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

SSS26-01 Room:303 Time:May 19 09:00-09:15

Pseudo Shot Records by Seismic Interferometry with VLBI (2)

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We recorded seismogram of VLBI driving at GSI Head Office in April, 2012. Ito et. al. (2012) reported properties of pseudo shot records calculated from VLBI driving, earthquakes, and traffic noise by cross-correlation in the SSJ 2012 Fall Meeting. We report properties of stacked pseudo shot records by VLBI driving, earthquakes, and traffic noise, respectively.

We categorized the pseudo shot records by seeing the original waveforms. We did not use records including obviously two or three kinds of sources. However, we have to note that each record is not free from other sources.

We can see at least a sound wave, surface wave, and other events in T-component of the stacked pseudo shot record with VLBI driving. We also can see events in R-component of the stacked pseudo shot record with VLBI but relatively much poorer than in the T-component. In the stacked pseudo shot records with earthquakes, one H-component that is T-component of the VLBI driving is much better than another H-component that is R-component of the VLBI driving. The almost same results are obtained with traffic noise. The source locations of earthquakes and traffic noise are not considered at the survey line arrangement. In other words, the improvements of these two stacked pseudo shot records are caused by the unclear waveforms with VLBI driving. Therefore, we conclude that it is effective that pseudo shot records are made with T-components seismogram of VLBI driving.

Acknowledgment: We thank the Physical Geodesy Division, Geodetic Department, GSI.

Keywords: seismic interferometry, VLBI, pseudo shot record

SSS26-02 Room:303 Time:May 19 09:15-09:30

Development of the cosmic-ray muons detecting system in boreholes to image the fault zone structure

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It is important to assess active fault's dips and dip directions in order to predict the seismic intensity. However, we cannot always get these data by geological surveys because the crush zone is easy to be eroded. In addition, digging has been necessary to know the width and density structure of the crush zone. However, we can easily investigate the structure if we use indirect way by the geophysical exploration. Therefore the technique using cosmic-ray muons, one of the method of the geophysical exploration, was applied to the new way exploring the fault zone structure.

In recent years, it has been shown the usefulness of this method using cosmic-ray muons by successful examples imaging active volcanoes and fault structure(e.g. Tanaka et al., 2007, 2008, 2009, 2011). Using this way, we can obtain the average density along the detecting direction and its result almost only depends on the density of the components. This unique property, which any other methods of the geophysical exploration do not have, may provide useful data unless its heterogeneity at the shallow part of the continental crust. However, traditional muon-detecting devices were set on the ground and caught muons coming only from the sky, so we have not been able to survey the underground structure. It is difficult to miniaturize the traditional muon detecting devise and put it into boreholes because traditional one has a function which detects paths of the muon.

In order to solve this problem, we developed a new technique. We gave up its function detecting their paths and introduced new one which statistically knows coming directions instead. Using this technique, we could miniaturize the muon-detecting devise. Putting it into a borehole, we are able to survey ground structure several hundred meters from the borehole inside. If we give a demonstration and can get a good estimation of the structure near a borehole, we can show it has the ability to assess fault zone structure from one borehole.

We gave a demonstration putting the detector into a well located in Hongo campus, the University of Tokyo, and investigated ground structure. The detector was installed from ground level to 60m depth and inferred the rock density near the well. The result showed good agreement with a past digging investigation data. Its spatial resolution is lower than the traditional one because of the miniaturization, but this result showed it is possible to image underground structure by using cosmic-ray muons.

It is expected as a new method to supply the knowledge of fault zone structure at the shallow part of the crust.

Keywords: muon, borehole, fault

Japan Geoscience Union Meeting 2013
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SSS26-03 Room:303 Time:May 19 09:30-09:45

Strategic seismic data acquisition and processing for the delineation of subducting slab

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In recent years, the quest for increased precision and channel capacity of receiver system led to the combination of telemetry and autonomous recorders with the deployment of dense seismic array for full-azimuth 3D or 100-200km long 2D survey. Furthermore, multi-scale and multi-mode survey layout has been realized by the simultaneous data acquisition of regional refraction, low-fold wide-angle reflection and standard reflection survey for the several targets on the same seismic line.

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

In order to build the detailed geophysical model of subducting Philippine Sea plate, we developed a processing workflow based on the combined tomographic analysis of refraction, wide-angle reflection, and CRS-driven reflection data. Through the strategic seismic data acquisition and processing for several reflection suvey around Tokyo metropolitan region, the geometry constraints for subduction megathrust and the connectivity of the spray faults were identified. Further, steady-creep and seismogenic asperities zone related the slip deficit on the plate interface were characterized by the distribution of reflection intensities for relative-amplitude preserved CMP/CRS ensembles.

Keywords: Subducting Slab, Seismic Reflection Profiling, Multi-dip CRS Analysis

Japan Geoscience Union Meeting 2013
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SSS26-04 Room:303 Time:May 19 09:45-10:00

The seismic experiment with artificial sources at the Nobi fault area (Preliminary Report)

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1) Introduction

The mechanism of the inland earthquakes is related to the concentration of the strain and accumulation of the stress. It is very important to know the relationship between the stress/strain and fault plane. The 1891 Nobi earthquake is one of the biggest inland earthquakes in Japan. We are doing geophysical observations at the area. We have done seismic studies at the Atotsugawa fault area. We obtained several data that the lower crust structure and fluid are very important factors to the cause of the inland earthquake. In the Nobi earthquake area, the seismic tomography studies figured out the existence of a low velocity structure beneath the fault. The low velocity region continues to the subducting Philippine Sea slab. It is expected that there is some close relationship between the cause of the inland earthquake and liquid in the crust. We did seismic experiment with artificial sources to declare the characteristics of the low velocity zone.

2) Content of exploration

The seismic experiment has done on November 15 and16, 2012. The profile line is located from Fukuchiyama, Kyoto to Ina, Nagano. The length of the profile line is about 280 km. The number of the seismic stations was 1793. Eight artificial sources with dynamite were used. The 500kg and 300kg dynamites are used for 6 and 2 shot points, respectively.

3) Results

We obtained fine seismic record at all of the shots. We can see clear first arrival and later phases. Those later phases seem to the reflected phases from Moho and upper boundary of the subducting Philippine Sea slab. Based on the iso-depth lines of the Philippine Sea slab, which were obtained from seismic studies, the configuration of the Philippine Sea slab is considered to be distorted in this area. The depth of the Philippine Sea slab is shallow at the eastern side. The minimum depth is located beneath the Nobi fault area. On the record section, the reflective zone can be detected at the center part of the profile line. The reflective zone is consistent with the depth of the subducting Philippine Sea slab.

In this area, the resistivity was researched. The low resistivity region was obtained along the fault. We will declare the characteristics of the low velocity region considering the relationship between the resistivity and low velocity regions.

Keywords: crustal structure, artificial source

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SSS26-05 Room:303 Time:May 19 10:00-10:15

Anisotropic feature inferred from receiver function and S-wave splitting analysis around the high strain rate zone

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In the high strain rate zone (HSRZ), E-W compressive stress field is observed, and large earthquakes with M>6 are frequently occurred. In this study, we try to reveal depth-dependent anisotropic feature in this region by using teleseismic receiver functions (RFs) and S-wave splitting information. As a target, we select NIED Hi-net stations N.TGWH and N.TSTH, which are located very close to the HSRZ. For RF analysis, we choose M>5.5 teleseismic events from October 2000 to September 2012. Low-pass filters with fc = 1 and 2 Hz are applied to estimate RFs. In the radial RFs, we find clear positive phase arrivals at 4 s in delay time for both stations. Since this time delay corresponds to 35 km-depth velocity discontinuity existence, these phases may be the converted phases generated at the Moho discontinuity. Seeing the back-azimuth paste-ups of the transverse RFs, we can find polarity changes of later phases at 4 s in delay time at the N.TSTH station. This polarity change occurs for direction of N0E (north), N180E (south), and N270E (west). Although we have no data in N90E (east) direction, this feature implies that anisotropic rocks may exist above the Moho. In order to check this feature, we consider 6-layered subsurface model and compare synthetic RFs with the observation. The first three layers are for thick sediments and upper crust including a dipping velocity interface. The fourth, fifth and sixth layer corresponds to the mid crust, lower crust and uppermost mantle, respectively. The best model infers that the mid- and lower-crust beneath the N.TSTH station should have strong anisotropy whose fast axis directs to the N-S, though the fast axis in the uppermost mantle seems to show E-W direction. At the N.TWAH station, we should consider that thick low-velocity mid crust whose fast axis directs to the N-S in order to explain clear negative phases arriving just before the Moho phase. To check anisotropic feature of these stations, we also apply S-wave splitting analysis to the local events. In order to avoid contaminations of scattered phases, we select seismic waveforms with incident angle less than 35 degrees. We select good S/N records and apply 2-8 Hz butter-worth type band-pass filter to the waveforms. Then, we estimate the leading S wave polarization direction (LSPD) and delay time of each event. We can select crustal earthquakes (< 30 km in depth) and the intermediate-depth earthquakes (80~120 km) which occur along the subducting Pacific slab. For deeper events, LSPD shows NW-SE. On the other hand, only for shallow events, LSPD indicates NNW-SSE. This result is consistent with the feature of RFs. We can conclude that the crustal anisotropic feature beneath these stations corresponds to the lineament on the ground surface, not to the E-W compressive stress field. The LSPD in the uppermost mantle may reflect to the lattice-preferred orientation of anisotropic minerals beneath the stations.

Keywords: High strain rate zone, Receiver function, Anisotropy, NIED Hi-net

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SSS26-06 Room:303 Time:May 19 10:15-10:30

Electrical conductivity structure beneath backarc side of Chubu District, Central Japan, revealed by the Network-MT

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Series of the Network-MT survey was performed in backarc side of Chubu district since 2005. The 1st campaign was performed in the vicinity of the Atotsugawa fault area (source region of the Hietsu Earthquake) from 2005 to 2008. We extended the research region to the west and the 2nd campaign was performed in the vicinity of the Noubi earthquake source region from 2011 to 2013. Since both the Philippine Sea Plate and the Pacific Plate are subducting beneath the area, and the Niigata-Kobe Tectonic Zone, where most significant strain rate accumulation was detected before the 2011 great Tohoku Earthquake by the dense GPS array (GEONET), we aimed at obtaining wide and deep resistivity structure beneath backarc side of Chubu district to investigate dehydration process on the subducting plates and generation mechanism of the Niigata-Kobe Tectonic Zone.

After showing two 2-D cross sections beneath Fuchu-Akigami and Takamatsu-Tsukechi lines obtained from the 1st campaign, 3-D image in the vicinity of the Noubi Earthquake source region obtained from the 2nd campaign will be shown. The 1st and 2nd image show clear correlation between the NKTZ (or active faults in the zone) and crustal and/or mantle wedge conductor, which indicates existence of connected fluids. The 3rd image reveals deep seated conductor beneath along the NKTZ, probably indicating existence of dehydration from the deep seated Pacific slab. Another conductor exists near the surface along the Noubi earthquake source fault, whereas mid-crust beneath the fault zone is highly resistive.

Keywords: resistivity structure, backarc side of Chubu Dstrict, Network-MT, Niigata-Kobe Tectonic Zone, crustal fluid

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SSS26-07 Room:303 Time:May 19 10:30-10:45

Local Vp/Vs ratio estimation in earthquake swarm area around Mt. Ontake

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Mt. Ontake is a stratovolcano in the central Japan. After the first historic eruption occurred in 1979, two small phreatic explosions occurred in 1991 and 2007. Since 1976, earthquake swarm activities in the southeast area of Mt. Ontake have been observed continuously. Although the annual number of earthquakes of this swarm has sometimes been up to 2000, the magnitudes of those have been less than M1. In this area, the M6.8 western Nagano Prefecture earthquake occurred on 14 September 1984.

The relationship between occurrence of earthquake swarm and fluid has been discussed (e.g., Nur, 1974). In the earthquake swarm area, fluid supply from lower crust is suggested from electrical conductivity surveys (e.g., Kasaya et al., 2002) and an analysis of Li and Sr isotopic compositions in spring water (Nishio et al., 2009). We estimated local Vp/Vs ratio, which is sensitive to fluid existence, in the source region of earthquake swarm around Mt. Ontake.

We directly estimated Vp/Vs ratio in the source region of earthquake swarm by using method of Lin and Shearer (2007). If dTp and dTs are P and S wave travel time differences for a common station of a pair of nearby events, respectively, Vp/Vs ratio in a micro area can be expressed as Vp/Vs=dTs/dTp where seismic velocity is constant. Given a number of different stations and event pairs, plotted points (dTp,dTs) should be on a straight line with slope Vp/Vs. This slope is obtained using grid search for the line with the minimum perpendicular distance to each plot. Because (dTp,dTs) plots have errors in both dTp and dTs values, we iterated grid search to equalize both dTp and dTs error scales. First, we determined Vp/Vs ratio in a micro area for each seismic station. Then we eliminated stations data in which Vp/Vs ratio did not converge by iterated grid search when we estimate Vp/Vs in a micro area. We used earthquake data from 1997 to 2011 listed in the JMA catalog and we set dimension of a micro area as 0.01 degrees x 0.01 degrees x 1.5 km depth to analyze the data.

At the depth from 4 to 7 km, we obtained Vp/Vs values in micro areas in the earthquake swarm area to be from 1.6 to 1.9. Vp/Vs values were estimated to be about 1.8 for micro areas where many earthquakes occurred. In another area, Vp/Vs values were estimated to be up to 1.9. At this depth seismicity extends to the southeast region of Mt. Ontake. At the depth from 7 to 10 km, Vp/Vs values were larger than those at the depth from 4 to 7 km depth for the whole analyzed areas. Vp/Vs values were estimated to be up to 2.0 in several areas. At this depth seismicity is concentrated in the east and northeast regions from Mt. Ontake. In micro areas where earthquakes intensely occurred, higher Vp/Vs values of about 1.9 were found. At the depth from 4 to 10 km, Vp/Vs values were increased gradually. We also conducted the double-difference tomography using same data set to estimate velocity and Vp/Vs structures around Mt. Ontake. As a result, we found that high Vp/Vs values were estimated in the source region of earthquake swarm area by the both method.

Several high Vp/Vs areas at the depth from 6 to 7 km in this study correspond to the region where deep crustal origin fluid is suggested by the electrical survey and isotopic analysis. The estimated high Vp/Vs values in the shallow area suggest fluid existence.

This study is supported by Multidisciplinary research project for high strain rate zone of the MEXT, Japan.
We thank to use the JMA earthquake catalog in this study.

Keywords: Vp/Vs ratio, earthquake swarm

SSS26-08 Room:303 Time:May 19 11:00-11:15

3D seismic velocity structure around Philippine Sea slab subducting beneath Kii Peninsula (3)

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1. Introduction

Kii Peninsula is a part of the source area of Nankai Trough megaquakes and the region through which the strong seismic waves propagate to the big cities in Kansai. Moreover, the rupture starting point is thought to be possibly at off the peninsula. After the 2011 Tohoku Earthquake the assumed source area of the Nankai Trough earthquake was readjusted and extended to a land side deeper portion. The extended portion corresponds to 30 - 40 km depth in the plate boundary, where hydrous minerals in the oceanic crust are dehydrated. The discharged fluids will influence the frictional condition of the plate boundary. Therefore, it is important to estimate accurately seismic velocity structure at these depths.

2. Current results

We carried out linear array seismic observations in Kii Peninsula since 2004 in order to estimate the structure of the Philippine Sea slab and the surrounding area. We have performed receiver function analyses for four profile lines in the dipping direction of the slab and two lines in the perpendicular direction so far. We estimated three dimensional shapes of seismic velocity discontinuities such as the continental Moho, the upper surface of the oceanic crust and the oceanic Moho (Fukui et al., 2012). In addition, we performed seismic tomography with a velocity model embedded the discontinuities and observed travel times at stations in the linear arrays (Shibutani et al., 2012). The results show the following features of the Philippine Sea slab. At the depth of 40 km the oceanic crust shows low velocity anomaly. As we go up to shallower depths, the low velocity anomaly seems to continue to the mantle wedge and to the lower crust. It becomes a large low velocity region at the depth of 16 km under the northwestern part of the Kii Peninsula. It is known that seismic activity is very high in the upper crust above the low velocity region. These features show that hydrous minerals in the oceanic crust are broken down by dehydration at the zone of deep low frequency events, then the discharged fluids flow into the mantle wedge and the lower crust, and reduce the velocity in the regions.

3. Updating the results

In the receiver function analysis, we update the image of S wave velocity discontinuities along Kameyama - Gobo profile line by adding new receiver functions. We make up eight new profile lines by selecting permanent stations and temporary stations in the linear arrays and draw up the receiver function images. We try to estimate more detailed 3D shapes of the discontinuities by interpreting the new images together with those for the above mentioned six profile lines. In the seismic tomography, we add more travel time data. We try to utilize events in wider areas as well as deep focused events in order to improve the resolutions in depths more than 40 km.

We used waveform data from permanent stations of NIED; JMA; ERI, Univ. of Tokyo; Nagoya Univ. and DPRI, Kyoto Univ.

Keywords: tomography, receiver function, Philippine Sea slab, Kii Peninsula, Nankai Trough megaquake

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SSS26-09 Room:303 Time:May 19 11:15-11:30

The estimation of S wave reflector in the northern Kinki region

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In order to forecast earthquakes, it is necessary to estimate more accurately the structures of the crust, such as the shape of reflectors and active faults. In the northern part of the Kinki region, dense seismic observation has been conducted, and we can estimate them with improved resolution. Using the data obtained from this observation network, we did a reflection analysis in the west coast region of Lake Biwa and Tamba region. As a result of the analysis, we found a distinct S wave reflector in the Tamba region. Furthermore, we found that the extent of this reflector is consistent with that of epicentral distribution in the Tamba region.

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SSS26-10 Room:303 Time:May 19 11:30-11:45

Travel time change of Toki seismic ACROSS signals observed by Hi-net in Tokai area from 2004 to 2012

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Travel time change of Toki ACROSS signals observed by Hi-net in Tokai region from 2004 to 2012 is reported on. At Toki station, the specifications of seismic signal being transmitted since Feb. 2004 are as follows: <Feb.2004 to Feb.2007> FM signal with a carrier frequency of 13.01 Hz, modulation period 50s in the frequency range 10.25-19.45Hz and ˜2700N in spectrum amplitude. <Mar.2007 to ongoing> FM signal with a carrier frequency of 13.005 Hz, modulation period 50s in the frequency range 10.245-19.445Hz and ˜2700N in spectrum amplitude. The signal and operational mode of rotary transmitter with the vertical rotation axis are optimized for acquiring the accurate tensor transfer function data in frequency domain and Green's function in time domain between the source and receivers located anywhere.

The major results observed at Hi-net Yaotsu (11.3km form Toki station) and Hourai (56.9km) are as follows: Travel time changes of maximum amplitude phases (including direct P wave, direct S wave and these later phases) were calculated using the cross-spectral method. Secular change of travel time is imperceptible at Yaotsu station. At Hourai station, travel time of seismic ACROSS signals are decreasing at the rate of about 0.5ms per year in S wave, about 0.3ms per year in P wave for several years now. This result may indicate stress accumulation in crust.

Acknowledgement: Hi-net data are provided by National Research Institute for Earth Science and Disaster Prevention, Japan (NIED). Toki ACROSS transmitting station is managed by Japan Atomic Energy Agency (JAEA).

Keywords: seismic ACROSS, cross-spectrum, seismic velocity change, secular change, The 2011 off the Pacific coast of Tohoku Earthquake

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SSS26-11 Room:303 Time:May 19 11:45-12:00

Seismic Structure under the Kanto Plain Derived from Receiver Function Analysis by using Improved Deep Subsurface Model

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The S-wavevector receiver function (SWV-RF) is useful for deep borehole records to image the seismic structures below the stations (Takenaka and Murakoshi, 2010). The SWV-RF is derived by deconvoluting the upgoing S-wave component with the upgoing P-wave component of the records (Reading et al., 2003). The most significant difference between the SWV-RF from deep borehole records and standard receiver function from the ground surface ones is relatively robust to the structure model in the SWV-RF. The SWV-RF can eliminate the free surface response and the first P-pulse entirely and give the complete representation of the converted waveform in principle. Murakoshi and Takenaka (2011) and Murakoshi and Takenaka (2012) applied the SWV-RF from the deep borehole records of the Hi-net (NIED) to obtain the seismic structures under the Kanto Plain, Japan. This method needs the structure model from the surface to the sensor location. In this study, we applied the SWV-RF analyis by using improved deep subsurface model for seismic structure under the Kanto plain.

Keywords: receiver function, Kanto Plain, crustal structure, plate structure, deep borehole

Japan Geoscience Union Meeting 2013
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SSS26-12 Room:303 Time:May 19 12:00-12:15

Attenuation structure beneath the Tokyo Metropolitan area

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The material properties of the complex subduction zone beneath the Tokyo Metropolitan can be estimated by the seismic attenuation Q of seismic waves observed at local seismic stations. Previous studies have provided us only with the large scale attenuation structure for all Japan (Jin & Aki, 2005; Nakamura et al., 2006; Edwards & Rietbrock, 2009) or only for the shallow part inside the Kanto basin (Kinoshita, 1994; Yoshimoto & Okada, 2009). In this study we aim to derive a detailed picture of the attenuation structure in the crust and upper mantle beneath the Kanto basin. The waveform data used in this study are recorded at the dense seismic array of the Metropolitan Seismic Observation network (MeSO-net). The station network is distributed on five lines with an average spacing of 3 km and in an area with a spacing of 5 km in the central part of Kanto plane. The 296 MeSO-net stations are equipped with a three-component accelerometer at a bottom of a 20-m-deep borehole, signals from which are digitized at a sampling rate of 200 Hz with a dynamic range of 135 dB. The attenuation of seismic waves along their path is represented by the $t*$ attenuation operator that can be obtained by fitting the observed P wave amplitude spectrum to a theoretical spectrum using an omega square source model. In order to accurately fit the spectral decay of the signal, only earthquakes that are recorded with intensity greater than 1 in the Japan Meteorological Agency (JMA) intensity scale are selected.

The waveforms of 452 earthquakes were selected from the JMA unified earthquake list from January 1st 2010 to May 31st 2011. A grid search method is applied to determine the $t*$ values by matching the observed and theoretical spectra. The $t*$ data where then inverted to estimate a 3D Qp structure under the Tokyo Metropolitan area, using a layered initial Q model. Grid points were set at 15 km spacing in the horizontal direction and with 10 km spacing at depth. We implemented the 3D velocity model estimated by Nakagawa et al., 2012 and in addition we set the initial Q values at 116 for the 0 km grids and to 400 for all the grids below them.

The obtained model suggests average Q values of 50~100 inside the Kanto basin. Furthermore, a low Qp zone is observed in the area where the Philippine Sea plate meets the upper part of the Pacific sea plate. This are is located at approximately 40 km depth, beneath the north-east Tokyo and west Chiba prefecture areas and is represented by Qp values of 300. Earthquakes occurring on the Pacific plate pass through this low Q area inside the Philippine sea plate and are attenuated significantly. This kind of anomalous wave attenuation must be taken in account when estimating the hypocenter of historical earthquakes. Combined with the detailed velocity structure beneath the Kanto basin, our results help us to understand the material properties of the subducting plates. The implementation of our findings in strong motion simulation studies could help towards a better understanding of the damage area of future earthquakes and mitigate the disaster of the effected areas.

Keywords: Attenuation, Tomography, MeSO-net

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SSS26-P01 Room:Convention Hall Time:May 19 18:15-19:30

Lateral variation in seismic velocity around a fracture zone by a dense seismic observation and high frequency sampling

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We precisely observed seismic wave velocity, and estimate a one-dimensional velocity structure and lateral variation in velocity structure around a fracture zone in the Mizunami Underground Research Laboratory (MIU), Gifu Prefecture, Japan. Two vertical shafts were excavated to 500m from the ground level (GL), and four horizontal research galleries were excavated at an interval of 100m; GL-100m, -200m, -300m, -400m, connecting the two shafts. The excavation work for a new horizontal gallery is made at GL-500m by using blasts. We observe the vibrations of blasts at a dense seismic observation with 10,000 Hz sampling. The observation composed of 9 pairs of three component accelerometer and one component velocity-type seismometer at the horizontal interval of about 20 m.

We estimated 5400 ± 30 m/s in the Toki Granite, a Late Cretaceous intrusion, and 2430 ± 40 m/s in Miocene sedimentary rocks of the Mizunami Group. These velocities correspond to 2 % and 26 % water contents, respectively, on the assumption that only water exists in pores by comparing the observed velocities with the velocities by a rock test. We also found lateral variation in seismic velocity associated with the fracture zone which trends NNW-SSE with a subvertical dip. We present in detail the velocity structure associated with the fracture zone.

SSS26-P02 Room:Convention Hall Time:May 19 18:15-19:30

Shear-wave anisotropy in the crust and uppermost mantle beneath Japan from broadband array analysis of surface waves

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Recent deployments of dense seismic networks enable us the broadband array analysis of surface waves such as the noise correlation analysis (1-30 s), and the array analysis of teleseismic waveforms (30-100 s). As a result, we can reduce the influence of crustal structure to the estimation of radial anisotropy ($V_{SH} <$ or $> V_{SV}$) in the mantle. The dense seismic networks are also useful for measuring phase velocities of surface waves as a function of azimuth. We can then estimate azimuthal anisotropy in the mantle, whose spatial coverage and depth resolution are much higher than body-wave studies. Although the estimation of seismic anisotropy beneath Japan is essential for discussing the stress, deformation and flow related to the subduction process, the broadband phase velocities of surface waves and their azimuthal dependences have not been reported yet. We analyze broadband surface waves recorded by Hi-net tiltmeters (two-component high-sensitivity accelerometer) for obtaining radial and azimuthal anisotropy beneath Japan.

The analysis is performed for each of 120 arrays, where an array is an aggregate of 5-10 stations within a circle with a radius of 50 km. For each array, we first measure average phase velocities of Rayleigh and Love waves (1) by applying the spatial auto correlation method (Aki, 1957) to continuous records at periods of 3-20 s, and (2) by applying an array analysis method to teleseismic waveforms at periods of 30-100 s. Using these phase-velocity measurements, we estimate one-dimensional radially anisotropic structure beneath each array. In addition, the azimuthal dependences of Rayleigh-wave phase velocities are estimated from teleseismic waveforms.

The preliminary results show the presence of radial anisotropy ($V_{SH} > V_{SV}$) in the crust beneath southern part of southwest Japan. In the uppermost mantle, the radial anisotropy ($V_{SH} > V_{SV}$) exists beneath entire regions expect for the coastal region near the Pacific Ocean. The fastest direction of Rayleigh-wave phase velocity is east-west at a period of 35 s where the wave has sensitivity to depths of about 30-70 km. The direction becomes north-south at a period of 75 s where the sensitivity exists at depths of about 70-150 km. Along the Itoigawa-Shizuoka tectonic line (ISTL), the direction is south-north at a period of 35 s, whereas the direction becomes east-west at a period of 75 s. In the western part of Hokkaido and eastern part of Tohoku, the direction is north-south at both 35 and 75 s.

For interpreting these results, we need to consider tectonics beneath Japan such as (1) the flow in the mantle due to subduction of the Pacific and Philippine Sea plates, (2) the paleo deformation frozen in the subducting plates, and (3) the east-west compression around the Hidaka Collision Zone and the ISTL. We will examine the uncertainty of estimated anisotropy, and will discuss the origin of anisotropy after comparing our results with previous results obtained by surface-wave tomography (Yoshizawa et al., 2010), S-wave splitting analysis (e.g., Nakajima and Hasegawa, 2004) and P-wave tomography (Ishise et al., 2005, 2008).

Keywords: anisotropy, crust, mantle, surface wave, noise correlation analysis

SSS26-P03 Room:Convention Hall Time:May 19 18:15-19:30

High resolution seismic reflection profiling across the Shiroishi fault, northeast Japan

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We collected and processed shallow high-resolution seismic reflection data in order to resolve shallow structures and to understand structural linkage between active faults and folds recognized at ground surface and deeper, complicated fold and thrust structures along the Shiroshi fault, northeast Japan. We deployed more than 200 seismic channels, 10-Hz geophones, and EnviroVib (IVI, Inc) as a seismic source along about 5-km-long seismic line. Common midpoint stacking by use of initial velocity analysis successfully illuminates subsurface geometries of active fault-related fold to 1-1.5 two-way time. Detailed seismic reflection analyses including refraction and residual statics, migration, deconvolution, and time-space variant bandpass filters, and depth-conversion by use of stacking velocities enable to obtain subsurface depth section of these active structures. The high-resolution depth section shows that west-dipping thrust fault imaged in the section is consistent with the location of the base of the fault/fold scarp that deforms middle to late Pleistocenefluvial sediments.

Keywords: Shiroshi fault, active fault, shallow seismic reflection profiling

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

SSS26-P04 Room:Convention Hall Time:May 19 18:15-19:30

Relationship between half-graben and high-velocities area at depths of 10km 6

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Figure1 indicates subducting and resurfacing of the hot plate and the ridge.This model may apply to Tanzawa area (Figure 1) and Central Hokkaido.

Figure 3 indicates high-velocities area at depths of 10km in Tohoku area along Pacific coast and off Tohoku. In the area above mentioned in Kitakami Mount, there is adakitic andesite.

Off Hachinohe , Miyako and Minamisanriku about 150km-200km,there are three high-velocities areas.

Under these high-velocities areas(intra Tohoku plate),beneath the boundary surface of upper and under plates ,there is law velocities area that is about 50km deep from north to south about 100km wide from east to west .This low velocities area ranges to Ibaragi Prefecture through near the epicenter of M9 on 2011,3,11 .

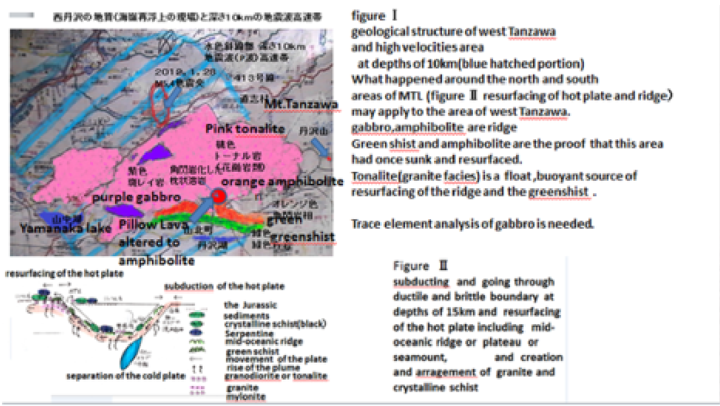
This huge **law velocities area's poisson's ratio is also law**. The similar area exists in Unzen in Nagasaki Prefecture from the ground to at the depths of about 30km and about 30km wide from east to west. That means the possibility of the existence of fluid maguma or a mass of **partial melted rock or kind of cristobalite** ,tridymite ,quartz from Off Tohoku to off Ibaragi Prefecture .(Refer Nakamura 2008 tomography)

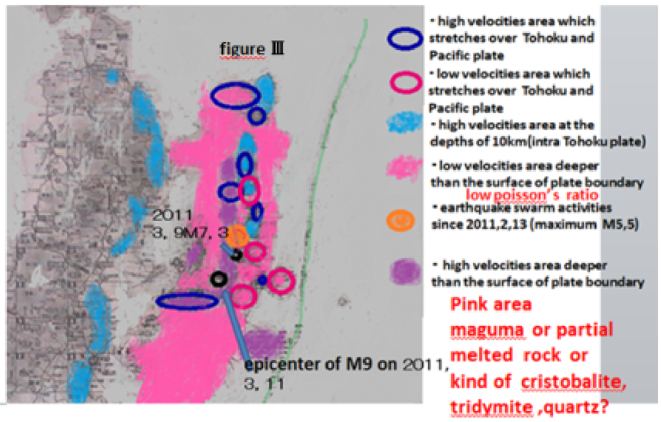
In the low velocities area above mentioned there exisits high velocities area from north (off Kamaishi) to south(around the epicenter of M9 on 2011,3,11)about 250km long about 20km wide from east to west.

Deep blue oval indicates the high velocities area which stretches over Tohoku Plate (upper) and Pacific Plate (under), and red oval indicates the low velocities area which stretches over the upper and under plates.

Near the latter area, foreshock of M9 on3,11 swarm activities since13 in February in 2011 (maximum 5,5M),M7,3 on 9 ,the main shock of M9 on 11th in March in 2011 occurred.

This ductile low velocities area pushed by following Pacific plate may be pressed flat and push up and stick to the upper plate (Tohoku plate) .In addition to strong sticking ,stretching over the upper and under plates of high and low velocities areas ,**this flexibility of huge low velocities area may have made earthquake activities seldom before M9 of 3,11 in 2011 and this may have had it difficult to find out the huge asperity of M9**.





Japan Geoscience Union Meeting 2013
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Seismic surveys of the earthquake faults appeared at the Fukushima-ken Hamadori earthquake

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Remarkable surface raptures appeared along the Itozawa fault and Yunodake fault at the earthquake (M7.0) on April 11th, 2011, in Iwaki city, Fukushima prefecture. This earthquake is considered as an induced earthquake of the 2011 Tohoku earthquake (M9.0). We conducted seismic surveys along three lines which cross the Itozawa fault (line1) and Yunodake fault (line2) respectively and extension area of the Yunodake fault (line3). The length of line1, 2, 3 are 6.6km, 6.5km and 4.2km, respectively. The seismic source was two - four Envirovibes. Intervals of source and receiver were 10m, respectively, and two sweeps were stacked at one source point for the three lines. In line1 and 2, intervals of source and receiver were 5m within 1km from the surface raptures of faults for high resolution survey and ten sweeps were stacked at 40m interval of source for deep reflection and refraction surveys. The source-receiver spreads were fixed for all receivers of each line. In line1, continuous reflectors are not seen in the shallower part and fault structure is difficult to identify. The CMP stacked time section is relatively more reflective to the east of the surface rapture and lacks continuous reflectors to the west of the surface rapture between 0.3s and 1.5s in two way time. This may show the inner condition of the basement rock. In deeper part, amplitude of reflectors decreases below 7km in depth. This boundary corresponds to the intensive area of hypocenters of aftershocks. In line2, a sedimentary basin is well imaged in the area of Tertiary and Quaternary sediments. The top of the basement shows complicated shape and reaches 700m in depth. Two small anticlines are recognized in the sedimentary layers. The velocity structure by ray tomography corresponds very well to the sedimentary structure by the reflection survey. In line3, the basement is 500m deep at the southern edge, almost flat and gently dips at two parts on the way northward and 800m deep at the northern edge. The sediments gently dip northward. Stratigraphic throws are not perceived on the whole seismic section of line3.

Keywords: Fukushima-ken Hamadori earthquake, Itozawa fault, Yunodake fault, Subsurface structure, Seismic survey

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Seismic imaging of the 2011 Iwaki earthquake area: Effect of Pacific slab dehydration on the rupture nucleation

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The 2011 Iwaki earthquake (M7.0) occurred on 11 April 2011 and it was a crustal earthquake with normal faulting along the Idosawa fault. Such a large earthquake was not expected at this fault before the Iwaki earthquake took place. In order to understand the generation mechanism of this earthquake, we need to study the detailed 3-D crustal and upper-mantle structure of the earthquake source area.

Tong et al. (2012) determined 3-D tomographic images of the crust and upper mantle in and around the source area of the Iwaki earthquake. Their results show that the Iwaki earthquake and its aftershocks mainly occurred in a boundary zone with strong variations in seismic velocity and Poisson's ratio, and prominent low-velocity anomalies are revealed in the lower crust and upper mantle under the Iwaki source area, which may reflect fluids released from dehydration of the subducting Pacific slab. Many previous studies have found that crustal fluids played an important role in the nucleation of large crustal earthquakes in the Japan Islands (e.g., Zhao et al., 1996, 2010; Wang and Zhao, 2006a, b; Cheng et al., 2011; Gupta et al., 2011; Padhy et al., 2011). It was suggested that the 2011 Iwaki earthquake was generated by a similar mechanism (Tong et al., 2012).

In this study, we selected 6912 earthquakes which occurred during a period from Jun. 2002 to Nov. 2012, which is over 1 year longer than the study of Tong et al. (2012. These earthquakes were recorded by the combined seismic network in Japan, and carefully selected based on the following criteria: (1) all the events ($M>1.5$) were recorded by more than 30 seismic stations; (2) to keep a uniform distribution of hypocenter locations and avoid the event clustering, we divide the study area into small blocks, and selected only one event in each block that was recorded by the maximal number of stations; (3) the uncertainty in the hypocentral location is < 4.0 km. As a result, 6912 events were selected that were recorded by 139 seismic stations in the study area. Different from Tong et al. (2012), we removed the offshore earthquakes which occurred over 20 km away from the Pacific coastline, because those events are located outside the seismic network and so they have poor hypocentral locations. Finally we used 163585 P-wave arrival times and 150182 S-wave arrival times from 5099 earthquakes recorded by 139 seismic stations. We have applied the tomographic method of Zhao et al. (1992) to our data set. The horizontal grid interval is 0.08 deg. in the Iwaki earthquake area and 0.15 deg. in the surrounding region. The final root-mean-square travel-time residual is 0.171 s for the P-wave data and 0.342 s for the S-wave data.

The obtained tomographic images are generally similar to those by Tong et al. (2012), while our present results have a better resolution and reliability. Prominent low-velocity anomalies are revealed in the crust and the upper-mantle wedge under the volcanic front, which reflect the arc-magma related hot anomalies. Fine low-velocity anomalies are also revealed very clearly in the lower crust and upper mantle under the Iwaki hypocenter as well as beneath the active Futaba fault which is located right beside the Fukushima Nuclear Power Plant (FNPP). We consider that these low-velocity anomalies reflect fluids from the dehydration of the subducting Pacific slab. The great 2011 Tohoku-oki earthquake (Mw 9.0) induced static stress change in the overriding Okhotsk plate, resulting in significant increase of seismicity in the Iwaki source area after the Tohoku-oki mainshock. Our results support the suggestion of Tong et al. (2012) that the Iwaki earthquake was triggered by the ascending fluids from the Pacific slab dehydration and the crustal stress variation induced by the Tohoku-oki mainshock. The similar structures in both the Idosawa and Futaba fault zones suggest that the security of the FNPP site should be strengthened to withstand a potential large earthquake in the future.

Keywords: Seismic tomography, The 2011 Iwaki earthquake, Crustal fluid

SSS26-P07 Room:Convention Hall Time:May 19 18:15-19:30

The basement structures of the northern Noto Peninsula based on the gravity anomalies

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Upper crustal block structures are usually defined by using surface information, such as geological and morphological data. The northern Noto Peninsula, central Japan, is divided into four geological block structures from tectonic geomorphological perspectives (Ota and Hirakawa, 1979). This division is based on the surface crustal movement. To image the geological blocks three-dimensionally, it is necessary to construct a subsurface structure model. Gravity survey can clarify the detailed subsurface structure with dense gravity measurement.

We compiled the data measured and published previously (Honda *et al.*, in press; Gravity Database of Southwest Japan, 2001; Geological survey of Japan, 2004; Geographical survey institute of Japan, 2006; The Gravity Research Group in Southwest Japan, 2001; Komazawa and Okuma, 2010; Hokuriku Electric Power Company, undisclosed) and calculated Bouguer anomaly in the northern Noto Peninsula. Based on this Bouguer anomaly, we analyzed subsurface density structures along 13 northeastern-southwestern profiles and 35 northwestern-southeastern profiles with the interval of 2 km using the two dimensional Talwani's method (Talwani *et al.*, 1959). In the analysis, we assumed a density structure with four layers: basement (density is 2670kg/m^3), Neocene volcanic rock (density is 2750 kg/m^3 or 2400 kg/m^3), Neocene sedimentary rock (density is 2200 kg/m^3), and Quaternary sedimentary rock (density is 1800 kg/m^3 or 1500 kg/m^3) (Honda *et al.*, 2008).

After the last presentation (Mizubayashi *et al.*, 2012), we improved the analyses results of the basement structure and verified the results. The method to construct the 3D basement structure by compiling many 2D structure profiles was not verified for the accuracy. We constructed the 3D block basement structure model from many 2D structure profiles, and compared the theoretical gravity anomaly from the 3D block model with the observed gravity anomaly. The verification of above method indicates that the pseudo 3D basement structure by compiling many 2D structure profiles reproduct the observed gravity anomaly not on the profiles but on the plane. Therefore our result of the basement structure calculated by 2D Talwani's method has the enough accuracy.

Acknowledgments
We thank to Gravity Database of Southwest Japan, Geological survey of Japan, Geographical survey institute of Japan, The Gravity Research Group in Southwest Japan and Hokuriku Electric Power Company for providing gravity data.

Keywords: gravity anomaly, Noto peninsula, basement structure

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Basal boundary depth of the Kazusa Group and its equivalents in the Kanto Plain inferred from seismic interferometry

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Sedimentary structure in the Kanto Plain has been investigated by using many geophysical approaches (e.g. seismic reflection survey). However, mainly because of the insufficient investigation point in the target area, there is still ambiguity in the local variation of sedimentary structure. In this study, we investigated the depth distribution of the basal boundaries of the Kazusa Group and its equivalents from the seismic interferometry of strong motion records.

Seismic waveforms of 231 local earthquakes recorded by the local seismic networks (MeSO-net, SK-net, SUPREME, K-NET, etc) were analyzed in this study. The autocorrelation function of SH displacement waveform from a single event was stacked for all events available at each station to obtain the reflection response of S-waves for shallow underground structure. In many reflection responses, we observed clear S-wave reflections from the basal boundaries of the Kazusa Group and its equivalents. These reflection phases are observed most clearly in the reflection responses from MeSO-net stations where a borehole seismometer is deployed at the depth of about 20 m. This result shows that the seismic interferometry of local earthquake waveforms is quite effective for investigating the sedimentary structure even in the densely populated area with high ground noise.

The depth of the basal boundaries of the Kazusa Group and its equivalents shows large local variations. For instance, the depth is shallow ($<$ 1.5 km) in the Kanagawa area and increases up to about 1.5 km towards the Tokyo area along the Tsukuba-Fujisawa observation line of MeSO-net. In contrast to this, we may summarize by the data analysis over whole target area that the lowest level of the basal boundaries of the Kazusa Group and its equivalents in the Kanto Plain (about 2 km) is located around Chiba City in the Boso Peninsula. We plan to show several sheets of the pseudo seismic reflection profile from the seismic interferometry to discuss the depth of the basal boundaries of the Kazusa Group and its equivalents in detail at poster presentation.

ACKNOWLEDGMENTS
Data provided by MeSO-net and SK-net are gratefully acknowledged. We thank Tokyo metropolitan government, Chiba, Gunma, Ibaraki, Kanagawa, Saitama, and Tochigi Prefecture, and Yokohama City. We also thank Earthquake Research Institute,University of Tokyo, Japan Meteorological Agency, National Research Institute for Earth Science and Disaster Prevention, and Tokyo Gas Co., Ltd.

Keywords: seismic interferometry, Kanto Plain, sedimentary structure, Kazusa Group

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Attenuation structure beneath the Tokai region, Central Japan using a spectral ratio method

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Slow earthquakes including Low frequency earthquake(LFE), Low frequency tremor, and Long term slow slip(LTSS) were reported in the central part of the Tokai district, central Japan. Slip rate and slip direction of LTSS were estimated by geodetic data. Slow earthquakes were suggested that they occurred by high-pressure fluid by analyzing the seismic velocity and the seismic attenuation. A Qp/Qs value is reported to be a sensitive and important indicator of water-saturation condition by experimental study. To clarify the spatial variation of physical properties in this region, we developed a new spectral analysis method and applied it to the waveform spectra for estimation of a seismic attenuation structure. In the shallow depths from the surface to 15 km, we found that there is a relatively low Qp/Qs and high Qs zone in the west side of Median Tectonic Line(MTL) whereas there is a relatively high Qp/Qs and low Qs zone in the east side of MTL. In lower crust of the land plate at depths of 15km to 25km low Qp/Qs and high Qs zone exists just above the region where large slip rates were observed during the LTSS between 2001 and 2005. On the contrary, the region just beneath the large slip zone has high Qp/Qs and low Qs. Comparing our result with a Qp and a seismic velocity structure derived from travel time tomography, we found the low Qp/Qs and high Qs zone approximately coincides with a zone of relatively high Qp and high velocity. Otherwise the zone of relatively high Qp/Qs and low Qs corresponds to a zone of low Qp, low velocity, and high VP/VS. A high Qp/Qs, low Qs, low Qp, low velocity, and high VP/VS can be interpreted as the zone which involves high-pressure fluid. Probably the low Qp/Qs and high Qs zone above the large slip zone works as a cap rock and prevent the fluid from moving upward, and then the fluid pressure becomes high and it affects the occurrence of slow slip in this region.

Keywords: Atteunuation structure, spectral ratio method, Q value, Tokai region, Slow slip

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3-D structure of the locked-sliding transition on the plate boundary beneath the southern part of Kii Peninsula

Eiji Kurashimo[1*], Takashi Iidaka[1], Takaya Iwasaki[1], Atsushi Saiga[2], Noriko Tsumura[3], Shin'ichi Sakai[1], Aitaro Kato[1], Fumihito Yamazaki[4], Kaoru Miyashita[5], Takuo Shibutani[6], Kiyoshi Ito[7], Tetsuya Takeda[8], Kazushige Obara[1], Naoshi Hirata[1]

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The Nankai trough region, where the Philippine Sea Plate (PHS) subducts beneath the southwestern Japan arc, is a well-known seismogenic zone of interplate earthquakes. The most recent great earthquakes occurred in 1944 (Tonankai Earthquake, M=7.9) and 1946 (Nankai Earthquake, M=8.0). Detailed crustal and upper mantle structure of the subducting PHS and the overlying southwestern Japan arc are important to constrain the process of earthquake occurrence. A series of active and passive seismic experiments were undertaken in 2004, 2009 and 2010 to obtain a structural image beneath the southern part of Kii Peninsula, southwestern Japan. In November 2004, two active seismic experiments were conducted (Ito et al., 2005; Kurashimo et al., 2005). One was carried out along a 195-km-long seismic line between Shingu and Maizuru (S-M line) in the north-south direction and the other was carried out along a 60-km-long seismic line between Otou and Kumano (O-K line) in the east-west direction. The 2009 passive seismic array observation was carried out along a 60-km-long seismic line between Minabe and Shimokitayama (M-S line) in the east-west direction (Kurashimo et al., 2010). In October of 2010, a deep seismic reflection profiling was conducted along the M-S line (Kurashimo et al., 2011). In order to obtain a three dimensional structural image beneath the southern part of Kii Peninsula, these active and passive seismic dataset are useful. Permanent seismic stations observed the controlled seismic signals as well as natural earthquakes. We combined the seismic array data with permanent seismic station data. The arrival times for the first P- and S waves obtained from local earthquakes and explosive shots were used in a joint inversion for earthquake locations and three-dimensional Vp and Vp/Vs structures, using the iterative damped least-squares algorithm, simul2000 (Thurber and Eberhart-Phillips, 1999). The seismic velocity structure shows that the high Vp zone (>7.5 km/sec) exits below about 25 km depth beneath the western side of the M-S line. This high Vp zone extends to the southward. Deep low frequency tremors are located outside of the high Vp zone and those are located in and around the high Vp/Vs zone.

Acknowledgement: We wish to thank the National Research Institute for Earth Science and Disaster Prevention and the Japan Meteorological Agency for allowing us to use their waveform data.

Keywords: philippine sea plate, seismic tomography, transition zone, nonvolcanic deep low frequency tremor

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Three-dimensional attenuation structure beneath Kii Peninsula

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Kii Peninsula is located near the seismogenic subduction zone where earthquakes along the Nankai Trough have been repeated in the interval of 100 to 150 years. Shallow earthquake swarm occurs at the northern part of Wakayama and non-volcanic deep low-frequency tremors were observed at the depths around 30-40 km from Ise Bay to Kii Cannel [Obara,2002]. Therefore, the Kii Peninsula is an area that is an area that is attracting attention from both sides of the disaster prevent and tectonics. Attenuation factor Q is considered to be the parameter which is sensitive to the physical properties such as rock type, temperature, fluid and so on. Then, we estimated source parameters of earthquakes, Q, amplification factor of seismic stations using the combined inversion method [Tsumura et al.,2000].

We picked 4339 P arrivals of 125 earthquakes to elucidate the subsurface structure beneath Kii Peninsula, and calculated amplitude spectra for time windows 1s by using FFT. The study area was divided into 480 blocks, each having a frequency independent Q. The study area is 134.75E-136.85E and 33.3N-34.75N, and the region is divided into 6 layers of 0-5, 5-10, 10-20, 20-35, 35-50, 50-80 km for the depth direction.

First, we made a checkerboard test to clarify the spatial resolution of the results obtained by the inversion. As a result, pattern of high and low Q are well recovered in the southern part of 34.45N in the top layer. In the second layer and third layer generally good resolution was seen in the southern part of 34.25N. Although good resolution area is limited below the fourth layer, estimated Q for the region where low-frequency tremors occur in shows better estimation. We will add another ray paths that penetrate the top and second layers and try to improve the resolution for the region where shallow earthquake swarm occurs. Detailed attenuation structure estimated from actual spectra will provide us a new information about physical properties for the tremors and the eaarthquake swarm areas.

Keywords: non-volcanic deep low-frequency tremors, Kii Peninsula, Q value, attenuation, tomography

SSS26-P12 Room:Convention Hall Time:May 19 18:15-19:30

The seismicity and the seismic velocity structure in the Northern Kinki District

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Micro-seismicity in the Northern Kinki District is active. However we do not know the cause and the relation between these seismic activities and crustal structure or active faults around there clearly.

In/around the Northern Kinki District, we are carrying out a dense array seismic observation using many temporary stations; 45 stations since November 2008 and additional 37 stations since April 2010.

The average station internal at the center of Tamba plateau is about 5km, so we expect to know the seismic structure beneath this region with higher resolutions than that derived from the permanent stations.

In this study, we estimate high-resolution seismic velocity structure using data from this dense observations. We will show the results of 3D seismic velocity tomography and discuss about the relations between the seismic activities and other geophysical and geological features of this area.

Keywords: the Northern Kinki District, seismic structure, seismic velocity tomography

SSS26-P13 Room:Convention Hall Time:May 19 18:15-19:30

Evaluation of earthquake amplification characteristic and seismogenic layer by in-situ deep underground rock properties

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1. Introduction

We drilled boreholes to the maximum depth of 2,000 m and measured underground rock properties continuously from ground surface to 2,000 m deep by various geophysical logging in near the root of the Sadamisaki peninsula in western Shikoku where very hard crystallite schist of the Sanbagawa belt is distributed over ground surface. We report results of examination about earthquake amplification characteristic and the depth of seismogenic layer.

2. Outline of survey

(1) Deep drilling of boreholes

2,000 m and 500 m deep (for seismic observation)

(2) Geophysical logging

P and S wave velocity logging (downhole method, sonic logging), density logging, geothermal logging

3. Results and Discussion

(1) Earthquake amplification characteristic

In drilling site, reclaimed layers and weathered rocks are distributed from ground surface to 50 m-deep and from 50 m to 2,000 m deep fresh and hard crystalline schist continue. In addition, there was no loss of drilling fluids.

S wave velocity is 2.2-2.6 km/s (50-620 m), 3.0 km/s (620-1,280 m), 3.3 km/s (1,280-2,000 m) by S wave velocity logging (downhole method) and it is the almost same by sonic logging. The depth of 2,000 m is equivalent to seismic bedrock.

Density is 2.7-3.0 g/cm^3 (50-2,000 m) by density logging. Although density changes according to lithology, there is no tendency to increase or decrease globally to the depth direction.

As a result of examining the earthquake amplification characteristic using the ground structural model set up from in-situ velocity and density structure, the transfer function from seismic bedrock (depth of 2,000 m) to the rock near ground surface is around 1, and seismic waves are hardly amplified.

In the future, we are going to improve the accuracy of evaluation about the earthquake amplification characteristic further by seismic observation with vertical array.

(2) Seismogenic layer

P wave velocity is 4.6-5.0 km/s (50-620 m), 5.2 km/s (620-1,280 m), 5.5 km/s (1,280-2,000 m) by P wave velocity logging (downhole method) and it is the almost same by sonic logging. It is supposed that the upper surface of seismogenic layer correspond to the layer which P wave velocity indicate about 6 km/s (for example, Irikura and Miyake, 2001; Yoshii and Ito, 2001; Hirose and Ito, 2006) and it is presumed that the upper surface of seismogenic layer in this study site is deeper than 2 km deep.

Geothermal gradient from 300 m to 2,000 m deep where we can disregard the influence of the seasonal variation of temperature is 2.81 ^{o}C/100m and geothermal in 2,000 m deep is 73.2 ^{o}C by geothermal logging. Heat flow calculated from thermal conductivity of boring cores is 74 mW/m^2, and it is presumed that the depth of D90% equivalent to the undersurface of seismogenic layer is about 15 km deep according to Tanaka (2004).

According to the catalog of the Japan Meteorological Agency, the generating depth of crustal earthquakes around this study site is about from 2 km to 12 km. Moreover, the under surface of seismogenic layer around this study site is about 15 km deep according to the Earthquake Research Committee (2011). These knowledge is adjusted with evaluation by in-situ deep underground rock properties in this study.

From these examination, it is estimated that the upper surface of seismogenic layer in this study site is deeper than 2 km deep, and the undersurface is about 15 km deep.

Keywords: earthquake amplification characteristic, seismogenic layer, deep underground rock properties, seismic velocity structure, heat flow

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Depth distribution of the Moho discontinuity beneath Kyushu, Japan, as derived from receiver function analyses

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In Kyushu, Japan, the crust is intricately moving and deforming under the influence of the subducting Philippine Sea plate, faulting of the Median Tectonic Line, and back-arc spreading. How those affect the movement and deformation of the crust is still controversial. Crustal thickness is affected by strain of the crust and flow of the mantle, which are keys to understanding tectonics and volcanism. We estimated the depth distribution of the Moho beneath Kyushu with receiver functions (RFs).

We used teleseismic waveform data obtained at stations of Hi-net established by National Research Institute for Earth Science and Disaster Prevention, and stations of the J-array established by Japan Meteorological Agency, Kyushu Univ., Kagoshima Univ., and Kyoto Univ. We calculated RFs with the extended-time multitaper method (Shibutani et al., 2008, BSSA). We stacked the RFs with a 3-d velocity structure estimated by Matsubara et al. (2008, Tectonophys.) and constructed an E-W cross-section at every 0.1 degrees of latitude from 31^{o}N to 34^{o}N.

We tried to estimate the depth distribution of the Moho beneath Kyushu from the cross-sections. Beneath the region south of 33^{o}N and east of 131^{o}E, the depth distribution was not estimated because we did not detect RF peaks corresponding to the phases converted at the Moho.

In the region between 31^{o}N and 32^{o}N, the Moho exists shallower than 35 km. In the region between 32^{o}N and 33^{o}N, the Moho exists deeper than 35 km beneath the part south of the Futagawa-Hinagu faults, and it exists at 30-35 km in depth beneath the part north of the faults. In the region between 33^{o}N and 34^{o}N, the Moho exists deeper than 35 km beneath the part west of 130^{o}E and northeastern part of the area between 130^{o}E and 131^{o}E, and it exists at 30-35 km in depth beneath the part east of 131^{o}E and southwestern part of the area between 130^{o}E and 131^{o}E.

In the region east of 130.3^{o}E, the Moho depth beneath the part south of 32^{o}N is 5 km shallower than that beneath the part north of 32^{o}N. Takayama and Yoshida (2007, JGR) analyzed GPS data observed in 1998-2002, and indicated that the part south of 32^{o}N displaces toward southeast and extends in SE-NW direction, and the part north of 32^{o}N does not largely displaces toward southeast. They interpreted that back-arc spreading and retreat of the slab cause the crustal extension. The crustal thinning would be caused by the crustal extension.

In the region west of 131^{o}E, the Moho is uplifted 5-10 km in a belt-like area parallel to the Futagawa-Hinagu faults. One side of the belt corresponds to the Futagawa-Hinagu faults and the Beppu-Shimabara graben exists in the area. The width of the belt is 70-80 km. Based on gravity data, Tada (1993, Mem. Geol. Soc. Japan) indicated that the Moho is uplifted at most 10 km in the region between 25 km north and 25 km south of Shimabara peninsula. Our finding of the uplift of the Moho is corresponding to the results of Tada (1993), and mantle upwelling can exist there.

Keywords: Kyushu, Moho, receiver function

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Re-analysis of Gravity Anomaly around the Tertiary forearc basin of Miyazaki Plane

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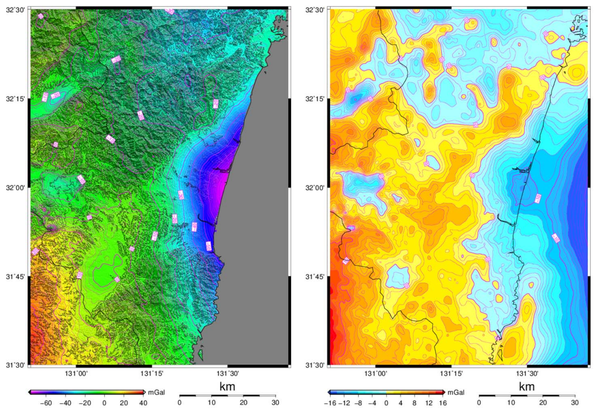
This paper describes structure of the Tertiary forearc basin of the Miyazaki Plane in Southwest Japan based on re-analysis of Gravity Anomaly. Gravity data sets used were 1) free-air anomalies restored from data included in a gravity measurement database in 'Gravity CD-ROM of Japan, Ver.2' (GSJ, 2004), and 2) free-air anomalies compiled in 'Gravity Database of Southwest Japan' (Shichi and Yamamoto, 2001). After Bouguer anomaly was calculated with average density of 2.35 g/cm3. Short-wavelength residuals of the Bouguer anomaly due to shallow (upper crustal) structures were derived by removing long-wavelength trends calculated by means of upward continuation. The length (height) of continuation was 3 km, so the residuals may represent geological structures shallower than 1-2 km. The short-wavelength Bouguer anomaly map shows NE-SW trending line associated with the geological structure, and distribution of the Miyazaki group filling the forearc basin. The steep gravity gradient that substantially coincides with the western margin of the Miyazaki group, forms some curve convex to the west, suggest that the Tertiary forearc basin is divided into the northern, central and southern basin.

Keywords: forearc basin, Gravity Anomaly, Coparison of Variance of Upward Residual, steep gravity gradient



Bouguer anomaly map with an assumed density of 2.35 g/cm3 short-wavelength Bouguer anomaly map

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P-wave velocity anisotropy in oceanic lower crust near the Ogasawara Plateau

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Ogasawara Plateau which is a large plateau with a radius of 150-200 km on the northwestern Pacific Basin is located near the plate boundary to the Philippine Sea Plate. Our multi-channel seismic surveys revealed that the Ogasawara Plateau is not wholly subducting under the Philippine Sea Plate and is colliding to an edge of the plate. Flat seafloor to the southeast of the plateau preserves magnetic lineation patterns indicating presence of oceanic crust in the area. From the result of seismic refraction surveys with ocean bottom seismographs and multi-channel seismic reflection surveys conducted on survey lines perpendicular (OGr13) and parallel (OGr16) to the magnetic lineation.

Though an average P-wave velocity in a lower crust of a constructed OGr13 velocity model is 6.9km/s, a constructed OGr16 velocity model shows an average P-wave velocity of 6.5 km/s in a lower crust involving seismic velocity reversals.

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Wide-angle OBS velocity structure and gravity modeling along the SAHKE transect, lower North Island, New Zealand

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As part of the Seismic Array HiKurangi Experiment (SAHKE) project, we acquired wide-angle reflection / refraction seismic data using ocean bottom seismometers (OBSs) along a transect across the southern North Island of New Zealand, where the Hikurangi Plateau, an early Cretaceous large igneous province, which subducts westward beneath Wellington, the capital city of New Zealand. The SAHKE project was designed to investigate the physical parameters controlling locking at the plate interface beneath the southern North Island and characterize slip processes in a major segment of the Hikurangi system. We deployed 16 OBSs with 5 km spacing off the east coast and 4 OBSs with 10 km spacing off the west coast. Controlled airgun sources were shot at every 100 m along a 350 km onshore-offshore transect. Although data from OBSs at shallow depths (~100 m) contain large amplitude ambient noise, first arrivals from the airgun sources can be traced up to over 100 km offset on record sections of most OBSs. We applied first-arrival travel-time inversion in order to obtain P-wave velocity structure along the 80 km-long OBS profile off the east coast. Starting with a simple stratified velocity model including subduction structure, we iteratively revise the initial model and put more constraints on the first arrival picks. The velocity structure to ~20 km depth was resolved, and the down going slab was clearly imaged. We picked travel times of reflected waves, and projected reflection points by applying a travel-time migration method using the first arrival velocity model. Reflection interfaces including the plate interface, a prominent phase that may represent the base of the Hikurangi Plateau and an interface between the upper and lower crusts are imaged. These interfaces can also be traced westward beneath the Wellington Region and consistent with observations from onshore active source data. We also observed P-wave arrivals with very fast apparent velocities (> 8.5 km/s) on the eastern-most OBSs, at offsets larger than ~120 km. These arrivals are not reversed but can be explained as a refractions from the base of the Hikurangi Plateau crust beneath the Chatham Rise or as an eclogite layer within lower crust. We use gravity data and Vp-density relationships to test the hypothesis that the lower crust of the Hikurangi Plateau has transformed to eclogite.

Keywords: Hikurangi subduction zone, Hikurangi Plateau, active seismic survey, ocean bottom seismometer

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Does the crustal flow intrude into the Longmen-Shan fault zone in the southeastern Tibetan plateau?

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The Longmen-Shan range front, characterized by convergent mountain building with a greater topographic gradient than anywhere else on the Tibetan Plateau, lies in a conjunctional area between the northwestern Songpan-Ganze terrane and the Sichuan foreland basin. The Songpan-Ganze fold system has obliquely collided with the Sichuan foreland basin, resulting in three large reverse-thrust and strike-slip faults along the Longmen mountain region with 250?300 km extents, including the Guanxian-Jiangyou fault (fore fault), the Yingxiu-Beichuan fault (central, principal fault), and the Wenchuan-Maowen fault (rear fault), oriented from southwest to northeast across the fault zone (Figure 1). The Longmen-Shan fault zone is one of the most extensively studied areas in the world, yet its deformation model and seismic generating mechanism remain subjects of vigorous debate. This paper presents a new three-dimensional (3-D) velocity model determined using 136,795 P and Pn phases and 121,292 S and Sn phases from 16,142 local earthquakes, together with two-dimensional (2-D) magnetotelluric (MT) profiles from previous studies, to investigate the nuclei of crustal deformation and earthquake generation along the reverse-thrust and strike-slip fault zone. It has been observed that anomalously low velocity, with low resistivity relative to the Sichuan foreland basin, is in sharp contrast to high-velocity and high-resistivity anomalies in the Songpan-Ganze block in the upper crust. The tomographic model presented here reveals two crustal bodies with anomalously low velocity and high conductivity underneath the Longmen-Shan fault zone, which is separated into three contrasting segments by the bodies. These low-velocity and low-resistivity bodies have been interpreted as being associated with extrusion of either fluids or products of partial melting from the lower crust, the upper mantle, or both. This suggests strong variations in the rheological strength of the rock along the fault zone. This finding implies that the coupling between these presumably fluid-bearing bodies and earthquake generation could be extremely complex and that there is dramatic variation from the southwestern portion to the northeastern segment along the fault belt. It is suggested here that this complex and variable deformation system along the fault zone played a principal role in controlling seismic generation and rupturing during the 2008 Wenchuan earthquake (Ms 8.0) and that it will do so again during possible future earthquakes in the region.

Keywords: Crustal flow, Crustal deformation, Longmen-Shan fault zone, seismic tomography, Crustal stress, continental colliding