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

SEM037-01 Room:301B Time:May 26 10:45-11:00

On the electrical conductivity structure beneath the back arc region of SW Japan based on both land and seafloor data

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The back-arc region of southwest Japan is an area of high seismicity. In this region, it has been pointed out that the subducting Philippine Sea plate affects the seismic and volcanic activities in that region. However, the precise relation has not been revealed yet. It is because the subsurface structure near the coastline area is actually difficult to infer precisely using the land observation data alone. Taking this into consideration, an EM research group, including Kyoto University and Tottori University, started the seafloor observation off the San-in region. Now, seafloor EM data have been obtained at 10 sites in total. However, there are not avalable 2-D or 3-D inversion codes for use near the coastline with adeguate ability to describe precise bathymetry. For example, Ogawa and Uchida (1996)'s 2-D inversion code, which is a finite element method (FEM) code often used to delineate conductivity structures beneath, is limited for rectangular elements to describe the bathymetry near coastlines. In our study, we adopted Utada (1987)'s FEM forward code because it adopts triangular elements which can readily express the arbitrary inclinations of the bathymetry in concern. We further improved it to achieve the accuracy in discription of bathymetry as well as the theoretical responses for both land and seafloor sites. The improvements are as follows:

1. We adopted the differentiation method of Li et al. (2008) to calculate more precise responses.
2. We improved the code so that we can use electric and magnetic fields that are observed at different sites.
3. We developed a code which generates the numerical mesh which precisely express the bathymetry near coastline by triangular elements.

To examine the accuracy of the improved code, we compared the responses calculated by the new code with the analytical solution in the hemi-cylindrical geometry (Ward and Hohnmann, 1988). As a result, we found the differences between two responses very small.

Finally, we tried to explain the observed data on the NS land-sea array extending to the north from the boundary between Tottori and Hyogo Prefecture. The 2-D modelling yielded a 2-D conductivity structure whose RMS is 3.3, and found following two noticeable features of the 2-D section.

1. A conductive anomaly found at 10 to 25km depths beneath the region near the coastline is extending seaward as far as 100km off the San-in region.
2. There appears a large conductive anomaly in the deeper extending part 50km to 200km off the San-in region.

In this presentation, we report the improvement of Utada (1987)'s FEM forward code and the result of the 2-D modelling.

Keywords: magnetotellurics, electrical conductivity structure, land-sea array, finite element method

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SEM037-02 Room:301B Time:May 26 11:00-11:15

Incorporation of seafloor topographic effects into marine 3-D MT inversion

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In recent years, seafloor magnetotelluric (MT) observation is carried out by using an increasing number of ocean bottom electromagnetometers (OBEMs) not only along a line but also in 2-D array. Thus, imaging electrical conductivity structures under the seafloor in 3-D is now feasible, if we have a capable tool to invert obtained EM responses.

We would like to emphasize that a 3-D treatment is indispensable especially for marine MT, because the electric and magnetic fields observed at the seafloor are heavily distorted by the rugged seafloor topography and the distribution of land and sea which are generally 3-D. It is very important to properly treat the distorted electric and magnetic fields for an accurate estimation of the conductivity structure beneath seafloor that is generally more resistive than seawater by several orders of magnitude. This problem may be solved by making a huge forward calculation covering a sufficiently wide area, but it is not practical simply because of the computational burden. Here we assume that the distorted electric and magnetic fields are separated into long-wavelength (more than a few tens of km) and short-wavelength (less than a few tens of km) components. Then we propose their separate treatment: The long-wavelength parts are incorporated into a 3-D inversion code (WSINV3DMT; Siripunvaraporn et al., 2005), and effects of the short-wavelength topographies are corrected with other 3-D forward code (e.g. FS3D; Baba and Seama, 2002).

The WSINV3DMT is one of 3-D inversion codes that are now of practical use, but the original WSINV3DMT is not applicable to marine MT data because of two reasons. 1) MT responses are calculated only at flat Earth surface. 2) We have to use fine mesh design because an observation site must locate exactly at the center of the top surface of a block, which needs large memory that even a highest performance computer can not handle. We coded an extended version of the WSINV3DMT by solving the two problems shown above so that it can be applied to the marine MT responses. Topographies longer than length of calculation blocks (the long-wavelength topographies) are incorporated into the extended version of the WSINV3DMT by converting the lateral change in volume fraction of seawater and crustal rock in a calculation block into the lateral change in conductivity, conserving horizontal conductance.

For the treatment of the effect for the short-wavelength topographies, we tested two ways through the inversions of synthetic data. In either case, we assume that the effect is expressed as a complex coefficient matrix to the MT impedance tensor for regional structure. The synthetic data is generated based on a real observation array and topography in the Philippine Sea (Shiobara et al., 2009). 1) Correction method: The data is corrected for effect according to Baba and Chave (2005) and then the corrected MT responses are inverted using the extended version of the WSINV3DMT. 2) Incorporation method: We further modified the extended version of the WSINV3DMT to input both MT responses and the topographic effect term which is separately simulated by forward modeling. In the inversion, sensitivity of the full (non-corrected) MT impedance to the conductivity is calculated, neglecting the coupling between the topographic effect term and subsurface structure. Both tests show that the inversions recovered given anomalies (a resistive and a conductive anomalies) beneath the seafloor. However, the second method is found to provide better result than the first one because the second one rather than the first one has good agreements in the amplitude and size of anomalies. In this presentation, results of synthetic test will be presented and the importance of taking into account the topographic effect will be discussed.

Keywords: Marine magnetotellurics, 3-D inversion, Topographic effects, Upper mantle resistivity structure, Ocean bottom electromagnetometer

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SEM037-03 Room:301B Time:May 26 11:15-11:30

Shallow resistivity structure of Sakurajima volcano - Re-analysis of the audio-frequency magnetotelluric data

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The 10th joint observation campaign of Sakurajima volcano was carried out under the framework of the 7th national project for prediction of volcano eruptions in 2007 fiscal year. Sakurajima volcano EM field experiment group (SVEMG) investigated the shallow resistivity structure by using the AMT (audio-frequency magnetotelluric) method as a part of the joint observation campaign, and presented the inferred 2-dimensional resistivity structure in the Japan Geoscience Union Meeting 2008 (SVEMG, 2008). However, the consideration of the resistivity structure was insufficient because a preliminary analysis had been made to data processing. As we made re-analysis of the data, we report on the result.

The measurement was done on Oct. 30th through Nov. 4th, 2007. Because the explosive Bulcanian eruptions often occur at the craters of Minami-dake that is a summit of Sakurajima volcano, we measured the electromagnetic fields at the frequencies of 1 to 10400 Hz along the three lines set on the northern, western, and southeastern flanks of the volcano. The observation sites were 27 in total. Because the measuring frequency is 1-10400Hz, information on the resistivity structure from the vicinity of surface to the depths of 1-2km can be obtained. The data quality was mostly good. The analysis was done by using the data of the frequency range between several thousand and 2Hz except a few sites.

As a result of the preliminary analysis, features of the following resistivity structures were clarified. The surface layers showed high resistivity (100-1000 ohm-m), probably corresponding to the lava. A low resistive layer of several ohm-m was widely found over the volcanic edifice at depths of 200 to 1000m, which would reflect a fracture zone filled with seawater. This conductive layer is likely to be deep beneath areas in the southwestern part of Sakurajima between the Nabeyama pumice cone erupted in 764, and the crater that effused lavas in 1914. Contrary, such depression of the conductive layer was not found around the Taisho crater located on the western flank.

These results were obtained from two-dimensional inversions, where the strike direction of the 2-D structure was assumed in the direction of each measurement line. However, the strike directions presumed by Groom-Bailey Decomposition showed almost north-south against all three lines. It means that two-dimensional strike was assumed in a direction almost orthogonal to a particular measurement line. Because three lines were set to surround the volcanic edifice, a three-dimensional analysis is necessary to explain all the data set without contradiction. Based on these, we will report a result of three-dimensional analysis of the data.

Keywords: resistivity structure, Sakurajima volcano, hydrothermal system

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SEM037-04 Room:301B Time:May 26 11:30-11:45

Temporal changes in electric resistivity at Sakurajima volcano from magnetotelluric observation (February to July, 2010)

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Continuous magnetotelluric (MT) measurements were conducted from February to July, 2010 at Sakurajima volcano. Six observation sites were established at locations approximately 2˜3 km away from the summit crater. The sampling frequency were 32Hz (15:00˜20:00 UT), 1024Hz (17:00˜18:00UT), and 32768Hz (23:10˜23:11). By applying the comb filter to reduce the harmonics of 60Hz and the robust MT response function estimation code (Chave and Thomson, 2004), we obtained the impedance tensor in the frequency range of 10,000 ˜ 1Hz. The diagonal component of impedance tensor (Zxy, Zyx) showed temporal variations in apparent resistivity of approximately +- 20% and phase of +- 3 %, which is similar to the previous observations in May 2008 to July 2009 (Aizawa et al., 2011, JVGR). The results are also similar to the previous paper in that the polarity of apparent resistivity change is not the same, and in that there are time lags of resistivity change. In this presentation, we will show the temporal change of the resistivity structure by the inversion, and will discuss the mechanism of the electric resistivity change.

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SEM037-05 Room:301B Time:May 26 11:45-12:00

Survey of resistivity structure of Izu-Oshima volcano by using Active, a kind of CSEM method

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ACTIVE is the system proposed for monitoring of resistivity changes in the underground structure of an active volcano (Utada et al.2007). The system consists of a transmitter, that is grounded wire and making alternative pulse DC current, dipole used to generate a controlled transient electromagnetic (EM) field and an array of receivers, that is induction coil and monitoring induction current with 1000Hz sampling, used to measure the vertical component of the transient magnetic field at various distances, with automatic operation of both units. We can estimate the resistivity structure and its changes by requiring response functions, which is the ratio of magnetic field of each sites divided by current of transmitter for each frequency.

We carried out a resistivity survey by using Active over the caldera of the Izu-Oshima Volcano, Central Japan, in January 2011. This survey aimed to monitor temporal changes in underground resistivity structure. At the same time we carried out MT survey there. So we could also compare the result with MT survey. This study will show the result of this survey and required techniques, 3D modeling, inversion and so on.

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SEM037-06 Room:301B Time:May 26 12:00-12:15

Electrical conductivity of sedimentary medium measured by electromagnetic pulses in the earth

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In order to confirm electromagnetic (EM) pulses which might be generated by strong stress impacts to the earth crust when the earthquakes occurred, we have been observing them by a sensor system inserted into a borehole of 100 m in depth.

One of observation sites is in the campus of Seto Marine Biological Laboratory of Kyoto University in Shirahama town, Wakayama prefecture, where is on a narrow peninsula. Since the sedimentary layer around the borehole at the site was composed of shells and sandstone, it was expected that sea water easily penetrate into the sedimentary layer and that EM waves from the sky would be rapidly decayed with the depth in the layer. However, we found that almost all of EM pulses detected at the bottom in the borehole were lightning generated ones which were counted to 10000 per day in the rainy season.

Under such the observation condition, we could clearly estimate the electrical conductivity of the sedimentary medium in the layer by using waveforms of the rapidly decayed EM pulses. It was, however, required that EM pulses used for the estimations of the conductivity should be linearly polarized in the both regions, above the ground and in the earth, because it was hard to compare amplitudes and phases between waveforms of ellipsoidal polarized pulses. Although, in general, if linearly polarized EM waves were obliquely incident to the ground their polarizations in the earth become ellipsoidal, when its incidence into the ground was vertically the penetrated waves in the earth represent linear polarization. Thus we have to select EM pulses with linear polarization at the both points for the estimation of electrical conductivity of the sedimentary medium.

For this purpose, we used tri-axial magnetic search coils at the depth of 95 m in the borehole and on the ground for checking polarizations of detected EM pulses. Waveforms of six analogue pulses of three directional components of a magnetic pulse detected at each detecting point were captured into a personal computer through a multi-channel AD convertor with a sampling period of 32 micro second. The timing of waveform capturing was triggered by a pulse of magnetic east-west component detected at the 95 m depth as pre-triggering AD conversions.

The measured results were as follows. A dominant frequency of detected EM pulses was about 5 kHz, the amplitude and the phase detected at the 95 m-depth were respectively depressed to 1/22 and had 83 micro-seconds delay against those detected on the ground. From these results, we obtained the conductivity of the sedimentary layer was 0.067 S/m. Using this value, the propagation velocity of the EM pulse in the sedimentary medium was 1/345 of the light velocity. Thus the travel time of the EM pulse from the ground surface to the depth of 95 m was coincident with the value of the delay time between waveforms. Therefore it has been proved that the obtained value of the electrical conductivity by this method was valid.

We are now conducting observations for detecting earth-origin EM pulses and to identify their source locations on real-time basis by a network with two or three observation sites. If we found an earth-origin EM pulse and determined its source location, we can obtain differential path lengths between path distances from the source location to each observation site. On the other hand, we can obtain time differences in detections of EM pulse at each observation site. Using the differences of path lengths and the time differences, we can obtain propagation velocity, and then we can obtain electrical conductivity in the medium near the depth of EM source location.

Keywords: electromagnetic (EM) pulses, measurement of electrical conductivity, detection of EM waves in a borehole

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An audio-frequency magnetotelluric survey along the 2010-East-profile across the Yasutomi and Kuresaka-touge faults

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The Yamasaki Fault System (YFS) of southwest Japan is a typical left-lateral strike-slip fault system that extends for over 80 km along a general strike of N60W?S60E. The northwestern part of the system consists of the Ohara, Hijima, Yasutomi, and Kuresakatouge faults and the southeastern part of this fault system consists of Biwako and Miki faults. Many micro-earthquakes have been recorded along the fault system (Shibutani, 2004), along with large historical earthquakes such as the magnitude 7.1 Harima Earthquake of 868 AD (Okada et al., 1987).

An audio-frequency magnetotelluric (AMT) survey was undertaken at nine stations along a profile across the Yasutomi and Kuresakatouge faults. MT responses of a frequency band between 10,400-0.35Hz were obtained at eight stations. After analyses of dimensionality and a regional strike of the resistivity structure beneath the study area, the apparent resistivity and phase data for both TM and TE modes were inverted simultaneously using the code of Ogawa and Uchida (1996). This preliminary resistivity model is characterized by (1) a near surface conductive zone between the Yasutomi and Kuresakatouge faults, (2) a moderately deep conductive zone beneath the Yasutomi fault, and (3) a moderately deep conductive zone to the south of the Kuresakatouge fault.

Keywords: conductivity, active fault, magnetotelluric

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Resistivity Structure beneath Kyushu by the Network-MT Data: Imaging of the Volcanic Formation along the Subduction Zone

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The Kyushu district is a typical high angle subduction zone in Japan, at which the hot Shikoku basin and the cold Philippine sea plate subduct beneath the Eurasian plate, and many quaternary active volcanoes, as the Aso volcano, the Kuju volcano and Kirishima volcano, are located along the volcanic front. And it is important to investigate structure beneath Kyushu for understanding the volcanic formation. In the Kyushu district, the Network-Magnetotelluric (MT) observations, which used telephone line networks of several tens kilometers electrode spacing for the measurement of voltage differences (Uyeshima, 1990), were carried out from 1993 to 1998 to cover the whole island of Kyushu. We reanalyzed these data sets, which have geoelectromagnetic information from the crust to upper mantle, in order to determine regional scale electrical conductivity structure and applied two-dimensional (2D) inversion analyses using the REBOCC inversion code (Siripunvaraporn and Egbert, 1999) to the Network-MT impedance responses. Here we adjusted appropriate the horizontal and vertical smoothing factors according to the intervals of the observation sites along each profile across the characteristic geology, tectonics and volcanoes. And we were able to get a rough grasp of the resistivity structure beneath whole Kyushu. Further, we found that a conductive block exists beneath the volcano of which the bottom extends to the backarc side and the forearc side including the Philippine Sea plate is resistive. Then we also carried out a three-dimensional (3D) inversion analyses to check the 3D effects on the obtained 2D imaging, especially, the ocean effect surrounding the Kyushu district. In this presentation, we would like to explain details on the 2D resistivity structure related to the subducting Philippine Sea plate and the active volcanoes as well as and checking 3D effects on the 2D imaging, and also introduce the future direction of this study.