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


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.

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# 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

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# 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

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

Yukio Oishi[1]*

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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 .

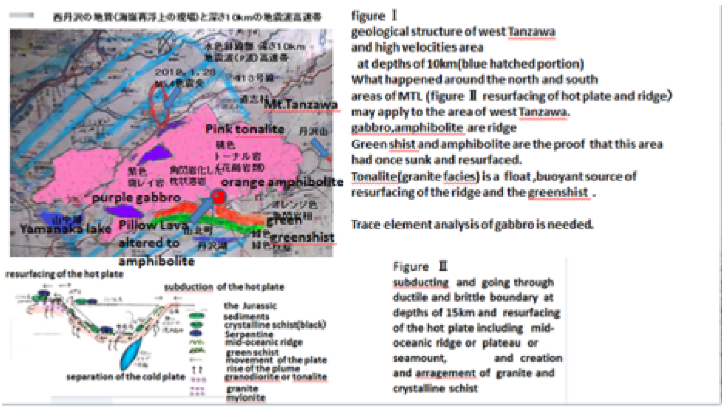
This huge **law velocities area's poisson's ratio is also law**. The similar area exists in Unzen in Nagasaki Prefecture from the ground to at the depths of about 30km and about 30km wide from east to west. That means the possibility of the existence of fluid maguma or a mass of **partial melted rock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

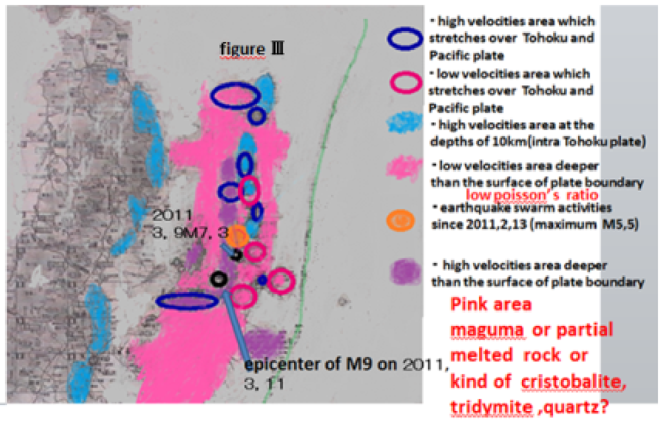
In the low velocities area above mentioned there exisits high velocities area from north (off Kamaishi ) to south(around the epicenter of M9 on 2011,3,11 )about 250km long about 20km wide from east to west.

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**.



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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

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# 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

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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

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# 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

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# 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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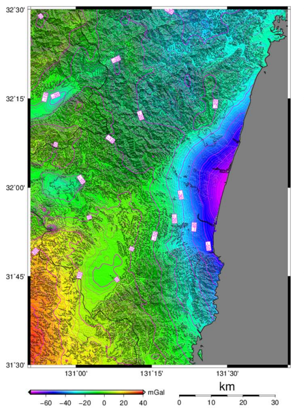
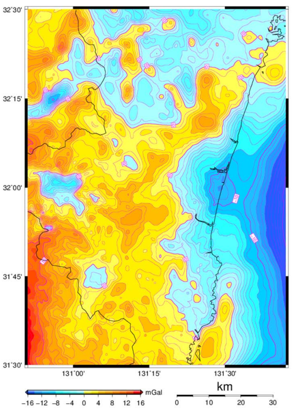
This paper describes structure of the Tertiary forearc basin of the Miyazaki Plane in Southwest Japan based on re-analysis of Gravity Anomaly. Gravity data sets used were 1) free-air anomalies restored from data included in a gravity measurement database in 'Gravity CD-ROM of Japan, Ver.2' (GSJ, 2004), 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