Japan Geoscience Union Meeting 2015
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SCG57-01 Room:A06 Time:May 27 14:15-14:30

Strategic seismic data processing for extraction of deep crustal reflectors through reconstructed velocity heterogeneity

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In recent years, the quest for increased precision and channel capacity of receiver system led to the combination of telemetry and autonomous recorders with the deployment of dense seismic array for 100-250km long 2D survey. Furthermore, multi-scale and multi-mode survey layout has been realized by the simultaneous data acquisition of regional refraction, low-fold wide-angle reflection and standard reflection survey for the several targets on the same seismic line.

In our study, multilateral approach beyond the conventional CMP stack is applied to the multi-scale, multi-mode seismic data for extraction of deep crustal reflectors through the reconstruction of velocity heterogeneity. The high-resolution velocity structure can be estimated by the hybrid profiling of reflection velocity analysis, turning-ray tomography and full-waveform inversion. The uncertainty of the tomography solutions is estimated using a nonlinear Monte Carlo approach with randomized initial models, and the velocity structure of upper crust is constrained by subsequent forward reflection and refraction modeling. In the last decade, many case studies have demonstrated that the Common-Reflection-Surface (CRS) stack based on paraxial ray theory produces an efficient alternative profile to conventional CMP stack with a pronounced signal-to-noise ratio. The combination of CRS-driven velocity attribute and full-waveform inversion with the short-wavelength structural heterogeneity has the potential imaging capabilities including velocity model for improved prestack depth migration.

We evaluated the relation between reconstructed velocity heterogeneity and the resolution of deep reflection patterns using typical multi-scale deep reflection data acquired in the northeast Japan.

Keywords: deep reflection, velocity heterogeneity, fullwave inversion, seismic reflection survey

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SCG57-02 Room:A06 Time:May 27 14:30-14:45

Estimation of seismic velocity discontinuity in the crust and uppermost mantle beneath the northern Kinki region

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The northern Kinki region constitutes Niigata-Kobe Tectonic Zone, and Philippine Sea plate subducts from southeast beneath this region. In addition, micro-earthquakes occur actively. It is known that the S-wave reflector exists at the depth of 25-30 km in this region (e.g. Aoki et al., 2013). Aoki et al. (2013) found that the three dimensional distribution of the S-wave reflector. They suggested that the fluid derived from mantle might make the S-wave reflector. The dehydration from the subducting Philippine Sea plate is considered as the source of the fluid. Thus, It is important to estimate the shape and the depth of the subducting Philippine Sea plate. Because the condition of temperature and pressure is important when hydrous minerals in the oceanic crust dehydrate.

Receiver function analysis is used to estimate the shape and the depth of the subducting plate. For example, Shibutani et al. (2013) estimated the structure of the Philippine Sea plate beneath Kii Peninsula by linear array observation. Ueno et al. (2008) estimated the depth of Philippine Sea plate and Moho discontinuity beneath Chugoku and Kinki region. However, They used only permanent seismic stations. It is hard to compare with local heterogeneous structure. On the other hand, dense seismic observation network has conducted since November 2008 in the northern Kinki region. We have observed with 170 seismic stations. The interval between stations is about 5 km. Thus, we can do receiver function analysis with high resolution by using the data obtained from this dense seismic observation network. Sasaki (2011) did preliminary analysis with 56 seismic stations. In this presentation, we show the shape and the depth of seismic velocity discontinuity by receiver function analysis, and discuss the relationship between the shape and the depth of seismic velocity discontinuity and the distribution of the S-wave reflector by Aoki et al. (2013).

Keywords: receiver function

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SCG57-03 Room:A06 Time:May 27 14:45-15:00

Seismic structure in the southern Ryukyu Trench subduction zone

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In the Ryukyu Trench subduction zone, many large earthquakes occurred historically. Recent seismic and geodetic studies indicate that the occurrence of very low frequency earthquake [Ando et al., 2012] and slow slip events [Heki and Kataoka, 2008; Nishimura, 2014] in the southern Ryukyu subduction zone. In addition, the result of offshore geodetic observation showed interplate coupling occurs near the trench [Nakamura et al., 2010], where plausible seismogenic zone of the 1771 Yaeyama earthquake (Mw 8.0) is located [Nakamura, 2009]. These results suggest that the interplate coupling is not so weak and it is possible for the large interplate earthquake to occur in this region. However, not only the fault plane geometry of past large earthquakes but also the local seismic structure is uncertain due to the sparse seismic observation network. To investigate the hypocenter distribution and the subducted plate geometry, we have conducted the passive seismic observation using 6 land stations and 30 ocean bottom seismographs (OBSs) from Nov. 2013 to Mar. 2014, as a part of "Research project for compound disaster mitigation on the great earthquakes and tsunamis around the Nankai trough region" .

We performed a seismic tomography to estimate the hypocenter location and plate geometry by using a part of obtained data, although the data picking is still in progress. The initial P-wave model was established by referring the result of active source survey [Arai et al., 2014], and the initial S-wave model was calculated by assuming a Vp/Vs value of 1.73. As the initial S-wave velocity model did not include the low-velocity sediment layer just beneath the OBSs, we calculated a station correction value for the S-wave arrival data by using the differential times of arrivals between PS converted waves and direct P-waves.

Preliminary result shows northwestern dipping hypocenter distribution and low velocity layer in the forearc region. We interpreted this layer as the subducted oceanic crust. In that case, most of earthquakes located within the oceanic crust and the uppermost oceanic mantle, and the dip angle of plate boundary gradually increased from 10 degrees near the trench axis to 30 degrees beneath the island arc. We will add more data and estimate more detail relationship between earthquake location and plate geometry.

Keywords: The Ryukyu Trench, Ocean bottom seismograph, Seismicity, Plate geometry

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SCG57-04 Room:A06 Time:May 27 15:00-15:15

Crustal structure in an arc-back-arc basin of the southeastern Japan Sea off Noto Peninsula deduced from seismic survey

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The Japan Sea is one of very well studied back-arc basins in the northwestern Pacific. Based on geophysical, geological, and petrological results, in the margin of the Japan Sea including the coastal area, the deformation, which includes the extension by the back-arc opening during the late Oligocene and the shortening since the late Pliocene, has developed (e.g., Tamaki, 1988; Sato, 1994). Little is known about the understanding of this deformation processes in this margin. Recently, in the eastern margin of the Japan Sea, it was found from the result that the deformation zone affected by the shortening and back-arc opening is distributed on the rifted island arc crust in the northern and southern parts, and on a structural boundary between the rifted island arc crust and the thicker oceanic crust in the northern part only by the seismic survey (No et al., 2014, Sato et al., 2014). However, in the other margin of the Japan Sea, we have little information about the relationship between a crustal structure and the deformation. To understand the deformation process in the margin of the Japan Sea, it is necessary to clarify the crustal structure, not only the transition area between the island arc and the back-arc basin, but also the back-arc basin area. In 2014, the seismic survey using ocean bottom seismographs (OBSs), an air-gun array, and a multi-channel hydrophone streamer was undertaken from the arc to the back-arc basin of the southeastern Japan Sea off western Noto Peninsula. For this study, we will present the crustal structure model.

The offshore seismic refraction/wide-angle reflection survey using 60 OBSs and a tuned air-gun array (7,800 cu. inch) was conducted the continental shelf off the western Noto Peninsula suffered from the crustal shortening, the southern Yamato Basin, to the Yamato Bank in the southeastern Japan Sea. This survey line has about 350 km length. In record sections of several OBSs and land stations, not only the first arrived phases but also later phases reflected from interfaces in the crust and uppermost mantle are visible.

The crust in the continental shelf area off western Noto peninsula is estimated as having about 24 km. The upper part of the crust has a lateral variation until depth of about 10 km. This variation may correspond to the characters of the deformation. On the other hand, the crustal thickness of the southern Yamato Basin off western Noto peninsula is about 13 km. This crust is thinner than that of the northern Yamato Basin off the northwest Sado-ga-shima island and Awa-shima island (e.g., Sato et al., 2014). In the Yamato Bank, the crust is estimated as having about 21 km and may have the character of the continental crust.

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SCG57-05 Room:A06 Time:May 27 15:15-15:30

Onshore-offshore deep seismic profiling across the Toyama basin: 2014 Kahoku-Tonami seismic survey

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We show preliminary results and interpretation of newly obtained deep seismic reflection profiling across Toyama sedimentary basin beneath Tonami Plain, to illuminate crustal architecture and deep to shallow structures of active faults in this region. We deployed 25 m interval offline seismic recorders covering 15 km long onshore seismic line extending from the Kureha Hills to the shoreline and connected with 2.5 km long bay cable. In addition, we deployed denser, 12.5-m-interval off-line recorders across the Tonami plain to the eastern flank of the Hodatsu Mountains to the west to illuminate shallow high-resolution structures and recent activity of blind thrust structures. Seismic signals enhanced by 25-m-interval shots using four vibroseis trucks were recorded by these onshore and offshore recorders simultaneously. Refraction tomography by use of shot records of 100-150 sweeps at about 5 km intervals suggests that P-wave velocity structure traced by the top of Vp 5 km/sec, presumably correlated with top of the pre Neogene granitic basement rocks appears located 5 km below the sea level beneath the Tonami Plain and delineates significant amount of subsidence of this region during Neogene, equivalent to the Toyama trough located to the north. Deep seismic reflection profile indicates that thick basin-fill beneath the Tonami Plain are strongly faulted and folded by moderately dipping thrust faults located both near topographic domain boundaries and underneath flat-lying alluvial plain. Architectures of folded sedimentary units suggest most of these structures are reactivated normal faults originally formed associated with Miocene extension tectonics. These structural characters of sedimentary basin are similar to other sedimentary basins extensively distributed in backarc regions, such as Niigata basin and northern Fossa magna basin. High-resolution seismic reflection profile indicates recent activity of these reactivated structures. Other important contribution from this experiment include that coastal plain along the Sea of Japan beneath the western portion of the seismic line is underlain by previously unrecognized, east-facing monocline and east-dipping thrust faults. In conclusion, these survey results provide great contribution to construct seismic source fault models for Tsunami and seismic hazard estimation.

*Research group for 2014 Kahoku-Tonami seismic survey: Ikeguchi, N., Yamauchi, K., Tanaka, S., Saka, M., Miyagawa, K., Tagami, K., Tsuji, H., Watanabe, S., Ando, M. (Earthquake Research Institute, University of Tokyo), Hidaka, K., Ouchi, K., Yamada, R. (Iwate University), Ono, A., Sato, H., Katori, T., Iida, K., Kokawa, M. (Niigata University).

Keywords: Sea of Japan, seismic source fault, crustal structure, seismic reflection survey, sedimentary basin

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SCG57-06 Room:A06 Time:May 27 16:15-16:30

Lithospheric Structure of the Hidaka Collision Zone, Hokkaido, from Reanalysis of 1998-2000 Hokkaido Transect Data VI

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The Hokkaido Island, located in the southernmost part of the Kuril trench region, has been under a unique tectonic environment of arc-arc collision due to the oblique subduction of the Pacific (PAC) plate. At the time of middle Miocene, the Kuril forearc sliver started to collide against Northeast (NE) Japan arc to form the Hidaka collision zone (HCZ) with complex structural features including the westward obduction of the crustal rocks of the Kuril arc (the Hidaka metamorphic belt (HMB)) along the Hidaka main thrust (HMT) and a thick foreland fold-and-thrust belt.

Re-analyses for a series data sets of seismic reflection/refraction experiments in HCZ, which started in 2012, are aimed to construct a more detailed collision model through new processing and interpretation techniques. A multi-disciplinary project of the 1998-2000 Hokkaido Transect, crossing the northern part of the HCZ in EW direction, collected high-quality seismic data on a 227-km seismic refraction/wide-angle reflection profile and three seismic reflection lines. Our reprocessing/re-analyses revealed interesting collision structure ongoing in the northern part of the HCZ. The westward obduction of the Kuril arc crust was clearly imaged along the HMT. This obduction occurs at a depth of 27-30 km, much deeper than in the southern HCZ (23-25 km). The CRS/MDRS processing to the reflection data firstly succeeded in imaging clear reflection events associated with the lower crust/Moho within the NE Japan arc descending down to the east. Gently eastward dipping structures above these events (in a depth range of 5-10 km) are interpreted to be fragments of Cretaceous subduction/arc complexes or deformation interfaces branched from the HMT.

The refraction/wide-angle reflection analysis including amplitude calculations revealed a series of eastward dipping interfaces at depths of 15-30 km east of the HMT, some of which show a very large Vp contrast exceeding 0.5-1.0 km/s. The subducted NE Japan arc meets the Kuril arc 20-40 km east of the HMT at a depth of 20-30 km. The above mentioned high Vp contrasts may result from the mixture of the upper crustal (low Vp) materials of the NE Japan arc and lower crustal (high Vp) materials of the Kuril arc.

Seismic reflection image in the southern HCZ reprocessed by almost the same techniques confirms a clear crustal delamination, where the upper 23-km crust is thrust up along the HMT while the lower part of the crust descends down to the subducted PAC plate. At the moment, the results in the northern HCZ do not provide positive evidence on shallow crustal delamination as found in the case of the southern HCZ, probably presenting important information on ”3D structure” of the HCZ.

Keywords: Hidaka Collision Zone, Kuril Arc, NE Japan Arc, Delamination

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SCG57-07 Room:A06 Time:May 27 16:30-16:45

Crustal structure and fluid distribution beneath the southern Hidaka collision zone based on 3-D resistivity modeling

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Erimo area, south end of Hokkaido Island is located on the south part of Hidaka collision zone where Kurile and the northeastern (NE) Japan arcs are collided. This area is an attractive research field to understand mechanism of continent evolution and deep inland earthquakes because 1) ultra-mafic rocks are outcropped although the delamination hypothesis of Kurile arc indicates uplift and down lift of upper-middle and lower crust rocks, respectively, and 2) inland earthquakes occurs anomalously depth (e.g. 1970 Hidaka earthquake M6.7). We conducted wideband and long-period magnetotelluric surveys at 27 sites in the Erimo area and obtained 3-D resistivity models based on inversion procedure. Reliable features of the inverted models and their interpretations are as follows. 1) A low resistivity zone (C-1) is distributed beneath the Hidaka main thrust (HMT) and extends to the upper most part of subducting Pacific slab. The high seismicity in the subducting slab in C-1 implies dehydration embrittlement. The C-1 around arcs boundary implies upwelling fluid along the HMT, which may affect the deep inland earthquake. 2) Ultra-high resistivity zone (R-1), which probably reflects dry metamorphic rocks, is distributed underneath the Hidaka metamorphic belt. The boundary between C-1 and R-1 is spatially consistent to the boundary between the delamination wedge and delaminated upper-middle crust (Ito, 2000). It supports the proposed collision model based on seismic surveys.

Figure caption: (a) Locations magnetotelluric stations. (b) A vertical cross-section of inverted resistivity model beneath the line X-X'. Gray lines denote geological boundaries based on seismic surveys (Ito 2000). White circles denote hypocenter between 2000 and 2012 by JMA. (c) Interpretation of the resistivity model.

Keywords: Hidaka collision zone, magnetotellurics, dehydration embrittlement, inalnd earthquake

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SCG57-08 Room:A06 Time:May 27 16:45-17:00

Crust composition in the Hidaka Metamorphic Belt estimated from seismic velocity by laboratory measurements

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The knowledge of rock composition is significant to understand the dynamics of the lithosphere in subduction systems. However, rock composition of the overriding plate is still poorly understood. To estimate rock composition of the lithosphere, it is an effective method to compare the elastic wave velocities measured under the high pressure and temperature condition with the seismic velocities obtained by active source experiment and earthquake observation.

Due to an arc-arc collision in central Hokkaido, middle to lower crust is exposed along the Hidaka Metamorphic Belt (HMB), providing exceptional opportunities to study crust composition of an island arc. Across the HMB, P-wave velocity model has been constructed by refraction/wide-angle reflection seismic profiling (Iwasaki et al., 2004). Furthermore, because of the interpretation of the crustal structure (Ito, 2000), we can follow a continuous pass from the surface to the middle-lower crust. We corrected representative rock samples from HMB and measured ultrasonic P-wave (Vp) and S-wave velocities (Vs) under the pressure up to 1.0 GPa in a temperature range from 25 to 400 ℃.

For example, the Vp values measured at 25 ℃ and 0.5 GPa are 5.88 km/s for the granite (74.29 wt.% SiO_2), 6.02-6.34 km/s for the tonalites (66.31-68.92 wt.% SiO_2), 6.34 km/s for the gneiss (64.69 wt.% SiO_2), 6.41-7.05 km/s for the amphibolites (50.06-51.13 wt.% SiO_2), and 7.42 km/s for the mafic granulite (50.94 wt.% SiO_2). And, Vp of tonalites showed a correlation with SiO_2 (wt.%). Comparing with the velocity profiles across the HMB (Iwasaki et al., 2004), we estimate that the lower to middle crust consists of amphibolite and tonalite, and the estimated acoustic impedance contrast between them suggests an existence of a clear reflective boundary, which accords well to the obtained seismic reflection profile (Iwasaki et al., 2014). And, we can obtain the same tendency from comparing measured Vp/Vs ratio and Vp/Vs ratio structure model (Matsubara and Obara, 2011).

Based on the velocity profile across the Kuril arc (Nakanishi et al., 2009) and measured ultra-sonic velocity of rock samples from HMB, we estimated rock composition of the Kuril arc. The Kuril arc has a thick middle to lower crust (6.5-7.3km/s), and shows more mafic lower crust than in HMB.

Keywords: elastic wave velocity, Hidaka Metamorphic Belt, acoustic impedance, tonalite, amphibolite

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SCG57-09 Room:A06 Time:May 27 17:00-17:15

Geodynamics of subducting slab under Izu collision zone

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The Philippine Sea plate subducts northward under the Honshu arc, Japan. The existence of relatively thick crust of the intraoceanic arc, Izu-Bonin arc, along the western margin of the Philippine Sea plate causes a complex tectonic environment. In the south Kanto area, an accretionary wedge composed of late Cenozoic sediments overlies the downgoing Philippine Sea plate. In western part of the south Kanto area, the Izu-Bonin arc has collided with the Honshu crust; remnant pieces of the Izu-Bonin arc such as the Tanzawa block were accreted to the Honshu crust. In order to interpret the geodynamics of the subducting slab under the izu collision zone, we examine mineral assemblages and dehydration process of the subducting lower crust of the Izu arc. Previous study infers that hornblende gabbro is a main constituent rock of the lower crust of the Izu-Bonin arc. Here mineral assemblages within the gabbroic composition from the Tanzawa gabbroic rocks was calculated by Theriak-Domino software, and stability fields of minerals and dehydration process are discussed. The estimated dehydration process and calculated stability fields of amphibole and garnet expects that phase change of gabbroic rocks to garnet-bearing rocks is an important process to explain the geodynamics of the subducting slab under the Izu collision zone. In this study, we propose a new hypothesis that the microearthquakes under the Izu collision zone may be triggered by phase change of gabbroic rocks to garnet-bearing rocks which seems to enhance stress concentration by volume change in the subducting lower crust.

Keywords: Izu collision zone, Philippine Sea slab, geodynamics

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SCG57-10 Room:IC Time:May 28 09:00-09:15

Estimation of fluid distribution from seismic velocity and electrical resistivity

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Geophysical mapping of fluids in the crust is critical for understanding crustal dynamics. Pore-fluids play important roles in geodynamic processes including seismic activities. Though a lot of studies have suggested the existence of aqueous fluids in the crust, the fluid distribution has not been quantitatively constrained. Seismic velocity and resistivity should be combined to make a quantitative inference on fluid distribution. It is impossible to infer the amount of fluid only from seismic velocity. Since the lithology of a study region is usually unknown, elastic properties of the rock matrix must be assumed. The fluid amount cannot be inferred only from electrical resistivity, either. The inference of the fluid amount requires the assumption on the fluid resistivity. The fluid amount estimated from resistivity must be identical to that estimated from seismic velocity. The combination of velocity and resistivity can thus constrain the rock matrix and fluid conductivity.

We propose a new method for estimating the amount of fluid from seismic velocity and resistivity. It utilizes an empirical relationship between the normalized resistivity and crack density parameter, which was obtained from measurements of elastic wave velocity and electrical conductivity in a brine-saturated granitic rock under confining pressures (Makimura and Watanabe, Poster session). Resistivity is normalized by the fluid resistivity. If we assume a lithology for the study region, we can estimate the crack density parameter from observed velocity. Using the empirical relation, we can obtain the normalized resistivity. Comparing the normalized resistivity with observed resistivity, we can obtain the fluid resistivity. If the fluid resistivity is an unrealistic value, we must modify the assumed lithology. Both the lithology and fluid resistivity can be constrained through these procedures.

The applicability and limitation of the empirical relation should be studied both experimentally and theoretically. In experimental studies, the relation should be studied in different rock types. A theoretical work on the network of grain boundary cracks will give us a basis of the relation.

Keywords: seismic velocity, resistivity, fluid

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SCG57-11 Room:IC Time:May 28 09:15-09:30

3-D Resistivity imaging of source regions of the Iwaki normal faulting sequences

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Following the 2011 Tohoku-Oki earthquake, M9.0, several areas of the inland Japan were activated due to significant change of the stress field. Among all, intense swarm-like seismicity associated with shallow normal faulting was induced in Ibaraki and Fukushima prefectures in the boundary area between Kanto and Tohoku districts, Japan. In order to elucidate a high-resolution model of crustal resistivity structure in this region and to get insights on causes of those induced earthquakes, MT surveys were performed in Jan. 2012 and from Dec. 2013 to Jan. 2014, by using Phoenix and Metronix Wideband MT instruments.

After estimating impedance tensors and induction vectors with the aid of the BIRRP code (Chave and Thomson, 2004), a 3-D phase tensor (PT) and induction vector (IV) inversion code was applied to the dataset. In order to investigate the influence of the initial model on the final structural model, we did several inversion runs with initial resistivity values ranging from 20 to 2000 Ohm-m. All the inversion runs could get respective final models with RMS of around 2. Although some differences in the final models are detected, overall characteristics and scales (in length and intensity) are similar for all the final models. Generally, induced earthquakes are distributed in the higher electrical resistivity zones. We delineated a separate low-resistivity anomaly directly beneath the hypocenter of the largest earthquake in the sequence (the M7.0 Iwaki earthquake), indicating crustal fluids in this region. Together with previously obtained seismic image (Kato et al., 2013), we hypothesize that strong crust underwent structural failure due to the infiltration of crustal fluids into the seismogenic zone from deeper levels, or stress accumulation on the edge of the isolated weak portion, causing the Iwaki earthquake.

Keywords: 3-D resistivity structure, source region of the Iwaki earthquake, localized crustal fluids

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SCG57-12 Room:IC Time:May 28 09:30-09:45

3D Resistivity Structure around the Epicenter of Iwate-Miyagi Nairiku Earthquake and Crustal Deformations

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The 2008 Iwate-Miyagi Nairiku Earthquake (M 7.2) was an unusually large earthquake, which occurred near the volcanic regions. To understand the mechanism of inland earthquakes, it is important to study the structure around the area. Okada et al. (2012) observed aftershocks precisely and estimated the seismic velocity structure. Iinuma et al. (2009) detected coseismic and aseismic slips with GPS observations. Mishina (2009) and Ichihara et al. (2014) conducted 2-D and 3-D MT surveys respectively. However, the MT station distributions of the previous MT surveys were sparse. We carried out denser surveys and showed more precise resistivity structures around the area. We conducted MT surveys at 66 stations (59 stations from October until November in 2012 and 7 stations from October until November in 2014) around the area and estimated 3-D resistivity structures using inversion code of Siripunvaraporn and Egbert (2009) with full impedance tensor as response functions. The result of our final resistivity structures is similar to the one in Ichihara et al. (2014), but is more complex. We found a low resistivity zone to the northeast of Mt. Kurikoma below 3km depth. This anomaly is connected with a low resistivity zone located under Mt. Kurikoma below 10km depth. The locations of aseismic and co-seismic slips in Iinuma et al. (2009) correspond to the locations of low resistivity and high resistivity zones in our model respectively. This may represent that low resistivity zones are brittle and high resistivity zones are ductile.

Keywords: Iwate-Miyagi Nairiku Earthquake, resistivity structure, magnetotellurics, fluid, deformation, post seismic deformation

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SCG57-13 Room:IC Time:May 28 09:45-10:00

Seismic velocity structure and fault rupture behavior in the source region of the 2008 Iwate-Miyagi nairiku earthquake

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We have studied a role of heterogeneity of the crustal structure to control fault behavior in the Ou backbone range based on the seismic tomography (Aoyagi and Kimura, 2014JpGU; Aoyagi et al., 2014 SSJ). In this paper, we focus on the velocity structure and its influence on fault behavior of the 2008 Iwate-Miyagi nairiku earthquake using the same dataset.

The result of the seismic tomography analysis in the upper crust shows the remarkable low Vp/Vs areas in the western and southern side of the Mt. Kurikoma volcano. The low Vp/Vs areas correspond well with the dense distribution of the late Neogene calderas (eg. Sanzugawa, Onikobe, Naruko caldera). Nakajima and Hasegawa (2003) reported similar results and inferred that the caldera has vapor-filled fracture systems near the surface. In contrast, high Vp/Vs areas are distributed in the NE side of the low Vp/Vs areas. Their sharp boundary runs from Yuzawa city to Iwate-Miyagi border in WNW-ESE direction. The source region of the Iwate-Miyagi nariku earthquake extends across the velocity boundary with NNE trend in the eastern part of the Mt. Kurikoma. The aftershock distribution is clearly concentrated in low Vp/Vs areas. Even in the NE (higher Vp/Vs) side of the velocity boundary, we can find narrow low Vp/Vs zone in which the aftershocks limitedly occurred in the eastern foot of the Mt. Kurikoma. The northern margin of the aftershock distribution corresponds well with the next high Vp/Vs area in NW direction.

These results suggest that lateral change of the crustal structure, such as material properties, might control the fault behavior (rupture termination). We interpret that the best account for the lateral change in the crustal structure can be found in the dislocation by the WNW striking sinistral faults during the back-arc opening.

Keywords: Iwate-Miyagi Nairiku earthquake, seismic velocity structure, seismogenic layer, fault rupture behavior

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SCG57-14 Room:IC Time:May 28 10:00-10:15

Crustal deformation around the Kamishiro fault and its implications for the 2014 Northern Nagano earthquake

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The Itoigawa-Shizuoka Tectonic Line (ISTL) is a major geologic boundary intersecting the Japanese mainland into the northeastern and the southwestern parts. It is also an active fault system that is supposed to have a high seismic potential. We have conducted dense GPS observation and identified a highly localized E-W contraction

around the Kamishiro fault at the northern ISTL. Kinematic modeling of this deformation pattern suggests that the fault is dipping to the east and accommodating the E-W contraction by aseismic faulting below the depth of 2-4 km.

On November 22, 2014, a Mw 6.3 earthquake occurred at the Kamishiro fault. The hypocenter is located at a depth of 5 km and surface rupture appeared for about 9 km along the fault trace. Considering the pre-seismic deformation pattern and aseismic fault slip at depth, this earthquake is considered to rupture the remaining shallow locked part. Thus no further large earthquake is not anticipated in this area in the near future although much larger event is expected to occur along the whole ISTL.

This earthquake caused a heavy damage on a small neighborhood called Horinouchi. It should be noted that the same neighborhood had experienced a severe damage by another earthquake in 1714. Considering that the locked portion is limited to the shallowest 5 km and strain rate around this area is very large, it is possible that the same fault segment was reactivated in 300 years, which is an unusually short recurrence interval as a intra-plate active fault. This example demonstrates an importance of dense as well as precise geodetic observation for seismic hazard evaluation and understanding the crustal seismogenesis.

Keywords: Kamishiro Fault, 2014 Northern Nagano Earthquake, GPS, crustal deformation

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SCG57-15 Room:IC Time:May 28 10:15-10:30

Urgent seismic observation for the 2014 Northern-Nagano Prefecture Earthquake and complex fault system

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The 2014 Northern-Nagano Prefecture Earthquake (MJMA 6.7) occurred in central Japan at 22:08 on November 22, 2014 (JST). A temporal seismic network has deployed two days before the main shock, because an earthquake swarm occurred 4 days ago. Then the main shock occurred and the region of aftershocks spread, we installed jointly 13 new observation sites to determine the seismic activity. It was possible to decide the precise hypocenters because observational data located right above the main shock was used. Strong lateral heterogeneity in the velocity of the source area resulted in the locations of the epicenters determined in this study being located approximately 2.5 km east of those reported by the JMA routine catalogue. Using those high-resolution seismic data for early days, one major source fault and some minor faults were identified. The main shock located on the high angle distribution that eastern dipped. Much distribution is also existed, and those aren't always parallel with the inclination of the main shock.

Keywords: 2014 Northern-Nagano Prefecture earthquake, urgent aftershock observation, precise aftershock distribution, multi-fault system

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SCG57-16 Room:IC Time:May 28 10:30-10:45

Aftershock distribution and crustal structure in and around the source area of the 2014 northern Nagano Pref. earthquake

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A shallow earthquake occurred in the northern Nagano Prefecture, at 10:8 PM Japan standard time on November 22, 2014, with the Japan Meteorological Agency (JMA) magnitude (M_{JMA}) of 6.7. The focal mechanism showed a reverse fault with a compression axis in a WNW-ESE direction. Aftershock area is located near the Kamishiro fault, which is a part of the Itoigawa-Shizuoka Tectonic Line. Revealing the relation between an active fault system and aftershock distribution is important to study long-term behavior of active faults. Precise aftershock distribution and detailed crustal structure in and around the source region of this earthquake is important to constrain the process of earthquake occurrence. To investigate aftershock distribution and crustal structure, we conducted a high-density seismic array observation in and around focal area. One hundred sixty-three seismic stations, approximately 1 km apart, were deployed during the period from December 3, 2014 to December 21, 2014. Each seismograph consisted of a 4.5 Hz 3-component seismometer and a digital data recorder (GSX-3). Waveforms were continuously recorded at a sampling rate of 250 Hz. The continuously recorded data were divided into event files, starting from an origin time determined by the JMA. In order to obtain a high-resolution velocity model, a well-controlled hypocenter is essential. Due to this, we combined the seismic array data with permanent seismic station data. We used 40 telemetered seismic stations in the present study. During the seismic array observation, the JMA located 977 earthquakes in a latitude range of 35.5-37.1N and a longitude range of 136.7-139.0E. We selected 100 local crustal events so that they were distributed uniformly in the study area. To investigate the aftershock distribution and the crustal structure, a tomography code simul2000 (Thurber and Eberhart-Phillips, 1999) was applied to the P- and S-wave arrival time data obtained from 100 local earthquakes. The hypocentral distribution of aftershocks shows a concentration on a plane dipping eastward in the vicinity of the mainshock hypocenter. The depth section of Vp structure shows that an eastward-dipping low-Vp zone exists along the estimated deeper extension of the Kamishiro fault.

Acknowledgement: We used the JMA unified earthquake catalog. We thank the National Research Institute for Earth Science and Disaster Prevention, the JMA, the University of Tokyo and Kyoto University for allowing us to use their waveform data.

Keywords: dense seismic array observation, seismic tomography, Kamishiro fault, aftershock distribution

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SCG57-17 Room:IC Time:May 28 11:00-11:15

Construction of a dense GNSS array in the San-in shear zone

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Introduction

An analysis of the GEONET (GNSS Earth Observation NETwork system) data operated by the Geospatial Information Authority of Japan (Nishimura, 2014) revealed that there is a distinct zone in which ongoing deformation is localized from an eastern part of Shimane Prefecture to Tottori Prefecture in the San-in area (hereafter the San-in shear zone). We constructed 13 new GNSS stations in order to clarify a detailed spatial pattern of deformation and a mechanism of strain localization in the San-in shear zone. Here, we report an overview of crustal deformation in the San-in shear zone and the new GNSS stations.

Characteristics and seismicity in the San-in shear zone

We recognize the following characteristics in a velocity distribution of the GEONET station in the San-in region and its vicinity. First, a northern limit of the observed northwestward velocity due to subduction of the Philippine Sea plate locates in and around the southern coastal area of the Chugoku district facing the Seto Inland Sea. Second, an inland region in the Chugoku district does not significantly move relative to a northern part of Hyogo Prefecture though the northern coast of Tottori Prefecture and an eastern part of Shimane Prefecture moves eastward with a velocity of 4 mm/yr. We call this deformed zone "the San-in shear zone". The San-in shear zone is more than 200 km long along the coast of the Japan Sea and accommodates right-lateral shear motion. Its width is variable, that is, less than 20 km in a eastern part of Tottori Prefecture and 50˜70 km in a western part of Tottori Prefecture and a eastern part of Shimane Prefecture.

There is a distinct band of high microseismicity along the coast of the Japan Sea in the San-in region, as suggested by previous studies. The San-in shear zone corresponds to the seismic band. It is interesting that several north-northwest (NNW) and south-southeast (SSE) alignments oblique to a general east-west alignment of seismicity and the shear zone. The NNW-SSE alignments may be explained by left-lateral Riedel shear R2 in a right-lateral shear zone.

Construction of new GNSS stations and a collection and analysis system for GNSS data

The 25-km average spacing of the GEONET stations is not enough to clarify a detailed pattern of deformation in and around the San-in shear zone. We, therefore, constructed 13 new stations along three lines across the San-in shear zone. We started to observe at 3 sites in Kurayoshi City and the other sites in August and December, 2014, respectively. GNSS data with 1-sec sampling in compact RINEX format are transferred every day. Daily coordinates are estimated with the PPP-AR (Precise Point Positioning with Ambiguity Resolution) strategy using GIPSY 6.2 software. The coordinates and vector maps can be browsed at http://www1.rcep.dpri.kyoto-u.ac.jp/˜nishimura/monitoring.html. Repeatability of daily coordinates for the new stations is comparable to that for the surrounding GEONET ones, which demonstrates data quality of the new stations. We expect that the detailed deformation will be clarified in a few years.

Acknowledgements

We thank boards of education of Tottori City, Kurayoshi City, Sakaiminato City, Nanbu Town, and Maniwa City and town offices of Hino Town and Nichinan Town for cooperating to construct new GNSS stations.

Keywords: strain concentration zone, GNSS, Crustal deformation, San-in district, inland earthquake

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SCG57-18 Room:IC Time:May 28 11:15-11:30

Strong spatial variations of stress within the Philippines produced by slip heterogeneity along the Philippine fault

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A detailed knowledge of the stress state of crust is a key factor to understand earthquake occurrence. Previous studies showed that the stress patterns are primarily controlled by the plate boundary forces [e.g. Zoback et al., 1989]. However, it has also be pointed out that observed complicated stress field is affected by other factors. To address this point it is important to investigate the stress state of various tectonic regions around the world.

The Philippines is located in a region of high crustal seismicity, bounded to the east and west by oblique subduction zones. In the last few years, seismic and volcanic observation network have substantially improved in the Philippines in particular during the SATREPS cooperative project ″ Enhancement of Earthquake and Volcano Monitoring and Effective Utilization of Disaster Mitigation Information in the Philippines ″ between PHIVOLCS and NIED. Using waveform from regional broadband seismic stations, moment tensor solutions are routinely determined at NIED. In this study, we investigated the stress states in the Philippine archipelago by using those moment tensor solutions.

As a first step, we classified focal mechanisms into three groups: 1) events within the overriding plate, 2) those along the interplate, and 3) those within the subducting plate. Then we applied the stress tensor inversion method developed by Michael (1987) to focal mechanisms within the overriding plate. The estimated σ1-axis is oriented to WNW-ESE, which is parallel to the slip vectors of the interplate events.

In order to investigate the spatial distribution of stress across the archipelago, we performed additional stress tensor inversions by dividing the entire region in sub-regions eastern and western of a stripe containing the NNE-SSW striking Philippine fault, which is a 1200km long strike-slip fault cutting through the islands. Additionally the region was subdivided along the strike of the fault. In the central and eastern sub-regions, σ1-axis are parallel to the orientations of relative plate motions. On the other hand, in the western region, orientations of σ1-axis are significantly different from those of the relative plate motions. In particular, the orientations of σ1-axis in southern part (Bohol) are substantially different from those of the relative plate motions. Also, the orientations of σ1-axis in northern part (Mindoro) are different from those in the entire Philippines.

The σ1-axes and σ3-axes in Bohol and Mindoro are opposite. The σ1-axis in Bohol and σ3-axis in Mindoro are almost parallel to the strike of the Philippines fault, which is consistent with the stress produced by left-lateral slip on the central part of the Philippines fault. This range corresponds to the Masbate fault characterized by a larger number of moderate-sized earthquakes, while the northern and southern extensions correspond to the segments which have generated several historical earthquakes [Bessana & Ando, 2005]. Our study suggests that more strain is released along the Masbate fault by moderate-sized events, while the northern and southern extensions are accumulating more strain which may be released as large earthquakes in the future. From the calculated stresses produced by the Philippines fault, based on dislocations in an elastic half-space model [Okada, 1992], as well as assuming a interplate coupling, we successfully reproduced the spatial features of stress orientations.

We also propose that a model considering the bending deformation of the overriding plate is also able to roughly explain the observed σ1-axes, based on a 2D finite element modeling, although it does not explain the strike-slip stress regime. By taking account of oblique subduction effects, we may reproduce the observations in more detail. However, we prefer the strike-slip on the Philippines fault as the cause of stress variation, because this simple model alone can sufficiently explain all the observations.

Keywords: the Philippines, focal mechanisms, stress tensor inversions, stress modeling

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SCG57-19 Room:IC Time:May 28 11:30-11:45

Spatial heterogeneities of deviatoric stress in Kyushu, Japan, inferred from the focal mechanism (2)

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We investigated the spatial variation in stress field in Kyushu Island, southwestern Japan. Kyushu Island is characterized by existence of active volcanoes (Aso, Unzen, Kirishima, Sakurajima) and shear zone (west extension of MTL). High activity of shallow earthquakes are found not only along active faults but also in the central area of the island where there are active volcanoes. We considered the focal mechanisms of the shallow earthquakes on Kyushu Island to determine the relative deviatoric stress field. Generally, the stress field was estimated by method of Hardebeck and Michael (2006), corresponding to a strike slip regime in this area. Minimum principal compression stress (sigma-3) with its direction of near north-south dominates in the entire region. However, the sigma-3 axes around the shear zone rotated toward normal direction to the zone. This result implied the shear stress reduction at the zone and was consistent with the right lateral fault behavior along the zone detected by strain rate field analysis for GPS data. On the other hand, normal faulting stress field dominates in Beppu-Shimabara area located middle of the island. This result and direction of sigma-3 are consistent with formation of Unzen graben and Hohi volcanic zone in the area.

Keywords: stress field, Kyushu, focal mechanism

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SCG57-20 Room:IC Time:May 28 11:45-12:00

Development of fault activity in Japan estimated from the response of the faults to the tectonic stress field

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The regional tectonic stress of the NE Japan arc continues from around 3.5 Ma to present (Sato, 1994). On the other hand, the initiation age of active faulting increased after 1.5 Ma (Doke et al., 2012). These results suggests that the response of the fault activity to the tectonic stress field takes long time (i.e. a few Ma). Then we study the maturity of the response of the fault activity to the regional tectonic stress field. In this study, we discuss the maturity of the field according to the present stress field and the present fault activity with the geodetic and geologic deformation.

The regional tectonic stress was estimated from the focal mechanisms of F-net by stress tensor inversion. The responses of the active faults and geological faults to the tectonic stress are calculated by using the slip tendency (Morris et al., 1996). The calculation results show that the most of high activity faults becomes active faults in the Tohoku region. On the other hand, some high activity faults have been geological faults in the Chubu and Kinki region. This difference of the response of faults to the tectonic stress in different regions is coherent with the geodetic and geologic deformation.

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Doke, R et al. Spatial patterns of initiation ages of active faulting in the Japanese Islands. Active Fault Research, 2012, 37: 1-15.
Morris, A.; Ferrill, D. & Henderson, D. Slip-tendency analysis and fault reactivation Geology, 1996, 24, 275-278

Keywords: crustal deformation processes, tectonic zone, fault acitivity

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SCG57-21 Room:IC Time:May 28 12:00-12:15

Evolution of fault zone architecture during the exhumation of the Median Tectonic Line in SW Japan

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Behavior of fault is controlled by the deformation of fault rocks at different physical conditions. The structure of fault zone along the Median Tectonic Line (MTL) has evolved through a series of faulting events at various temperatures. The analysis of structures in the fault zone, therefore, helps to understand how fault rocks deform at different physical conditions. We present detailed observations of the MTL at a large outcrop exposed at Awano-Tabiki in the eastern Kii Peninsula, Japan.

At the Awano-Tabiki outcrop, the MTL juxtaposes the Sanbagawa metamorphic rocks to the south against sedimentary rocks corresponding to the Izumi group to the north. The lithological boundary strikes almost E-W and dips to the north. The Sanbagawa metamorphic rocks were variably damaged to the south by faulting for the distance more than 20 m from the lithological boundary. The fault rocks are strongly comminuted within a distance of a few meters from the lithological boundary forming the fault core region. There is a sharp fault gouge zone with the width less than 20 cm in the fault core region forming the principal slip zone.

The detailed analysis of the structures within the outcrop revealed the evolution of the fault zone during the exhumation. In the hanging wall of the principal slip zone, asymmetric composite planar fabrics are well developed, indicating dextral sense of shear. These structures were cut by the principal slip zone. In the principal slip zone slipped as a normal fault with dextral sense of shear. The principal slip zone has been moved as a normal fault with sinistral sense of shear and then a dip slip normal fault after the normal faulting with dextral sense of shear.

Keywords: fault zone architecture, fault gouge, fault striation, Normal Fault

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SCG57-22 Room:IC Time:May 28 12:15-12:30

How do fault zones develop?: Findings from the observation of natural fault rocks

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While earthquakes occur by fracturing of rocks, it has been known that they occur along the existing faults, not everywhere in the crust. Accordingly, the development of fault structures is an important topic to analyze seismic activities. However, not much has been known about this problem. For example, since faults consisting of fracture zones are weak planes, some geologists believe that the width of fracture zones does not increase because of concentrated displacement only along fracture zones. On the other hand, it has been known that the width of fracture zones increases with increasing displacement. Schrank et al. (2008) have shown that fracture zones are initiated as discrete fault plane, which subsequently becomes anastomosing fracture zones, and finally the undeformed parts surrounded by fracture zones become fracture zones, thereby increasing the volume of them. Takeshita and El-Fakharani (2013) have shown a similar development of fracture zones for hand-specimen scale shear zones in the Sambagawa quartz schist deformed at the conditions of frictional-viscous transition. According to this study, the formation of micro-fracture zones is accommodated by dynamic recrystallization of quartz, and accompanied by the precipitation of very-fine-grained muscovite from the solution which percolates along micro-shear zones, thereby leading to the formation of polycrystals consisting of very-fine-grained quartz and muscovite along the micro-fault. As time passes, the micro-shear zones become anastomosed, and the width and grain sizes of constituting quartz and muscovite increase. Since the fracture zones consist of very-fine-grained minerals, they are perhaps deformed by dissolution-precipitation creep at low stress. Stress concentration is inferred to occur in the undeformed lenses surrounded by micro-shear zones, where new micro-shear zones are developed. The same processes are repeated with time, thereby leading to the increased volume of fracture zones (i.e. growth of fracture zones). Although this study has been conducted on fracture zones at hand-specimen scale, the fracture zones at outcrop and map scales are perhaps developed by similar processes. There are two key processes for the development of fracture zones. One is its anastomosing development, which is in accord with the geometries of fracture zones at outcrop and thin-section scales observed by geologists. At map scales, these correspond with the segment and jog structures, which have been well known structures inherent to natural faults. We will report an example of small-scale fault jog structures, which has been recently found along the Median Tectonic Line, Mie Prefecture, southwest Japan (Arai and Takeshita, 2015, JpGU). The other key process is the percolation of fluid along fracture zones, and resultant alteration reaction of minerals and enhancement of dissolution-precipitation creep via fluids. Relating to this topic, we will report mass transfer via fluids in fracture (cataclasite) zones of the Median Tectonic Line, which leads to the weakening of fault zones (Kaneko et al., 2015, JpGU).

Keywords: growth of fault zone, shear or fracture zone, dissolution-precipitation creep, anastomosing fault zone, frictional-viscous transition, mass transfer via fluids

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SCG57-23 Room:IC Time:May 28 12:30-12:45

Element migration via fluids with progress of fracturing along the Median Tectonic Line, Mie Prefecture, southwest Japan

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Dissolution and precipitation (i.e. chemical reaction) pervasively occur via fluids in brittle fault rocks (cataclasite) resulting in either softening or hardening of rocks. In this study, we used the core samples obtained at the Matsusaka-Iitaka observatory of AIST, which penetrate the MTL at depth 473.9 m, and revealed element migration via fluids with progress of fracturing.

Along the MTL mylonite and cataclasite are distributed in the Ryoke belt. We used the cataclasite samples (depth 439-473 m) immediately above the MTL that originated from tonalite and relatively undeformed tonalite samples (depth 87 m, 88 m, 317 m and 358m).

Based on optical thin section observations, we classified the cataclasite samples into four groups: relatively undeformed (UN), weakly (W), moderately (M) and strongly (S) deformed rocks based on the degree of cataclasis. We investigated the major element migration based on the whole rock composition determined by X-ray fluorescence analysis. We applied principal component analysis to the data of XRF to reveal the causes of the major element migration. Further, we analyzed changes of the mineral assemblage with increasing cataclasis based on X-ray diffraction. We also analyzed changes of the mineral assemblage resulting from element migration with a point counting method under optical microscope aided by image analyses.

To analyze element migration with the increasing degree of fracturing, we determined the changes in the whole rock major elements in deformed samples using isocon plots. In this study, we treated Zr as an immobile element. We calculated the volume change of deformed rock samples as $V = [(1/S)-1] \times 100$, assuming no density change during deformation, where S is the slope of the line connecting the origin of isocon plot and an immobile element.

We analyzed these for the following three pairs, which showed the volume changes of +21 % for W vs UN, +33 % for M vs W, and +52 % for S vs W, respectively. With the increasing degree of fracturing from UN to W rocks, Si, Na and K increased, because K was settled in muscovite, and Si and Na were released in fluids as solutes, by feldspar-to-mica reaction. The fluids invaded into the pore spaces created by fracturing and deposited quartz there, and Na was used for albitization of oligoclase. On the other hand, TiO2, FeO*, MnO, MgO, CaO decreased from UN to W rocks and increased from W to M or S. LOI (loss on iginition) and Al2O3 increased during throughout the fracturing. The increase of CaO was caused by forming of laumontite and prehnite, while that of FeO*was caused by forming of iron sulfide and chlorite. The increase of MgO and MnO was caused by forming of chlorite, and that of TiO2 was caused by forming of sphene. Further, the increase of Al2O3 was caused by forming of chlorite, muscovite and laumontite, and that of LOI was caused by forming of chlorite and muscovite. Since not only muscovite and chlorite with lower coefficients of internal friction, but also calcite with less viscosity increased a lot from W to M or S rocks, it can be inferred that the strength of cataclasites become lower from W to M or S rocks.

Keywords: Median Tectonic Line, mass transfer, cataclasite, isocon diagram, resolution precipitation reaction, reaction softening

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SCG57-24 Room:IC Time:May 28 14:15-14:30

Estimation of deformation environment of Asuke Shear Zone using pseudotachylyte and mylonite

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Brittle to ductile fault rocks such as cataclasite, pseudotachylyte and mylonite are distributed along the NE-SW trending Asuke Shear Zone in the Inagawa granite bodies of the Ryoke Belt, Chubu region. Movement sense of Asuke Shear Zone includes both sinistral and normal components (Sakamaki et al., 2006). In this study, we carried out (1) paleostress analysis using twined calcites that fill amygdules in pseudotachylyte and (2) estimation of deformation temperature based on crystallographic preferred orientations (CPO) patterns of quartz mylonites.

(1) There are many amygdules developed in the thick (about 11 cm) pseudotachylyte vein with zircon FT age of about 53 Ma taken at Taburi outcrop. The minerals filling the amygdales in this sample are mostly quartz and calcite, and planar deformation twin develop in many calcite. Deformation twin is shear deformation in the twin plane, and can be used to estimate the paleostress state like a fault. This method has been applied mainly on limestone, marble, calcite vein, and also on amygdules filled with calcite (Craddock and Magloughlin, 2005). This time, we estimated the paleostress state by means of Hough-transform-based multiple inversion method (Yamaji et al., 2006) application to 1491 sets of slip data measured from twinned calcite that filled amygdules (a part of results are already reported (Kanai and Takagi, 2014)). As a result, the stress states are consistent with the movement sense of Asuke Shear Zone.

(2) Fault vein and injection vein of the pseudotachylyte from Oshima outcrop has undergone a ductile deformation. C-axis CPO pattern of quartz from 4 sets of fault vein and injection vein of mylonitized pseudotachylyte were determined using SEM-EBSD method with a HKL Channel 5 EBSD system (Oxford Instruments). As a result, the CPO pattern in 3 samples of the fault veins show a Z-maximum pattern and in all 4 injection vein samples shows a random fabric.

Z-maximum CPO pattern suggests that the dislocation creep took place at less than 350-450 ℃, and random CPO pattern suggests that the deformation in the diffusion creep (Bouchez, 1977; Takeshita and Wenk, 1988; Sakakibara, 1995). From such CPO patterns and occurrence of mylonite, Asuke Shear Zone is considered to have received repeated deformation to form the pseudotachylyte and mylonite in brittle-plastic transition zone (300 - 400 ℃ in anhydrous conditions; Stockhert et al., 1999).

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Keywords: Asuke Shear Zone, brittle-plastic deformation, amygdule, calcite twin, quartz c-axis CPO

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SCG57-25 Room:IC Time:May 28 14:30-14:45

Frictional properties of Shionohira Fault Gouge

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The April 11, 2011 Fukushima-ken Hamadori Earthquake created co-seismic surface ruptures trending in the NNE-SSW direction from Tabito-Nameishi to northwestern Isizumi-Tsunaki in Tabito-cho, Iwaki City, Fukushima Prefecture, which were newly named as the Shionohira Fault by Ishiyama et al. (2011). However, the same N-S trending lineaments were recognized to exist even though no surface ruptures occurred from the south of Tabito-Nameishi to the boundary between the Fukushima and Ibaragi prefectures. In an attempt to elucidate the differences of active and non-active segments of the Shinohara fault, results of low and high-velocity friction experiments on the fault gouges sampled from two surface outcrops of active segment are discussed in this report.

All experiments were conducted using a rotary-shear low to high-velocity frictional testing apparatus at the State Key Laboratory of Earthquake Dynamics, Institute of Geology, China Earthquake Administration. The apparatus is capable of producing slip rates of 60 mm/year to 2.1 m/s on a pair of cylindrical specimens of 40 mm in diameter, and temperature and pressure up to 500 degree in centigrade and 70 MPa by using TiAlCr alloy piston.

Gouge samples were taken from the thick fault gouge in crystalline shist of several tens of centimeter at Betto outcrop,and gouge from the contact between sandstone and crystalline shist at Shionohira outcrop. They were dried in an oven for 20 hours at 60 degree in centigrade and were gently disaggregated to make gouge powder. Gouge particles $<$150 micro meter were selected for experiments using a 100-mesh sieve to avoid having too large particles in thin gouge layer. Wet and dry gouge experiments have been conducted at the initial compression of fault gouge samples from 1 to 5 MPa, at slip rates from 0.0002 mm/s to 2.1 m/s and at normal stresses of 1.0 to 2.0 MPa. Friction strengthening or weakening behavior is also examined.

The results revealed high friction coefficients of around 0.6 to 0.8 under non-porous conditions, but very low coefficients of around 0.1 to 0.2 under porous conditions for both outcrop samples. The results also indicated the sample taken from the active segment of Shionohira fault to show a velocity strengthening behavior whereby the friction coefficient became slightly higher as velocity increased.

Keywords: friction properties, fault gouge, Shionohira fault, friction coefficient, low and high velocity friction experiment, Fukushima-ken Hamadori earthquake

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SCG57-26 Room:IC Time:May 28 14:45-15:00

Structural development of the basin associated with bends on the North Anatolian fault in NW Turkey

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The Marmara Sea in western Turkey contains three subbasins with water depths reaching 1250 m, called from west to east the Tekirdag, Central and Cinarcik basins. These basins are active subsiding marine basins forming along the North Anatolian Fault (NAF) which is 1500 km-long and accommodates the current GPS-derived about 25 mm/yr westward motion of the Anatolian platelet relative to Asia. The Quaternary active Cinarcik basin is representative of the basin that developed in the wake of Tuzla bend along continental transform NAF. The basin is oblique time-transgressive half graben and is bordered by the master northern strand of the transform.

We use existing deep-penetration, low-resolution migrated multichannel seismic reflection (MCS) data and new migrated high-resolution MCS data for seismic stratigraphic interpretations in Cinarcik basin. All the seismic reflection data are used to correlate five stratigraphic horizons which contain stacked low-stand shelf-edge deltas. These five seismic horizons related to the geological boundaries with the known age information are used to calculate thicknesses, depth changes and tilts of the strata within the basin.

The Cinarcik basin has an asymmetric structure and within the basin strata are progressively tilted obliquely toward the bend and toward the border fault, where subsidence is fastest. Yet, nearest the bend is also where the basin is youngest and shallowest. Away from the bend the subsidence rate decreases while the basin get deeper and older. This common pattern is accounted for by time-transgressive basin growth. On the transtensive side of the bend, slip on the transform is oblique normal and the hangingwall side subsides forming the basin. Subsidence continues along the fault and the basin get progressively deeper away from the bend. Eventually, the basin reaches its maximum depth, but can continue to grow longitudinally along the fault.

Keywords: North Anatolian Fault, Marmara Sea, Cinarcik Basin, Multi-Channel Seismic Reflection, Seismic Stratigraphy, Basin Formation

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SCG57-27 Room:IC Time:May 28 15:00-15:15

The spatial viscosity variation in the crust beneath the western North Anatolian Fault

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The GPS velocity profiles across the western North Anatolian Fault (NAF) near the location of the 1999 Izmit rupture are characterised by: (i) before the earthquake, strain rate is localised in a region $<$100 km wide across the near-fault zone, and (ii) after the earthquake, near-fault relative velocities are up to ~150 mm/yr, being significantly higher than the long-term relative displacement rate of Anatolia with respect to Eurasia (~22 mm/yr). We previously showed that these characteristics can be explained if a localised weak zone (LWZ) in the mid-crust directly beneath the NAF northern strand is embedded in a relatively high viscosity background crustal layer [Yamasaki et al., 2014, J. Geophys. Res., 119, 3678-3699]. This study expands upon the previous study of Yamasaki et al. [2014], investigating in more detail a likely spatial viscosity variation beneath the western North Anatolian Fault (NAF), for which a simplified 3D finite element model is employed to solve the linear Maxwell visco-elastic response to periodically repeating right lateral strike-slip earthquakes under the presence of a constant-rate far-field loading. We tested in this study whether the LWZ in the mid-crust is required to be centred on the NAF northern strand. Horizontal offset of the LWZ from directly beneath the rupture zone of the 1999 Izmit earthquake should be less than ~10% of its width in order to preserve the approximate anti-symmetry of the GPS velocity profiles. We find that a LWZ between the NAF northern and southern strands, which may be expected from the spatial variation of low resistivities in the magnetotelluric (MT) images of Tank et al. [2005, Phys. Earth Planet. Inter. 150, 213-225] and Kaya et al. [2013, Geophys. J. Int. 193, 664-677], does not explain the GPS velocities. We therefore find no simple one-to-one relation between viscosities and resistivities beneath the western NAF. In this study we also investigate possible depth-variation of the background viscosity structure on which the LWZ centred on the NAF northern strand is superposed, and find that the background viscosities are required to be greater than ~2×10^{20} Pa s at depths shallower than ~30 - 35 km in the 40 km thickness of the crust in order to explain the high strain-rate zone in the pre-seismic velocity profiles.

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SCG57-28 Room:IC Time:May 28 15:15-15:30

Numerical modeling on intersesimic and post-seismic vertical deformation of NE Japan: Role of rheological heterogeneity

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Nation wide deployment of dense geodetic network has clarified the strain accumulation and release processes through the megathrust earthquake cycle for the NE Japan subduction zone system. Prior to the 2011 Tohoku Oki earthquake, vertical deformation was characterized by rapid subsidence in the forearc and gentle uplift in the backarc. The large subsidence is only observed in a latitude range between N37 and N40 degrees. At the Tohoku Oki earthquake, coseismic vertical deformation shows a subsidence simply increasing eastward reaching a 1.2 m on the Oshika Peninsula. Post-seismic deformation over the three years shows concentric distribution of uplift and subsidence around the epicentral area: uplift in the forearc, subsidence in the volcanic front to backarc, and uplift in further backarc to Japan Sea side. The pattern of the observed uplift and subsidence across the island arc in the middle of the NE Japan, crossing the largest slip of the Tohoku Oki earthquake, is opposite that in the interseismic period (Nishimura, 2014). Here, we developed two dimensional and three dimensional finite element models of the NE Japan subduction zone to simulate the vertical crustal deformation during the megathrust earthquake cycle. Two dimensional model transects and three dimensional model includes an area of large coseismic slip of the Tohoku Oki earthquake. Temperature dependent heterogeneous viscosity structures were utilized to investigate the role of rheological heterogeneity (Muto et al., 2013). Deformation along plate boundary is the kinematically assigned using the split node method. During interseismic period, backslip is given to a locked portion at a plate convergence rate of 80 mm/year. At the coseismic step, the amount of slip corresponding to slip deficit accumulated during the interseismic period for 500 years is given along the locked portion. Our preliminary models indicate that the pattern of vertical deformation implies the rheological heterogeneity normal to the NE Japan island arc. Especially the model with presence of rheological contrast between thick, cold forearc and weak volcanic front reproduce similar pattern of vertical deformation observed in the interseismic period. Those results strongly suggest that the incorporation of rheological heterogeneity is required to explain the strain accumulation process in three-dimensional subduction zone systems from the geodetic observation.

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Keywords: Subduction zone earthquake cycle, post-seismic deformation, interseismic deformation, rheology, finite element model

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SCG57-29 Room:IC Time:May 28 15:30-15:45

Modeling viscoelastic deformation and strain anomaly around the Ou Backbone Range after the 2011 Tohoku-oki earthquake

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This study investigates the viscoelastic deformation processes of the northeastern Japan island arc after the Tohoku-oki earthquake by considering the heterogeneous rheological structure. Recently, Shibazaki et al. (2014) calculated the effective viscosity of the Japanese island arc crust and upper mantle, considering the thermal structure obtained by dense geothermal observations using Hi-net boreholes (Matsumoto, 2007) and by Tanaka et al. (2004). They reproduced several elongated low-viscosity regions in the crust and upper mantle of the northeastern Japan arc, striking transverse to the arc, which correspond to hot fingers. Recently, Miura et al. (2014) found a postseismic strain anomaly along the Ou Backbone Range after the 2011 Tohoku-oki earthquake. This postseismic anomaly could have been affected by the existence of low-viscosity anomalies caused by the hot fingers.

We develop a finite element model of the viscoelastic deformation processes after the Tohoku-oki earthquake, considering the realistic crustal and mantle structures, and coseismic fault slip distribution (Iinuma et al., 2012). Our numerical results show that significant extensional viscous deformation occurs in the low-viscosity regions in the crust and upper mantle. This deformation causes significant subsidence in the back-arc region and Ou Backbone Range, but uplift near the Pacific coast. We also try to reproduce the decreases in areal strain along the Ou Backbone Range observed by Miura et al. (2014). In the case where low viscosity zones are extended to the shallower part of the crust, we can reproduce the areal strain decrease which is caused by contraction along the N-S direction. In our model, we cannot reproduce the expansion of areal strain decrease over time along the arc observed by Miura et al. (2014). To model this phenomenon, we would probably need to consider afterslip after the Tohoku-oki earthquake.

Keywords: the Tohoku-oki earthquake, the northeastern Japan arc, viscoelastic deformation, the Ou Backbone Range, strain anomaly

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SCG57-30 Room:IC Time:May 28 15:45-16:00

Modeling and simulation for the development of Holocene marine terraces in the Boso peninsula

NODA, Akemi[1*] ; MIYAUCHI, Takahiro[2] ; SATO, Toshinori[2] ; MATSU'URA, Mitsuhiro[3]

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In the southernmost part of the Boso peninsula, we can observe the well-developed Holocene marine terraces, called the Numa I-IV terraces. It has been confirmed that the lowest terrace (Numa IV) is the shore platform emerged at the time of the 1703 Genroku earthquake, which is considered to be a megathrust earthquake occurred at the plate interface beneath the Boso peninsula. From the similarity in the present altitude pattern between the Numa IV terrace and the others, it has been believed that the Numa I-III terraces also emerged by the occurrence of past Genroku-type earthquakes (Matsuda et al., 1978; Shimazaki & Nakata, 1980; Shishikura, 2003). In the case of large interplate earthquakes, however, the coseismic slip region is stuck soon, but the remaining parts of the plate interface go on slipping aseismically during the interseismic period. Then, the coseismic vertical displacement pattern gradually fades out with time (Matsu'ura & Sato, 1989). Therefore, the formation of the Numa I-III terraces should not be ascribed to the occurrence of past Genroku-type earthquakes, but to the Holocene sea-level fluctuation and the steady uplift of the southern Boso peninsula due to steady plate subduction (Matsu'ura & Noda, SSJ 2014 Fall Meeting, Abstracts, D11-03). In the present study, to verify such an idea, we developed a quantitative model for coastal landscape evolution by considering erosion, deposition, land uplift, and sea-level fluctuation, and then performed numerical simulations for the formation of Holocene marine terraces in the southern Boso peninsula.

The evolution of coastal landscape can be described by the following conceptual equation: altitude change = - erosion + deposition + land uplift - sea-level rise. In modeling sea-land interaction at shore, we supposed that the erosion rate is proportional to the dissipation rate of wave energy (Anderson et al., 1999), and the deposition rate of the floating materials produced by erosion decays exponentially as they are transported seaward. In the numerical simulation of Holocene marine terraces in the southern Boso peninsula, we used the steady uplift rate (1-4 mm/yr) due to plate subduction (Hashimoto et al., 2004). For the Holocene sea-level changes, we used a fluctuation curve obtained from the time series data of mean sea-level altitudes based on deep-sea oxygen isotope ratios (Siddall, et al., 2003) by fitting with cubic B-splines.

A set of sea cliff and shore platform is rapidly formed about a stationary point of the sea-level fluctuation curve. The Holocene sea-level fluctuation curve (from 10 kyrBP to the present) has seven stationary points, and so basically seven marine terraces are formed one by one over the period. In the case of low uplift rate, however, most of older terraces sink beneath the present sea level, and so we cannot observe them. Even in the case of high uplift rate, the relationship between the age and the present altitude of terraces is not simple, because the overlap and/or reverse of older and younger terraces occur frequently. Endo and Miyauchi (JSAF 2011 Fall Meeting, Abstracts, P-06) have confirmed such complexity through the reexamination in ages and altitudes of Holocene emergent coastal geomorphology in the southern Boso peninsula. In the present numerical simulation, taking the uplift rate to be 3-4 mm/yr, we obtained four well-developed marine terraces, corresponding to the Numa I-IV terraces. Even in this case, it should be noticed that the highest terrace is not the oldest terrace.

Keywords: Marine terrace, Sea level change, Steady land uplift, Erosion, Deposition

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SCG57-31 Room:IC Time:May 28 16:15-16:30

Interpretation of multiple earthquake cycles based on the slip- and time-dependent fault constitutive law

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The occurrence of the Mw9.0 Tohoku-oki earthquake in 2011 brought two essential problems in subduction-zone dynamics to light. The first problem is why did such an extraordinarily large earthquake occur in the same place where ordinarily large earthquakes have repeated every 40 years over the past two centuries? In other words, is the multiple earthquake cycles physically explainable? The second problem is when will the surface deformation pattern in northeast Japan be back? In other words, how will the frictional strength of ruptured areas be recovered? To address these problems, first, we need to change the conventional concept of asperity. Since Lay & Kanamori (1981) proposed an asperity model of earthquakes, the asperity has been thought to be an actual entity that means a strongly coupled portion of faults or a fundamental unit of seismic rupture areas. If it is so, plural asperities cannot occupy the same place. Then, no multiple earthquake cycle exists, though the chain rupture of adjacent asperities is possible. Recently, following the idea of spectral analysis, Matsu'ura (2012) redefined the asperity as a notional entity to represent the spatial irregularity in frictional properties (peak strength and critical slip-weakening displacement) of faults. For example, a specific mode in spectral analysis of peak strength corresponds to the asperities of a specific size. Then, plural asperities with different sizes can be in the same place, but it is only a necessary condition for multiple earthquake cycles. Another necessary condition is the scale dependence of critical slip-weakening displacement, which results from the upper fractal limit of fault surface geometry (Matsu'ura et al., 1992). Otherwise the dynamic rupture of a small asperity would easily trigger the dynamic rupture of the largest basement asperity. From the laboratory rock experiments (e.g., Ohnaka & Shen, 1999) and the numerical simulations based on the slip- and time-dependent fault constitutive law (Aochi & Matsu'ura, 2002), we can derive the following quantitative relations on the scale-dependence of frictional properties; 1) the critical slip-weakening displacement is proportional to the upper fractal limit of fault surface geometry and inversely proportional to the abrasion rate of fault surface, and 2) the recovery time of peak strength is proportional to the square of the upper fractal limit and inversely proportional to the adhesion rate. The scale-dependence of fault healing time (the second relation) means that the strength recovery of larger asperities is slower than that of smaller asperities. So, the time needed for the complete recovery of the surface deformation pattern in northeast Japan depends on the fault healing time of the largest basement asperity, which would be very long.

Keywords: 2011 Tohoku-oki earthquake, multiple earthquake cycle, asperity model, slip- and time-dependent friction law

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SCG57-32 Room:IC Time:May 28 16:30-16:45

Why do horizontally shortening sedimentary basins subside?

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It is mysterious that horizontally shortening sedimentary basins subside. In the region shortened horizontally, it is possible that material excess occurs and that the crust becomes thicken. Then, the topography becomes high there. However, the sedimentary basins in Japan, for example, the Niigata and Osaka basins, are subsiding and also shortening. It is difficult to explain these phenomena by thrust faulting, since the amount of uplifts by thrust faulting on the hanging wall side is much smaller than that in the foot wall side. It is plausible that increasing differential stress due to subsidence accelerates horizontal shortening, since the vertical principal stress decreases by the subsidence.

Keywords: high strain region, stress, sedimentary basin, subsidence, intraplate earthquake, active fault

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SCG57-33 Room:IC Time:May 28 16:45-17:00

Formation of backarc inner rifts and their shortening deformation in Honshu island, Japan

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The opening of the Sea of Japan has been developed with multi-rift axis. Deep seismic data across the rift system have been accumulated in northern to central Honshu, Japan. We present the structure of such rift basins, and discuss the formation and deformation of the failed rifts in northern Honshu.

The rift structure in the Niigata and Northern Fossamagna basin has been investigated by onshore-offshore deep seismic reflection/wide-angle reflection surveys. We got continuous onshore-offshore image using ocean bottom cable and collected offshore seismic reflection data using two ships to obtain large offset data in the difficult area for towing a long streamer cable. The velocity structure beneath the rift basin was deduced by refraction tomography in the upper curst and earthquake tomography in the deeper part. It demonstrates larger P-wave velocity in upper mantle and lower crust, suggesting a large amount of mafic intrusion and thinning of upper continental crust. The deeper seismicity in the lower crust beneath the rift basin accords well to the mafic intrusive rocks. The syn-rift mafic intrusion in the crust forms convex shape and the boundary between pre-rift crust and mafic intrusive shows outward dipping surface. Due to the post rift compression, the boundary of rock units reactivated as a reverse fault, commonly forming a large-scale wedge thrust and produced subsidence of rift basin under compressional stress regime. Such structural feature is revealed in the Niigata, northern Fossamagna and Toyama basins. The northern part of the Itoigawa-Shizuoka tectonic line (ISTL) is initially produced as trans current fault bound the southern rim of the Niigata rift basin and subsequence counter-clock-rotation of northern Honshu, it behaved as a normal fault. From the view point of Miocene tectonics, the southern extension of the northern ISTL is the Kanto tectonic line, trending WNW-ENE. Along this line thick syn-rift sediment as well as high P-wave velocity in the lower crust. The rift bounded faults dipping outward from the rift axis in this zone and shows same characters in the failed rift along the Sea of Japan coast.

Keywords: failed rift, backarc basins, the Sea of Japan, crustal structure, shortening deformation, fault-related fold

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SCG57-34 Room:IC Time:May 28 17:00-17:15

The eastern continental margin of Cretaceous Asia and sedimentary basins in Japan

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The tectono-sedimentary history of the Cretaceous arc-trench system of Japan
has been reconstructed on the basis of conventional geological studies on the paired metamorphic belts, granite batholith belt, and various sedimentary basins. The recently developed detrital zircon chronology can add more critical constraints in reconstructing the sedimentary settings of varisou basins with respect to the coeval arc complex and conterminous continent on the back-arc side. We reported several preliminary results on U-Pb age spectra of zircon grains from various Cretacesou sandstones in Japan, and the mutual comparison among them allows us to discriminate/characterize various sedimentary units and basins. In particular, we could identify back-arc, intra-arc, and fore-arc basins for the Cretaceous Japan with respect to the Asian continent.

Keywords: Cretaceous, sedimentary basin, detrital zircon, Asia, U-Pb age

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SCG57-35 Room:IC Time:May 28 17:15-17:30

Classification of subduction zones based on the spatial correlation of topography, gravity anomaly and volcanic front

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In order to understand the diversity and complexity of subduction zones, Uyeda (1982) proposed a classification of subduction zones with end-members of Andean type and Mariana type. This classification is widely accepted and we often see it even in standard textbooks. However, this classification does not always reflect the real subduction zone characteristics. For example, we cannot see the correlation between the slab age and slab dip angle (Lallemand et al., 2005). How should we classify a subduction zone like Tohoku arc, which is very old but has a low dip angle?

The most conspicuous features of subduction zones are topography, gravity anomalies, and volcanism, other than seismicity. Their strikes are basically parallel to the trench. So, based on the spatial correlation among the topography, gravity anomalies, and volcanic front in island arcs, subduction zones can be classified. Before classification, I eliminated the subduction zones that have large variation in topography and/or gravity anomalies along the trench, have an obscure and/or oblique volcanic front, and are nearby ridge subduction. The total number of subduction zones classified is 30. Theories that constitute the background of this study are a kinematic plate subduction model (Matsu'ura & Sato, 1989) that well explains the characteristics of topography and gravity anomaly in subduction zones (low in trench and high in arc and outer rise), and a study for the location of volcanic front on arcs (England et al., 2004) that clarified the importance of thermal structure on this problem.

The result of the classification is as follows. Type I: volcanic front coincides with high gravity anomaly and topography in the fore-arc; Type II-a: volcanic front locates in the back-arc and coincides with high topography; Type II-b: volcanic front locates in the back-arc and does not coincides with high topography. The number of subduction zones for each type is 6, 12, and 6, respectively. All subduction zones classified to type I are oceanic, while all subduction zones classified type II-a are continental except for Kuril. Other interesting characteristics are also found.

Keywords: subduction zone, island arc, topography, gravity anomaly, volcanic front

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SCG57-P01 Room:Convention Hall Time:May 27 18:15-19:30

Dynamics that connects massive earthquake and cross section structure of Aomori, Iwate, and Miyagi

MASE, Hirofumi[1]*

[1]none

In convergence zones, high temperature bodies are formed diagonally-on-and-under the plate of low temp. and the bodies are drawn each other. The mantle wedge and the plate, get on the high temp. body that heads westward from the east, head westward. And, they are placed by the high temp. body that heads eastward from the west and compressed. I think this is the main spring and structure in it. I explained in each respect of the theory, experiment, and application.(1)(2)

This time concerns the structural understanding of the north off Miyagi. First of all, I can recognize the feature of Miyagi(Section d-d') again by the comparison with Aomori(Sec. a-a'). Hot4 of the high temp. is extended to the west more and Hot5 is extended to the east more. And, the direction of the main spring is almost horizontally. Moreover, because there is no remarkable hot section in (the wedge in the east coast east)(W), modeling and repro.-experiment in the slip zone of 3.11 were easy. Hot4 that surges from the west has the tendency to be stuck well to the slope in the east part, and stagnates. And, the material accumulates about there. As a result, the land is formed and maintained. However, in the eastern edge, pressure tends to come off to the under east. Because W is pushed from the west true side, flaking-off along the boundary can be expected.

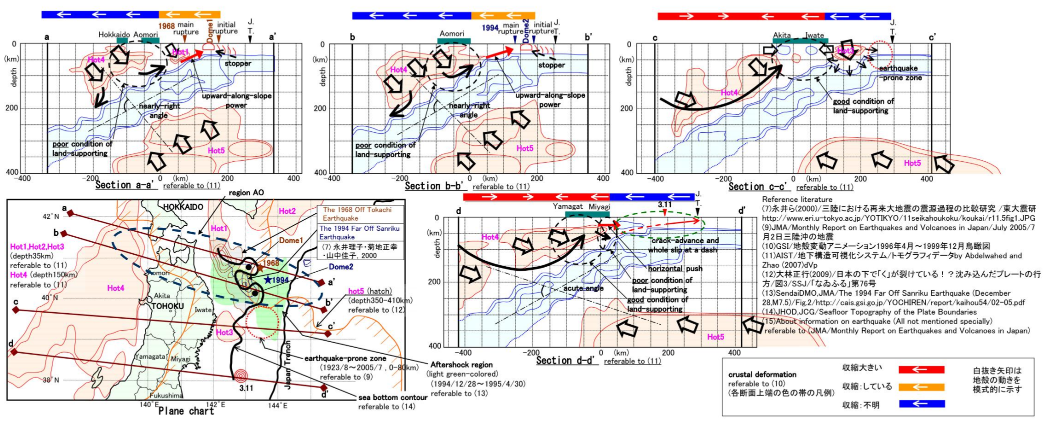
The feature of Aomori is entirely different. Because Hot 4 and Hot 5 do not extend, the angle of the mainspring and the slope is squarely near. And, Hot 4 approaches the slope first and develops along it. Therefore, the land does not develop. Because W is pushed from the under west diagonally, flaking-off deviates from the boundary on the way and pushes up bottom of the sea. Material collects there and Dome develops. Because, on the east side from that place, power to stop the Dome is generated in the reaction from the under east diagonally, flaking-off along the boundary will not happen easily here similarly. Though Sec. a-a' and Sec. b-b' look like, more active slip of climbing up the slope is expected in the former because it has the engine(Hot 1) also in W. Region AO in the Plane chart is peculiar in these reasons.

In comparison with off Miyagi, following matters were mysterious (8). In the large earthquake(EQ) in 1968 and 1994, the position of initial rupture(IR) and main rupture(MR) is mutually away (7). It seems the 1994 EQ destroyed from the shallow to the depth widely (13).

However, according to the above-mentioned structural understanding, it can explain that the characteristic of large EQ in region AO is having the seismic source process that ,on the east side of the Dome, the stopper moves first(IR) and ,west side, the large slip starts(MR).

The temp. structure of Iwate(Sec. c-c') is intermediate as a whole. It is peculiar that there are low temp. bodies under the land and there is huge Hot 3 in W. Hot 3, Hot 4, and Hot 5 pull each other mutually. The underground is pushed from east and west and the land is supported by steady pressure. I think that Sanriku can exist for this. Because Hot 3 is pulled to the under east diagonally, point of W and subducting slab are pushed immediately. This and earthquake-prone zone(9) relate.

(1)MASE/SSJ2010/P3-47 (2)MASE/JpGU2012/SCG67-P06 (3)MASE/SSJ2012/P2-75 (4)MASE/JpGU2013/SSS28-P09 (7)NAGAI et al.(2000)/ERI U-Tokyo (8)MASE/JpGU2014/SSS30-P01 (9)JMA/Monthly Report/July 2005 (13)SendaiDMO,JMA/The 1994 Far Off Sanriku Earthquake



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SCG57-P02 Room:Convention Hall Time:May 27 18:15-19:30

Crustal study of the Northern Scandinavian Mountains from receiver functions analysis and surface wave ambient noise

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The Scandinavian Mountains are a topographic anomaly on the North-East Atlantic passive margin. With heights above 1 km adjacent to the low-lying Baltic Shield (average altitude of 500 m), this mountain range has undergone a rejuvenation by an uplift event during the Neogene. The absence of a crustal root expected from Airy isostasy calculations , the variation of gravity anomaly and the possibility of a low velocity zone in the upper crust suggest variations in density within the crust. This mechanism will explain the (isostatic) equilibrium of the mountain range. With this perspective two passive seismic experiments were deployed in 2007-2009 (SCANLIPS2) and 2013-2014 (SCANLIPS3D) across the Northern Scandinavian Mountains. These 2 experiments allow a better characterization of the crust in terms of Moho depth, Poissons ratio and shear wave velocity. Here we will show a new Moho map compiled from our new results together with previous studies (LAPNET-POLNET, SNSN and NORSAR network) in this region. This map shows a crustal thickening from West to East (40 km to 50 km) without any obvious influence of the transition from the Scandinavian Mountains to the Baltic Shield. From our receiver functions only, inverse modelling does not confirm the presence of a low velocity zone in the upper crust as suggested in previous work in the area using P receiver functions and controlled source experiments. We therefore use Rayleigh waves ambient seismic noise to better constrain the shear wave velocity at the short periods (3- 30 s). Finally a joint inversion of the P-receiver functions and surface wave ambient noise used to build a new 2D crustal model across the Northern Scandinavian Mountains. This new crustal model confirms the assumption of the variation densities within the crust like the source of this topographic anomaly on this passive margin.

Keywords: Scandinavian Mountains, Neogene uplift, variation density, P-Receiver Functions, Rayleigh waves dispersion curve, joint inversion

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SCG57-P03 Room:Convention Hall Time:May 27 18:15-19:30

Seismic velocity structure off the Boso Peninsula, Central Japan, revealed by an ocean bottom seismographic experiment

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Off the Boso Peninsula, central Japan, where the Sagami trough is in the south and the Japan trench is in the east, there is a triple junction where the Pacific plate (PAC), the Philippine Sea plate (PHS) and the North America plate (NA) meet each other. In this region, PAC subducts beneath PHS and NA, and PHS subducts beneath NA. Due to these subductions, numerous seismic events took place in the past, such as the Enpo-Boso earthquake 1677, Genroku-Kanto earthquake 1703, the Taisyo-Kanto earthquake 1923, and the Boso slow slip events. In order to understand these events, it is important to image structure under Kanto region, and many researchers attempted to reveal the substructure from natural earthquakes and seismic experiments.

Because most of the seismometers are placed inland area and the regular seismicity off Boso is inactive, it is difficult to reveal the precise substructure off Boso area only from analyzing natural earthquakes. Although several marine seismic experiments were held, vast area remains unclear off Boso Peninsula. In order to improve the situation, a marine seismic experiment was conducted from 30th July until 4th of August,2009. The survey line has 216 km length and 20 Ocean Bottom Seismometers (OBSs) were placed on it.

In this study, we analyzed the airgun data acquired from the OBSs by using PMDM(Progressive Model Development Method; Sato and Kenett, 2000) and FAST(First Arrival Seismic Tomography, ;Zelt and Barton, 1998), then obtained 2-D seismic velocity structure.

According to the previous studies, the P wave velocity of the upper surface of Philippine Sea plate (UPHS) is around 5 km/s, then, we drew the line which represents the UPHS at 5.0 km/s zone. The result shows that the UPHS inclines gently toward east, and the high P-wave velocity area which has 35 km width, locates off southernmost Boso Peninsula, 4 km depth from the sea surface.

The estimated depth of UPHS corresponds to that of Nakahigashi et al.(2012) and Kimura et al. (2009). We also compared our result with other studies and delineated the isodepth contours of UPHS off the Boso Peninsula. We gained a rough image that the 10 km isodepth contour is almost parallel to the Sagami trough, the 15 km isodepth contour runs toward east, and the 20 km isodepth contour runs toward northeast. It indicates that the Philippine Sea plate subducts gently off the Boso Peninsula and it gets sharpened gradually toward the land.

The width and location of the high P-wave velocity area correspond to that of a bump on the UPHS revealed by Tsumura et al. (2009). The velocity is higher than 6 km/s in the center therefore, we concluded that the bump is the buried seamount and our result supports the result of Tsumura et al. (2009).

Acknowledgement

The marine seismic experiment was conducted by R/V Hakuhou-maru of Japan Agency for Marine-Earth Science and Technology, and the OBSs were retrieved by Shinchyo-maru of Shin-Nihon-Kaiji co. Ltd. (Present, Fukada salvage co. Ltd.).

We would like to thank captains and the crew of Hakuho-maru and Shinchyo-maru.

This study was supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, under its Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions.

Keywords: Off-Boso, Seismic velocity structure, Philippine Sea plate

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Compilation of thermochronologic ages of bedrocks in Japan: For understanding the deformation over geologic time

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For understanding of the relationships between stress and strain and separation of elastic and inelastic deformations in the crust of the Japanese Islands, comparison and investigation of deformations over various time scales are significant (e.g., Ikeda et al., 2012; Nishimura, 2014). The authors are attempting to estimate vertical strain rate of the NE Japan Arc over geologic time by using low-temperature thermochronology, as a part of "Crustal dynamics — Unified understanding of intra-island deformation after the great Tohoku-oki earthquake — " . Although vertical deformation in the NE Japan Arc over the geologic time has been investigated in the plains and coastal areas on the basis of the relative heights and formation ages of the marine and fluvial terraces (e.g., Koike & Machida, 2001; Tajikara & Ikeda, 2005; Matsu'ura et al., 2008, 2009), few quantitative data is available in the mountainous regions where higher uplift rates are possible. As the preliminary step toward thermochronometric studies in the mountainous regions in the NE Japan Arc, we compiled previous thermochronometric ages over the Japanese Islands to review previous thermochronometric data in the NE Japan Arc and to understand vertical deformation of the Japanese Islands over the Japanese Islands. We are compiling mainly about fission-track (FT) ages regarding the items, such as author(s) and year of publication, journal, study area, lithology, sample code, latitude, longitude, altitude, apatite FT age and error, zircon FT ages and error. At present, we have compiled >350 apatite FT ages and >600 zircon FT ages from >70 articles including unpublished data. The result of the compilation suggests: 1) still more data have been reported in the SW Japan Arc than in the NE Japan Arc, 2) in the Kitakami and Abukuma regions, pacific coasts of the NE Japan, apatite FT and zircon FT ages of late Cretaceous were reported (Goto, 2001; Ohtani et al., 2004), indicating total denudation since that era is less than 2-3 km, and 3) in the Iide and Echigo mountains along the Japanese Sea coast of the NE Japan, a few apatite FT ages younger than the end of Neogene were obtained (Goto, 2001; Sueoka unpublished data), implying recent rapid uplift and denudation. By following the compilation results, we are planning to apply thermochronometric methods, e.g., FT analyses and (U-Th)/He dating, to the mountainous regions in the NE Japan Arc, especially in the areas where young ages were reported or no age was obtained.

Keywords: thermochronology, data compilation, deformation over geologic time

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SCG57-P05 Room:Convention Hall Time:May 27 18:15-19:30

Formation and development of incipient shear zone in the lower crust: Example from the Hasvik gabbro, Norway

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Gabbroic rock is a major constituent of the lower crust, and it consists mainly of plagioclase and pyroxene. Although dislocation creep of plagioclase has generally been considered to govern the rheology of the lower crust, when the grain size of the constituent minerals is small enough, grain-size-sensitive creep dominates the mechanical behavior of the lower crust. The process of grain-size reduction is a fundamental factor in controlling the strength of the lower crust. Instead of dynamic recrystallization, the nucleation that results from the fracturing and crushing of minerals have to be considered as potentially important processes. In this study, to clarify the initial process of shear zone formation in the lower crust, we describe microstructural and petrological characteristics of shear zones developed in the Hasvik gabbro of the Seiland Igneous Province in northern Norway (e.g., Tegner et al., 1999).

Shear-zone networks are developed in the Hasvik gabbro, and the shear zones are made up of fine (a few tens of microns), equant, but slightly elongate grains of the recrystallized plagioclase, amphibole and pyroxene. On the other hand, in the primary magmatic crystals of plagioclase and pyroxene, intragranular and intergranular fractures are found. Newly crystallized amphiboles are found along the boundaries between magmatic plagioclase and pyroxenes, in the intragranular fractures within pyroxenes, and at the margins of pyroxene porphyroclasts in the shear zones. Recrystallized grains of plagioclase, clinopyroxene, and orthopyroxene have compositions that differ from the magmatic ones, which suggests they formed by nucleation and growth. Based on conventional plagioclase-amphibole thermobarometry (Holland and Blundy, 1994; Bhadra and Bhattacharya, 2007), the shear zones have formed at temperatures and pressures of 750-800 ℃, 0.8±0.2 GPa. The observed primary minerals cut by fractures suggest high-temperature fracturing in the absence of high pore pressures, which implies a high strength of the lower crustal gabbros and high stresses at fracturing. The viscously deformed shear zones are characterized by the lack of crystallographic preferred orientation (Okudaira et al., submitted) and a small grain size, suggesting that the mechanism of deformation of the fine-grained plagioclase and orthopyroxene has been diffusion accommodated grain-boundary sliding during and/or after their nucleation and growth.

Keywords: gabbro, lower crust, brittle fracturing, grain-size reduction, grain-size-sensitive creep

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Measurements of elastic wave velocity and electrical conductivity in a brine-saturated granite under confining pressures

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Geophysical mapping of fluids is critical for understanding crustal processes. Seismic velocity and electrical resistivity structures have been revealed to study the fluid distribution. However, the fluid distribution has been still poorly constrained. Observed velocity and resistivity should be combined to make a quantitative inference on fluid distribution. The combined interpretation requires a thorough understanding of velocity and resistivity in fluid-saturated rocks. We have studied elastic wave velocities and electrical conductivity in a brine-saturated granitic rock under confining pressures.

A fine grained (100-500 ?m) biotite granite (Aji, Kagawa Pref., Japan) was selected as a rock sample for its small grain size and textural uniformity. Cylindrical samples (D=26 mm, L=30 mm) were heated to 100-600oC to increase the amount of crack (open grain boundary), and filled with 0.1 M KCl aqueous solution. A linear relationship was found between the highest temperature and the crack density parameter, which was estimated from velocities measured at atmospheric pressure. Velocity and electrical conductivity were simultaneously measured by using a 200 MPa hydrostatic pressure vessel. The pore-fluid was electrically insulated from the metal work by using plastic devices. The confining pressure was progressively increased up to 150 MPa, while the pore-fluid pressure was kept at 0.1 MPa. It took 3 days or longer for the electrical conductivity to become stationary after increasing the confining pressure.

Velocity and conductivity showed reproducibly contrasting changes with increasing confining pressure. Elastic wave velocities increased by less than 10% as the confining pressure increased from 0.1 MPa to 50 MPa, while electrical conductivity decreased by an order of magnitude. The changes were caused by the closure of cracks under pressure. The steep decrease in conductivity at low pressures suggests that there are more cracks with smaller aspect ratios. Both velocity and conductivity showed no remarkable changes at higher pressures. An empirical relationship between the normalized conductivity and crack density parameter was obtained. This relationship might be applied to a combined interpretation of seismic velocities and electrical resistivity.

Keywords: seismic velocity, electrical conductivity, resistivity, fluid, crack

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SCG57-P07 Room:Convention Hall Time:May 27 18:15-19:30

Measurements of elastic wave velocity and conductivity in a brine-saturated sandstone under confining pressures

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Geophysical mapping of fluids is critical for understanding crustal processes. Seismic velocity and electrical resistivity structures have been revealed to study the fluid distribution. However, the fluid distribution has been still poorly constrained. Observed velocity and resistivity should be combined to make a quantitative inference on fluid distribution. The combined interpretation requires a thorough understanding of velocity and resistivity in fluid-saturated rocks. We have studied elastic wave velocities and electrical conductivity in a brine-saturated sandstone under different confining and pore-fluid pressures.

Berea sandstone (OH, USA) was selected as a rock sample for its high porosity (~20%) and permeability (~10-13 m2). It is mainly composed of subangular quartz grains, with small amounts of feldspar grains. Microstructural examinations showed that clay minerals (e.g., kaolinite) and carbonates (e.g., calcite) fill many gaps between grains. The grain size is 100-200 micrometers. Cylindrical samples (D=26 mm, L=30 mm) were saturated with 0.1 M KCl aqueous solution. Measurements have been made using a 200 MPa hydrostatic pressure vessel, in which confining and pore-fluid pressures can be separately controlled. An aqueous pore-fluid is electrically insulated from the metal work by using a plastic devices. Elastic wave velocity was measured with the pulse transmission technique (PZT transducers, f=2 MHz), and electrical conductivity the four-electrode method (f=100 mHz - 100 kHz) to minimize the influence of polarization on electrodes.

Confining and pore-fluid pressures work in opposite ways. Increasing confining pressure closes pores, while increasing pore-fluid pressure opens them. For a given pore-fluid pressure, both compressional and shear velocities increase with increasing confining pressure, while electrical conductivity decreases. When confining pressure is fixed, velocity decreases with increasing pore-fluid pressure while conductivity increases. The closure and opening of pores can explain observed changes of velocity and conductivity. In contrast to a granitic rock, a brine-filled sandstone showed only relatively small changes in conductivity. These contrasting behaviors might reflect the difference in pore geometry between two rock samples.

Keywords: seismic velocity, conductivity, resistivity, sandstone, fluid

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SCG57-P08 Room:Convention Hall Time:May 27 18:15-19:30

Grain growth in sintered polycrystalline diopside

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Grain growth kinetics were studied in sintered polycrystalline diopside. The starting material was prepared from two types of diopside single crystals (I :$Ca_{0.99}Na_{0.01}Mg_{0.97}Fe_{0.03}Si_2O_6$, II:$Ca_{0.97}Na_{0.02}Mg_{0.86}Fe_{0.13}Si_2O_6$). They were crushed and milled to particle size of $<1\mu$m. The powders were pressed into cylindrical shape under a uni-axial pressure of 2.0 MPa for 10 minutes. The pellets were then sintered at 1130 - 1280 ℃ for 2h and 6h. As a result, grain size increased and the porosity decreased with increasing sintering temperature or sintering time. The experimental data can be fit the following relation, $D_f^n - D_0^n = kt$ where n is a constant, D_f and D_0 are the grain size at time t = t and t = 0 respectively, and k is a rate constant. For the sintered polycrystalline diopside, the parameter $\log_{10}k$ (μm^n/s) was determined to be -3.3 or -4.8 for n = 2.59 or 2.64 respectively.

Keywords: grain growth, sintering, diopside, polycrystalline

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Tectonic provinces of the Northern Fossa Magna region depicted by means of the crustal movement and seismic activity

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In the Northern Fossa Magna (NFM), large crustal earthquakes had been occurred in 1847 (the Zenkoji Earthquake) and recently. Understanding the tectonic provinces of the upper crust is important in order to clarify the generation mechanism of the crustal earthquakes. The purpose of this study is revealing the tectonic provinces of the NFM region depicted by means of the regional characteristics of the crustal activity. The author investigated the crustal movement and the depth of the seismogenic layer by analyzing GNSS observation data and hypocenter data, respectively.

Velocity field and strain rate field were estimated by analyzing GNSS observation data of GEONET and University of Toyama, from October 2007 to March 2011. The depth of the seismogenic layer was evaluated using the JMA unified hypocenter catalog from January 2003 to March 2011. Noises and low-frequency events were removed from the catalog with hypocenters that focal depth is shallower than 40 km and magnitude is larger than 0.1. Relocation and declustering process of the hypocenters were not conducted in this study. The depth of the seismogenic layer was evaluated by means of the methods of Ito and Nakamura (1998), the depth which 10%, 50%, and 90% of hypocenter occur are defined as the upper, middle, and lower depth of the seismogenic layer.

As the results, considerable lateral variation in the crustal activity was revealed in and around the Niigata-NFM region. The strain concentrate zone consisted of the WNW-ESE trend contraction strain more than 0.15 ppm/yr distributes from the north region of Niigata Prefecture to the central region of Nagano Prefecture, and this zone corresponds to the northeastern part of the Niigata-Kobe Tectonic Zone (Sagiya *et al*., 2000). The displacement direction in the horizontal velocity field changes from eastward in the northwestern part of the Niigata-NFM region to northward in the southern part. The depth of the seismogenic layer shows lateral variation of about 10 km beneath the NFM region, and the inland region with a relatively shallow depth of the seismogenic layer corresponds the location of active volcanoes. Focal mechanisms of the shallow crustal earthquakes in the NFM region show reverse fault type and strike-slip fault type. These different mechanisms indicate that seismotectonic stress varies around this region.

These results suggest the existence of the geodetic and seismological tectonic boundary that trends to NE-SW direction and inclines toward the west. This tectonic boundary is located obviously on the west side of the geological tectonic boundary, the Shibata-Koide Tectonic Line (Yamashita, 1970) and Tsunan-Matsumoto Tectonic Line (Kosaka, 1984), along the eastern margin of the Shin'etsu sedimentary basin. A conclusive model for the tectonic provinces of the Niigata-NFM region shows that the tectonic boundary separates the whole crust into two provinces which having different characteristics in the horizontal velocity field, seismogenic layer depth, and surface geology. The lateral variation in the seismogenic layer along the geodetic and seismological tectonic boundary might be the cause of generating the shallow crustal earthquakes in the NFM region. In order to discuss about the detailed tectonic provinces of the NFM region, it is necessary the crustal activity are evaluated by various observations with high spatial resolution.

Keywords: tectonic province, tectonic boundary, Northern Fossa Magna, strain concentrate zone, seismogenic layer

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SCG57-P10 Room:Convention Hall Time:May 27 18:15-19:30

Seismic survey around the largest slip area of the 2011 Tohoku-oki earthquake

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The slip amount during the 2011 Tohoku-oki earthquake exceeded tens meters at the near-trench region off Miyagi, though few meters caused at off Sanriku (e.g., Iinuma et al., 2012). Such the spatial variation of the coseismic slip seems to reflect the variation of the physical property on the interplate fault, which can be correlated with a seismic velocity structure. In this study, to understand the mechanism of enormous coseismic slip of this megathrust event, we investigate the heterogeneity of the seismic velocity structure around the fault.

Many seismic refraction surveys were carried out at off Miyagi and Sanriku regions. Azuma et al. (2013) found the high-Vp anomaly in the overriding plate, corresponding the backstop block (Tsuru et al., 2002), at the area of 38?38.5N and 20 km from the trench axis (Figure 1). This Vp anomaly overlapped the large slip area during the 2011 earthquake, and they suggested that the heterogeneous structure in the overriding plate controlled the extent and amount of the coseismic slip near the trench based on the 2-D structure model along a seismic profile. It is expected that similar correlation between the seismic velocity and the amount of coseismic slip is broadly observed in the trench slope area, if the coseismic slip was actually controlled by the material heterogeneity, e.g. the distribution of backstop brock.

To confirm broad consistency of the previously identified structural variation, we conducted a seismic survey on October 2014 in the gap area where no seismic surveys have been conducted (Figure 1). We set two survey lines, with a length of 180 km, which run slightly oblique against the Japan Trench axis. Along the profiles, 17 and 20 ocean bottom seismometers (OBSs) were deployed. The spacings of the OBSs were 10 and 8 km, along the land-ward and trench-ward profiles, respectively, taking into account the difference in depths to the plate interface. We used an airgun array composed of four guns with a total volume of 100 liters as a controlled source. During the shooting operation, we also collected near-vertical reflection data by a 48-channel hydrophone streamer with a length of 1.2 km.

The obtained wide-angle data showed clear first arrivals within the offset range of 60 km, and later phases interpreted as the wide-angle reflections from the plate interface. Further analyses of the obtained data set will provide a velocity structural model to clarify more detailed distribution of the backstop block and to reinforce the interpretation based on the spatial correlation between the high-Vp block and large coseismic slip area of the 2011 Tohoku-oki earthquake.

Figure 1. Map view of surveyed area. Red lines and yellow plots indicate survey lines and deployed OBSs′ positions of this study. Black line indicates the profile of Azuma et al. (2013). Blue arrow represents the high Vp area detected by Azuma et al. (2013). Gray lines were surveyed by Ishihara et al. (2015). Black blocks shows the distribution of sedimentary prism obtained by reflection surveys (after Tsuru et al., 2002). Color-filled contour represents the coseismic slip distribution of the 2011 Tohoku-oki earthquake (Iinuma et al., 2012).

Keywords: crustal structure, 2011 Tohoku-oki earthquake

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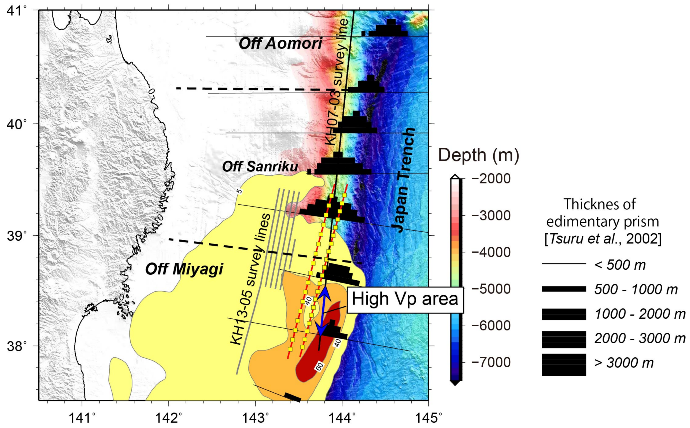

Figure 1

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SCG57-P11 Room:Convention Hall Time:May 27 18:15-19:30

Grain growth of nanocrystalline labradorite

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Plagioclase is a solid solution series that ranges from albite to anorthite endmembers (with respective compositions $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$). Plagioclase is a major constituent mineral in the Earth's crust. Its physical and chemical properties are important for establishing the overall rheology of Earth's crust. Previous experimental studies on sintering on plagioclase were mostly concentrated on the endmembers under the high-pressure conditions, thus there are few reports on sintering of plagioclase with intermediate composition.

In this study, sintering of labradorite polycrystalline were performed by using nanoscale powders of natural labradorite, and grain growth kinetics was studied in sintered polycrystalline labradorite. We prepared nanoscale mineral powders from natural crystals of labradorite (Ab38An62) by milling. Sintering experiments were carried out at a temperature of 1100-1210 ℃ with controlling time after milling and formed mineral powders. Starting materials were characterized by electron probe micro analysis (EPMA). The resultant materials were characterized by X-ray powder diffraction (XRD), secondary electron microscope (SEM) and Xray fluorescence (XRF) analysis.

Grain growth occurred with increasing sintering temperature or sintering time. The experimental data can be fit the following relation, $D_f{}^n$-$D_0{}^n$ = kt where n is a constant, D_f and D_0 are the grain size at time t = t and t = 0 respectively, and k is a rate constant. For sintering, a temperature of 1100-1210 ℃ with controlled time can provide high dense aggregates of labradorite with an average grain size of 0.5micro m, porosity of 3vol% and volume reduction of 60%. In this study, we found that high dense and fine grain polycrystalline Labradorite can be made from nano-sized powders ($<$100nm) by atmospheric pressure sintering.

Keywords: plagioclase, sintering, grain growth

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Effects of seismic velocity anomaly zone below Northeast Japan on displacement of the 2011 Tohoku earthquake

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2011 M9 Tohoku earthquake, Japan, has the 500-km long and 200-km wide source region and large deformation was observed over the Japanese islands. Japan is deployed with dense GPS observation network. Analyzing the spatial features of the crustal deformation data, we can obtain not only information of the source of the Tohoku earthquake but also that of crustal structure. The Northeast Japan arc is formed by the subduction of the Pacific plate below the Eurasian plate. The volcanic front is located along the Ou Range. Studies of seismic tomography has revealed low velocity region below the volcanic front due to the intrusion of hot materials and high velocity region below the Pacific coast due to crustal thinning and ascending of mantle materials. In this study, we construct a finite element model incorporating 3-D crustal structures and examine the effect of crustal heterogeneity on the surface deformation using slip distribution obtained from inversion of the surface displacements due to the Tohoku earthquake. We utilize the large, land-based Japan GPS array as well as seafloor geodetic constraints in the inversion. Our FEM considers a region of 4500 km x 4900 km x 670 km, incorporating the Pacific and the Philippine sea slabs by interpolating models for the Tohoku region and the Nankai trough, as well as the Kuril, Ryukyu and Izu-Bonin arcs. As the geometry of the plate boundaries, we used the model interpolating the existing local plate boundary models. The model region is divided into about 500,000 tetrahedral elements with average dimension ranging from 5-100 km. We also test the role of gravity on coseismic results, with initial results suggesting that gravitational loading is not an important factor because of the shallow dip of the upper Pacific slab. As for the elastic structure, we used PREM model. To represent high and low velocity zone under the Pacific coast and volcanic front, respectively, we introduced 80-km thick region in the model. We also computed with the associated layered structure model to check the effect of crustal heterogeneity. We obtained almost the same slip distribution for both the layered and crustal heterogeneity models, indicating that the deviation of the displacement due to crustal heterogeneity from layered model does not affect slip inversion. Using these results, we calculated surface deformation for models. We compared the two results by patterns of residual displacements, which is obtained by subtracting computed displacements from observed displacements. In the case of layered model, most of Northeast Japan shows eastward residual vectors and the westward vectors can be found along the Pacific coast. These residuals are diminished in the crustal heterogeneity model, so this model better explains the observation. In this way, we can extract information of detailed elastic structure by using broad surface deformation field data. This will allow us to calculate more realistic stress state in the crust.

Keywords: 2011 Tohoku Earthquake, Crustal deformation, Finite element modeling, Seismic velocity structure, Northeast Japan arc, Active fault

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A method to estimate friction coefficient from orientation distribution of meso-scale faults

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Static friction coefficient controls the brittle strength of earth's crust of which deformation is recorded as faults. It is difficult to estimate the friction coefficient of ancient geological faults because fault gouge does not preserve its physical property. This paper proposes a method to determine friction coefficient from orientation distribution of fault planes.

Stress tensor inversion techniques have been applied to geological meso-scale faults to calculate a reduced stress tensor, which is composed of three principal stress orientations and a stress ratio. Angelier (1989) tried to determine all six independent components of stress tensor including magnitudes of principal stresses, assuming that the ratio of normal and shear stresses on observed fault surfaces exceeds the friction coefficient. The assumption allows us to estimate the friction coefficient of meso-scale faults as the slope of linear boundary of distribution of points representing normal and shear stresses on Mohr's diagram. However, there has been remained uncertainty in the estimation since the recognition of the line has been done manually on the diagram.

This study computerizes the estimation of friction coefficient as follows. Meso-scale faults are assumed to slip when they satisfy the cohesionless Coulomb's failure criterion represented by the linear friction envelope. The principal stress axes and stress ratio are presumed to be stable, while the changes in the magnitude of differential stress and the fluid pressure are taken into account. When the two parameters fluctuate to cause faulting, the Mohr's circle moves to leftward (negative direction of effective normal stress). Then, a upper left part of the Mohr's circle is cut off by the friction envelope and the faults corresponding to the part are activated. If such events are repeated with various values of differential stress and fluid pressure, the orientation distribution of activated faults should have concentration around the tangential point between the friction envelope and the Mohr's circle normalized to satisfy sigma_1=1 and sigma_3=0. According to the above-mentioned concept, the new method searches for the direction of linear gradation in the frequency of fault planes on the normalized Mohr's diagram. The slope of friction envelope is given by linear contour lines of frequency of faults.

The method was applied to natural fault-slip data gathered from the Pleistocene Kazusa Group, eastern Boso Peninsula. The strata are composed of sandstones and slitstones. Stress inversion analysis (Sato, 2006) gave a WNW-ENE trending tensional stress. The friction coefficient was determined to be 0.66 +0.05/-0.05, which is typical value for sandstone.

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Sato, K., 2006, Tectonophys., 421, 319-330.

Keywords: stress tensor inversion, fault-slip analysis, friction coefficient, orientation distribution

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SCG57-P14 Room:Convention Hall Time:May 27 18:15-19:30

Landward migration of active folding estimated from topographic developments along the eastern margin of the Japan Sea

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The Quaternary tectonics of the Japan arc is characterized by strongly crustal deformation, whose mode and rate are quite different from those of the preceding late Pliocene. The Tohoku district, on the eastern margin of the Japan Sea, lies within a strongly compressive area that has been experiencing large, contractional, crustal deformations, since the late Pliocene (Sato and Amano, 1991). Fold-and-thrust structures (Sato, 1989) and fold-topographic structures with distributed reverse faults (e.g., Okamura et al., 1995) have developed in response to this contractional deformation. Geodetic surveys in the Tohoku district have detected zones with a high rate of horizontal strain (Sagiya et al., 2000). When the contractional deformation continues to the present, the high strain rate zones at the geological and geodetic scales should be overlapped. However, the high horizontal strain-rates recognized at geological and geodetic time-scales are spatially heterogeneous. Rates are consistent in the Niigata region, in the southwestern part of the Tohoku district, but not in the Akita region in the northwestern part of the district. There is, therefore, a need to constrain the spatial differences in the horizontal strain-rate between the geological and geodetic time-scales, in order to understand regional tectonic differences across the district.

We focus here on the erosional and topographic evolution of fold structures developed since the late Pliocene in the Akita and Niigata regions. We measured the distance between the fold hinge lines and the mountain ridge lines. We targeted 44 folds that were activated since the late Pliocene, comprising 12 and 32 folds in the Akita and Niigata regions, respectively. Spatial variations in the normalized deviations are consistent with the systematic eastward migration of fold growth in the area. The topographic behavior indicates that the landward migrating of the fold growth is generally constant.

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Keywords: fold, fault, topography, earthquake, deformation, high strain rate zone

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Block-in-matrix fabric by frictional grain-boundary sliding of the Hioki melange of Shimanto belt, Shikoku, Japan

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We report lithology, deformation structures, and clay mineral contents of the Hioki melange, which constitutes part of the youngest (late Oligocene to early Miocene) portion of the Shimanto accretionary complex, Shikoku, Japan. The Hioki melange is comprised essentially of a dark gray shaly matrix that envelops blocks and large rafts of mainly sedimentary rock. Although it is regarded as accreted within a few kilometers below the surface (e.g., Hibbard et al., 1993; Underwood et al., 1993), the deformation process of the melange still remains unclear. The deformation mechanism of the melange is essential information to understand this problem.

The lithology and deformation structures are observed using core samples and outcrops along coastline at Muroto, Kochi, Japan. The core samples were collected at two localities (HK01 and HK02) and are about 40 m length, respectively. The whole of the samples show block?in?matrix fabrics. The ratios of the blocks change irregularly between 0 to 40 %. Furthermore, some fracture zones are observed throughout the samples. Some of these fracture zones contain clay minerals. In the field, block?in?matrix fabrics are also observed throughout the study area. The size of blocks ranges from millimeter to meter scale. There were three shapes in the blocks, which are brecciated, boudinage, and layered blocks. Some blocks are injected by shale. The matrix, which is partly folded, is composed of dark gray shale and some green tuff and dark brown shale. Microscopic observation revealed that the shear displacement of the matrix has been achieved by grain boundary sliding and some pressure solution. Attitudes of bedding plane, cleavage foliation, and major axis of boudinage blocks are parallel in many cases.

Clay mineral contents were investigated by XRD analysis on 23 samples (7 samples for HK01, 5 samples for HK02, and 11 samples for outcrops) throughout the study area. The result shows that illite is the major mineral in all samples. In addition, chlorite is contained in the samples of HK02 and the northern half of outcrop, and kaolin minerals are contained in the fracture zone.

Two possible explanation are concerned for the process of the block-in-matrix fabric of the Hioki melange. One explanation is that this fabric has formed under the condition that the contrast in competence between the sand (block) and the shale (matrix) is relatively high. In this case the sand layers have consolidated and deformed by brittle failure, although the shale layers have deformed by grain boundary sliding. In this case, blocks from same layer should form a line. It is a future problem to confirm. Another explanation is that host strata of the Hioki melange have deposited as mud layer with some boulders. In this explanation, sandstone blocks may have been transported by debris flow and/or submarine landslide. On the other hand, the fracture zones have formed in the consolidated melange, which have been uplifted to shallower part of the accretionary prism.

Keywords: block-in-matrix fabric, grain boundary sliding, Shimanto belt, melange

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Changes in seismic velocity and electrical conductivity in a brine-saturated granite under uni-axial compression

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Geophysical observations have shown that fluids exist pervasively within the crust. Fluids are mainly situated at intra-grain cracks and open grain boundaries. Since the opening of cracks strongly depends on the stress state, bulk properties such as seismic velocity and electrical conductivity, which are strongly affected by fluid-filled cracks, should be anisotropic under a stress state. In order to understand the anisotropy in velocity and conductivity under stress, we have been constructing an experimental system for studying the anisotropy in elastic wave velocity and electrical conductivity in a brine-saturated granitic rock under uni-axial stress.

The loading system is composed of a hand press (Maximum load: 20 kN), a load cell and stainless steel end-pieces, which contains ultrasonic transducers for velocity measurements in the axial direction. A fine grained (100-500 ?m) biotite granite (Aji, Kagawa Pref., Japan) was selected as a rock sample for its small grain size and textural uniformity. A cylindrical sample (D=26 mm, L=30 mm), to the cylindrical surface of which ultrasonic transducers are mounted for velocity measurements in the radial direction, is assembled with end-pieces, and then loaded. One compressional wave velocity and two shear wave velocities can be measured in the axial and two radial directions. Electrical impedance can also be measured in the axial and radial directions.

Preliminary runs on a dry rock sample have showed that velocities in the axial direction increased significantly with the axial compression. No significant change was observed in velocities propagating in the radial directions. These observations can be explained by the closure of cracks perpendicular or subperpendicular to the compression axis. Experiments on wet samples will also be reported in this poster.

Keywords: seismic velocity, electrical conductivity, anisotropy, fluid, compression, stress

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Detrital zircon chronology of the Upper Cretaceous Atokura Formation in northern Kanto Mtn., Japan

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The Cretaceous sandstones of the Atokura nappe in the northern Kanto Mtns. in central Japan were analyzed for detrital zircon U-Pb chronology by LA-ICP-MS. The results documented two distinct age groups; i.e., 150-300 Ma (Permian to Jurassic) and 1600-2600 Ma (Neoarchean to Mesoproterozoic). As there are no correlative candidates for provenance in the neighborhood, the Cretaceous strata of the Atokura nappe were likely exotic. The occurrence of Jurassic granitoids is currently limited to the Hida belt in central Japan, while no Precambrian basement is exposed at all in Japan. Judging from the allochthonous mode of occurrence, the Atokura nappe was derived originally from the back-arc domain of the Cretaceous Japan.

Keywords: Cretaceous, sandstone, detrital zircon, U-Pb age, LA-ICP-MS, Japan

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Dislocation creep induced layer structures ? in mafic rocks, Tanzawa Mountain

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Tanzawa plutonic complex is located in the northen part of Izu-Bonin-Mariana (IBM) arc. The complex has been exposed by the collision of IBM arc and Japan islands. The exposed process is related to uplifting of Tanzawa plutonic complex along the Kannawa fault. Mafic rocks near the Tanzawa plutonic complex show metamorphosed and deformed textures. The purpose of this study is to reveal microstructures of metamorphosed mafic rocks occurred near the Tanzawa plutonic complex. They are highly deformed and show well-developed layer structures. The mafic rocks consist mainly of amphibole and plagioclase. Amphibole grains are elongated. Plagioclase grains are polygonal. The mean grain sizes of amphibole are in a range between 30 and 110 micron, whereas those of plagioclase are in a range between 25 and 115 micron. Within the well layered rocks, aspect ratios become smaller, as increasing grain sizes. Crystal-preferred orientations (CPOs) of amphibole and plagioclase were measured by a scanning electron microscope (SEM) equipped with electron back-scattered diffraction (EBSD). Amphibole CPOs show (100) [001] patterns. Plagioclase CPOs show (001) [100] patterns. It suggests that their deformation mechanisms are dominantly dislocation creep. Some elongated amphibole grains have grain boundaries perpendicular to the foliations, which appear to be also an evidence of dislocation creep. Consequently, the mafic rocks could result from dislocation creep during the development of layer structures associated with uplifting of the Tanzawa plutonic complex.

Keywords: amphibolite, Tanzawa, amphibole, plagioclase, CPO

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Brittle and ductile textures preserved in Kashio mylonite along the Median Tectonic Line, Sakuma-cho, Shizuoka

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Kashio mylonite exposed along the Median Tectonic Line in the central Japan is one of the most famous fault rocks in Japan. The purpose of this study is to reveal microstructural development of Kashio mylonites in the Urakawa area,Sakuma-cho, Shizuoka Prefecture. Kashio mylonite occur along the Ohchise-gawa River and Shippei-sawa. In this study, four Kashio mylonites were classified into three types: protomylonite, mylonite, and ultramylonite. The whole rock chemical compositions show that they were derived from the igneous rocks such as tonalites. Two protomylonites have larger (˜4mm) plagioclase and amphibole porphyroclasts and show composite planar structures. The plagioclase porhyroclasts were fractured but partly dynamically recrystallized into fine-grains. All quartz grains were dynamically recrystallized into fine (about 40 micron) grains. One mylonite consists of very fine-grained quartz (about 20 micron) and plagioclase bands with small amount of plagioclase porphyroclasts. One ultramylonite consists of very fine-grained matrix of quartz, plagioclase and K-feldspar (about 10 micron). Ultramylonite were fractured such as cataclasitic rocks after the mylonitization. Crystal-preferred orientations (CPO) of quartz were measured in the four mylonitic samples. Quartz CPO patterns suggest that prism <a>slip system is dominant, whereas the ultramylonite have a weak cross girdle pattern of c-axis. It suggests that the ultramylonite was progressively developed during deformation under the retrogressive condition. As a result, these mylonitic rocks have undergone three stages of the deformation event. The first stage of deformation occurred in the ductile regime of plagioclase, resulting in the fine-grained plagioclase and Y-maxima CPO patterns of quarts c-axes. The second stage of deformation occurred in the brittle regime of plagioclases, resulting in fracturing within plagioclase porphyroclasts and the weak cross girdle CPO pattern of quartz c-axis in the ultramylonites. Finally, the third stage of deformation occurred in the brittle regime of both quartz and plagioclase, resulting in the development of cataclasite. The results support that the Kashio mylonites have been deformed during progressive retrogression associated with the development of Median Tectonic Line.

Keywords: Median Tectonic Line, Kashio mylonite, CPO, ductile regime, brittle regime

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Thickness of seismogenic layer within the crust on the Japan Sea side

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1. Introduction

We investigate the depth of the seismogenic layer in order to estimate the lower limit of the seismogenic fault plane since this depth is related to the size of the earthquake caused by the active fault. We have index D10 and D90 as the upper and lower limit of seismogenic layer, respectively. D10 is defined as the depth above which 10 % of the whole crustal earthquakes occurred from the surface. D90 is the depth above which 90 % of the crustal earthquakes occurred from the surface. The difference between the D10 and D90 is the thickness of the seismogenic layer.

2. Data and method

NIED Hi-net has a catalog of hypocenters determined with one-dimensional velocity (1D) structure (Ukawa et al., 1984). We construct the system to relocate the hypocenters from 2001 to 2013 with magnitude greater than 1.5 on the Japan Sea side shallower than 50 km depth with three-dimensional velocity (3D) structure (Matsubara and Obara, 2011). We estimate the D10 and D90 from the hypocenter catalog with 3D structure.

3. Result

The many earthquakes determined shallower than the 5 km with 1D structure are relocated to deeper with 3D structure and the earthquakes deeper than 15 km are relocated to about 5 km shallower. D10 becomes deeper and D90 becomes shallower with 3D structure.

From Akita to Niigata prefecture, D90 is deeper than the other area and D90 beneath the Japan Sea is much deeper than the inland area. The thickness of the seismogenic layer in this area is also thick from 8-16 km. On the west side of the area, D90 is very shallow as 11-16 km and the thickness of the seismogenic layer is also thin as 2-7 km from Toyama to Tottori.

4. Discussion

Omuralieva et al. (2012) relocated the JMA unified hypocenters with 3D structure. D90 became shallower than that from the JMA catalog. Very deep D90 beneath the northern Hokkaido and from Akita to Niigata is consistent with our result.

5. Conclusion

Using 3D structure, the depth of shallow earthquakes is relocated to deeper and that of the deep earthquakes is relocated to shallower then D10 deepens, D90 shallow, and the thickness of the seismogenic layer becomes thinner. The thickness of the seismogenic layer is thick beneath the region from the Akita to Niigata prefecture on the northeastern Japan Sea side, however, that is very thin beneath the region from Toyama to Tottori prefecture on the west side of the Japan Sea coastal area.

Keywords: seismogenic layer, D90, D10, seismic fault

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P-wave velocity structure at shallow depths around the northern limit of the 2011 Tohoku earthquake

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Before 2011 Tohoku earthquake, some seismic surveys had been conducted within the co-seismic slip area of the earthquake. However structures may have been changed after the earthquake due to the co-seismic slip. We need to compare the structures of the same area of different times in order to reveal changes caused by the 2011 Tohoku earthquake. Therefore, a refraction-reflection seismic survey was conducted in 2013 at the same area of the 1999 and 2001 surveys. Seven 100 km long profiles were surveyed parallel to the Japan Trench. Forty-four OBSs were deployed and hydrophone streamer was towed behind the shooting vessel. Air-gun array was used as controlled seismic sources. Because the area of 2013 survey includes the co-seismic slip area of the 2011 Tohoku earthquake, the changes of structure may be revealed by comparing results of 1999 and/or 2001 survey with that of the 2013 survey. Especially the profiles include the northern limit of the co-seismic slip area of the 2011 Tohoku earthquake in their north, so it may be possible to put constraints on the northern limit.

We could identify some differences on the seismic reflection sections and in the recorded waveforms between the 2001 and 2013 surveys. It is, then, expected to reveal some structural changes before and after the 2011 Tohoku earthquake.

We constructed 1-D V-p structures to about 2km depth beneath the seafloor for each OBS station by applying the Tau-P method. Then we constructed 2-D V-p structure models by referring to the 1-D V-p structures for profiles so that the models explain travel times of shallow P-wave arrivals.

Keywords: the northern limit of the 2011 Tohoku earthquake, controlled source seismic survey, ocean-bottom seismometer(OBS)

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Seismic basement structure in and around the northeastern Kanagawa Prefecture inferred from the seismic interferometry

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1. Introduction

Detailed information on seismic basement structure is required for understanding the formation process of the Kanto sedimentary basin. In this study, we investigated the seismic basement structure in and around the northeastern Kanagawa Prefecture by the pseudo reflection seismic profiles from the seismic interferometry of local earthquake waveforms, with other geophysical information from geophysical exploration and deep borehole observation.

2. Data and Analysis

Twenty-seven thousand seismic waveforms of the local earthquakes recorded by SK-net, K-NET, and MeSO-net, were analyzed in this study. Following Yoshimoto et al. (2009), we analyzed the SH displacement waveforms of moderate size earthquakes. After the calculation of the autocorrelation functions of each SH displacement waveform with a length of 10s from the S-wave onset, autocorrelation functions from all events were stacked at each station to obtain the reflection response of S-wave for shallow underground structure.

3. Result

We found clear reflective surfaces in the pseudo reflection seismic profiles. As for the Atsugi-Yokohama survey line, it was found that significant reflective surface is inclined to the east from 2s to 6s in two-way tarveltime. We interpreted this reflective surface as the top of the Shimanto belt, comparing the geological information at Sagamihara borehole (Ozawa et al., 1999). The observation stations located at the north of the Tama River show very reflective surface compared with those located above the Shimanto belt. Since this reflective surface is observed at the vicinity of Koto borehole and Fuchu borehole, we interpreted this reflective surface as the top of the Chichibu belt.

The boundary of the Shimanto belt and the Chichibu belt is found to be located nearly along the Tama River, slightly shifting to the south near the northeastern Yokohama City. The top of the Shimanto belt in the south side of this boundary was found at 6s in two-way tarveltime in the mideastern Yokohama City, and it is about 1s deeper than the top of the Chichibu belt in the north side. It was also found that the Shimanto belt becomes shallower toward the west in western Yokohama City (in and around Asahi-ku and Totsuka-ku). These results are consistent with the seismic traveltime analysis (Yokohama City, 2000). As for the top of the Chichibu belt, it's depth was estimated to be nearly horizontal in the east of Chofu, Tokyo, however, it becomes suddenly shallower at the westward of Fuchu.

ACKNOWLEDGMENTS

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Seismic reflection profiling off-Tottori and Fukui, SW Japan, for seismic and tsunami hazards in the Sea of Japan

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To estimates Tsunami and seismic hazards along the coastal area of Sea of Japan, more detailed survey to identify source faults are needed. A research project funded by MEXT named ”the integrated research project on seismic and tsunami hazards around the Sea of Japan” began in FY 2013. To obtain the information of source faults, we performed deep seismic reflection profiling off-Fukui and Tottori area in the southwestern part of Honshu, Japan. Multi-channel seismic reflection data were acquired along four seismic lines in off-Fukui area and five seismic lines off-Tottori in the area within 50 km distance from the shoreline. Total length of seismic line is 190 km in off-Fukui and 280 km in off-Tottori. We used two vessels; a gun-ship with 3020 cu. inch air-gun and a cable-ship with a 2-km-long, streamer cable with 168 channels and 1050 cu. inch air-gun. The survey area consists of stretched continental crust and marked by densely distributed syn-rift normal faults. The thickness of Neogene basin fill is 5 km in off-Tottori and 3 km in off-Fukui. The rift basin fill along the arc-parallel normal faults were strongly deformed in late Miocene by basin inversion. The gently dipping Pliocene sediments cover the folded strata unconformably. Some of the Miocene reverse faults displaced late Pliocene sediments. Latest fault system is high-angle faults, whose displacement is preserved in topographic features. Judging from the patter of reflection the fault system is strike-slip faults.

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Crustal deformation in Hokkaido after the 2003 Tokachi-oki earthquake using GNSS data

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The Tokachi-oki earthquake (M_w = 8.0) occurred on the plate interface along the Kurile trench on 26 September 2003. Large interplate earthquakes like this are generally accompanied by the postseismic deformation. Postseismic deformation of this earthquake is well observed by GNSS. It is proposed that afterslip and viscoelastic relaxation are dominant mechanisms for the postseismic deformation. Afterslip is aseismic slip that occurs in and around the slip area of the mainshock. It lasts for several days to several years. Viscoelastic relaxation is the crustal deformation caused by flow of viscoelastic material due to the change of stress distribution. It lasts for several years to several decades and its effect is more widely distributed than that of afterslip [e.g. Scholz, 2002]. The effect of viscoelastic relaxation should be eliminated from the observed data when we infer the interplate coupling, especially its healing process after the mainshock, so an estimation of that is important. Theoretically, we can use a difference of relaxation times between two mechanisms to eliminate it, but we don't know when it actually starts to play a dominant role in postseismic crustal deformation.

Several previous studies, such as Miyazaki et al. (2003), Ozawa et al. (2004), and Baba et al. (2006) inverted the observed displacement data and inferred the afterslip distribution of this earthquake. Tanaka (2007) showed that the effect of viscoelastic relaxation is detectable in the observed data by a forward calculation. However, all of them use the data observed for only 2 years after the event, so we analyze the crustal deformation data for 7 years after the event observed by GNSS at the GEONET stations and investigate the effect of both afterslip and viscoelastic relaxation. We, here, describe the feature of the observed deformation after the Tokachi-oki earthquake.

Before the calculation of the deformation velocity after the event, we eliminate linear trends and the significant coseismic displacement of 3 earthquakes occurred near Hokkaido on 15 November 2006, 11 September 2008 and 5 June 2009 [Kimura & Miyahara, 2013]. We estimate the velocity by piecewise linear approximation. The horizontal velocity is estimated every year. The vertical velocity is estimated every year for first 3 years after the earthquake and every 2 years for the remaining period.

The observed data in the Tokachi, the Kushiro and the Nemuro regions were affected by double Kushiro-oki earthquakes on 29 November and 6 December 2004 (M = 7.1, 6.9, respectively). The postseismic deformation of these earthquakes lasted for 2 years in the eastern Tokachi, the Kushiro and the Nemuro regions near the hypocenter. In the western Tokachi region, the postseismic deformation lasted for 1 year. From 3 years after the Tokachi-oki earthquake, vertical velocity in the Tokachi and Kushiro regions was larger than that of in the stations near Cape Erimo, so we propose that the effect of viscoelastic relaxation was increasing there relatively and/or afterslip area moved to northeast.

In the Douou region, that is northwestern region of hypocenter, from 4 years after the mainshock, spatial decay of horizontal velocity is notably smaller than that in the northern and northeastern regions.

From examining the data analysis, we concluded that viscoelastic deformation started to play a dominant role in postseismic deformation after 3 years following the mainshock. We assumed a 2-layers structure model consisting of an elastic layer overlying a viscoelastic half-space and estimated the thickness of the first layer and the viscosity of the half-space by grid search. As a preliminary result, we obtained 60 km and 8.0×10^{18} Pa s for the elastic thickness and the half-space viscosity, respectively. The viscoelastic model almost explains the deformation in the northwest and southeast region of Asahikawa.

Acknowledgments: We used the GNSS data(F3 solution) provided by GSI.

Keywords: postseismic crustal deformation, viscoelastic relaxation, 2003 Tokachi-oki earthquake, GNSS

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SCG57-P25 Room:Convention Hall Time:May 27 18:15-19:30

Moho discontinuity beneath the Japanese Islands inferred from grid search analysis of receiver functions

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Information on seismic velocity and seismic velocity discontinuities is important to clarify the characteristics of the seismogenic zone. In particular, investigation on the crustal structure and the crustal thickness is the key to understanding the stress concentration and strain accumulation process. Recent travel time inversion analyses have elucidated 3D velocity structures in the whole areas in the Japanese Islands. However, very few studies have paid attention to velocity discontinuities due to the limitation of spatial resolution. A receiver function analysis can extract velocity discontinuities at any depth. In this study, we applied the grid search analysis of receiver functions to estimate the depths of Moho discontinuity beneath the Japanese Islands.

We first searched for the best-correlated velocity structure model between an observed receiver function at each station and synthetic ones for 10 seconds from the direct P arrival. Synthetic receiver functions were calculated from many assumed one-dimensional velocity structures that consist of a sediment layer and one or two velocity discontinuities from the ground surface to the depths of 50 km. We considered only the positive S-wave velocity steps. Observed receiver functions were stacked without considering backazimuth or epicentral distance. Telemetric seismographic network data covered on the Japanese Islands and several temporal dense seismographic stations are used. We selected events with magnitudes greater or equal to 5.0 and epicentral distances between 30 and 90 degrees based on USGS catalogue.

As a result, we clarify spatial changes of the depths of Moho discontinuity. They tend to increase in mountain regions and become shallow toward the surrounding areas with some undulations in most part of the Japanese Islands. This grid search analysis extracts the oceanic Moho of subducting plates in some areas near the Pacific coastline and beneath the south western Japan. This result suggests that velocity gaps of the subducting plates are larger than that of the overriding plate. We also show the Itoigawa-Shizuoka Tectonic Line (ISTL) is the boundary of the velocity structure in the Japanese Islands. The uppermost mantle along the ISTL shows relatively low P-wave velocities compared to the neighborhood areas. The southwestern Japan side is covered in the relatively high velocity and low Vp/Vs in the crust. On the other hand, the northeastern Japan side has heterogeneities of velocity perturbations. Low S-wave velocity and high-Vp/Vs areas exist just beneath the Moho discontinuity. This may be the reason the depths of Moho discontinuity interpreted from depth-converted receiver functions are deeper than the estimation from tomographic imaging and travel time of the refracted seismic waves in several areas.

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Reassessment of the stress history in the eastern Boso Peninsula, central Japan

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There are numerous mesoscale faults in the Neogene to Quaternary Awa and Kazusa Groups in the earstern Boso Peninsula (Kinugasa et al., 1969). The counterclockwise change of the Philippine Sea plate motion was argued on the basis of the stress history reconstructed by fault striation analyses in the peninsula (Angelier and Huchon, 1987; Yamaji, 2000). However, there has been no consensus on the timing of N-S or NE-SW compression. The timing was said to be about the late Pliocene by Kinugasa (1969), before 3-2 Ma by Angelier and Huchon (1987) and before 1.2 Ma by Yamaji (2000). In this research, we reinvestigated the stress history by using a recent technique of paleostress analysis (the Hough-transform-based inversion method: Yamaji et al., 2006; Sato, 2006).

We investigated mesoscale faults cropping out along the east coast of the Boso Peninsula and collected about 1,400 fault-slip data in the Awa and Kazusa Groups. The result of the fault striation analysis is as follows; a vertical axial compression, N-S extension and NW-SE extension were detected from the upper Katsuura Formation to the Umegase Formation. In addition to the above-mentioned three stresses, we detected NE-SW compression from the Amatu Formation to the Kurotaki unconformity and an early stage extension from the Amatsu and Kiyosumi Formations. The clarified stress history is summarized as follows; the early stage extension before ~3 Ma, the NE-SW compression at 3-2 Ma, the NW-SE extension at 2-0.8 Ma, the N-S extension after 0.8 Ma and the vertical axial compression at the present.

The most important discovery of this study is that the compression was episodic from 3 to ~2 Ma. In this presentation, we discuss the relationship between the paleostress and the past position of the TTT junction.

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Keywords: Boso Peninsula, stress history, fault striation analysis

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Analysis of fault rocks along Median Tectonic Line in Tsukide, Itaka town, Matsusaka city, Mie prefecture

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Median Tectonic Line (MTL) is extended more than 800 km in the East-West direction in Southwest Japan, and it is the largest fault, which defines the boundary between Sambagawa belt belonging to the Outer Zone of Southeast Japan and Ryoke belt belonging to the Inner Zone of Southeast Japan. Cracks are initiated when the accumulated strain exceeds the strength of rocks, and we call the displacement along cracks faulting, which could generate earthquakes. However, it is difficult to directly observe presently occurring fault movement in the underground. Therefore, it is very important to observe the outcrop of faults, which were active in the past for understanding the development of fractures along faults. In this study, we described geological map around the MTL, which is distributed in Tsukide, Iitaka town, Matsusaka-city, Mie-prefecture, and carried out rock descriptions. Then, we showed brittle fracture formed by faulting along the MTL, and the development of geological structures related to the faulting.

In this study, we mapped (i.e. investigated lithology) five valleys in high resolution using a 50 m scale, which extend approximately 150m in N-S direction, in the area spanning 900m in E-W direction, including the MTL. As a result of field study, it has been found that the MTL dips north at high angles. We showed that around the MTL four kinds of rocks are structurally overlain in order of the Sambagawa pelitic schist (50m+), pelitic schist derived from chert-laminite (90m), cataclasite (80m), and protomylonite derived from Ryoke Granitoids (15m+). We sliced the cataclasite samples and the protomylonite ones, and observed them under a microscope. Then, we observed the gradual alteration of plagioclase to muscovite, and chlorite deposited in cracks from the fluids which percolated along brittle fractures. We classified deformed granitic rock samples into four groups: not fractured, weakly, moderately, and strongly fractured rocks based on the degree of cataclasis. The schistosities of Sambagawa metamorphic rocks in the study area strike East-West directions, and the boundaries between Sambagawa metamorphic rocks and Ryoke Granitoids are also traced in the East-West directions. Therefore, we can show that the MTL generally strikes the East-West directions. Minor faults in Sambagawa metamorphic rocks strike NE-SW and dip north at moderate angles. Therefore, they are interpreted to be Riedel shears formed in relation to large-scale, left-lateral shear along the MTL in the East-West direction. Based on our detailed geological mapping in this area, it has been found that the trace of the MTL is displaced by 70m in the North-South direction in the center of this area, which could indicate a fault jog (step). Faults generally exhibit non-monotonous structures (fault jog) such as bending, echelon arrangement, and junction. Fault jogs are the end areas or the stop areas of fracturing, and it is considered that there are asperities which indicates the area greatly slipped just adjacent to them (e.g. Sugiyama et al,. 2003). In the future study, we must investigate the structures of fault jog in detail. Further, we showed that the rocks are strongly fractured near the MTL, and are moderately fractured far from the MTL. The degree of alteration of plagioclase conforms to this result. From these results, it can be inferred that the fracturing along the MTL propagated from the rocks in direct vicinity to the MTL to the remote ones, and the cataclasite zone grew over time.

Keywords: Median Tectonic Line, fault rock, cataclasite

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Characteristics of island arc deformation due to steady plate subduction

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Steady plate subduction elastically brings about permanent lithospheric deformation in island arcs, though this effect has been neglected in most studies based on dislocation theory. We investigate the characteristics of the permanent lithospheric deformation using a kinematic model, in which steady slip motion is given along a plate interface in the elastic lithosphere overlying the viscoelastic asthenosphere under gravity. As a rule of thumb, long-term lithospheric deformation can be understood as a bending of an elastic plate floating on non-viscous fluid, because the asthenosphere behaves like water in a long term. The steady slip below the lithosphere-asthenosphere boundary does not contribute to long-term lithospheric deformation. Hence, the key parameters that control the lithospheric deformation are only the thickness of the lithosphere and the geometry of the plate interface. Slip on a plate interface generally causes substantial vertical displacement, and the gravity always tries to retrieve the original gravitational equilibrium. For a curved plate interface gravity causes upward bending of the island arc lithosphere, while for a planar plate interface gravity causes downward bending. Larger curvature and thicker lithosphere generally causes larger deformation. When the curvature changes along the plate interface, internal deformation is also involved intrinsically, which modifies the deformation field due to gravity. Because the plate interface generally has some curvature, at least near the trench, upward bending of the island arc lithosphere, which involves uplift of island arc and subsidence around the trench, is always realized. On the other hand, the deformation field of the island arc lithosphere sensitively depends on lithospheric thickness and plate interface geometry. These characteristics obtained by the numerical simulation are well consistent with observed topography and free-air gravity anomalies in subduction zones, where a pair of topography and gravity anomaly, high in the arc and low around the trench, exists without exceptions all over the world, while there are large variety in the amplitude and horizontal scale.

Keywords: island arc, crustal deformation, viscoelasticity, gravity anomaly

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Structure of the PHS in the southernmost area of the Southern Japanese Alps using dense seismic array records

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The southernmost area of the southern Japanese Alps is located within a focal region of the anticipated Tokai earthquake and at the western edge of the Izu collision zone. The structure of the subducting Philippine Sea Plate (PHS) in this area, however, remains enigmatic. To investigate the structure of the subducting PHS as well as the physical property of the oceanic crust, we deployed a temporary, dense array consisting of 34 portable seismic stations extending 50 km in the southernmost area of the southern Japanese Alps. The seismic line started from Umegashima, Aoi-ku, Shizuoka city, and ended at Haruno-cho, Tenryu-ku, Hamamatsu city in Shizuoka prefecture. We applied receiver function and seismic tomography to the observed data, and discussed lateral variations of the plate interface and physical properties of the subducting oceanic crust in the studied area.

The analysis in this study is as follows.

1. We estimated velocity discontinuities by applying receiver function analysis to the seismic waveforms recorded by both the present array and five Hi-net stations near the array for teleseismic events with epicentral distance from 30 to 90 degrees.

2. We estimated seismic velocity structures by applying the double-difference tomography method (Zhang and Thurber, 2003) to the arrival time data. We used seismic waveforms of 354 local earthquakes retrieved at both the seismic array deployed by the present study and permanent seismic stations (45 stations) around the array.

3. To investigate seismicity in the studied area, we relocated the earthquakes from January 2004 to October 2014 applying the double-difference relocation (Waldhauser and Ellsworth, 2000) using the final velocity model estimated by seismic tomography.

We interpret the configuration of the PHS in the receiver function image. As overall character, the plate interface beneath the seismic array gradually becomes shallow toward the northeastern side. The plate interface interpreted in the present study well matches with those proposed by Matsu'ura et al. (1991), Kato et al. (2010), and Ito et al. (2013) at the both edges of the section. For example, Hirose et al. (2008) delineated the smooth plate interface of the PHS. However, the interpretation in this study suggests that the plate interface of the subducting PHS is not simply smooth, but has a convex, complex structure in the studied region. Interestingly, this complex configuration well correlates with the spatial distributions of intraslab earthquakes. A likely explanation is bucking deformation of the PHS due to the effect of collision and subduction. Subduction of a sea mountain beneath the seismic line as seen in the southwest part of the studied area (e.g., Kodaira et al., 2004) is another possible explanation. The reason is under discussion.

From the center to the southwestern side of our seismic section, oceanic crust is characterized by relatively low Vs with a high Vp/Vs ratio. The oceanic crust in this area does not host any significant seismicity. In contrast, at the northeastern side of our seismic section, a low Vp/Vs ratio seems to be present within the oceanic crust, and hosts active seismicity therein. A plausible explanation of the low Vp/Vs ratio within the oceanic crust is that intra-oceanic island arc crust is subducting beneath the northeast side of our seismic section. We suggest that different amount of water trapped within the subducting oceanic crust beneath the studied area may control lateral variations of activity level of non-volcanic tremors or deep low-frequency earthquakes at down-dip extension.

Keywords: southernmost area of the southern Japanese Alps, Philippine Sea Plate, receiver function, seismic tomography, intra-oceanic island arc crust, deep low-frequency earthquakes

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SCG57-P30 Room:Convention Hall Time:May 27 18:15-19:30

Holocene vertical movement history in northern Sanriku coast, NE Japan, related to megaquake cycle

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The 2011 off the Pacific coast of Tohoku Earthquake (The 2011 EQ below) was associated with the distinct subsidence along the Pacific Coast of NE Japan in addition to inter-seismic rapid subsidence by the asperity (coupling) of Eurasia (North American) plate and Pacific plate (Ozawa et al., 2011). Especially, the southern Sanriku coast which largely subsided has been reversely uplifting as an after-slip movement, recovering one fourth of coseismic subsidence (GIS, 2014). If after-slip movement continues at the same speed, the coast will start inter-seismic subsiding by the reinforcing interplate coupling after relatively short recovery of coseismic subsidence (Ikeda, 2014). According this scenario, the vertical movement of northern Sanriku coast out of the 2011 EQ source area is possibly controlled by the similar megaquake cycle. We reconstructed the vertical movement history in the southern Sanriku coast based on the mapping of Holocene emerged coastal topographies and ages, and examined the megaquake cycle managing the history considering the geodetic subsidence measured at the tide-gauge station.

Tephrochronologically age-determined MIS 5e marine terrace height of 30 m shows average uplift rate of 0.2 mm/yr in geological long term. Holocene emerged coastal topographies and dates present three times of rapid uplift events; about 1,000 years ago just before B-Tm ash fall, before 3,300 years ago and before 4,800 years ago. Records of Hachinohe tide-gauge station in the past 60 years indicate the mean subsidence rate of 2 mm/yr. We built the vertical movement diagram synthetically explaining the above results.

Emergences of coastal topographies suggest three sudden uplift events which are named E1, E2 and E3 in chronological order. Assuming that the geodetic subsidence (2 mm/yr) continued during 1,000 years between E3 and the present, E3 was associated with 6-7m uplift. Setting that the gradient of straight line connecting heights of emerged topographies attained just after uplift events satisfies the long-term uplift rate of 0.2 mm/yr, E2 was accompanied by 5-6 m uplift 3,800 years ago, and E1 by 4-5 m 6,200 years ago. These abrupt uplift phenomena is likely generated by an near-shore faulting (Miyauchi, 2012), which is not sufficiently testified by geophysical exploration yet. Correlating these uplift events with the ongoing after-slip uplift event after 2011 EQ, plate-boundary megaquakes associated with distinct coseismic subsidence necessarily occurred off the northern Sanriku coast, namely from the northern Japan Trench to the southern Kuril Trench, just before those uplift events. Such megaquakes are estimated to occur at least three times in Holocene.

Keywords: Holocene, Emerged coastal topography, Vertical movement history, After-slip movement, northern Sanriku coast, megaquake

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Crust and upper mantle structure of the New Madrid Seismic Zone: Insight into intraplate earthquakes

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The New Madrid Seismic Zone (NMSZ) is seismically the most active region in the Central and Eastern United States and an ideal area to study intraplate earthquakes. A sequence of at least three large earthquakes (M $>$7.0) occurred here in 1811-1812, and palaeo-seismic records show evidence of large earthquakes about 500 years apart in the past 2000 years. The distribution of local earthquakes recorded since 1974 delineates three linear faults in the NMSZ: (1) the NE-trending Cottonwood Grove-Blytheville Arch fault along the central Reelfoot rift, (2) the NW-trending Reelfoot Fault, and (3) the NNE-trending New Madrid North Fault. The activation of these mid-continental faults and their controls on duration of the seismic activity remain poorly understood. One of the fundamental questions is: what makes the NMSZ different from the surrounding intraplate areas in North America, especially the areas within the same geologic settings?

We determined a 3-D P-wave velocity model of the crust and upper mantle down to 400 km depth to investigate structural heterogeneity and its influences on the generation of intraplate earthquakes in the NMSZ. We used 4871 high-quality arrival times from 187 local earthquakes and 30,846 precise travel-time residuals from 1041 teleseismic events recorded by the Earth-Scope/USArray Transportable Array. Our results show that, beneath the Reelfoot rift, a significant low-velocity (low-V) zone exists in the upper mantle down to 200 km depth, with a large volume of 200 km x 200 km x 150 km. The origin of the low-V zone may be related to the passage of the Bermuda hotspot and the stalled ancient Farallon slab materials foundering in the mantle transition zone. This low-V zone may have relatively low shear strength and act as a viscously weak zone embedded in the lithosphere, being apt to concentrate tectonic stress and transfer stress to the seismogenic faults in the upper crust, leading to the large intraplate earthquakes in the New Madrid Seismic Zone.

Keywords: New Madrid, earthquake, crust, mantle, velocity structure

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The property of fault zone and fault activity of the Shionohira Fault, Fukushima Prefecture, Japan

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Co-seismic surface ruptures trending NNE-SSW direction were formed from Tabiuto-Nameishi to northwestern Ishizumi-Tsunaki in Tabito-cho, Iwaki City, Fukushima Prefecture, by the April 11, 2011 Fukushima-ken Hamadori Earthquake. This earthquake was characterized by the westward dipping normal slip faulting, and the maximum displacement was about 2 m (e.g., Kurosawa et al., 2012). These surface ruptures were newly named the Shionohira Fault by Ishiyama et al. (2011).

Before the 4.11 earthquake, the N-S trending several faults were described in this area as the Itozawa Fault in Active Faults in Japan, New Edition (The Research Group for Active Faults of Japan, ed., 2011). The surface ruptures of 4.11 earthquake are corresponding to a part of the Itozawa Fault (western trace of the Itozawa Fault by Tsutsumi and Toda, 2012). The geomorphological features of active faults were not found in the northward of the Gozaisyo highway. On the other hand, the N-S trending lineament are recognized from the south of the Tabiuto-Nameishi to the boundary between the Fukushima and Ibaraki Prefectures, though surface ruptures did not appear in this area. The authors study the differences of active and non-active sections by the 4.11 earthquake, and here the authors show the results of observation of fault outcrops along the Shionohira Fault.

A lot of new fault outcrops were formed by the 4.11 earthquake, however most of them are composed of foot-wall with fault plane, and the structures of hanging-wall are difficult to observe. Only a few outcrops have basement rocks of the hanging-wall and hoot-wall with fault plane. Three of these outcrops (Kyodo-gawa, Shionohira and Betto) were selected to investigation. In addition, a fault outcrop (Nameishi-minami) located in about 300 m south to the southern tip of the surface ruptures was investigated. We carried out observations of outcrops, polished slabs and thin sections, and X-ray diffraction (XRD) to the fault materials.

As a result, the fault zones originated from schists were investigated at Kyodo-gawa and Betto. The thick fault gouge is cut by a fault plane by 4.11 earthquake in each outcrops. The fault materials originated from schists are fault bounded with (possibly Neogene) weakly deformed sandstone at Shionohira. The thin fault gouge is found along the fault plane by 4.11 earthquak. A small-scale fault zone with thin fault gouge are observed in Nameishi-minami. According to XRD analysis, smectite was detected in the gouges from Kyodo-gawa, Shionohira and Betto, while it was not contained in the gouge from Nameishi-minami.

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Keywords: Shionohira Fault, active fault, fault gouge, property of fault zone, X-ray diffraction, Fukushima-ken Hamadori Earthquake

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Deformation process of the Miocene Misaki assemblage at Cape Muroto, Shikoku, Japan

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We report the geologic structure of the Misaki assemblage, which constitutes part of the youngest portion of the Shimanto accretionary complex, Shikoku, Japan. It is interesting to compare the deformation process of this strata with that of the present Nankai accretioary complex. We divided the Misaki assemblage into ten lithofacies, and described lithologic map and geologic cross section of the study area.

The northern part of the study area consists mainly of hemipelagic calcareous mudstone and deformed sandstone and mudstone. In contrast, the southern part of the study area consists of folded turbidite and conglomerate. These strata dip to the west more than 70^o and are intruded by Miocene igneous rocks. Many minor faults are observed in the study area.

These lithologic and structural data suggests a deformation process of the Misaki assemblage as follows: (1) deposition of ocean plate stratigraphy, (2) offscraping by frontal thrusts, (3) intrusion of igneous rocks along one of the thrusts, and (4) tilting of the whole strata.

Keywords: accretionary complex, Shimanto belt, Muroto, fault

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SCG57-P34 Room:Convention Hall Time:May 27 18:15-19:30

Interseismic plastic deformations at ancient crustal seismogenic zones in the Hidaka metamorphic belt and Napier Complex

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Pressure solution-precipitation structures are characteristically abundant in pseudotachylyte-producing fault zones in the Hidaka metamorphic belt, Hokkaido, northern Japan (Toyoshima et al., 2004; Wada et al., 2005). The zones occurred at the lowermost part of upper continental Hidaka crust. Pseudotachylytes formed under granulite-facies conditions (lower continental crustal conditions) occur at Tonagh Island in the Napier Complex, Eastern Antarctica (Toyoshima et al., .1999). Seismic faulting (pseudotachylytes-producing faulting) and plastic deformation (formation of ultramylonite) alternated under lower continental crustal conditions in Tonagh Island (Toyoshima et al., 1999). I illustrate interseismic deformations related to the Hidaka and Tonagh pseudotachylytes as examples of ancient seismogenic zones in upper and lower crust, respectively.

Modes of occurrence of the Hidaka pseudotachylytes indicate that seimic slip with pseudotachylyte generation and slow plastic deformation (pressure solution with precipitation) occurred alternatively and repeatedly in the same fault zones and fault surfaces (Wada and Toyoshima, 2006, 2007). Pressure solution-precipitation is likely one of the principal deformation mechanisms for interseismic plastic deformation and time-dependent strength recovery of fault zones (Wada and Toyoshima, 2006, 2007). The pressure solution-precipitation processes lead to increase in number of grain-to-grain contact and in real contact areas of the fault surfaces, resulting in healing of the fault zones (Wada and Toyoshima, 2007). Very thin and sharp shear zones filled with very fine-grained materials cut the pressure solution-precipitation structures and are cut by pseudotachylytes-producing faults. The shear zones are deformation structures formed immediately before seismic faulting in the upper Hidaka crust.

Granulite-facies ultramylonites are characteristically abundant in and along the Tonagh pseudotachylyte-producing fault zones. There are two different types of the granulite-facies ultramylonites in microstructures of recrystallized plagioclase grains: type 1 and 2. Type 1 ultramylonites have polygonal medium grains of plagioclase with smooth grain boundaries and very weakly undulose extinction. Type 2 ultramylonites include very fine grains and elongated fine grains of plagioclase with strongly undulose extinction and irregular grain boundaries. Type 2 ultramylonites occur along granulite-facies pseudotachylytes-generating fault surfaces and have been cut by fault veins of pseudotachylyte. Some of the granulite-facies pseudotachylytes became type 1 and 2 ultramylonites, which have also been cut by other granulite-facies pseudotachylytes. These may also be conspicuous difference between dynamic recrystallization mechanisms of plagioclase immediately before and after seismic faulting.

Keywords: pseudotachylyte, pressure solution, ultramylonite, plastic deformation, interseismic deformation, time-dependent strength recovery

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SCG57-P35 Room:Convention Hall Time:May 27 18:15-19:30

Study on heterogeneous structure beneath the Beppu-Haneyama fault zone

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The Beppu-Haneyama fault zone is the active fault zone in Japan, running from the Beppu Bay to western part of Oita prefecture. In the Beppu area, the seismogenic layer is thin (about 10km). Since the structure beneath this layer could affect the thickness, we need to get acquaintance of subsurface structure. This study estimated the heterogeneous structure of this fault zone from distribution of the reflectors based on seismological analysis.

We analyzed the data observed at seismic stations deployed by Kyushu and Kyoto Universities, NIED and JMA. For simplicity, we assumed homogeneous velocity structure to analyze the observed data. Normal move-out (NMO) processing was applied to detect reflectors. Seismic section normal to the strike direction of the fault zone reveals that reflective zone of the depth about 25km, which could correspond to the Moho discontinuity. Since numerous reflected waves beneath the seismogenic zone were detected. The distribution of the reflectors generating these reflected phase might relate to the thickness of the zone.

Keywords: Beppu-Haneyama fault zone, heterogeneous structure, reflector

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Anomalous seismic wave intensity distribution in the Tokyo Metropolitan area.

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The intensities of seismic waves observed at the dense seismic array of the Tokyo Metropolitan Seismic Observation network (MeSO-net) inside the Kanto basin, display unusual distribution patterns. In several occasions, the highest intensities are not observed in the area above an earthquakes hypocenter but appear sifted more than 20 km away. In order to understand the source of this unusual intensity distribution pattern, it is crucial to understand how the waves attenuate before they reach the surface. The attenuation of seismic waves along their path is represented by the $t*$ attenuation operator that can be obtained by fitting the observed seismic wave spectrum to a theoretical spectrum using an ω^2 model. In order to create a high quality dataset, only 1449 earthquakes that are recorded with intensity greater than 0 in the Japan Meteorological Agency (JMA) intensity scale are selected from the JMA unified earthquake list from April 1st 2008 to October 2nd 2013. A grid search method is applied to determine the $t*$ values by matching the observed and theoretical spectra. The $t*$ data where then inverted to estimate a 3D Q structure with grid points set at a 10 km spacing. We implemented the 3D velocity model estimated by Nakagawa et al., 2012 and in addition we set the initial Q values at 100 for the 0 km grids and to 400 for the grids below them. The obtained model suggests average Q values of 50$\sim$100 inside the Kanto basin. Furthermore, a low Q zone is observed in the area where the Philippine Sea plate meets the upper part of the Pacific sea plate. This area is located at approximately 40 km depth, beneath the north-east Tokyo and west Chiba prefectures and is represented by Q values $<$300. Earthquakes occurring on the Pacific plate pass through this low Q area inside the Philippine sea plate and are attenuated significantly. The estimated attenuation distribution at the MeSO-net station for these earthquakes implementing our 3D Q model greatly coincides with the observed seismic wave intensity distribution. Stations where our model predicts high attenuation display low intensity values whereas stations where our model predicts low attenuation display high intensities. The implementation of our findings could help towards a better understanding of the damage area of future earthquakes and mitigate the disaster of the affected areas.

Keywords: Attenuation, Tomography, MeSO-net