Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

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

ABE, Susumu[1*] ; SATO, Hiroshi[2] ; ISHIYAMA, Tatsuya[2] ; SAITO, Hideo[1]

[1]JGI, Inc., [2]ERI, Univ. of Tokyo

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

AOKI, Sho[1*] ; IIO, Yoshihisa[1] ; SHIBUTANI, Takuo[1] ; KATAO, Hiroshi[1] ; MIURA, Tsutomu[1] ; YONEDA, Itaru[1] ; SAWADA, Masayo[1]

[1]DPRI, Kyoto Univ

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

Japan Geoscience Union Meeting 2015
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SCG57-03 Room:A06 Time:May 27 14:45-15:00

Seismic structure in the southern Ryukyu Trench subduction zone

YAMAMOTO, Yojiro[1*] ; TAKAHASHI, Tsutomu[1] ; KAIHO, Yuka[1] ; ISHIHARA, Yasushi[1] ; ARAI, Ryuta[1] ; NAKANISHI, Ayako[1] ; OBANA, Koichiro[1] ; MIURA, Seiichi[1] ; KODAIRA, Shuichi[1] ; KANEDA, Yoshiyuki[2]

[1]JAMSTEC, [2]Nagoya University

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

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

SATO, Takeshi[1*] ; NO, Tetsuo[1] ; MIURA, Seiichi[1] ; KODAIRA, Shuichi[1] ; ISHIYAMA, Tatsuya[2] ; SATO, Hiroshi[2]

[1]JAMSTEC, [2]ERI, Univ. of Tokyo

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

ISHIYAMA, Tatsuya[1*] ; SATO, Hiroshi[1] ; KATO, Naoko[1] ; KURASHIMO, Eiji[1] ; TODA, Shigeru[2] ; KOSHIYA, Shin[3] ; KOBAYASHI, Kenta[4] ; NO, Tetsuo[6] ; SATO, Takeshi[6] ; KODAIRA, Shuichi[6] ; SHIRAISHI, Kazuya[6] ; HIGASHINAKA, Motonori[6] ; ABE, Susumu[1] ; RESEARCH GROUP FOR 2014 KAHOKU-TONAMI, Seismic survey[1]

[1]Earthquake Research Institute, University of Tokyo, [2]Aichi Educational University, [3]Iwate University, [4]Niigata University, [5]Research and Development center for Earthquake and Tsunami, Japan Agency for Marine-Earth Science an, [6]JGI, Inc

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

IWASAKI, Takaya[1*] ; TSUMURA, Noriko[2] ; ITO, Tanio[3] ; SATO, Hiroshi[1] ; KURASHIMO, Eiji[1] ; HIRATA, Naoshi[1] ; ARITA, Kazunori[4] ; NODA, Katsuya[5] ; FUJIWARA, Akira[5] ; ABE, Susumu[5] ; KIKUCHI, Shinsuke[6] ; SUZUKI, Kazuko[7]

[1]Earthquake Research Institute, the University of Tokyo, [2]Graduate School of Science, Chiba University, [3]Heisei Teikyo University, [4]The Hokkaido University Museum, Hokkaido University, [5]JGI, Inc., [6]JAPEX, [7]Schlumberger Ltd.

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

ICHIHARA, Hiroshi[1*] ; MOGI, Toru[2] ; YAMAYA, Yusuke[3] ; HASHIMOTO, Takeshi[2] ; UYESHIMA, Makoto[4] ; OGAWA, Yasuo[5]

[1]Japan Agency for Marine-Earth Science and Technology, [2]Institute of Seismology and Volcanology, Hokkaido University, [3]Advanced Industrial Science and Technology, [4]Earthquake Research Institute, the University of tokyo, [5]Volcanic Fluid Researach Center, Tokyo Institute of Technology

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

YAMAUCHI, Koichi[1*] ; ISHIKAWA, Masahiro[2] ; SATO, Hiroshi[1] ; IWASAKI, Takaya[1] ; TOYOSHIMA, Tsuyoshi[3]

[1]Earthquake Research Institute, The university of Tokyo, [2]Yokohama National University, [3]Niigata University

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

ISHIKAWA, Masahiro[1*] ; TSUBOKAWA, Yumiko[1] ; HONDA, Satoko[1]

[1]Yokohama National University

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

WATANABE, Tohru[1*] ; MAKIMURA, Miho[1]

[1]Graduate School of Science and Engineering, University of Toyama

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

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

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

UYESHIMA, Makoto[1*] ; OGAWA, Yasuo[2] ; ICHIKI, Masahiro[3]

[1]Earthquake Research Institute, The University of Tokyo, [2]Volcanic Fluid Research Center Tokyo Institute of Technology, [3]Graduate School of Science, Tohoku University

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

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

SUZUKI, Atsushi[1*] ; OGAWA, Yasuo[2] ; SAITO, Zenshiro[1] ; USHIODA, Masashi[2]

[1]Department of earth and Planetary Sciences, Tokyo Institute of Technology, [2]Volcanic Fluid Research Center, Tokyo Institute of Technology

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

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

AOYAGI, Yasuhira[1*] ; KIMURA, Haruo[1] ; ABE, Shintaro[2]

[1]CRIEPI, [2]AIST

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

SAGIYA, Takeshi[1*] ; TERATANI, Naoko[1] ; NISHIMURA, Takuya[2] ; YARAI, Hiroshi[3] ; SUITO, Hisashi[3]

[1]Nagoya University, [2]Kyoto University, [3]Geospatial Information Authority of Japan

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

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

SAKAI, Shin'ichi[1*] ; KURASHIMO, Eiji[1] ; OBARA, Kazushige[1] ; IWASAKI, Takaya[1] ; TAKAHASHI, Hiroaki[2] ; MATSUMOTO, Satoshi[3] ; KAMIZONO, Megumi[3] ; OKADA, Tomomi[4]

[1]Earthquake Research Institute, the University of Tokyo, [2] Institute of Seismology and Volcanology, Graduate School of Science, Hokkaido University, [3] Institute of Seismology and Volcanology, Faculty of Sciences, Kyushu University, [4]Research Center for Prediction of Earthquakes and Volcanic Eruptions, Tohoku University

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

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

KURASHIMO, Eiji[1*] ; HIRATA, Naoshi[1] ; IWASAKI, Takaya[1] ; SAKAI, Shin'ichi[1] ; OBARA, Kazushige[1] ; ISHIYAMA, Tatsuya[1] ; SATO, Hiroshi[1]

[1]ERI, Univ. Tokyo

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

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

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

NISHIMURA, Takuya[1*] ; HOSO, Yoshinobu[1] ; MIURA, Tsutomu[1] ; YONEDA, Itaru[1] ; KOIKE, Toshiki[1]

[1]Disaster Prevention Research Institute, Kyoto University

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

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

YOSHIDA, Keisuke[1*] ; PULIDO, Nelson[1] ; FUKUYAMA, Eiichi[1]

[1]National Research Institute for Earth Science and Disaster Prevention

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)

MATSUMOTO, Satoshi[1*] ; OHKURA, Takahiro[2] ; MIYAZAKI, Masahiro[1] ; SHIMIZU, Hiroshi[1] ; ABE, Yuki[3] ; INOUE, Hiroyuki[2] ; NAKAMOTO, Manami[1] ; YOSHIKAWA, Shin[2] ; YAMASHITA, Yusuke[3]

[1]Institute of Seismology and Volcanology, Kyushu Univ., [2]Aso Volcanological Laboratory , Kyoto Univ., [3]Earthquake Research Institute, Univ. of Tokyo

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

MIYAKAWA, Ayumu[1*] ; OTSUBO, Makoto[2]

[1]Institute of Geology and Geoinformation (IGG), Geological Survey of Japan, AIST, [2]National Institute of Advanced Industrial Science and Technology (AIST), Institute of Earthquake and

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.

Sato, H. The relationship between late Cenozoic tectonic events and stress field and basin development in northeast Japan Journal of Geophysical Research, 1994, 99, 22261-22274
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

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

SHIGEMATSU, Norio[1*] ; KAMETAKA, Masao[2] ; INADA, Noriyuki[2] ; MIYAWAKI, Masahiro[2] ; TOGO, Tetsuhiro[1] ; FUJIMOTO, Koichiro[3]

[1]Institute of Earthquake and Volcano Geology, AIST, [2]Dia Consultants Co. Ltd., [3]Tokyo Gakugei University

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

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

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

TAKESHITA, Toru[1*] ; KANEKO, Yumi[1] ; ARAI, Shun[1]

[1]Hokkaido University

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

KANEKO, Yumi[1*] ; TAKESHITA, Toru[1] ; SHIGEMATSU, Norio[2] ; FUJIMOTO, Koichiro[3]

[1]Hokkaido University Graduate school of science, [2]Active Fault and Earthquake Research Center, Geological Survey of Japan, National Institute of Advan, [3]Tokyo Gakugei University

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

KANAI, Takuto[1*] ; TAKAGI, Hideo[1]

[1]Waseda University

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).

References

Bouchez, K. L., 1977, *Tectonophysics*, **39**, 25-50.
Craddock, J. P. and Magloughlin, J. F., 2005, *Tectonophysics*, **402**, 153-168.
Kanai, T. and Takagi, H., 2014, *Abst. 121th Ann. Meet. Geol. Soc. Japan*, **R15-P4**, 277.
Murakami, M., Kosler, J., Takagi, H. and Tagami, T., 2006, *Tectonophysics*, **424**, 99-107.
Sakakibara, N., 1995, *Jour. Sci. Hiroshima Univ.*, **10**, 267-332.
Sakamaki, H., Shimada, K. and Takagi, H., 2006, *Jour. Geol. Soc. Japan*, **112**, 519-530.
Stockhert, B., Brix, R. M., Kleinschrodt, R., Hurford, J. A. and Wirth R., 1999, *Jour. Struct. Geol.*, **21**, 351-369.
Takeshita, T. and Wenk, H. R., 1988, *Tectonophysics*, **149**, 345-361.
Yamaji, A., Otsubo, M. and Sato, K., 2006, *Jour. Struct. Geol.*, **28**, 980-990.

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

AOKI, Kazuhiro[1*] ; SESHIMO, Kazuyoshi[1] ; TANAKA, Yoshihiro[1] ; KAMETAKA, Masao[2] ; SAKAI, Toru[2] ; OKAZAKI, Kazuhiko[2] ; SHIMAMOTO, Toshihiko[3]

[1]Japan Atomic Energy Agency, [2]Dia Consultants, [3]Institute of Geology, China Earthquake Administration

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

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

KURT, Hulya[1*] ; SORLIEN, Christopher[2] ; SEEBER, Leonardo[3] ; STECKLER, Michael[3] ; SHILLINGTON, Donna[3] ; CIFCI, Gunay[4] ; DONDURUR, Derman[4] ; OKAY, Seda[4]

[1]Istanbul Technical University, Department of Geophysics, [2]Earth Research Institute, University of California, Santa Barbara, [3]Lamont-Doherty Earth Observatory of Columbia University, [4]Dokuz Eylul University, Institute of Marine Sciences and Technology

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

YAMASAKI, Tadashi[1*] ; HOUSEMAN, Gregory A.[2]

[1]Geological Survey of Japan, AIST, [2]University of Leeds

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 ˜$2x10^{20}$ 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

MUTO, Jun[1*] ; SHIBAZAKI, Bunichiro[2] ; IINUMA, Takeshi[3] ; NISHIMURA, Takuya[4]

[1]Tohoku University, [2]International Institute of Seismology and Earthquake Engineering, Building Research Institute, [3]Iinuma Takeshi International Research Institute of Disaster Science, Tohoku University, [4]Disaster Prevention Research Institute, Kyoto University

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.

References:

Muto, J., B. Shibazaki, Y. Ito, T. Iinuma, M. Ohzono, T. Matsumoto, and T. Okada (2013), Geophys. Res. Lett., 40, doi:10.1002/grl.50906.

Nishimura, T. (2014), J. Disaster Res., 3, 294-302.

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

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

SHIBAZAKI, Bunichiro[1*] ; MATSUMOTO, Takumi[2] ; MUTO, Jun[3] ; IINUMA, Takeshi[4] ; MIURA, Satoshi[5]

[1]International Institute of Seismology and Earthquake Engineering, Building Research Institute, [2]National Institute for Earth science and Disaster Prevention, [3]Department of Earth Sciences, Tohoku University, [4]International Research Institute of Disaster Science, Tohoku University, [5]Graduate School of Science, Tohoku University

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]

[1]Kozo Keikaku Engineering Inc., [2]Graduate School of Science, Chiba University, [3]The Institute of Statistical Mathematics

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

Japan Geoscience Union Meeting 2015
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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

MATSU'URA, Mitsuhiro[1*]

[1]Institute of Statistical Mathematics

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?

IIO, Yoshihisa[1*]

[1]DPRI., Kyoto Univ.

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

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

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

SATO, Hiroshi[1*] ; ISHIYAMA, Tatsuya[1] ; KATO, Naoko[1] ; ABE, Susumu[3] ; SHIRAISHI, Kazuya[3] ; INABA, Mitsuru[2] ; SHIORI, Abe[1] ; KURASHIMO, Eiji[1] ; NO, Tetsuo[4] ; SATO, Takeshi[4] ; KODAIRA, Shuichi[4] ; MATSUBARA, Makoto[5]

[1]ERI, Univ. Tokyo, [2]JGI Inc., [3]JAPEX Co., Ltd., [4]JAMSTEC, [5]NEID

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

ISOZAKI, Yukio[1*] ; NAKAHATA, Hiroki[1] ; AOKI, Kazumasa[2]

[1]Dept. Earth Science & Astronomy, Univ. Tokyo, [2]Okayama University of Science

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

FUKAHATA, Yukitoshi[1*]

[1]Disaster Prevention Research Institute, Kyoto University

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