Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS031-01 Room:105 Time:May 23 10:45-11:00

Reflection from the subducting Pacific plate detected by MeSO-net

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The subducting plate interface generates various secondary seismic waves by conversion, reflection, and scattering. These seismic waves are useful to resolve the configuration and impedance contrast of the plate interface.

Twenty years ago, Obara and Sato (1988) and Obara (1989) found the reflected wave from the top boundary of the subducting Pacific plate beneath the Kanto region within the later coda part of shallow earthquakes. Based on the high-sensitivity seismograph network operated by the National Research Institute for Earth Science and Disaster Prevention, the reflector was located at depth ranging from 70 to 120 km just beneath the Tokyo metropolitan area. The reflection coefficient was very high, suggesting the existence of the fluid.

The Earthquake Research Institute, the University of Tokyo has been constructing the Metropolitan Seismic Observation network (MeSO-net) as a part of "Special Project for Earthquake Disaster Mitigation in the Tokyo Metropolitan Area" promoted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. The spacing of MeSO-net stations is from 2 to 5 km, therefore, the waveform pattern is quite coherent between neighbor stations even though high noisy area. By using the MeSO-net data, we investigated the reflected wave from the top boundary of the Pacific plate.

According to the previous studies, we selected earthquakes with depth shallower than 40 km and magnitude greater than 3 in the Kanto and Tokai area. The reflected wave is most predominant in the frequency range from 4 to 16 Hz. Therefore, we applied the band pass filter to the MeSO-net accelerometer waveform data and plotted pasted-up seismograms recorded at some linear station arrays. In order to find the reflected wave easily, the theoretical arrival time is also plotted on the paste-up seismograms.

The reflected wave is clearly observed for earthquakes that occurred west of Tokyo. The arrival of the reflected wave is very unclear and the amplitude gradually increased. The duration of the reflected wave is sometimes longer than 10 seconds. The reflection points having very clear reflected waves are distributed beneath from Tokyo Bay to eastern Kanagawa area. The arrival of the reflected wave is generally coincident with the theoretical arrival time; however, there are some fluctuations. This may indicate that the reflector has some topographic change. The long duration of the reflected wave may be explained by the back scattering with a strong reflector or thick reflective layer at the top of the slab.

Keywords: Pacific plate, Reflection, MeSO-net

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS031-02 Room:105 Time:May 23 11:00-11:15

Plate structure below the Boso Peninsula, central Japan, estimated from converted waves observed by the MeSO-net (2)

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The Philippine Sea plate (PHS) is subducting below the Kanto region, central Japan. The great 1923 Kanto earthquake (M7.9) occurred on the PHS and its largest aftershock (M7.6) occurred in the next day of the mainshock off the Boso Peninsula, southeastern Kanto. Knowledge about the factors which control source regions of these phenomena is important to reveal their generation mechanisms. Converted waves are often observed between P and S arrivals for earthquakes off the Boso Peninsula. Detailed examination of numerous seismograms and seismic survey revealed that they are converted at the submarine volcaniclastic and volcanic rock layer (hereinafter, VCR-layer) widely distributed on the PHS (Kimura et al., 2010). Recently, dense seismographic network, called 'MeSO-net', has been under construction at the Tokyo metropolitan area. In the previous study, we showed that clear later phases are also observed by the MeSO-net and they correspond to the SP converted waves excited at the bottom of the VCR-layer. In this study, we determined a configuration model of the conversion plane by taking advantage of the dense distribution of the MeSO-net.

We determined the configuration model by try and error. Initial velocity model was constructed based on the structure revealed by Kimura et al. (2010). We also considered surface thick sedimentary layer to evaluate traveltimes accurately. For this purpose, we incorporated the subsurface structure of the Japan Seismic Hazard Information Station (J-SHIS) (Fujiwara et al., 2009). We considered layers with Vp smaller than 3800 m/s as sediments and replaced shallow part of our velocity model with J-SHIS model. For analysis, finite difference traveltime calculation program, called 'FAST' (Zelt and Barton, 1998), was used.

We obtained a preliminary model in which the conversion plane has a dipping angle of 45 degree with a strike in the N20E direction at the eastern coast of the Boso Peninsula 18 km depth. This model has the smallest RMS (root-mean-square) of traveltime residuals. In the case that the observed wave is the SP converted wave at the bottom of the VCR-layer, this model shows that the plate boundary of the PHS is dipping westward. SP converted waves were also observed for nearby earthquakes and they can be explained by this model, too.

Such significant undulation of the plate boundary is likely to affect the occurrence of earthquakes. Location of the undulation corresponds to the western edge of the region of repeating earthquakes. The southern extension along the strike of the dipping plane coincides with the boundary between the source regions of the 1923 Kanto earthquake and its largest aftershock. These observations imply that the configuration of the plate boundary controls the distribution of repeating earthquakes and the segment boundary of the great earthquakes. Takeda et al. (2007) made a unified configuration model of the PHS near the subduction entrance (Sagami trough) by compiling previous seismic surveys and showed that the dipping angle of the PHS is larger at the western part of the Sagami trough. Our result is consistent with the result of Takeda et al. (2007), however, our result indicates that the spatial change of the dipping angle is more abrupt. Further study considering the spatial change of the plate boundary structure including the VCR layer is necessary to reveal the plate dynamics in more detail.

Acknowledgements: We used the subsurface structure of the Japan Seismic Hazard Information Station (J-SHIS) (Fujiwara et al., 2009).

Keywords: Kanto region, MeSO-net, converted wave, plate boundary, 1923 Kanto earthquake, segment boundary

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SSS031-03 Room:105 Time:May 23 11:15-11:30

Geometry of the Philippine Sea slab beneath the northeastern part of the Kanto plain, central Japan

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Introduction

Beneath the metropolitan Tokyo, the Philippine Sea plate (PHS) subducts on the Pacific plate. To reveal the interaction of two slabs is significant for understanding the potential of devastative slab earthquake. In June to July 2010, we performed the deep seismic profiling along the Kujukuri-Kasumigaura seismic line at the northeastern part of the Kanto plain to reveal the geometry of down going PHS-slab. To obtain the detailed image of contact part of the two slab, we deployed the linear array of seismometers along Tsukuba-Mito and Kasumigaura-Tsukuba (Kurashimo et al., 2011: JpGU).

Kujukuri-Kasumigaura Seismic line

Onshore-offshore integrated seismic survey was carried out along the off Kujukuri to Kasumigaura. The length of seismic line is about 70 km, including 50 km long onshore seismic line. The used seismic sources were air-guns (3,020 cu. Inch), four vibroseis trucks and dynamite shots (< 200 kg).Seismic signals were recorded by fixed 1520 channel recording system. Shot interval is 100-150 m at onshore line, and 50 m at offshore seismic line. High-energy shots by stationary sweeps of vibroseis trucks, stationary shooting of air-guns and explosives were carried out at 12 locations along the seismic line.

Upper surface of PHS

We made a low-fold stacking section using the high-energy shot records. The depth section was produced using the velocity structure obtained by earthquake tomography observed by MeSo-net data. The obtained seismic section portrays the northward dipping reflectors. At the Kujukuri the depth of the upper surface of the reflectors is 25 km and the reflective part has 5 km thickness. The reflectors can be trace down to the 38 km in depth beneath Kasumigaura.

Shallow sediment layer

On the seismic section, 750 to 1000 m thick Upper Pliocene sediments cover the pre-Tertiary rocks. The upper surface of Pre-Tertiary shows horizontal geometry. At the southern part of the seismic section, the sediments show onlap with northward dipping at 10 degrees. This onlap is result regional uplift of the Boso peningsula in middle Pliocene.

Keywords: Philippine Sea plate, seismic reflection profiling, slab geometry, crustal structure, Kanto, tectonics

Japan Geoscience Union Meeting 2011
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SSS031-04 Room:105 Time:May 23 11:30-11:45

Subsurface structures of active blind thrusts in Kanto plain

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We show subsurface geometry of active blind thrusts in Kanto plain revealed by deep seismic reflection profiles. Moderately dipping blind thrusts are distributed beneath the Kanto plain underlain by several thousand meters thick Neogene sedimentary units. Locations of blind thrusts are well consistent with large gradient of gravity anomaly. Deep seismic reflection profiles corroborate that these blind thrusts are reactivated listric normal faults comprising Miocene half graben. While rates of slip along these structures are commonly slow (~0.1 mm/yr) based on offsets of late Pleistocene terrace deposits, their proximity to the metropolitan area urges more intense effort to identify their potential seismic hazards including locations, sizes, rates of slip, and geometries of blind thrusts.

Japan Geoscience Union Meeting 2011
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SSS031-05 Room:105 Time:May 23 11:45-12:00

Seismic basement S-wave reflection beneath the Tokyo Metropolitan Area inferred from seismic interferometry

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The properties of the seismic basement S-wave reflection beneath the Tokyo Metropolitan Area were investigated by the seismic interferometry. Twenty-seven thousand seismic waveforms of the local earthquakes recorded by the MeSO-net stations and the SK-net stations were analyzed in this study. These waveforms were high-pass-filtered, and then were integrated to be converted to displacement waveforms. After the calculation of the autocorrelation function of each SH displacement waveform with a length of 10 s from the S-wave onset, the autocorrelation functions from all events were stacked at each station to obtain the reflection response of S-waves for shallow underground structure. Our waveform analysis revealed that the seismic basement reflection phase can be found on the most of the reflection responses obtained.

Adopting Qs value in the sedimentary layer reported by Kinoshita and Ohike (2002), we estimated the S-wave reflection coefficient for the seismic basement beneath the Tokyo Metropolitan Area. The magnitude of the reflection coefficient shows a large regional variation, possibly because of the regional difference of the impedance contrast at the seismic basement surface. The values of the reflection coefficient up to 0.5 were estimated in southern Ibaraki Prefecture and northern Chiba Prefecture, whereas the values about 0.1 and less were estimated in Kanagawa Prefecture. Small reflection coefficients observed in Kanagawa Prefecture is likely related to the low S-wave velocity in the seismic basement rocks that are the part of the Shimanto Belt (a Cretaceous-Neogene accretionary complex). Although there is a large scatter in the refection coefficients estimated, it is worthy to note that the magnitude of the reflection coefficient shows apparent depth dependence. The magnitude of reflection coefficient is approximately 0.3 for the seismic basement depth shallower than about 2km. However, the magnitude of the reflection coefficient decreases down to 0.2 and less as the seismic basement depth increases, implying the magnitude of the impedance contrast at the seismic basement surface decreases with increasing depth.

Our result shows that the seismic interferometry for the seismic waveforms of local earthquakes is quite effective for investigating the local variation of the seismic basement S-wave reflection even in the densely populated area with high ground noise.

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, and National Research Institute for Earth Science and Disaster Prevention.

Keywords: seismic interferometry, seismic basement, MeSO-net, SK-net, reflection coefficient

Japan Geoscience Union Meeting 2011
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SSS031-06 Room:105 Time:May 23 12:00-12:15

Examination of integrated velocity model of shallow and deep structure in Chiba Prefecture

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In this study, a detailed microtremor mesurement is executed in respect in the whole area of Chiba Prefecture, and it is examined to upgrade an existing velocity structure model from the S wave velocity structure of the obtained ground and the H/V spectral ratio by microtremor mesurment of single point and microtremor array measurement the purpose is to examine it concerning the ground amplification characteristic in detail. It is one of the important problems to construct about the ground model who is appreciable of seismic ground motion characteristics of the wideband of about 0.1-10 seconds to upgrade the estimation of strong ground motion. It is indispensable to integrate the shallow and deep structure model by whom modeling has been separately executed up to now, and to advance constructing of the model who can reproduce the record of seismic observations. In order to overcome the above problem, we executed a lot of microtremor measurements in and around the sedimentary basins. And we are studying the upgrade of the integrated subsurface structure model by using the phase velocities of the Rayleigh waves and H/V spectrum ratio obtained from the microtremor measurements together with the establishment of the technique itself. In this study, the S wave velocity structure, Q value, and the amplification characteristic were examined in detail.

The method for construction of more best shallow and deep integration structure model is scheduled to be examined by analyzing collaboration inversion by assuming present shallow and deep integration structure model to be an early model, and using the result of the microtremor array and the microtremor of a single point in the future.

Keywords: Integrated structure model, strong-motion, microtremor measurements, S-wave velocity, Q-value

Japan Geoscience Union Meeting 2011
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SSS031-07 Room:105 Time:May 23 12:15-12:30

Surface-wave phase velocity inversion using Markov Chain Monte Carlo method

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Microtremor exploration is often used to know an S-wave velocity profile. This method is especially popular in constructing S-wave velocity model for strong motion estimation. Accordingly many microtremor explorations have been conducted in the Tokyo Metropolitan area in Japan (e.g., Yamanaka and Yamada, 2006). These models must be improved using additional explorations for reliable estimations of strong motion. We must understand resolution of the model parameters for a further improvement of a basin model.

The estimation of surface wave phase velocity and its inversion to S-wave velocity profile is the main technological elements in the microtremor array exploration. The least square methods are the one of the often used techniques in the phase velocity inversion. Heuristic algorithms, such as GA and SA are also frequently used in the inversion (e.g., Yamanaka, 2007). One of the advantages of the heuristic inversion methods is the no requirement of calculation of derivatives of an objective functions and matrix inversions. Therefore the algorithms based on these approaches are so robust and used in various kinds of geophysical and seismological inversions. Although the heuristic methods can globally search model parameters in parameter space, it is sometimes difficult to estimate model sensitivity in these approaches.

Recently Markov Chain Monte Carlo Method (MCMC) is examined to sample model parameters for estimation of probability density function (pdf) of the parameters from random sampling with a statistic way (For example, Iba, 2005). According to Bayesian inference theory, posterior pdf is calculated from a prior pdf of parameters and likelihood function. If we assume a uniform pdf for the prior pdf, we can estimate pdf of model parameters from likelihood function which is proportional to error function. This allows us to estimate model parameters and their resolutions from observed data numerically. In this study I investigate applicability of MCMC method to Rayleigh wave phase velocity inversion using numerical tests, and apply the technique to actual phase velocity data from microtremor explorations in the Kanto basin, Japan.

A 4-layers model for deep sedimentary layers in the Kanto basin is used in the numerical tests. We generate synthetic phase velocity for fundamental Rayleigh waves at periods from 0.5 to 10 seconds, and add noises. The observation errors are included as standard deviation of the synthetic data which are set to be 5 to 40 % of the synthetic data. S-wave velocity and thickness of each layer is used as unknown parameters. The Metropolis-Hastings approach is used in the MCMC calculation. 210000 models were examined in the sampling of the parameters. After deleting initial parts of the sampled data, we calculated average and standard deviations of the sampled parameters for the inverted results. The averages of parameters are close to true ones with exception of slight differences for parameters of the third layers. This implies that the assumed data at periods less than 10 seconds is not enough. We also found that observed phase velocity must be obtained with an observational standard deviation of 10 % for estimation of the parameters with 10 % accuracy.

MCMC method can not find a model with the minimum misfit, but can provide a pdf of model parameters. This is one of the advantages of the MCMC methods over the other heuristic approaches. We will try to use the technique to understand a resolution of 3D S-wave velocity profiles from microtremor explorations in the Kanto basin for future improvements of the basin model. This technique is also attractive in the other geophysical and seismological inversions as a promising tool to estimate resolution of model parameters.

Keywords: microtremor exploration, basin model, surface wave, phase velocity, S-wave velocity, Markov Chain Monte Carlo

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS031-08 Room:105 Time:May 23 12:30-12:45

Ground motion prediction and results utilization for next Tokyo metropolitan earthquakes

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In the Tokyo metropolitan area and its vicinity (almost equivalent to the southern Kanto region), magnitude (M) 8 plate boundary earthquakes, such as the 1923 Taisho Kanto earthquake and the 1703 Genroku Kanto earthquake, occur every 200 years or so. In addition, large earthquakes with magnitudes of 7 occur even during a quiet period of 200 years between neighboring M8 earthquakes or, in particular, its later half of 100 years, causing severe damage to Edo (ancient Tokyo) or Tokyo. These M7 events are called 'Tokyo metropolitan earthquakes.' It is thought that five Tokyo metropolitan earthquakes occurred in the Meiji era for which more documents are available compared with previous eras. Based on this acknowledgement, the Earthquake Research Committee of the Japanese government announced that the long-term probability of the occurrence of a Tokyo metropolitan earthquake within 30 years from the present was evaluated to be about 70%.

In this study, referring to Sakai (2010), we first choose a few Tokyo metropolitan earthquakes with a large occurrence probability and potential influence to the Tokyo metropolitan area. We then make their source models using the recipe of Irikura and Miyake (2011) or other. However, this kind of recipe is mostly for crustal earthquakes (shallow inland earthquakes), though Tokyo metropolitan earthquakes are rather deep plate-boundary or in-slab earthquakes with depths of several tens km. Some parameters and equations in the recipes should be revised accordingly. We then have to make a velocity structure model for the southern Kanto region using the recipe of Koketsu et al. (2009) or other, but we have already constructed the first-grade model (model improved using seismic records) of this region for the long-period ground motion hazard maps 2009. Therefore, we use this model with minimum revisions.

We carry out ground motion simulations for long-period components, compute short-period components by the stochastic Green's function method, and then hybidly combine them into broadband ground motions with a matching period of 2 to 3 s. These results are time-domain waveforms predicted on the engineering bedrock at various sites in the Tokyo metropolitan area. Their response spectra are also provided for the utilization in the fields of engineering and others. In addition, based on our experiences of the long-period ground motion hazard maps, we also make distribution maps of peak ground velocities, seismic intensities, duration time, response spectra at various periods, and so on for further utilization in these fields.

Keywords: Tokyo metropolitan earthquakes, ground motion prediction, results utilization