Fundamental structure model of island arcs and subducted plates in and around Japan -II

*Takaya Iwasaki[1], Hiroshi Sato[1], Masanao Shinohara[1], Tatsuya Ishiyama[1], Akinori Hashima[1], Makoto Matsubara[2], Yumi Amemiya[3]

1. ERI, the University of Tokyo, 2. NIED, 3. OHTI

The eastern margin of the Asian continent is under complicated tectonic environment, dominated by subduction and collision of the Pacific (PAC), Philippine Sea (PHS) and Eurasia (EU) plates. Crustal activities in and around the Japanese Islands, which have a wider range spatial extent with different time scale, are dominated by strong interplate interactions. The 2011 Tohoku earthquake (M=9.0) produced a large amount of coseismic and post-seismic crustal deformations and remarkable changes in seismic activity in in broader region of easternmost Asia, providing good opportunities to study response of trench-arc system due to a mega thrust earthquake on the plate boundary. Quantitative understanding for such phenomena requires to develop fundamental structure models including plate boundaries and crust and uppermantle structures from the fore- to back-arc provinces. This paper presents results of our research aiming to construct key items for fundamental structure models for island arcs, namely, (1) topography, (2) plate geometry, (3) fault models, (4) the Moho and brittle-ductile transition zone, (5) the lithosphere-asthenosphere boundary, and (6) petrological/ rheological models.
Our modelling area is set 12°-54° N and 118°-164° E to cover almost the entire part of Japanese Islands together with Kuril, Ryukyu and Izu-Bonin trenches. Geometry of the subducted Pacific and PHS plates are modelled through the two steps. In the first step, we constructed “base” models, which have rather smooth surfaces in our whole model area, from earthquake catalogues provided by JMA, USGS and ISC. As the second step, regional plate configuration with shorter wave-length (<50-100 km) is constrained particularly in the vicinity of Japan from recent results by seismic tomography, RF analysis and active source experiment. Our analysis indicates that the plate boundaries in the regional models are systematically shallower than those from the base models in a depth range of 10-50 km. This probably indicates that the regional models represent the structural boundary of the subducted plate, while the base models its mechanical boundary. In the Kanto area, the geometry of the PHS plate is very complicated due to the existence of the triple junction and the collision of Izu-Bonnin arc to the EU plate. We defined the plate geometry of the PHS plate from results of active seismic experiments and seismic tomography studies as well as natural earthquake observation (Sato et al., 2005; Nakajima & Hasegawa, 2007; Hirose et al., 2008a,b, Nakajima et al., 2009, Sato, 2009, Uchida et al., 2010). The northern margin of the PHS plate under the NE Japan arc west of the Japan trench is based on the result by Uchida et al. (2010), which is almost consistent with the southern end of aftershock distribution and major aftershock fault of the 2011 Tohoku earthquake.
So far, detailed Moho structure was presented by several authors (Zhao et al., 1994; Shiomi et al., 2009; Katsumata, 2010; Igarashi et al., 2011; Matsubara et al., 2016). We intends to combine these results with global crust model (crust 1.1, Laske et al. 2013), to generate Moho depth models for EU, PHS and PAC plate in our model region. We are newly developing software packages necessary for this work. As an example, the Moho model by Katsumata (2010) beneath the Japanese islands is extended to the surrounding region using crust 1.1 model. For the PAC and PHS plates, the Moho depths beneath the subducted oceanic crust are assumed from our plate boundary model, which are merged to those beneath the oceanic basin. These models are still tentative, and should be revised by incorporating structural information from active source experiments.

Keywords: island arc, plate boundary, Moho, fundamental structure, active margin, subduction zone

Crust and uppermost mantle structure of the Japanese Islands inferred from receiver function analysis

*Toshihiro Igarashi[1], Takashi Iidaka[1]

1. Earthquake Research Institute, University of Tokyo

Recent travel time inversion analyses have elucidated crust and mantle structures of whole areas in the Japanese Islands. However, they estimated only spatial changes with relatively long wavelength, and it was difficult to extract clear velocity discontinuities. Also, the resolution of their S-wave velocity structures near the ground surface was insufficient than that of P-wave velocities. Therefore, the spatial distributions of the crustal velocity discontinuities and the Moho depths are poorly understood. In this study, we show the crust and uppermost mantle velocity structures and the velocity discontinuities beneath the Japanese Islands from receiver function analyses.
We improved an estimation method of crustal velocity structure beneath each seismic station by Igarashi et al. [2011]. This method searches the best-correlated receiver function between observed one calculated from teleseismic seismograms and synthetic one based on assumed crustal velocity structure by using a grid search method. We constructed velocity structures which consist of a sediment layer, one to three crustal layers and two upper mantle layers. They cover both the crustal velocity structures and Moho depths of the Japanese Islands estimated by previous researchers. We use seismic stations installed by the National Research Institute for Earth Science and Disaster Resilience, the Japan Meteorological Agency and Earthquake Research Institute, the University of Tokyo. We selected the 13,736 teleseismic events, which have the epicentral distance between 30° and 90°, magnitude greater than 4.5, and occurred in the period from September 1989 to February 2016.
The estimated crustal structure is characterized by areas with low-velocity layers. In several plains and basins, we identify a thick sediment layer. The surrounding areas of active volcanoes correspond to the low-velocity zones in the crust. The Itoigawa-Shizuoka Tectonic Line seems to a border of crustal velocity structure. The southwestern side has the relatively stable high-velocity areas, whereas the northeastern side is heterogeneous spatially. In the lower crust, low-velocity structures are distributed in the eastern part of the Niigata-Kobe Tectonic Line and some part of the Median Tectonic Line. There are low-velocity zones around the Moho discontinuity along the middle part of the island arc. The crustal thickness tends to increase in mountain regions and decrease toward the surrounding areas with some undulations. The Moho discontinuity of the subducting Philippine Sea plate has distinct velocity change near the southern coastline of the Japanese Islands, and the velocity contrast is larger than that of the overriding plate. We suggest that S-wave velocity transition layers exist in the uppermost mantle just beneath the Moho discontinuity in broad areas of the Japanese Islands. The transition layers probably indicate crustal evolution or melting around the Moho discontinuity of the island arc.

Difference in erupted magma volume inferred from the crustal density structures of the Izu-Bonin-Mariana arc and the northeast Honshu arc

*Kenta Mishiro[1], Yoshiyuki Tatsumi[2], Katsuya Kaneko[1]

1. Graduate School of Science, Kobe University, 2. Kobe Ocean-Bottom Exploration Center

Volcanic activities in the Izu-Bonin-Mariana (IBM) arc and the northeast Honshu arc are caused by subduction of the Pacific plate. Because these arcs are similar features (e.g., subduction rates and linear density of active volcanoes), it is inferred that magma generation rates in both the arcs are similar. Nevertheless, erupted magma volume at the IBM arc (10.22 km^3/km) is much larger than that at the northeast Honshu arc (1.80 km^3/km). Moreover, major composition of magma erupted at the IBM arc is basaltic while that at the northeast Honshu arc is andesitic. In this study, we try to explain these differences between the two arcs on the basis of crustal structures of the two arcs.

The IBM arc is the juvenile oceanic arc and the crustal thickness is about 25 km. Inferred from P-wave velocity, the rhyolitic crust is located at 0-5 km depth, the andesitic crust is located at 5-11 km depth and the basaltic crust is located at 11-25 km depth in the IBM arc (Takahashi et al., 2008). The northeast Honshu arc is the mature continental arc and the crustal thickness is about 35 km. Inferred from P-wave velocity, the rhyolitic crust is located at 0-5 km depth, the andesitic crust is located at 5-25 km depth and the basaltic crust is located at 25-35 km depth in the northeast Honshu arc (Iwasaki et al., 2001).

Mineral assemblages, P-wave velocity structure and density structure of these crusts are estimated by using Perple_X (Connolly, 2005). First, we estimate compositional structures of the crusts which reproduce observed P-wave velocity structure of the crusts (Takahashi et al., 2008; Iwasaki et al., 2001), then evaluate density structures of the crusts. The estimated density structure of the IBM arc is about 2800 kg/m^3 in the middle crust and 3100-3200 kg/m^3 in the lower crust while that of the northeast Honshu arc is about 2750-2900 kg/m^3 in the middle crust and 3150-3200 kg/m^3 in the lower crust.

An ascending magma forms a magma chamber at a level with neutral buoyancy. Assuming that the ascending magma is a mantle-derived primary basalt magma with 1.65 wt% H_2O and 20 % crystals by crystallization, the density comparison between the crusts and the ascending magma indicate that the depth of the magma chamber is less than 5 km for the IBM arc and 14-21 km for the northeast Honshu arc.

For eruption of the magma in the chamber, the magma needs water saturation by crystallization and foaming. Because the magma chambers at the IBM arc is shallower and has lower water solubility than at the northeast Honshu arc. Based on experimental results by Williams and McBirney (1979), the magma is saturated in water by about 50 % differentiation for the IBM arc while about 80 % for the northeast Honshu arc, suggesting that eruptable magmas are 50 % and 20 % of the ascending magma for the IBM and the northeast Honshu arcs, respectively. In addition, the magma by 50 % differentiation is basaltic while by 80 % differentiation is andesitic (Tatsumi and Suzuki, 2009). Namely, these simultaneously explain the two differences between the IBM and the northeast Honshu arcs, the erupted magma volume and composition.

We conclude that the crustal density structure is one of important factors governing volcanic activity in arcs.

Keywords: erupted magma volume, crustal structure, IBM arc, northeast Honshu arc

Structural Features around the LFT Zone beneath Western Shikoku based on Converted *Ps* amplitude variations

*Katsuhiko Shiomi[1]

1. National Research Institute for Earth Science and Disaster Resilience

Low-frequency tremors (LFTs) in the Nankai region southwest Japan are actively distributed along the down-dip limit of the recurrent megathrust source regions. This fact implies that the LFT activities might be strongly related to stress changes in the source regions along the Philippine Sea plate. To understand the mechanisms of LFTs, knowledge about the structural features both inside and outside of the LFT active zone is important. In this study, we investigated variation of converted *P*-to-*S* (*Ps*) phase amplitude from receiver functions (RFs) along the subducting oceanic Moho. Teleseismograms recorded at the NIED Hi-net and F-net seismic stations were used. Since converted phase amplitude depends on its ray parameter, we selected earthquakes with ray parameter range from 0.050 to 0.077, and applied amplitude correction coefficients. We read converted *Ps* amplitudes of RFs with reference to the previous studies [e.g. Shiomi *et al.*, 2008; 2015]. Since the selected events were not uniformly distributed in back azimuth (BAZ, θ), we calculated an average and its standard deviation for each 5-degree bin. Then, we fit a simple function constructed with $\sin\theta$, $\sin 2\theta$ and bias component to the data with the least square fitting algorithm. The bias components, named 'standard amplitude' by Shiomi and Park [2009], gradually decayed as the oceanic Moho becomes deep. As the slab's dip angle beneath western Shikoku is almost constant, this feature reflects a gradual phase transition from amphibolite to eclogite with water release in the oceanic crust. At almost all stations, $\sin\theta$ component is dominated. This component corresponds to the contribution from the dipping interface mainly, and the estimated plunge azimuth (305±10deg) is consistent with the previous models. On the other hand, at the several stations located at the northern edge of the active LFT zone, 4-lobed backazimuthal distribution was dominant. This means that the oceanic crust beneath the down-dip edge of the LFT zone becomes anisotropic caused by the phase transition. Our observation implies that water dehydrated from the oceanic crust rises to the inter-plates, and the LFTs become active.

Acknowledgement: This study was partially supported by JSPS KAKENHI Grant Number JP16H06475 in Scientific Research on Innovative Areas "Science of Slow Earthquakes".

Keywords: Low-frequency tremor, Ps converted phase, Philippine Sea plate

Seismic reflector above the non-volcanic tremor along the Philippine Sea Plate

*Takashi Iidaka[1], Toshihiro Igarashi[1], Takaya Iwasaki[1]

1. Earthquake Research Institute, University of Tokyo

The Philippine Sea plate is subducting beneath the southwestern Japan. Many studies have been done in this area. One of the interesting phenomena at the subduction zone is non-volcanic tremor occurs at the plate boundary (Obara, 2002). Many large earthquakes have occurred at the Nankai Trough region. To know the seismic structure, several seismic explorations using artificial sources have been done at the region. The configuration of the Philippine Sea plate and P-wave structure were estimated by the seismic experiments (e.g, Kodaira et al., 2002; Iidaka et al., 2004; Iwasaki et al., 2016). Igarashi and Iidaka (2017) studied that receiver function analyses to estimate the plate boundary of the Philippine Sea slab and S-wave velocity structure in the crust and uppermost mantle beneath the Japanese Islands. The S-wave velocity structures were estimated using a grid search method between the observed receiver function and synthetic calculation. The P-wave and S-wave seismic structures are compared with the source area of non-volcanic tremor.

It is remarkable characteristic of the seismic experiments in this region that the clear reflected wave around the plate boundary was detected. The clear reflected wave was explained as a reflected wave at the top of the extremely low-velocity layer, which was located at the top of the subducting Philippine Sea slab (e.g, Kodaira et al., 2002; Iidaka et al., 2004). The P-wave velocity values of the thin layer were 3 km/s and 2 km/s in the Nankai and Tokai regions, respectively (Kodaira et al., 2002; Iidaka et al 2004). Similar strong reflector was also detected at the eastern part of the Kii Peninsula (Iwasaki et al., 2016). The locations of the strong reflectors are compared with the source area of the non-volcanic tremor. In the Nankai region, the depth of the reflector was located at 10 km –30 km (Kodaira et al., 2002). The source area of the tremor is located at the deepest part of the low velocity layer. In the Tokai region, the extremely low velocity layer is located just above the source area of the tremor. Iwasaki et al. (2016) also reported that the strong reflector was located just above the source area of the tremor in the eastern part of the Kii peninsula. At the three areas, the strong reflector was located above the source area of tremor. The seismic structure of the S-wave structure at the tremor area was characterized to be high-velocity mantle wedge and low-velocity oceanic crust (Igarashi and Iidaka, 2017). It is expected that the low velocity layer seems to be related to the dehydration of the oceanic crust.

The non-volcanic tremor had been reported at many subduction zones. Song et al. (2009) reported the ultra low velocity layer in the Mexico subduction zone. The ultra low velocity layer is located at top of the slab. The low velocity layer is located in shallower than tremor area. The extremely low-velocity layer has been reported at several subduction zones. The research of the characteristics of the low-velocity layer is very important to know the source of the non-volcanic tremor.

Keywords: plate boundary, reflector, non-volcanic tremor

Seismic structure beneath Ryukyu arc, Japan, inferred from S-wavevector receiver functions

*Takumi Murakoshi[1], Hiroshi Takenaka[2], Masanao Komatsu[2], Nobuyuki Yamada[3]

1. National Defense Academy, 2. Okayama University, 3. University of Teacher Education Fukuoka

This study describes the seismic images of the crust and uppermost mantle beneath the Ryukyu arc, Japan by using S-wavevector receiver function (SWV-RF) analysis at virtual subsurface receivers. The SWV-RF has a great advantage that the problem of unclearly seismic images beneath very thick sedimentary basin due to the records include strong effect of reverberation within the sedimentary layer can be overcome (Takenaka and Murakoshi, 2010, AGU). In this study, we applied the SWV-RFs from broadband seismic records of the F-net (NIED) and ETOS (JMA) to obtain the seismic images of Moho and subducted Philippine Sea plate beneath the Ryukyu arc, Japan. In this presentation, we will show the estimated seismic structure beneath the Ryukyu arc, which is derived from the depth-converted SWV-RFs.

Acknowledgement: We have used F-net data (NIED), ETOS data (JMA) and deep subsurface structure model by J-SHIS (NIED).

Keywords: reciever function, Ryukyu arc, crustal structure

Crustal structure in the margin of the Japan Sea back-arc basin off Hyogo to Tottori deduced from the seismic survey

*Takeshi Sato[1], Tetsuo No[1], Seiichi Miura[1], Shuichi Kodaira[1]

1. Research and Development Center for Earthquake and Tsunami, Japan Agency for Marine-Earth Science and Technology

The Japan Sea is one of back-arc basins in the northwestern Pacific. It has been inferred from geophysical, geological, and petrological data that the back-arc opening of the Japan Sea was taken from the Early Oligocene to the Middle Miocene (e.g., Kano et al., 2007). After 3.5 Ma, in the eastern and southwestern margin of the sea, the crustal shortening occurred by a strong compression (e.g., Sato, 1994, Itoh et al., 1997). Therefore, in these regions, deformation zone such as fault-fold belts have developed because of the extension associated with the opening and shortening, and the destructive earthquakes occurred (e.g., Okamura et al., 2007). Recent results of seismic surveys in the eastern margin of this Sea revealed that the crustal structure formed by the back-arc opening had a connection with the distribution of this deformation zone (e.g., No et al., 2014). This show that it is necessary to clarify the back-arc opening process in order to the understand deformation process including active faults and folds. Even though the southern margin of the Japan Sea is interpreted as the region of the complex formation process (e.g., Jolivet and Tamaki, 1992), we have little information of the detailed opening and deformation processes in this margin because of a lack of the crustal structure. To obtain the structure and this information, we conducted the active-source seismic survey using ocean bottom seismographs (OBSs) and multi-channel streamer (MCS) in this margin from the Yamato back-arc basin to the coastal area of the southwestern Japan arc off Hyogo to Tottori in 2016. The seismic survey using 50 OBSs, a tuned air-gun array (7,800 cu. inch) and MCS system was conducted from the coastal area off Hyogo, Oki Trough, Oki Ridge, Yamato Basin to the Kita-Oki Bank. This survey line has about 225 km length. The MCS survey was also conducted in this margin off Tottori. The survey line of this MCS survey is same as the line by Sato et al. (2006). In record sections of several OBSs, not only the first arrived phases but also later phases reflected from interfaces in the crust and uppermost mantle are visible. Also, the MCS profile clearly images the sedimentary layer and the undulations of the basement.
The Oki Ridge has about 23 km of the crustal thickness. The upper part of the crust with P-wave velocity of 5.4-6.2 km/s corresponding to the continental upper crust has about 10 km. This shows that the Oki Ridge may have the character of the continental crust. On the other hand, the crustal thickness and the distribution of P-wave velocity in the Yamato Basin differs from that in the Oki Ridge. The upper part to middle part of the crust from the Oki Trough to the coastal area has a large lateral variation.

Keywords: Crustal structure, Japan Sea, arc-back-arc basin

Seismic image across the epicentral area of 2016 Tottoriken-chubu earthquake to the southern part of Yamato basin

*Hiroshi Sato[1], Tatsuya Ishiyama[1], Naoko Kato[1], Shigeru Toda[2], Shinji Kawasaki[3], Susumu Abe[4], Akira Fujiwara[3], Tanaka Yasuhisa[3], Johan S Claringbould[1], Anne D Van Horne[1]

1. Earthquake Prediction Research Center, Earthquake Research Institute, The University of Tokyo, 2. Aichi University of Education, 3. Japex Geosicence Institute, 4. Japan Petroleum Expolaration Co., Ltd.

Due to stress buildup by the upcoming Nankai Trough megathrust earthquake, SW Japan has been in seismically active period for last 20 years. In terms of the mitigation of earthquake and tsunami hazards, to construct seismogenic source fault models is first step for evaluating the strong ground motions and height of tsunamis. Since 2013, we performed intense seismic profiling in and around the southern part of the Sea of Japan to construct source fault models. In 2016, a180-km-long onshore –offshore seismic survey was carried out across the volcanic arc and back-arc basins (from Kurayoshi to the Yamato basin). Onshore section, CMP seismic reflection data were collected using four vibroseis trucks and fixed 1150 channel recorders. Offshore part we acquired the seismic reflection data using 1950 cu inch air-guns towing a 4-km-long streamer cable. We performed CMP reflection and refraction tomography analysis. Obtained seismic section portrays compressively deformed rifted continental crust and undeformed oceanic backarc basin, reflecting the rheological features. These basic structures were formed during the opening of the Sea of Japan in early Miocene. The sub-horizontal Pliocene sediments unconformably cover the folded Miocene sediments. The opening and clock-wise rotation of SW Japan has been terminated at 15 Ma and contacted to the young Shikoku basin along the Nankai trough. Northward motion of Philippine Sea plate (PHS) and the high thermal regime in the Shikoku basin produced the strong resistance along the Nankai trough. The main shortening deformation observed in the seismic section has been formed this tectonic event. After the initiation of the subduction along the Nankai trough, the rate of shortening deformation was decreased and the folded strata were covered by sub-horizontal Pliocene sediments. The amount of shortening is largest in the inverted half-grabens located near the coast of Honshu island. The thrusting trending parallel to the arc has been continued from Pliocene to early Pleistocene along the limited fault system. The change in the direction of the motion of PHS at 1 Ma produced major change in stress regime from NS compression to EW compression in the back-arc. Following the change of stress regime, former reverse faults reactivated as strike-slip fault. Reuse of pre-existing faults are common, and crustal deformation concentrates relatively narrow zone in the back-arc failed rifts. Two-months after from our survey, Mw 6.2 Tottoriken-chubu earthquake occurred just beneath the onshore part of the seismic line. The source fault corresponds to the boundary of abrupt change in P-wave velocity, however there were no surface ruptures and distinctive geologic faults. The bottom of seismogenic layer corresponds to TWT 4.5 sec., which is almost the top horizon of reflective middle crust.

Keywords: 2016 Tottori-ken Chubu earthquake, Crustal structure, Seismic reflection profile, Opening of the Sea of Japan

Earthquake source fault model for Kanto area based on seismic reflection profiling and geologic data

*Tatsuya Ishiyama[1], Hiroshi Sato[1], Naoko Kato[1], Susumu Abe[2]

1. Earthquake Research Institute, University of Tokyo, 2. Japan Petroleum Exploration Co., Ltd.

We present a new earthquake fault model for the Kanto region including Tokyo metropolitan area, based on interpretation of the seismic reflection data coupled with geologic data including surface geology and borehole stratigraphy. The Tokyo metropolitan area, underlain by Neogene and Quaternary sediments more than 5 km thick, is currently deformed by blind thrusts that could generate hazardous earthquakes. Deep seismic reflection profiles indicate that newly identified, steeply dipping blind thrusts are reactivated normal faults originally formed by middle Miocene extensional tectonics. Despite very slow (less than 0.1 mm/yr) late Quaternary slip rates, our work suggests the presence of prev, iously unrecognized faults that pose more seismic hazards to Tokyoand urges more intense efforts to shed more light on the recent slip rates, magnitude and recurrence of the past earthquakes on them.

Fault geometry on Miura-hanto fault group revealed by an integrated seismic profile using various resolution seismic reflection data

Hidefumi Tanoguchi[1], *Shintaro Abe[2], Noriko Tsumura[1], Hiroshi Mori[3], Ryoyu Arai[4], Yasuhira Aoyagi[5]

1. Chiba University, 2. AIST, Geological Survey of Japan Research Institute of Earthquake and Volcano Geology, 3. Shinshu University, 4. Kawasaki Geological Engineering Co.Ltd, 5. Central Research Institute of Electric Power Industry

To evaluate how intraplate earthquakes affect the deformation of the surface layer and growth of active faults, it is important to elucidate the continuity of the faults from seismogenic layer to the shallow part. Around the Miura-hanto fault group (MHFG) targeted in this study, several seismic reflection surveys were conducted to clarify fault geometries and those activities. Further long seismic survey line was set crossing at high angle with the trend of the MHFG from Sagami bay to Tokyo bay to reveal the geometry of the Philippine Sea plate’s upper surface.
Since spatial resolutions of these surveys arranged from several centimeter to several hundred meter order, it makes us possible to discuss a detailed fault geometry of MHFG from the sea bottom to the depth of the PHS plate boundary by creating integrated profile.
This integrated profile shows that Takeyama fault and Kitatake fault continue from the shallow part to the deep part with their dip loosening. If these faults are extended with their tilts as they are, they seem to merge into an interface derived from the Philippine Sea Plate (PSP). In other words, the MPFG may change those dip angles from steep to gentle as increasing depth and it may be branch faults from the PSP which continues to the deeper part.
In order to understand earthquakes which are expected to occur at the MHFG, we checked a velocity structure around the faults and examined a spatial relationship between it and distribution of local earthquakes’ hypocenters. Then we found that very few earthquakes were observed at the depths between surface and 10km along the estimated faults where P wave velocities show approximately 5km, while most of local earthquakes occurred in the depth deeper than 10km. In the source region of another intraplate earthquake such as Iwate-Miyagi earthquake, Okada et al, (2012) estimated a P wave velocity structure and revealed that the aftershocks are concentrated within the region of Vp>6km/s. Their results might indicate that such part of the faults can radiate the usual seismic waves. Therefore, the shallower part of MHFG down to the depth pf 10 to 15km, accompanied with the displacement at the source region, may deform without generating string ground motion.

Keywords: Miura-hanto fault group, Active fault, Seismic reflection survey

Fault Distribution and Structural Characteristic in the northern Nansei-Shoto Islands, Japan

*Rei Arai[1], Shoshiro Shimizu[1], Nobuaki Sato[1], Minako Katsuyama[1], Goro Ando[1], Narumi Takahashi[1], Shigeyoshi Tanaka[1], Yoshiyuki Kaneda[2]

1. Japan Agency for Marine-Earth Science and Technology, 2. Kagawa University

The Nansei-Shoto Islands, located along the Ryukyu Trench which extends over 1,200 km from Kyushu, Japan to the Taiwan collision zone, had experienced less seismic history in comparison to the other subduction zone such as the Nankai Trough and the Japan Trench.
Over the past few hundred years, there were a dozen of M7+ class earthquakes had occurred within this subduction zone, and the most of them caused miner damages except the 1771 Great Yaeyama Tsunami and the 1911 Kikai Island Earthquake, the largest historic earthquake observed along the Nansei-Shoto subduction zone. Due to a large percentage of the population of an island lives in coastal region, earthquake generated tsunami is the most life threatening factor. Through decades, various studies had been done identifying offshore faults which could possibly cause an earthquake and tsunami.
In this project, as a part of “the Comprehensive evaluation of offshore fault information project” by the Ministry of Education, Culture, Sports, Science and Technology, JAMSTEC has carried out collecting seismic reflection data from various institutes and private companies combined with reflection/refraction data from JAMSTEC seismic projects. Also in order to obtain unifying high resolution seismic profile out of seismic data from different survey ages and various survey specifications, the original data were reprocessed by state-of-the-art data processing methods which capable of interpreting subsurface structures and fault morphology.
The forearc structure of the northern Nansei-Shoto subduction zone is very different to the southern subduction zone. In the southern subduction zone, the Philippine Sea plate subducts beneath the steep slope continental shelf with minimum volume of accretionary prism, while in the northern subduction zone, the extensive accretionary prism has been developed in front of the continental shelf. The factor of the difference is likely the amount of sediment supply from the incoming oceanic plate. Also the incoming oceanic plate shows a complicated morphology of ridges, sea mounts such as Amami Plateau and Kikai Sea Mount, and its high relief feature probably cause the complex faulting in the accretionary prism (Kasahara and Sato, 1997).
At the margin of the northern Okinawa Trough, there are numbers of normal faults develop in the thick continental shelf sediments, which exhibits the Trough increases its depth gradually without distinctive edges seen in the southern Okinawa Trough. Faults identified in the northern Okinawa Trough are classified into two types; normal faults resulted from the present trough’s growing tectonics, and at the southwestern offshore of Kyushu where NW-SE extensional tectonics fields dominates, lateral transforming faults are identified which presumably continuous from Kyushu region.

Keywords: offshore fault, seismic reflection survey, Ryukyu Trench, Okinawa Trough

Seismic Reflection Survey at Niitsuru Aizumisato Fukushima

*Shinobu Ito[1], Sawako Kinoshita[1], Kazuo Yamaguchi[1], Youhei Uchida[1], Takeshi Ishihara[1]

1. Geological Survey of Japan, AIST

We have tried to understand geological structure in Aizu Basin for utilization of geothermal energy. We conducted boring survey at Niitsuru area, Aizumisato in the 2016 fiscal year. Niitsuru area is where the Sagase River runs on an alluvial fan from southwest, turns toward southeast, and run together with the Miyakawa from south to north. The surface trace of the West Aizu Basin Fault Zone shows mainly NS direction, but the trace to the south of Niitsuru area shifts toward west to the north of Niitsuru area. The main trend of geological structure in Aizu Basin is NS direction, but the geological structure in Niitsuru area is relatively more complex. The boring survey is effective to understand geological structure. However, it is important to understand not only boring data but also spatial extent of geological structure. Seismic reflection survey is one of the most effective tools.

Fukushima Prefecture conducted seismic reflection survey at Yonezawa, on the south of Niitsuru area. The strike direction of the West Aizu Basin Fault at Yonezawa is almost NS. It is easy to conduct seismic reflection survey because some roads lead straightly east to west. On the other hand, a prefectural road and a railway (JR Tadami Line) block roads east to west at around the borehole in Niitsuru main area. Moreover, it is difficult to deploy a telemetry seismic recording system over railways without bridges. Therefore, we designed seismic reflection survey along three EW survey lines to the south of the borehole.

The survey was conducted from September 5 to 16 in 2016. The Aizumisato Niitsuru 1 Survey Line (AMN1) is deployed near the borehole, and the length of the line is about 440m. Whole survey line of AMN1 is located east of the railway, and we used only telemetry system. The Aizumisato Niitsuru 2 Survey Line (AMN2) is located about 500m south to the AMN1, and the length of the survey line is about 520m. We deployed both telemetry system and self-recording system because the survey line crosses the railway. The west end of the survey line is the prefecture road 59. The Aizumisato Niitsuru 3 Survey Line (AMN3) is located about 200m south to the AMN2. The survey line crosses the prefecture road the prefecture road 59. West of the road 59 is a paved road, but east is a dirt road. The length both of the west and the east is about 100m, and we fixed a deployment of the telemetry system. The sampling interval for AMN2 with both telemetry and self-recording system is 1ms, but that for AMN1 and AMN3 with only telemetry system is 0.5ms. We used horizontal single component geophones with GS32CT (f_o =10Hz). We also used a transportable vibrator system. Sweep frequency of the vibrator is 20 to 160Hz, sweep duration is 7s, and recording duration before cross correlation is 8s. Spatial intervals of both sweep points and recording points are 2ms, number of recording channels is 96, and sweep count at each sweep point is 5 to 10 corresponding to offset length.

We confirmed good shot records for telemetry system. On the other hand, it is impossible to see shot records for self-recording system without some processing. After the survey, we also confirmed shot records for self-recording system with telemetry system. We are going to apply seismic processing to these records.

Keywords: West Aizu Basin Fault Zone, seismic reflection survey

Seismotectonic characteristics in the Yun-Chia-Nan area, Southwest Taiwan: Insight from seismic ambient noise

*Chih-Yin Lin[1]

1. Department of Earth and Environmental Sciences, National Chung Cheng University, Minhsiung, Chiayi, Taiwan

The seismic ambient noise tomography (ANT) has been wildly used in regions lack of earthquake data to image subsurface seismic velocity as well as its spatial-temporal variations using surface wave type of Green's function extracted from cross correlation of seismic ambient noise. Due to vigorous collision of the Eurasian Plate and the Philippine Sea Plate, the deformation front of Taiwan composes complex folds and fault systems. The Yun-Chia-Nan area is suited in southwest segment of the deformation front, where includes southern portion of the Western Foothills and the Coastal Plain. The detailed physical properties for the above mentioned areas are not well known as a result of less seismicity. Thus, we had conducted a 2-year project to deploy a temporary broadband array with 14 stations. The project is not only to monitor seismic activities in the Yun-Chia-Nan area, but also to derive an average 1-D shear-wave velocity structure using seismic ambient noise.
By analyzing time domain empirical Green’s function (TDEGF) from the cross correlation of seismic ambient noise between station-pairs, we are able to obtain 1-D shear-wave velocity profile. Our results indicate that between the period of 1–10 s, shear-wave velocity shows prominent low value in the upper crust. We also compare time variant of shear-wave velocity profiles derived from a station pair (HNME-RELI) located in the east of the Chukuo fault. Interestingly, we find that, after 10-years, shear-wave velocity becomes greater as depth is beyond 2 km. This feature might imply crack closing due to intensive orogenic process in Taiwan.

Keywords: Ambient Noise, 1-D shear-wave velocity structure

Study on property of seismogenic activity for Chianan area

*JING-YUAN HUANG[1], YI YING WEN[1], SHIH CHUNG WEN[1]

1. National Chung Cheng University

Previous study has suggested Chianan area as the region with higher probability to generate large earthquake in next 30 years. In this study, we collect the P and S arrival data (2008/11~2015/12) determined by the Central Weather Bureau (CWB) and two local seismic networks, which were operated by National Center for Research on Earthquake Engineering (NCREE) and Integration of geodynamic research in Chiayi area (ITCH) projected by National Chung Cheng University, respectively. Through applying the 3D relocation analysis and stress inversion, we attempt to further understand the properties of seismic activity and the implication of the tectonic structures in this area.

Our results show that: (i) The faulting mechanisms do not exactly correspond with the regional tectonic stress and active faults in this area. The primary strike-slip faulting mechanism might be related to the preexisting normal fault. (ii) The lowest friction coefficient was obtained in the southwest region to the Meishan fault with a value of 0.3. This might respond to the complicated fracture system of the Meishan fault. (iii) The seismic activities in Chianan area most range between 5 to 15 km depth, and the various friction coefficients (0.3~0.5) indicate the complex fault structure and heterogeneity in this region. We hope this integrated seismic data and study result can provide some helpful information for potential seismic-hazard assessment in Chinan area.

Keywords: Chianan area, Seismic activity, Stress inversion

Seismotectonics of the Taiwan Shoal Region in the Northeastern South China Sea: Insights from the Crustal Structure

*Jinlong Sun[1], Huilong Xu[1], kuiyuan Wan[1]

1. South China Sea Institute of Oceanology, Chinese Academy of Sciences

An earthquake cluster, which included the great September 16, 1994, earthquake, occurred in the Taiwan Shoal region on the outer rise of the Manila Trench. Several previous studies had given important information to better our understanding of the September 16, 1994 earthquake. However, little is known about the earthquake cluster. To understand the mechanisms that controlled and generated the earthquake cluster, it is important to investigate the deep crustal structure of the Taiwan Shoal region. We present a two-dimensional seismic tomographic image of the crustal structure along the OBS2012 profile, which is based on ocean-bottom seismograph (OBS) data. The structure exhibits a high-velocity anomaly in the upper crust beneath the Taiwan Shoal, which is flanked by low-velocity anomalies. We studied 765 earthquakes (Richter magnitude M_L>1.5) that occurred from 1991 to 2015. An analysis of the earthquake epicenters, regional faults, and crustal structure allowed us to better understand the nature of the active tectonics in this region. The results of these analyses indicate that (1) the high-velocity area represents major asperities where stress is concentrated and corresponds to the location of the earthquake cluster; (2) the earthquake cluster was influenced by fault interactions. However, the September 1994 earthquake was independent of these seismic activities and instead was associated with the reactivation of a pre-existing fault, and (3) an accumulation of compressive stress may trigger future damaging earthquakes in the Taiwan Shoal region, because the slab pull was resisted by the exposed pre-collision accretionary prism and the resistive force caused the in-plane compressive-stress accumulation.

Keywords: earthquake cluster, crustal structure, Taiwan Shoal

Sedimentary structure of Bohai Bay Basin from teleseismic receiver functions

*Yan Wu[1], Lupei Zhu[2], Zhifeng Ding[1]

1. Institute of Geophysics, China Earthquake administraion, 2. Saint Louis University

We calculated P receiver functions from 895 teleseismic events which were recorded by 70 temporary stations from Sep. 2006 to Sep. 2009. For the stations were located on thick sedimentary structures, it is difficult to identify the P to S converted phases from the Moho discontinuity. The first few seconds after the direct P arrival are mainly controlled by the sedimentary structure response which includes the Ps phase generated by the bottom of the basin and its multiple reverberations in the basin. Based on these characteristics, we used the Neighborhood Algorithm method to invert the data and try to find the best basin velocity model that produces the best fit between the theoretical receiver functions and observed receiver functions in the least-square sense. The results show that there is a series of depressions and uplifts orienting in the NNE direction in BBB. The sedimentary depth in the Jizhong depression is about 3~6 km. There are several secondary depressions and uplifts alternating in the NNE or NE direction in the Jizhong depression. The thickest sedimentary layer is located in the eastern Jizhong depression. The above shows the characteristics of a half rift valley (rift valley)-half horst (horst) structure. The ratio of the P velocity to S velocity in the uplifts is larger than the one of the depressions. It may be caused by the lack of the Paleogene stratum in the uplifts. The proximity of geothermal fields and the high Vp/Vs-ratio depressions shows a close relationship between the high temperatures of the stratum and the large ratios of P velocity to S velocity; The average of S velocity of the sedimentary in the uplift is smaller than the one in the depression, and the thicker sedimentary area always has a higher average S velocity. These characteristics show a relationship of thick sedimentary and high average S velocity. It may be because that the thicker sedimentary area has a thicker Paleogene stratum and the S velocity of the Paleogene stratum is much higher than the ones of the Neogene and Quaternary stratums. The sedimentary structure provides a base to determine crustal structure beneath the BBB.

Keywords: Neighborhood Algorithm method, Teleseismic receiver function, Seidimentary Structure

Lithosphere structure of the Yamato Basin from receiver function analysis

*Takeshi Akuhara[1,2], Kazuo Nakahigashi[3], Masanao Shinohara[2], Tomoaki Yamada[2], Yusuke Yamashita[4], Hajime Shiobara[2], Kimihiro Mochizuki[2]

1. Now at Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, 2. Earthquake Research Institute, University of Tokyo, 3. Tokyo University of Marine Science and Technology, 4. Disaster Prevention Research Institute, Kyoto University

Large earthquakes have occurred around the Japan Sea, including the 2007 Chuetsu-oki Earthquake. To estimate the risk of potential earthquakes and tsunami, better understanding of the lithosphere structure beneath the Japan Sea is an issue of importance. Revealing the lithosphere structure would also help constrain the formation process of the Japan Sea, which has been considered due to back-arc opening. In this study, we conducted receiver function analysis using broad-band ocean-bottom seismometers (BBOBS) installed at the Yamato Basin from 2013 to 2016. The final goal of this study is to detect a lithosphere-asthenosphere boundary (LAB), which provides fundamental information of the oceanic plate i.e., thickness of the lithosphere. Teleseismic P waveforms recorded by horizontal sensors at offshore sites are significantly affected by multiple reflections and conversions within the sediment layer beneath the seafloor. These multiple phases have potential to overprint signals from the LAB. We, therefore, first estimated shallow (< 20 km) crustal velocity structure from receiver function waveform inversion. Then we searched for the depth and contrast of the LAB which can better explain observed waveforms than any structure models without the LAB. As a result, we acquired good waveform fitting with only the shallow crustal structure. We also found that the LAB located at 70 km depth can improve the waveform fitting. Unfortunately, we could not identify LAB-related signals visually due to dominating sediment reverberations. Statistical approach is left for future studies to confirm whether this improvement in the waveform fitting truly represents the existence of the LAB or not.

Keywords: Lithosphere structure, Ocean-bottom seismometer, Receiver function analysis

3D velocity model in the region of Nansei-Shoto

*Minako Katsuyama[1], Shoshiro Shimizu[1], Rei Arai[1], Nobuaki Sato[1], Shigeyoshi Tanaka[1], Narumi Takahashi[1,2], Yoshiyuki Kaneda[1,3]

1. Japan Agency for Marine-Earth Science and Technology, 2. National Research Institute for Earth Science and Disaster Resilience, 3. Kagawa University

Introduction
This is a part of the project "Comprehensive evaluation of faults information on offshore Japan", by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The project consists of three themes, 1) Collecting seismic survey data and building a database of offshore faults, 2) Interpreting distribution of active faults using seismic data collected, and conducting the seismic re-processing by leading-edge seismic technology for the seismic data obtained in previous decades, 3) Building the fault models for a simulation of strong motion and tsunami disaster, based on the interpreted faults.
Our purpose of this study is make a 3D velocity model in the Nansei-Shoto to provide with the support we needs to interpret faults.
The Nansei-Shoto is one of the islands arcs along the West Pacific continental margins (Philippine Sea Plate subducts Eurasian Plate) and has typical topographic features as an islands arc, where marginal seas, volcanic fronts, islands arcs, sedimentary basins and trenches are regularly and zonally aligned toward the Pacific Ocean.

Methods and data
3D velocity model was constructed by seismic data, well data (ex. T-D curve), and ocean bottom seismometer(OBS) refraction survey data which were obtained by a various agencies and private companies. Horizons such as acoustic basment and unconformity were interpreted using reflection seismic sections. Conrad discontinuity and Mohorovicic discontinuity were interpreted on refraction surveys and consulted previous study. Layer structure and velocity model were created on these horizons by calculation using "Decision Space Geoscience". The bin size of model creation is 1,000m horizontally (in the case of crust, 500m is applied) and 100m vertically, respectively.

Result
We obtain a result that understands geological structure in Nansei-Shoto. So in this session, we will take a discussion concerning structural characteristic based on the 3D velocity model.

Keywords: 3D velocity model, Nansei-Shoto, Ryukyu islands, subduction zone

Fault distribution around the Nansei-Shoto

*Nobuaki Sato[1], Shoshiro Shimizu[1], Narumi Takahashi[1,2], Rei Arai[1], Goro Ando[1], Minako Katsuyama[1], Shigeyoshi Tanaka[1], Yoshiyuki Kaneda[1,3]

1. Japan Agency for Marine-Earth Science and Technology, 2. National Research Institute for Earth Science and Disaster Resilience, 3. Kagawa University

This is a part of the project "Comprehensive evaluation of faults information on offshore Japan", by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The project consists of three themes, 1) Collecting seismic survey data and building a database of offshore faults, 2) Interpreting distribution of offshore faults using seismic data collected, and conducting the seismic re-processing by leading-edge seismic technology for the seismic data obtained in previous decades, 3) Building the fault models for a simulation of strong motion and tsunami disaster, based on the interpreted faults. This report is the outcome, fault distribution around the Nansei-Shoto (Ryukyu Islands), in 4th year since the start of the project.
Interpretation of fault distribution must be based on features of geography and geological structure from seismic reflection data. Bathymetric data are one of the important clue to understand offshore fault distribution. The effective use of high resolution bathymetric data makes progress in the comprehensive study of the relationship among seafloor topography, subsurface structure and seismicity. In the project, we have created detailed bathymetric maps around the Nansei-Shoto (e.g. red relief image map) by the integration of topographic data including high quality bathymetric data with multi-narrow beam echo sounder, and achieved the interpretation of offshore faults with the bathymetric map, seismic profiles by front-line seismic processing and earthquake mechanism information from the Japan Meteorological Agency. As a result, 441 offshore faults were found out around the Nansei-Shoto through the project.
The Ryukyu Islands is a chain of islands that extends about 1,200 km from Kyushu to Taiwan. The Ryukyu Islands system is located at a convergent plate margin where the Philippine Sea Plate is subducting beneath the Eurasia Plate along the Ryukyu Trench. In the southwestern Ryukyu arc, the subduction is oblique to the trench, while in the northeastern Ryukyu arc, it is perpendicular to the trench. The Oblique subduction causes extensional stress in the back-arc and compressive or extensional stresses in the fore-arc depending on the sense of arc curvature and the relative motion of the plates.
The study area can be divided into three regions, based on differences in the basic stress pattern and developing fault type: back-arc, fore-arc, and island arc. In the back-arc basin called as the Okinawa Trough, there are numerous normal faults with echelon structures, east-northeast to northeast trending, resulted in the initial rifting and subsequent spreading process. In the southeastern area of the Kyushu Island, where is a rift zone in the northeastern extension of the Okinawa Trough and is under E-W compression with strike-slip faulting type, normal faults and lateral strike- slip faults develop concurrently. For the fore-arc region, on the trench side, reverse faults, that are considered to be spray faults derived from the plate boundary, exist within accretionary prism or fore-arc basins, meanwhile on the island arc side, normal faults are formed on the terrace slope in parallel to the island arc. In the island arc region, normal faults, which cut perpendicular to the axis of the arc like transvers fault, develop such as the Tokara Gap, the Kerama Gap and the Miyako Saddle, and these structural gaps play structural transmit zone between the trench and the trough.
Here we will introduce the fault distribution with several seismic profiles around the Nansei-Shoto.

Keywords: offshore fault, seismic reflection survey, Ryukyu Arc, Ryukyu Trench, Okinawa Trough

Downward continuation of multichannel seismic data for full waveform inversion -Synthetic modeling-

*Akane Ohira[1,2], Shuichi Kodaira[1,2], Tetsuo No[2], Gou Fujie[2]

1. Yokohama National University, 2. Japan Agency for Marine-Earth Science and Technology

In order to constrain the physical properties of fine scale crustal structure, it is necessary to integrate borehole-scale physical property data and regional-scale seismic data. Recently high-resolution reflection images and detailed seismic velocity structures have become available by using a combination of a synthetic ocean bottom experiment (SOBE) method [Harding et al., 2007] with pre-stack depth migration and/or full waveform inversion, in addition to the conventional data processing of multichannel reflection data [e.g., Arnulf et al., 2012; 2014; Harding et al., 2016]. The SOBE method is based on the downward continuation [Berryhill 1979], which is a technique to extrapolate the observed wavefield to an arbitrary surface by applying Kirchhoff’s integral extrapolation, for the purpose of improving the imaging condition. However, most previous studies using the SOBE method are limited to data from mid-ocean ridges, where the seafloor depth is shallow, with few exceptions [Ghosal et al., 2014]. Here we present the results of synthetic modeling tests to evaluate the effect of the downward continuation to multichannel seismic data obtained in other tectonic region (e.g., subduction zone). At first, we redatumed both shot and receiver gathers from synthetic streamer data (up to 12 km offsets) to a depth close to the seafloor, and confirmed that the refraction phases from shallow part of the crust become first arrivals at near offsets. As a next step, we plan to a travel time tomography using the first arrivals, and compare the spatial resolution with that of original data. In this presentation, we will discuss the effect of the downward continuation and application methods to real seismic data and geometries.

3-D seismic velocity structure and distribution of reflection intensity near the main slip area of the Boso Slow Slip Event

*Akihiro Kono[1], Toshinori Sato[1], Masanao Shinohara[2], Kimihiro Mochizuki[2], Tomoaki Yamada[2], Kenji Uehira[3], Takashi Shimbo[3], Yuya Machida[4], Ryota Hino[5], Ryosuke Azuma[5]

1. Graduate School of Science, Chiba University, 2. Earthquake Research Institute of Tokyo University, 3. NIED, 4. JAMSTEC, 5. 5Graduate School of Science, Tohoku University

Off the Boso Peninsula, Japan, the Pacific plate (PAC) is subducting westward beneath both the Honshu island arc (HIA) and Philippine Sea plate (PHS), while the Philippine Sea plate is subducting northwestward beneath the Honshu island arc. These complex tectonic interactions have caused numerous seismic events such as the Boso Slow Slip Events (SSEs). To better understand these seismic events, it is important to determine the structure under this region.
Although many previous studies have attempted to reveal the structure from natural earthquakes and seismic experiments, still further work is needed for farther offshore.
We conducted a marine seismic experiment off the east coast of the Boso Peninsula, from July to August 2009. Airgun shooting was conducted along the 4 survey lines, and 27 Ocean Bottom Seismometers (OBSs) in total were deployed in the area.
In the 2016 fall meeting of the Seismological Society of Japan (S06-11; Kono et al.), we presented 2-D seismic velocity structures and distribution of the reflection intensity from the upper surface of the PHS (UPHS) under the 3 seismic survey lines, and we showed that some strong reflections have seen close to the main slip area of the Boso Slow Slip events (SSEs). This time, we additionally used the data from the off-line OBSs to estimate a 3-D seismic velocity structure and distribution of the reflection intensity from the UPHS in the off-line area, which is close to the main slip of the Boso SSEs.
We estimated 3-D P-wave velocity structure from the airgun data recorded in the OBSs by using the PMDM (Progressive Model Development Method; Sato and Kennett, 2000) and the FAST (First Arrival Seismic Tomography; Zelt and Barton, 1998). Next, we will pick the reflection traveltimes likely reflected from the UPHS and apply them to the Traveltime mapping method (Fujie et al. 2006) to estimate locations of the reflectors. It seems that reflections from the UPHS can be seen in several off-line OBS data, and we are still working on estimating distribution of the reflection intensity.
Acknowledgement
The marine seismic experiment was conducted by R/V Hakuhou-maru of Japan Agency for Marine-Earth Science and Technology, and the OBSs were retrieved by Shincho-maru of Shin-Nihon-Kaiji co. Ltd. (Present, Fukada salvage co. Ltd.). We would like to thank captains and the crew of Hakuho-maru and Shincho-maru. This study was supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of japan, under its Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions, and from the Grants in Aid for Scientific Research (25287109).

Keywords: 3D seismic refraction survey, Ocean Bottom Seismometer (OBS), Philippine Sea plate, Boso slow slip event, Traveltime mapping

Three dimensional seismic velocity structure in the Hyuganada region, western part of Nankai Trough, Southwestern Japan, revealed by an integration analysis of inland and ocean-bottom seismic observation data

Kentaro Kondo[1], *Hiroshi Shimizu[1], Yusuke Yamashita[2], Hiroshi Yakiwara[3], Kodo Umakoshi[4], Takeshi Matsushima[1], Shuichirou Hirano[3], Kazunari Uchida[1]

1. Institute of Seismology and Volcanology, Kyushu University, 2. Disaster Prevention Research Institute, Kyoto University, 3. Nansei-Touko Observatory for Earthquakes and Volcanoes, Kagoshima University, 4. Faculty of Environmental Science, Nagasaki University

In order to understand the preparation process and potential of interplate earthquakes, we need to reveal the characteristic of interplate coupling. The Hyuganada region is located at the western end of Nankai Trough, and the heterogeneity of interplate coupling has been studied by the analysis of small repeating earthquakes and slow slip events. In this study, we estimate three dimensional seismic velocity structure on the Hyuganada region by using both inland and ocean-bottom seismic observation data, and try to obtain the knowledge about the structure which controls the strength of interplate coupling.
We used the arrival time data and hypocenter locations of 675 earthquakes which were detected inland and ocean-bottom seismic observations. Three dimensional seismic velocity inversion was carried out by the double difference tomography method (Zhang and Thurber, 2003). The initial velocity model and station corrections used in the inversion were obtained by the Joint hypocenter determination method (Crosson, 1976). We evaluated the resolution of the result by the Checkerboard Resolution test (CRT; Grand, 1987).
Our results show that the subducting slab is high velocity and the mantle wedge is low velocity and high poisson's ratio, which are common feature in the subduction zones. In addition, the results indicate the subducting Kyushu Palau ridge is relatively low velocity, and the poisson's ratio in the slab seems to be decreasing with depth, which are possibly related with the interplate coupling distribution in this region estimated by Yamashita et al. (2012).

Keywords: seismic velocity structure, Hyuganada, interplate

Seismic wave attenuation and local depth of seismogenic layer in the crust beneath Kyushu, Japan

*Azusa Shito[1], Satoshi Matsumoto[1], Takahiro Ohkura[2]

1. Institute of Seismology and Volcanology, Kyushu University, 2. Institute for Geothermal Sciences, Kyoto University

Attenuation of seismic wave energy is caused by two factors: scattering and intrinsic absorption. The former is the scattering of seismic wave energy due to random heterogeneities in seismic wave velocity and the density of the medium, while the latter is the conversion from seismic wave energy to heat energy by internal friction due to anelasticity of the medium. Quantifying scattering and intrinsic attenuation is important to understanding the structure of the lithosphere in terms of seismotectonic features. In this study, we separately estimate scattering and intrinsic attenuation by applying the multiple lapse time window analysis (MLTWA) technique [Hoshiba et al., 1991].

In all the studied area, intrinsic attenuation dominates over scattering attenuation at low frequencies (1-2 Hz), whereas scattering attenuation predominates at higher frequencies (> 2 Hz). The results show strong spatial variations in scattering and intrinsic attenuation that depend mainly on the tectonic setting. Areas with strong scattering and intrinsic attenuation geographically correlate with the locations of the volcanoes and active faults.

We compare the relationships between scattering attenuation and intrinsic attenuation quantitatively in the typical tectonic settings, volcanoes and active faults. Areas with relatively strong scattering attenuation correspond to the volcanoes, while area with relatively strong intrinsic attenuation correspond to the active faults. We also compare the scattering attenuation and intrinsic attenuation with local cut off depth of inland earthquakes, D90 defined as the depth, above which 90% of the earthquakes occur [Matsumoto et al., 2016]. Areas with relatively strong scattering attenuation correspond to shallow seismogenic layers. The areas geographically correlate with volcanoes.

Acknowledgments
This work was partly supported by JSPS KAKENHI Grant Number JP15J40067.

Keywords: seismic wave attenuation, seismogenic layer

Tomographic imaging of the 2016 Kumamoto earthquake area

*Kei Yamashita[1], Dapeng Zhao[1], Genti Toyokuni[1]

1. Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science,Tohoku University

On 16 April 2016, the Kumamoto earthquake (M7.3) occurred due to the rupture of the Futagawa-Hinagu fault zone in Kyushu. Its big foreshocks took place at 21:26 on 14 April 2016 and 00:03 on 15 April (M6.5 and M6.4, respectively), and more than 4000 aftershocks with a seismic intensity greater than 1 have occurred by 31 December 2016. The Beppu-Shimabara rift zone and the Beppu-Haneyama fault zone in Ooita Prefecture have been activated, where several active arc volcanoes exist, such as Aso, Kuju, and Tsurumi-dake. Hence, the influences of the 2016 Kumamoto earthquake on volcanic activities are concerned. To clarify the generating mechanism of the Kumamoto earthquake, we applied seismic tomography methods to study the 3-D velocity structure of the crust and upper mantle beneath the Beppu-Shimabara rift zone.

Our study region is in the range of 30.5N ˜ 34.5N and 129.0E ˜ 133.0E in Kyushu. We inverted a large number of high-quality arrival-time data of P and S waves using the isotropic tomography method of *Zhao et al*. (1992, 2011) and P-wave anisotropic tomography method of *Wang and Zhao* (2013). The lateral grid interval is ˜20 km for the isotropic tomography and ˜40 km for the anisotropic tomography. In the crust and mantle wedge, grid nodes are set up at depths of 1, 10, 25, 40, 60, 80, 100, 120, 140, 160, 180 and 200 km. In the subducting Philippine Sea (PHS) slab which is assumed to be 4% faster than the surrounding mantle, grid nodes are set up at depths of 5, 15 and 30 km below the slab upper boundary. We used 195 seismic stations, and the arrival-time data are selected from the Japan Unified Earthquake Catalogue and the seismic database of Tohoku University.

Main results of this work are summarized as follows.
(1) In the mantle wedge under the Kyushu forearc, our tomographic results revealed predominant low-velocity (low-V) zones, which reflect forearc mantle serpentinization due to abundant fluids from the dehydration of the PHS slab (e.g., *Abe et al*., 2013). Our anisotropic tomography shows that the fast-velocity direction (FVD) is trench-parallel under the forearc area.
(2) In the mantle wedge beneath the volcanic front and the back-arc area, significant low-V zones are revealed, and the FVD is found to be trench-normal, which reflect arc magmatism caused by a combination of the PHS slab dehydration and corner flow in the mantle wedge (e.g., *Zhao et al*., 2011; *Wang and Zhao*, 2013).
(3) In the Beppu-Shimabara rift zone, the big foreshocks and the main shocks are located in a high-velocity zone in the upper crust. However, significant anomalies of low-V and high Poisson's ratio are imaged in the lower crust and the uppermost mantle beneath the source zone. These results suggest that fluids from the PHS slab dehydration ascend through the mantle wedge to the upper crust, which infiltrated the Futagawa-Hinagu fault zone and triggered the 2016 Kumamoto earthquake *(Zhao and Liu*, 2016).

References

Abe, Y., T. Ohkura, K. Hirahara, T. Shibutani (2013) Along-arc variation in water distribution in the uppermost mantle beneath Kyusyu, Japan, as derived from receiver function analyses. *J. Geophys. Res*. **118**, 3540-3556.

Wang, J., D. Zhao (2013) P-wave tomography for 3-D radial and azimuthal anisotropy of Tohoku and Kyushu subduction zones. *Geophys. J. Int*. **193**, 1166-1181.
Zhao, D., A. Hasegawa, S. Horiuchi (1992) Tomographic imaging of P and S wave velocity structure beneath northeastern Japan. *J. Geophys. Res*. **97**, 19909-19928.
Zhao, D., W. Wei, Y. Nishizono, H. Inakura (2011) Low-frequency earthquakes and tomography in western Japan: Insight into fluid and magmatic activity. *J. Asian Earth Sci.* **42**, 1381-1393.
Zhao, D., X. Liu (2016) Crack mystery of the damaging Kumamoto earthquakes. *Science Bulletin* **61**, 868-870.

Keywords: tomography, the 2016 Kumamoto earthquake

Earthquake Distribution and Velocity structure in Nagaoka Region

*Shutaro Sekine[1], Yoshihiro Sawada[1], Keiji Kasahara[1], Shunji Sasaki[1], yoshihiro tazawa[1], Shintaro Abe[2], Masayuki Yoshimi[2]

1. Associatinon for the Development of Earthquake Prediction (ADEP), 2. National Institute of Advanced Science and Technology (AIST)

The Nagaoka region is located on the high strain rate zone at eastern margin of Japan Sea, and it is also the area where the Chuetsu Earthquake and the Chuetsu-oki Earthquake have occurred. Between the two large faults, another faults are confirmed on the western margin of the fault zone of the Nagaoka plain. To investigate the activity of faults, the Association for the Development of Earthquake Prediction (ADEP) determined to newly construct a high-density seismic observation network (AN-net) in the region from 2010. We add the data of the AIST Kashiwazaki seismic observation network where is deployed just to the south of AN-net. In this study, we estimate the distribution of the earthquakes, and velocity structures in this region.
The seismic station of the AIST consists of the 15 stations. Each stations has velocity seismograph, which data is acquired offline. We merge the AN-net and AIST data manually. 101 earthquakes is used in the tomography.
In this study, we calculate P- and S- velocity structure by Double Difference tomography. After 2010 when the AN-net was constructed, arrival times of each earthquakes is picked manually in the AN-net region. Before 2010 and region of the Surrounding AN-net, we get the arrival data from JMA unified earthquake catalog. The number of absolute P- and S-wave arrival times used in the tomography is 369,852 and 328,375, respectively, with the relative arrival times for the manually picked P- and S- waves reaching 1,364,619 and 1,151,624, respectively, from 15,010 earthquakes which occurred from October 1997 to 2017. By adding the observation point located in the southern part of AN - net, the southern part of the Nagaoka plain is estimated better.
Acknowledgement
In this study, we use the JMA unified earthquake catalog. The earthquake catalog used in this study is produced by the JMA, in cooperation with MEXT. The catalog is based on seismic data provided by NIED, JMA, Tohoku Univ., and the Univ. of Tokyo.

Keywords: tomography, velocity structure

Gravity survey across the northern region of Senboku Graben along southern area of central Osaka bay

*Kunihiro Ryoki[1]

1. Institute of Geoscience and Electric Resource Science, Department of Electric and Electronic Systems, Hyogo Polytechnic Center

1. Summary
It is concerned that Earthquake damage due to a buried active fault which is not well known in the city on the sedimentary basin, where the population is concentrated. It is an urgent task to grasp the basement structure at these places. Recently the author has clarified the gravitational structure of the Uemachi Fault Zone in the Senboku area of Osaka (eg, Ryoki (2011), Ryoki (2015), etc.) Along the bay area of Takaishi, the graben structure was estimated in gravity measurement (Ryoki, 2016), and then the position of the northern margin of the coastal area of the Uemachi Fault Zone (Yoshioka et al., 2013) was confirmed. This time, the gravity has been measured along east-west survey line set to place about 3 km to the north of Ryoki (2016) 's survey line.

2. Target area
The survey line (Fig. 1) lay about 8 km east-west from east end of Gakuen-cho, Naka-ku, Sakai City, to the quay of Hamadera waterway in Hamaderakoen-cho, Nishi-ku. Among this, the 2.2 km, from the west point of Ishidu rever to the south point of Hamadera Koen Station, almost coincides with Sakai 2nd survey line of seismic reflection method (Sakiyama, 1997).

3. Method
LaCoste & Romberg relative gravimeter G-308 was used for the gravity easurement. Measurement points were the baseline standard point of the Geospatial Information Authority of Japan (GSI) and the reference point / auxiliary point of the public block area in principle. The survey results of these points were used for gravity correction. When the auxiliary point of the block district survey was lost, its original position was confirmed on the map and it was set as the gravity measurement point. No terrain correction has been added to measurement value because there was regarded as plains.

4. Result
Fig. 2 shows the results of free air anomalies and simple Bouguer anomalies projected in the east-west direction. The horizontal axis in Fig. 2 is the distance from the west end of the survey line. Fig. 1 also shows the location of the estimated active fault (1) located near the distance of 0.40 km, which indicated by Yoshioka et al. (2013). And in the vicinity of 0.96 km a concealed active fault (2) with active flexure accompanying this, an active fault (3) with somewhat inaccurate location near 1.68 km, around 3.60 km active fault (4) whose position is somewhat unclear. All of these faults are orthogonal to the current survey line in general.

5. Conclusion
Among the results shown in Fig. 2, it is due to the terrain effect of Hamadera Waterway with a width of 170 m or more that the Bouguer gravity anomaly shows low value at the start of the survey line. From the Bouguer anomaly distribution shown in Fig. 2, it is suggested that the fault (3) has west fall and the fault (4) has east fall. On the other hand, the gravity anomaly value rises smoothly from around the distance of 4.00 km. This suggests probably due to the fact that the survey line is along the outer circumference of

the Mikunigaoka high gravity anomaly area.
In order to conduct a more detailed discussion based on the above measured values, it is necessary to apply terrain correction and earth gravity correction. In addition, dense gravity measurement should be done to acknowledge that the graben structure lay under the west side from the Hamadera Waterway, where is a petroleum or other chemical industry complex that is located in a vast landfill site and it is a difficult area for outsiders to enter for security.

References

Geospatial Information Authority of Japan (GSI) (2017) : Reference point result browsing service, http://sokuseikagis1.gsi.go.jp/index.aspx.
Iwata, T. *et al.* (2013) : Preponderant Investigation in Uemachi Fault Zone, 2010 - 2012, p. 66 - 163.
Nakata, T. *et al.*(1996) : 1:25,000 Osaka Seinen-Bu, Active Fault Map in City Zone, D1-No. 333.
Ryoki, K. (2011) : Journal of Kinki Polytechnic College, vol. 19, p. 18 - 19.
Ryoki, K. (2015) : Japan Geoscience Union 2015 convention proceedings, SSS31-P05.
Ryoki, K. (2016) : Japan Geoscience Union 2016 convention proceedings, SSS26-P01.
Sugiyama, Y. (1997) : Research materials of active fault, p. 105-113.
Yoshioka, T., *et al.* (2013) : Preponderant Investigation in Uemachi Fault Zone, 2010 - 2012, p. 5 - 65.

Keywords: Osaka Plan, Uemachi fault zone, subsurface structure, reverse fault, digital geographic information, public control point

図１　重力測定点の位置　A–A’:今回の測定点，B–B’:領木(2016)の測定点

Fig. 1 Position of gravity measurement points. A - A ': current measurement points, B - B': measurement points by Ryoki (2016).

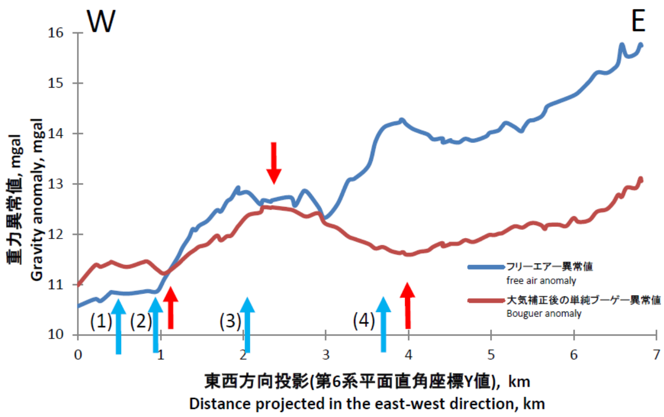

図２　重力異常稠密測定の結果 東西断面　赤色矢印は単純ブーゲー異常値の極値の位置を示し，青色矢印は吉岡・他(2013)による活断層位置を示す．

Fig. 2 Profile of gravity anomaly in dense survey East-West section. Red arrows indicate the points of the extremal value in the simple Bouguer anomalies. Blue arrows indicate the points of active fault (after Yoshioka, et al., 2013).

Probing shallow region structure of Atotsugawa fault fracture zone with cosmic-ray muon detector in borehole

*Katsuya Yamazaki[1], Akimichi Taketa[1], Kentaro Omura[2]

1. Earthquake Research Institute, the University of Tokyo, 2. NIED

This presentation will give a brief overview of technique of underground density structure measurement and observation system using cosmic-ray muon detector from a borehole. Thereafter, results of measurement campaign and parameter estimation in 2016 at Atotsugawa fault fracture zone in Gifu prefecture, Japan will be presented.

Fault zone parameters such as strike, dip, density and width of fractured zone are important to predict seismic intensity and disaster scale of earthquake. However, it is necessary to do spatially wide and dense investigation to probe these parameters by previous methods. We have developed new method to measure wide area density structure including a fault from one observation site using cosmic-ray muon radiography technique.

The muon radiography technique uses high penetration power of cosmic-ray muons. Cosmic-ray muons can penetrate several kilometers of rocks and they attenuate in their paths. Average density on their paths is measured with the amount of muon attenuation. The muon attenuation depends on the density of the penetrated material without dependence on other parameters such as chemical and structure heterogeneity. Therefore, this method provides reliable measurement of shallow region of crustal structure without effect of heterogeneity. This technique can be applied to huge object like a volcano and a fault. However, cosmic-ray muons come only from the sky, and this method could not measure underground object other than uplifting object.

In order to overcome the challenge and measure under ground fault structure, we developed compact muon detector system to install it in a borehole that has 15 cm diameter. The detector has limited angular resolution due to its small size. Zenith angle is limited to one direction by statistically. In azimuthal angle, it resolves in eight directions. Underground density structure is measured by moving the detector along with depth direction. Wide area (several hundred meters) density structure including a fault is measured from one borehole.

We did measurement campaign at Atotsugawa fault zone in Gifu prefecture, Japan in 2016. The measurement was up to 100 m depth. As a result, low-density region was detected in the direction, which is consistent with the result of trenching survey. Moreover, fault zone parameters were estimated with the result of density structure.

Keywords: Cosmic-ray, Muon, Muography, Fault, Atotsugawa, Borehole

Characteristics of the PL waves observed by the borehole strain and stress meters of Tono Research Institute of Earthquake Science

*Osamu Murakami[1], Hiroshi Ishii[1], Yasuhiro Asai[1]

1. Tono Rearch Institute of Earthquake Science, Association for the Development of Earthquake Prediction

We deployed the network of the borehole strain and stress meters in the Tono region in Japan. We found that we could observe the long-period ground motion between P and S waves arrivals in the strain and stress records from some large earthquakes. The dominant periods of these long-period ground motions range from about 10 seconds to 30 seconds. Because these periods are shorter than the typical periods of the W phase (100 –1000 seconds order), these long-period ground motions are not W phases.
We also found these long-period ground motions between P and S waves arrivals in the F-net seismograms. While we clearly found these waves in the radial components, it was difficult to find these waves in the transverse components. Because of this observation, we consider that the long-period ground motions between P and S wave arrivals are PL waves.
In order to clarify the causes of the differences of these PL waves, we estimated the dominant periods of the PL waves observed by the strain and stress meters in our network for many large earthquakes in Japan. We will present the results obtained from this analysis.

Keywords: long-period ground motion between P and S arrivals, PL waves, strainmeters, stressmeters, borehole

Seismic reflection imaging of the Morimoto fault, Kanazawa, central Japan

*Naoko Kato[1], Tatsuya Ishiyama[1], Hiroshi Sato[1], Shigeru Toda[2]

1. Earthquake Research Institute,University of Tokyo, 2. Aichi University of Education

To estimate seismic hazards, understanding the relationship between active fault and seismic source fault is crucial. To estimates seismic hazards, more detailed survey to identify source faults is needed. A research project funded by MEXT named "the integrated research project on seismic and tsunami hazards around the Sea of Japan" began in FY 2013. To obtain the information of a seismogenic source fault, we performed seismic reflection profiling across the Morimoto fault, north eastern boundary fault of the Kanazawa plain. This fault is northern part of the Morimoto-Togashi fault zone, extend for 26-km along the eastern boundary of the Kanazawa plain (Active fault Research Group, 1991; Togo et al., 1998). The length of seismic line is approximately 9 km. We used a medium size vibrator truck (IVI Envirovib). We deployed 10 Hz geophones at 10 m interval covering whole seismic line. The sweep signals (8-100Hz for high resolution reflection profiling, 8-40Hz for refraction profiling) were recorded by fixed 885 channels. The seismic data were processed using conventional CMP-reflection methods and refraction tomography (Zelt & Barton, 1998). Seismic section portrays the image down to 1.5 seconds (TWT). The resultant depth converted seismic section show a simple monocline produced by an east-dipping reverse fault. A vertical separation by this fault is about 700 m. Judging from the horizontal reflectors on the hanging wall, fault geometry shows simple plane with constant dip angle.

Keywords: Morimoto fault, seismic reflection profiling, active fault

Seismic Reflection Survey at West Aizu Basin Fault Zone, Northeast Japan

*Sawako Kinoshita[1], Shinobu Ito[1], Kazuo Yamaguchi[1], Youhei Uchida[1], Takeshi ISHIHARA[1]

1. Geological Survey of Japan, AIST

Aizu Basin in northeast Japan is an inner structural basin with 30 km length and 13 km width that is surrounded by two reverse faults: West Aizu Basin Fault zone and East Aizu Basin Fault zone. West Aizu Basin Fault zone that extends about 35 km with a strike of north-south direction is divided into Toudera, Niitsuru, and Sensakibara segment according to the geometry of the surface structure. The alluvium, Holocene fan deposits and terrace are distributed in the Aizu basin, whereas Late Miocene to Early Pleistocene fluvial strata deposited to the west of the basin (Fukushima Pref, 2000; Yamamoto et al, 2005). Historical records suggest that the earthquake with magnitude of 6.9 that hit Aizu Basin in 1611 occurred along West Aizu Basin Fault zone (Sangawa, 1987). There are several complicated small sub-segments of fault in the gap area between Toudera and Niitsuru segments with a length of about 2 km in east-west direction, where Sagase River that flows from a southwest direction forms fan delta. A seismic reflection image across the northern edge of Niitsuru segment identified flexure zones at 300 m to the east of the western boundary of the basin, suggesting the idea that the fault lines predicted by surface topography represents denudation (Fukushima Pref, 2000). The purpose of this study is to gain more insight into the spatial distribution of West Aizu Basin fault zone at a gap region between Toudera and Niitsuru segments by a shallow reflection imaging. We conducted S-wave reflection survey along three lines (Line 1, 2, and 3) that cross the fault zone. Sweep signals were produced by portable vibrator ElViS III (GEOSYM) with a sweep length of 7 seconds and frequencies between 20 and 160 Hz, and received signals were recorded on 10 Hz GS-32CT horizontal geophones (Geospace). The repeat counts of sweeps at each shot point are from 3 to 10 and both shot and receiver intervals are set to be 2 m. Geophones with 96-channels spread moved laterally along each survey line in step of 48-channels and a total number of shot and receiver points at Line 1, 2, and 3 is 219, 260 and 96, respectively. Correlated shot gathers with sweep signals show high signal-to-noise ratio at all survey lines. CMP stacking with NMO corrections using 0.4 km/s for S-wave velocity reveals the reflections at about 0.3 second in a time profile. These phases are consistent with the seismic reflector found at a depth of about 100 m below the northern end of Niitsuru segment (Fukushima Pref, 2000). Reflections at 0.3 second have different slopes between the western and eastern part, suggesting a deformation structure related to fault activities. To clarify this deducation, further analyses need to be executed and the comparison with the drill core data near Line 1 must have key information.

Keywords: seismic reflection survey, West Aizu Basin Fault Zone

Seismic interferometry imaging of subsurface structure in the southernmost area of Southern Japanese Alps

*Hasegawa Daima[1], Toshiki Watanabe[2], Tanio Ito[3], ken'ichi Kano[4], Susumu Abe[5], Akira Fujiwara[6], Yoshinori Kouchi[7]

1. Depertment of Earth and Planetary Sciences, Nagoya University, 2. Earthquake and Volcano Research Center, Graduate School of Environmental Studies, Nagoya University, 3. Teikyo Heisei University, 4. Shizuoka University, 5. JAPEX, Co. Ltd., 6. JGI, Inc., 7. Geosys, Inc.

The Philippine Sea (PHS) plate is subducting beneath the Japanese island arc toward northwest direction in the Tokai district. The eastern Tokai area is a transition zone from the collision zone of Izu arc to the subduction dominated area. To understand the subsurface structure in this area, a 4-month seismic observation using a dense seismic linear array was conducted in the southernmost area of Southern Japanese Alps in 2013. In this study, seismic interferometry imaging was applied to the seismic records of the array observation. Seismic interferometry retrieves the zero-offset reflection response at a receiver by calculating the autocorrelation of the transmission response of normal incidence at the receiver (Claerbout, 1968). We used the regional deep earthquakes occurred at the Pacific Ocean slab as seismic sources to image the PHS plate and crustal structures.
Some clear, coherent reflectors were imaged at the depth of 10 km and 20 km in theS-wave reflection depth profile. These reflectors correspond to the S-wave velocity contrast in the S-wave velocity structure obtained by seismic tomography (Kawasaki, 2015). The reflector at the depth of 20 km shows a good match with the upper boundary of PHS plate estimated by previous studies (Matsu'ura et al., 1991, Hirose et al., 2008, and Kawasaki, 2015). For the reflectors at the depth of 10 km, our current interpretation is a boundary between geological units of accretionary deposits in the crust.

Keywords: seismic array observation, Seismic interferometry imaging, reflection depth profile

Estimation of subserface temperature by geophysical data using Artificial Neural Network

*Kotaro Sugano[1], Toru Mogi[2], Toshihiro Uchida[3], Tatsuya Kajiwara[4]

1. Hokkaido University Graduate School of science,School of Science, 2. Graduate School of Engineering, Hokkaido University, 3. National Institute of Advanced Industrial Science and Technology, 4. Geothermal Engineering Co., Ltd

Accurate estimation of the underground temperature is essential for the resource evaluation of a geothermal reservoir. However, the quantity of temperature data measured in boreholes is usually limited and therefore the estimation of temperature distribution at depth is often difficult. General relationship between resistivity and temperature has been studied in laboratory experiment by using drilling samples, but it is not always applicable because there are many factors that affect the resistivity value.

We have tried to indirectly estimate the underground temperature by geological and geophysical data. By using Artificial Neural Network (ANN) trained by geological and geophysical data, this study aims to estimate underground temperature by resistivity data obtained from magnetotelluric (MT) sounding. MT investigation can estimate resistivity of deep underground easily and reasonably. If we can estimate temperature of deep underground from MT data, for example, we can find a promising geothermal reservoir and decide the location for development of a geothermal power plant.

We chose the Kakkonda geothermal area, Iwate Prefecture, Japan, as a test site of this study. It is because the area is underlain by a high-enthalpy geothermal system, reaching 500℃ at 3700m depth. In addition, many drillings and geological surveys were carried out before so we can get many data to educate the ANN.

We educated the ANN by each borehole position, depth and temperature data from well logs, resistivity data from MT sounding, and micro-earthquake hypocenter distribution that disappeared below the brittle-ductile boundary. After that, we tested various ANN structures to verify output temperature with observed temperature in the well-WD-1 up to 2.5 km depth. Then we estimated temperature up to 3.7 km depth of WD-1 to use the constructed ANN showed good result at testing.

As a result, we obtained good agreement up to about 3.1 km depth by several constructed ANNs. However, fitness was not good at blow the sealing layer (appeared at around 3.1 km depth), because resolution of resistivity structure of deeper part is too coarse to emerge changing temperature.

Keywords: Neural Net Work

Crustal seismic anisotropy of Tohoku region, Japan constrained by ambient noises

*Kai-Xun Chen[1], Yuancheng Gung[1], Ban-Yuan Kuo[2], Tzu-Ying Huang[2]

1. National Taiwan University, 2. Institute of Earth Science, Academia Sinica

We present 3D crustal models of Vs and Vs azimuthal anisotropy of Tohoku region, Japan. We construct the models by using short to intermediate periods Rayleigh waves derived from noise interferometry and a wavelet-based multi-scale inversion technique.

We employ the Welch’s method to derive the empirical Green’s functions (EGF) of Rayleigh waves from one year of continuous records of 123 short-period stations of the dense high-sensitivity seismograph network (Hi-net), operated by National Research Institute for Earth Science and Disaster Prevention (NIED). We compute EGFs for about 3500 station pairs with interstation distance less than 300 km. For each qualified EGF, we measure Rayleigh wave dispersion in the period range from 3 to 16 seconds.

There are few interesting features in the resulting models: 1) The lateral variations of the crustal Vs and Vs azimuthal anisotropy are closely related to three major factors, surface geology, Quaternary volcano activity and the plate motion. 2) In the shallow crust (< ~ 10km), the prominent high velocity anomalies are observed in the eastern part of the volcano belt, and they can be attributed to the old sedimentary (Palaeozoic to Mesozoic) and plutonic rocks locating in the northeastern and the southeastern Tohoku, respectively. In the middle crust, the volcano belt is clearly identified by low velocity anomalies. 3) Patterns of the Vs azimuthal anisotropy demonstrate a strong depth-dependent variation. The anisotropy in the shallow crust is characterised by the typical orogeny parallel anisotropy (OPA), with fast polarization directions (FPD) parallel to the strikes of the mountain ranges, while the pattern of the lower crust anisotropy correlates fairly with the absolute plate motion. None of the above correlations is observed in the middle crust (~ 9 - 20 km), where the distribution of FPD presents rather chaotic pattern and the corresponding anisotropy is weak.

Keywords: Tohoku, Hi-net, ambient noise, surface wave tomography

Azimuthal anisotropy of Rayleigh-wave phase velocity from ambient noise tomography in south-central Mongolia

*Jiatie Pan[1], Qingju Wu[1], Yonghua Li[1], Sergei Lebedev[2], Munkhuu Ulziibat[3], Sodnomsambuu Demberel[3]

1. Institute of Geophysics, China Earthquake Administration, Beijing, China, 2. Dublin Institute for Advanced Studies, Geophysics Section, 5 Merrion Square, Dublin 2, Ireland, 3. Research Center of Astronomy & Geophysics of Mongolian, Academy of Science, Ulaanbaatar, Mongolia

Although far from any subduction zone, it is interesting that the Mongolian Plateau has high and young (<30 Ma) topography culminating at ~4000 m as well as extensive volcanic activity. The seismic anisotropy could offer constraints on the past and present deformation in the crust and upper mantle. This study for the first time presents the azimuthal anisotropy of Rayleigh-wave phase velocity at periods ranging from 8s to 30s using ambient noise tomography in south-central Mongolia (SCM). Continuous time-series of vertical component between August 2011 and July 2013, recorded by 69 broadband stations temporarily deployed in SCM, have been cross-correlated to obtain estimated Rayleigh wave Green's functions. Applying the frequency and time analysis technique based on the continuous wavelet transformation, a total number of 1478 inter-station phase velocity dispersion curves have been measured. Moreover, Rayleigh wave phase velocity and azimuthal anisotropy maps at periods from 8 s to 30 s have been reconstructed with a grid knots spacing of 50 km. The inversion results reflect the structure from the shallow crust to upper mantle up to approximately 50 km depth. The S-wave velocity structure as well as the azimuthal anisotropy has weekly lateral heterogeneity beneath SCM, with perturbation about ±2% to the phase velocity and ±1% to the azimuthal anisotropy, respectively. At short periods (<10s), the phase velocity variations are well correlated with the principal geological units in SCM, with low-speed anomalies corresponding to the major sedimentary basins or Gobi area and high-speed anomalies coinciding with the main mountain ranges. At long periods (e.g. 30 s), the phase velocity distribution is mainly associated with the crustal thickness. The Middle Gobi area always characterized with low-speed anomalies from 8 s to 30 s is possibly related to Cenozoic volcanism. Overall, the fast direction as well as the phase velocity distribution in the northern domains of Mongo-Okhotsk Suture (MOS) is very different from that in the southern domains, indicating the significant differences of distribution of the phase velocity and the azimuthal anisotropy between two sides of MOS may related to the closure of Paleo-Mongo-Okhotsk Ocean. In another words, this study may give geophysical evidence for the location of the front edge of the closure of Paleo-Mongo-Okhotsk Ocean.This work was supported by NSFC (41574054) and the international cooperation project of the Ministry of Science and Technology of China (2011DFB20210).

Keywords: Rayleigh wave, phase velocity, azimuthal anisotropy, ambient noise tomography, south-central Mongolia

Regional-scale cross-correlation analysis of seismic ambient noise in the Central Indonesia.

*Masyitha Retno Budiati[1], Genti Toyokuni[1], Tomomi Okada[1]

1. Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University

The central Indonesia has a complex tectonic structure which is characterized by several subduction zones (e.g., double subduction zones beneath Molucca Sea) and active faults (e.g., Palu Koro, Matano and Hamilton faults). However, due to the limitation of studies, the information of seismic velocity changes beneath the desired regions is needed for monitoring those structures. Currently, cross-correlation functions (CCFs) retrieved from ambient seismic noise are assumed as the representation of the surface wave green function that can show the response of the Earth. Based on this assumption, the asymmetrical signal of the ambient noise cross-correlation results and its spectral amplitude are investigated in order to figure out the propagation direction of surface waves and to understand the dominant frequency components of the CCF. In the present study, we used the vertical component of continuous and broadband (20 sps) seismograms recorded at five permanent stations in and around Sulawesi Island (station codes: BKB, LUWI, SANI, TNTI, and TOLI2). The data period encompasses 1 January to 30 April 2015 (four months). The data were divided into 20 minutes segments with time shift in every 5 minutes to enhance the signal to noise ratio (SNR). We applied taper, whitening, band-pass filter at the frequency band of 0.01 Hz - 1 Hz and binalization in each data segment as the preprocessing steps, then selected the feasible segments and calculated CCF between two contemporaneous segments from two stations. We further stacked the CCFs for 1 day to obtain day-averaged CCFs and finally stacked the day-averaged CCFs over 3 months to retrieve stabilized Rayleigh wave signals. Our preliminary results show that the SNR measurements are enhanced for several pairs after calculating 3-month-averaged CCFs and represent clear Rayleigh waves. The asymmetric shapes of the CCFs indicate that the Rayleigh waves propagated towards Sulawesi Island from the surrounding areas. The maximum spectral amplitudes of the CCFs also exist at frequency of 0.05 Hz - 0.2 Hz which suggest that the dominant energy of the ambient-noise Rayleigh waves are generated by microseisms.

Keywords: Seismic ambient noise, Rayleigh waves, Central Indonesia

Retrieval of P wave Basin Response from Autocorrelation of Seismic Noise-Jakarta, Indonesia

*Erdinc Saygin[1], Phil Cummins[2], David Lumley[1,3]

1. Centre for Energy Geoscience, School of Earth Sciences, University of Western Australia, Perth, Western Australia, Australia, 2. Research School of Earth Sciences, Australian National University, Canberra, ACT, Australia, 3. School of Physics and Astrophysics, University of Western Australia, Perth, Western Australia, Australia

Indonesia's capital city, Jakarta, is home to a very large (over 10 million), vulnerable population and is proximate to known active faults, as well as to the subduction of Australian plate, which has a megathrust at abut 300 km distance, as well as intraslab seismicity extending to directly beneath the city. It is also located in a basin filled with a thick layer of unconsolidated and poorly consolidated sediment, which increases the seismic hazard the city is facing. Therefore, the information on the seismic velocity structure of the basin is crucial for increasing our knowledge of the seismic risk.
We undertook a passive deployment of broadband seismographs throughout the city over a 3-month interval in 2013-2014, recording ambient seismic noise at over 90 sites for intervals of 1 month or more. Here we consider autocorrelations of the vertical component of the continuously recorded seismic wavefield across this dense network to image the shallow P wave velocity structure of Jakarta, Indonesia.

Unlike the surface wave Green's functions used in ambient noise tomography, the vertical-component autocorrelograms are dominated by body wave energy that is potentially sensitive to sharp velocity contrasts, which makes them useful in seismic imaging. Results show autocorrelograms at different seismic stations with travel time variations that largely reflect changes in sediment thickness across the basin. We also confirm the validity our interpretation of the observed autocorrelation waveforms by conducting 2D finite difference full waveform numerical modeling for randomly distributed seismic sources to retrieve the reflection response through autocorrelation.

Keywords: Seismic Noise, Autocorrelation, Interferometry