are distributed, and 3 km outside there. Vertical grids were designated with the interval of 1 km above the depth of 4 km and as 2 km below. We used pseudo bending (Um and Thurber, 1987) and LSQR method (Paige and Saunders, 1982) for ray tracing and matrix inversion, respectively.

As a result, we obtained detailed hypocenter distributions and velocity structure at depths of 2-6 km in the mainshock and swarm source regions. Hypocenters in the swarm region are located in the region with low Vp/Vs ratios, while few earthquakes occur in the region with high Vp/Vs ratios. We suggest that the difference in amount of cracks and fluids contained in them controls the seismic activity. The rupture propagation associated with the mainshock is considered to be confined under the ground by a low-velocity region and horizontally by a high Vp/Vs region.

SSS25-09 Room:302 Time:May 21 11:15-11:30

Slow slip event induced by earthquake swarm in inland of northern Hokkaido?

Mako Ohzono[1*], Hiroaki Takahashi[1], Masayoshi Ichiyanagi[1], Ryosuke Azuma[1], Teruhiro Yamaguchi[1], Takuji Yamada[1], Yuichiro Tanioka[1]

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Northern Hokkaido is one of the high seismicity areas. Coordinate time series of a GNSS observation site GEONET0851 (Horonobe) started to show an abnormal trend in July 2012 when an earthquake with M4.2 and following swam took place in northern Hokkaido. In order to extract detailed crustal deformation and confirm abnormal coordinate time series at other GPS sites, we analyzed GPS data obtained from GEONET and our dense GPS network, which we have installed to monitor detailed crustal deformation process in the northern Hokkaido. As a result, northeastern region from the hypocenter of earthquake swarm in 2012, which is located between two active fault zones, shows mainly E-W extensional field following the M4.2 earthquake and swarm activity similar to the deformation suggested at the site GEONET0851. On the other hand, eastern part of this region crossing the Toikanbetsu fault zone indicates mainly E-W constructional field at the same time. These results suggest a possibility of local crustal deformation related to the inland seismic activity. There would be two possible causes of this event. One is the inelastic deformation in the crust, and the other is a slow slip event on a preexistent fault, which would be a structural boundary. Comparing multi-geophysical data, we will further investigate the cause of this abnormal crustal deformation and the relationship with the seismic activity.

Keywords: crustal deformation, inland earthquake, slow slip

SSS25-10 Room:302 Time:May 21 11:30-11:45

Modeling stress field around the fault of the 1995 Kobe earthquake (M7.2) using focal mechanisms 2

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Recent numerous studies about stress field estimated from focal mechanism of microearthquakes succeeded to estimate stress field in seismogenic zone. They showed heterogeneous feature around the fault. Matsumoto et al. (2012) have developed a method that models stress field composed by regional stress field and inelastic deformation in the medium. Stress variation resulting from inelastic deformation in a medium can be expressed as equivalent body forces in the medium. Thus we applied the method to the focal mechanism data of the earthquake in the aftershock area of the 1995 Kobe earthquake. The tension and compression axes inferred from the focal mechanisms of the microearthquakes generally have the same direction that could coincide with principal direction of tectonic stress in this region. However, the axes of the focal mechanisms at some parts of the earthquake fault change their direction. We performed the method to the data with assumptions that are 1) slip of the microearthquake occurred on the pre-existing small fault in the direction of maximum share stress on the fault, 2) stress field consists of the regional stress and the moment tensors at the spatially distributed grid points along the fault. The maximum direction of the obtained regional principal stress is in ESE-WNW as expected from the general tendency of focal mechanisms. The estimated moment tensors became larger at the edges of the earthquake fault. In addition, that was also relative large at around the initiation point of the earthquake. The results of the moment tensors revealed interesting information about the stress field in the target region. The inelastic deformations at the both edges of the earthquake fault and at the middle of the fault, which might relate to the initiation and termination of the earthquake rapture.

Keywords: Stress field, Kobe earthquake, focal mechanism, inelastic deformation

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SSS25-11 Room:302 Time:May 21 11:45-12:00

Comparison between geologically determined fault slip and seismologically determined stress along the Atotsugawa Fault

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We compared fault-slip data observed at outcrops and seismologically determined stress tensors along the Atotsugawa Fault. The seismologically determined stress tensors show the maximum principal stress orient horizontally WNW-ESE, and depth dependence of the solutions (Imanishi et al., 2011).

We obtained fault slip data at four outcrops located at eastern, middle and western part of the fault. The fault slip data obtained at three of four outcrops are consistent with the seismologically determined stress tensor, especially that for deep part of the fault. The fault slip data obtained at the other outcrop are not consistent with the seismologically determined stress tensor.

The fault slip data obtained at the Atera fault are also consistent with the seismologically determined stress tensor (Tonai et al., 2011). Therefore, the comparison between fault-slip data observed at outcrops and seismologically determined stress tensor is possibly useful to identify if a fault is active. Topographical analysis is necessary to understand the inconsistent fault slip data with seismological data at one outcrop.

Keywords: Atotsugawa Fault, stress tensor inversion, fault slip data, microearthquakes, active fault

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SSS25-12 Room:302 Time:May 21 12:00-12:15

A stress concentration model for the 2007 Noto Hanto earthquake fault

Yoshihisa Iio[1*], Youichiro Takada[1], Takeshi Sagiya[2], Group for the Atotsugawa Joing Observation[1]

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In order to clarify the process by which intraplate earthquakes are generated, we constructed a stress concentration model for the 2007 Noto Hanto earthquake fault. We introduced a vertical strike slip fault located immediately beneath the earthquake fault, and modeled that the slip on this vertical fault generated that on the earthquake fault

Keywords: intraplate earthquake, lower crust, stress accumulation process, Niigata-Kobe tectonic zone, Weak Zone

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SSS25-13 Room:302 Time:May 21 12:15-12:30

Systematics of element migration via fluids in cataclasites and ultimate cataclasites by metasomatism

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We have analayzed mass transfer in cataclasites using core samples drilled through the Median Tectonic Line (MTL), Idaka-town, Mie-prefecture. This borehole penetrates through the MTL at the depth of c. 474 m, and the 20m thick lowermost part of the upper plate of the MTL belonging to the Ryoke belt is mostly composed of ultramylonite derived from tonalite. This ultramylonite experienced cataclastic deformation to various degrees, which can be divided into relatively non-, weakly, moderately and strongly deformed rocks based on the degree of cataclasis determined by the density of shear fractures. For all the samples (n=22), bulk chemistry was measured with XRF, and it has been found that the bulk chemistry of these rocks greatly changes with increasing degree of cataclasis. For this reason, the isocon diagram was constructed assuming Al as an immobile element for both sets, non-deformed rocks versus weakly deformed rocks, and weakly deformed rocks versus moderately or strongly deformed rocks. As a result, we have found the following facts. (1) During the increasing cataclasis from the non- to weakly deformed rocks, the mass increase of c. 25% occurred, and Si, Na and K increased, while Ca, Mg and Fe decreased. (2) During the increasing cataclasis from the weakly to moderately or strongly deformed rocks, the mass decrease occurred up to c. 25% for the strongly deformed cataclasites, and Ca, Mg and Fe increased, while Si, Na and K decreased. This means that the sense of element migration became reversed with increasing cataclasis. Further, since element migration in cataclasites resulted in the changes in volume fraction of constituting minerals, we analyzed the mineral mode of these using the point count method under an optical microscope. As a result, in the weakly deformed rocks, quartz veins were formed and plagioclase was sericitized, while in the moderately or strongly deformed rocks calcite veins were formed and chlorite was precipitated, correlated with the element migration in these rocks. Accordingly, the cataclasites derived from tonalite mylonite ultimately became calcite and chlorite rich rocks. These mass changes and element migration and resultant changes in constituting minerals were interpreted in the following way. From the non- to weakly deformed rocks, dilatancy occurred due to fracturing, and silica-rich fluids flowed into the pore space created by fracturing, and quartz was precipitated there. On the other hand, from the weakly to moderately or strongly deformed rocks, strong tectonic compression perhaps expelled the pore fluids, where a lot of silica was dissolved from quartz. However, why Ca, Mg and Fe, which were also perhaps dissolved in the pore fluids, were not precipitated as minerals in the weakly deformed rocks, but precipitated as calcite and chlorite, respectively in the moderately or strongly deformed rocks, remains to be unknown. Ca-metasomatism also occurs in mafic and ultramafic rocks, which is either accompanied by brittle deformation or not. In the future, the integrated research is necessary to clarify the process and mechanism of migration of Ca, Mg and Fe.

Keywords: element migration, metasomatism, cataclasite, volume change due to fracturing, dissolution and precipitation, isocon diagram

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

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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

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

SSS25-P02 Room:Convention Hall Time:May 21 18:15-19:30

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

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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?

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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.

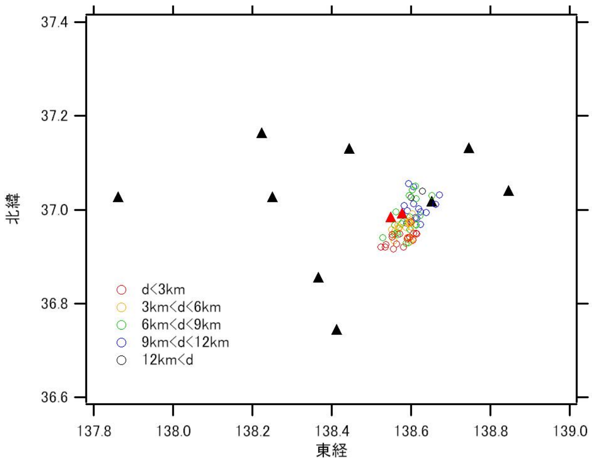
Aftershock distributions for large earthquakes have often been used for the determination of the fault plane. For example, it was based on the aftershock distribution that the 1994 Northridge earthquake was assigned to a south-dipping fault plane, although the nearby 1971 San Fernando earthquake had 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



SSS25-P04 Room:Convention Hall Time:May 21 18:15-19:30

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

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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 (mmˆ(-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=6.0729ˆ(-3) x (delta d)ˆ1.7543 (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