Improving accuracy of electoromagnetic fields in finite element method

*yusuke kinoshita[1], Yasuo Ogawa[1], Atsushi Suzuki[1]

1.Tokyo Institute of Technology

Electromagnetic induction problem in two- or three-dimensional heterogeneous media needs numerical solutions. In particular, for magnetotelluric problem, we need both horizontal electric and magnetic fields at the surface. If we use finite element method and solve for electric fields, electric field will be obtained with reasonable accuracy, but the magnetic field at the ground surface is estimated using rotation of electric field using a cell below the ground surface. Normally, we use a linear functions as a shape function, which gives an interpolation function within the element. This conventional approach underestimates the magnitude of magnetic field, where derivative is replaced by a finite difference. This problem can be demonstrated using a simple one-dimensional problem, the accuracy of the magnetic field calculation is dependent on the thickness of the first cell under the ground. To overcome this difficulty, usually, we use fine grid cells near the ground surface, which will lead to a large number of unknowns in the finite element solution. We have introduced a new type of shape function which exactly describes the solution within the uniform element cell. Using this shape functions, the magnetic field at the ground surface can be by far more accurately obtained, even with cells with large sizes. We will demonstrate this merit on calculation using two-dimensional resistivity structure for TM mode.

Time-domain inversion of the electrical conductivity profile in the Earth using ground-based magnetic observatory data.

*Kodai Iwashita[1], Hiroaki Toh[2]

1.Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University, 2.Data Analysis Center for Geomagnetism and Space Magnetism, Kyoto University

We estimated radial electrical conductivity distribution in the Earth using both vector geomagnetic observatory data and a forward solver in time-domain. The major difference between the time-domain and frequency-domain approach rests in the way of processing the finite-length time series of transient inducing and induced fields. In the frequency-domain, response functions are usually estimated at discrete frequencies, by splitting the time-series into multiple segments and applying Fourier transformation to each segment. As the periods increase, quality of response functions is reduced in the case of the frequency-domain approach. In addition, the frequency-domain approach should not be applied to the transient data since Fourier transformation premises periodicity for the time-series in concern. On the other hand, the time-domain approach exploits all the data in the time-series by fitting the entire waveform of the magnetic field including rapid variations such as sudden storm commencements. The quality of long period signals that are able to penetrate the deeper region of the Earth is not reduced in the time-domain. We can, therefore, estimate the deep distribution of conductivity using shorter time-series than in the frequency-domain. Specifically, we applied the time-domain approach to the vector geomagnetic observatory data with one minute sampling interval all around the globe. In order to extract the induced field, we subtracted the vector average for 5 quietest days of the month from the raw time-series. Contrary to the newly available data sets from recent low-Earth-orbiting satellite missions, the traditional ground-based data has biased distribution over the globe. We eliminated observatories in some congested places. We then separated the residual time-series into internal and external origin. The separated internal magnetic field can be reproduced using forward response of the radially symmetric conducting sphere to the separated external magnetic field. A heterogeneously conducting shell was placed at the top of the radially symmetric sphere so as to account for large scale surface contrast such as ocean-continent distribution. We solved an inversion problem with an objective function consisting of linear combination of data misfit and a regularization term that constrains the smoothness of the conductivities. Moreover, we estimated the internal Gauss coefficients' sensitivities for each shell of the radially symmetric conducting spheres by F-test and revealed that the lower mantle conductivity has a large influence on the magnetic field on the surface of the Earth after about more one day from the instance when the external magnetic field was applied. As a result, we estimated a conductivity profile of the Earth. This is the first profile that was estimated by a combination of inversion in time-domain and the vector geomagnetic observatory data over the globe. We will further discuss the necessary length of time-series in order to estimate the lower mantle conductivity accurately.

Keywords: conductivity, magnetic storm

Experimental relationship between dielectric properties and ilmenite content with the effect of porosity for the understanding of Moon’s subsurface structure

*Norihiro Nakamura[1], Shiori Mikuniya, Tsuyoshi Miyamoto[2], Atsushi Kumamoto[3]

1.Department of Earth Sciences, 2.Center for Northeast Asian Studies, 3.Department of Geophysics

Mare basalt stratigraphy on the Moon helps to advance our understandings of a lunar volcanic evolution and the thermal history of the Moon. Lunar Radar Sounder (LRS) onboard Kaguya spacecraft employed 5 MHz electromagnetic wave to receive a backscattering wave from both the lunar surface and buried layers at depths of a few hundreds of meters within major lunar maria. Kaguya LRS study found a heterogeneous distribution of horizontal subsurface features, which correlates negatively with high concentration of ilmenite ($FeTiO_3$) as a strong absorber for low frequency electromagnetic waves. Although bulk rock density (or equivalently porosity) and chemical composition are critically important parameters in predicting the subsurface layering, their quantitative relations with dialectic properties are not clear for Apollo returned lunar samples with variable porosities and variable compositions. Previous experimental studies suggested that the real part of the dielectric properties is constant and independent of TiO_2 content when normalized to a constant porosity, suggesting less absorption. However, this studies contradicts the LRS observation with a strong absorption. In this presentation, we show the effect of ilmenite content on complex dielectric properties (dielectric constant and loss tangent) with the effect of porosity, using lunar analog samples as a mixture of ilmenite and cement. Measurements of dielectric properties of the analog samples at 5 MHz demonstrated that both dielectric constant and loss tangent have power-law dependences with the content of ilmenite. The power-law relations between ilmenite contents and complex dielectric constant for analog samples were derived in a range of ilmenite content up to 30 wt% by a least square regression. In addition, by considering a mixture of the poreless lunar analog samples and air, I derived a new experimental relationship between dielectric properties and ilmenite content with the effect of porosity by Lichtenecker’s mixture formula. The power-law dependence of complex dielectric constant with the content of ilmenite gives a quantitative estimation of lunar dielectric constant through a radar sounding, and explains why LRS could detect subsurface layers beneath high concentration area of ilmentite in lunar maria.

Development of Two-Dimensional Inversion of Marine DC resistivity survey

*keiichi ishizu[1], Chatchai Vachiratienchai[2], Weerachai Siripunvaraporn[2], Tada-nori Goto[1]

1.Graduate School of Engineering,Kyoto University, 2.Faculty of Science, Mahidol University

Deep-towed marine DC resistivity survey has been developed recently to detect the shallow boundary roof of the electrically resistive gas-hydrate zone, which is not imaged well by seismic reflection surveys. Similar to the land DC resistivity, its response is the apparent resistivity as a function of electrode spacing which needs to be inverted in order to obtain a “true” resistivity structure. Here, we developed a two-dimensional inversion of marine DC resistivity survey based on the model space Occam’s inversion method. The finite-difference (FD) method is applied in the forward modeling calculation to solve potential difference between electrodes, which is later used to generate the apparent resistivity. The accuracy of the forward code was tested with various synthetic models. We found that our forward code produces the results as accurate as the analytical solution for layered Earth case, particularly when the sub-seafloor structure has high conductivity. For complicated structures, it produces the results similar to those from other forward codes.
For the inversion, we first started applying to the synthetic models consisting of layered Earth. The inversion spent about 2 iterations to converge from an initial RMS of around 19 to 1 RMS. The inverted model clearly image the shallower boundary of resistivity anomaly imbedded into the sub-seafloor structure. Our preliminary results imply that our developed inversion code is promising for the real surveys.

Keywords: DC-resistivity survey, Marine exploration, Resistivity

Along axis variation in electrical resistivity distribution around the 2011 Tohoku-oki earthquake

*Hiroshi Ichihara[1,2], Takafumi Kasaya[2], Kiyoshi Baba[3], Makoto Yamano[3]

1.Kobe University, 2.Japan Agency for Marine-Earth Science and Technology, 3.Earthquake Research Institute, the University of Tokyo

The 2011 Tohoku-oki earthquake (M9.0) was associated with huge fault slip over 80 m in the shallowest part of the plate interface where aseismic slip behavior was widely believed (e.g. Iinuma et al., 2012; Fujiwara et al., 2011). A key factor to understand the “anomalous” fault behavior is pore fluid around the plate interface because it controls shear strength of fault.
In order to discuss fluid distribution around the rupture zone, we acquired marine magnetotelluric data between 2009 and 2012 based on ocean bottom electro-magnetometers (OBEM) at 22 sites along three parallel survey lines; one line crosses the center of fault ruptured zone including the shallowest huge slip area (line C, along latitude 38N); another line crosses the north end of ruptured zone where tsunami origin was estimated (Ichihara et al., 2013) despite the significant fault slip is not estimated (line B, along latitude 39N); and the other line crosses the south part of fault ruptured zone where azimuth of trench axis is significantly different with the north lines (line D, along latitude 37.5N).
We estimated resistivity distribution beneath the line C using the 2-D inversion code based on Ogawa and Uchida (1996). The estimated resistivity profile shows a low resistivity zone in the shallowest part of plate interface. On the other hand, resistivity is relatively high in the deeper plate interface. They indicate that the huge fault slip occurred in the pore fluid rich area whereas the fault slip is small in the dehydrated area. In the presentation, resistivity distribution beneath the line B and line C will be shown to discuss variations of resistivity structures in along-axis direction.

Keywords: 2011 Tohoku-oki earthquake, Electrical conductivity, Resistivity, magnetotelluric, northeastern Japan arc

Electrical conductivity of carbonate in subducted slab

*Shigeaki Ono[1], Kenji Mibe[2]

1.Japan Agency for Marine-Earth Science and Technology, 2.Univ. of Tokyo

Carbon is recycled, mainly as carbonates, by means of a subduction process into the deep Earth. The extent of the deep mantle cycle that largely depends on the preservation of carbonates during subduction is so far unknown. Previous experimental studies demonstrate that Mg- and Ca-bearing carbonates should be stable in mantle conditions. Therefore, it is important to investigate the physical properties of carbonate minerals for an understanding of the behavior of carbon in the deep mantle. Recent advances in geophysical observations have allowed mapping of the electrical conductivity of the Earth’s mantle interior. Electrical conductivity measurements on carbonates at high pressures and high temperatures can help the estimation of the distribution of carbon in the deep mantle.

The starting material were synthetic carbonates, magnesite ($MgCO_3$), aragonite ($CaCO_3$) and dolomite ($(Mg,Ca)CO_3$). In this study, a conventional multi-anvil high-pressure apparatus was used [1]. The cell assembly was kept at 383 K in an oven, and was removed just before the compression experiments began. The experiments were performed at pressures up to 6 GPa and temperatures up to 1000 K. Alumina was used as an insulator between the electrical resistivity measurement lines and the heater lines. The resistivity of alumina used in this study was sufficiently higher than that of the sample at high pressures and high temperatures. The complex impedance was measured with a Solartron 1260 Impedance/Gain-Phase Analyzer with a 1296 Dielectric Interface over a frequency range of 0.05 Hz to 1 MHz. The impedance data of the samples were acquired at temperatures in the range of 500 to 1000 K at each 50 K interval. The measured conductivity was fitted to an Arrhenius equation to calculate the activation enthalpy, energy, and volume.

The activation enthalpies of dolomite and magnesite decrease as pressure increases. In contrast, that of aragonite increases as pressure increases. It is known that the activation volume is related to the electrical conduction mechanism. In the case when extrinsic ionic conduction is the dominant mechanism of the electric conductivity, it is expected that the activation volume would have a positive value. Therefore, the ionic conduction mechanism would be dominant in aragonite [2]. In contrast, the negative activation volume would be expected for minerals with a hopping conduction mechanism. Thus, magnesite and dolomite exhibit hopping conduction at high pressures and high temperatures.

The electrical conductivities of magnesite [1] and dolomite [3] were of the same order of magnitude as that of olivine. Therefore, it is difficult to identify the Mg-dominated rock bodies in the upper mantle from the perspective of electrical conductivity. In contrast, the electrical conductivity of aragonite [3] was one to two orders of magnitude higher than that of olivine. When the Ca-dominated carbonate rocks, such as marine sediments, in the subducted slabs are dragged into the deep mantle, the electrical conductivity of the aragonite-dominated rock bodies is higher than that of the surrounding rocks in the upper mantle. It is known that the electrical conductivity of wet rock, which contains a hydroxyl ion component in its minerals and/or a fluid phase, is higher than that of dry mineral. The calcium carbonates could contribute to the higher electrical conductivity in the same way as the water effect.

[1] Mibe & Ono (2011) Electrical conductivity of $MgCO_3$ at high pressures and high temperatures, Physica B, 406, 2018-2020.

[2] Ono & Mibe (2013) Electrical conductivity of aragonite in the subducted slab, Eur. J. Mineral., 25, 11-15.

[3] Ono & Mibe (2015) Influence of pressure and temperature on the electrical conductivity of dolomite, Phys. Chem. Minerals, 42, 773-779.

Keywords: Electrical conductivity, Carbonate, Subducted slab, High pressure and high temperature

Three-dimensional resistivity structure of Asama Volcano

*Yoshiya Usui[1,2], Yasuo Ogawa[1,2], Koki Aizawa[3], Wataru Kanda[1,2], Takeshi Hashimoto[4], Takao Koyama[5], Yusuke Yamaya[6], Masaaki Mishina, Tsuneomi Kagiyama[7]

1.Graduate School of Science, Tokyo Institute of Technology, 2.Volcanic Fluid Research Center, Tokyo Institute of Technology, 3.Institute of Seismology and Volcanology, Faculty of Sciences, Kyushu University, 4.Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University, 5.Volcano Research Center, Earthquake Research Institute, University of Tokyo, 6.Fukushima Renewable Energy Institute, National Institute of Advanced Industrial Science and Technology, 7.Aso Volcanological Laboratory Institute for Geothermal Sciences Graduate School of Science Kyoto University

Asama volcano is an andesitic composite volcano located in central Japan. The present active crater locates at the eastern part of the complex. At the west of the crater, there is a horseshoe-shaped caldera, which was formed after the collapse of an old stratovolcano at around 24,000 years ago. In order to reveal the relationship between volcanic activities and subsurface structure, two-dimensional resistivity structure of Asama volcano has already been obtained by Aizawa *et al.* (2008) from the data of dense magnetotelluric survey. However, three-dimensional steep topography around Asama volcano can distort the observed response functions. Therefore, in this study, we performed three-dimensional inversion with the same data set as the previous study. In the inversion, we utilized the scheme proposed by Usui (2015), which enabled us to incorporate precise topography around the mountainous area into the computational mesh with the aid of the unstructured tetrahedral element.
The measurement stations used in the inversion consist of 36 magnetotelluric stations and 37 audio-magnetotelluric stations, and we used full components of the impedance tensor and the vertical magnetic transfer function. Though some stations of them measured only electric fields, the different locations of electric and magnetic fields were taken into account in the inversion algorithm. Galvanic distortion parameters were also estimated as model parameters in addition to subsurface resistivity values.
In the obtained resistivity structure, there is a spherical resistive body at the altitudes from 0.5 to 1.5 km under the collapse caldera. From impedance phases, Aizawa *et al.* (2008) inferred that the resistive body was isolated. By the three-dimensional inversion, we confirmed that the resistive body under the caldera was isolated. We found that hypocenter locates around the isolated resister under the caldera. Aizawa *et al.* (2008) suggested that this resistive body is old solidified magma and it impedes the ascending magma. The result of our analysis supports the suggestion.
In addition, at the depths deeper than 0 km below sea level, resistivity of the west of the summit was relatively higher than surrounding area. This higher resistivity area is elongated to WNW–ESE direction and locates over the location of dyke intrusions estimated from seismic and geodetic measurements (Takeo *et al.*, 2006). This high resistivity area also corresponds to high P-wave velocity and high-density area revealed by Aoki *et al.* (2010). They suggested that the high velocity is due to the solidification of repeatedly intruded magma. Our result is consistent with this interpretation since the porosity of solidified magma is considered to be low and it can lead to high resistivity in that area. On the other hand, the surrounding conductive area may consist of higher porosity rocks with saline water.

Keywords: magnetotelluric method, volcanic structure, 3-D topography, 3-D inversion, unstructured tetrahedral element

Sparse 3-D magnetic inversion using combined L1-L2 norm regularization: read data analysis.

*Mitsuru Utsugi[1]

1.Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University

This study proposed an inversion method to determine a 3D magnetic model that reproduces the observed magnetic anomaly. To obtain a sharp and focused magnetic model, proposed method used the combination of L1 and L2 norm regularization. Both of L1 and L2 regularization methods are very popular and promising way for an ill-posed inverse problem. They have useful advantages, but also have drawbacks. The L2 regularization improves the stability of the solution by replacing the ill-posed problem to a nearby well-posed problem, but resultant solution has too smooth nature. L1 regularization provides sparseness of the model, but resultant solution has excessively sparse nature in the case of the potential inverse problem. By incorporating these methods together, we can obtain a stable and appropriately sparse solution. However, in this case, we have to choose two regularization parameters that control the strength of L1 and L2 regularization. So, the way to select these parameters is a critical problem. This paper also provided a procedure to choose the suitable regularization parameters based on L-curve criterion. In our presentation, we show the detail of our proposed inversion method as well as the results obtained by applying our proposed method to the real data acquired by the aeromagnetic survey on some volcano.

Keywords: inversion, geomagnetic structure, sparse regularization

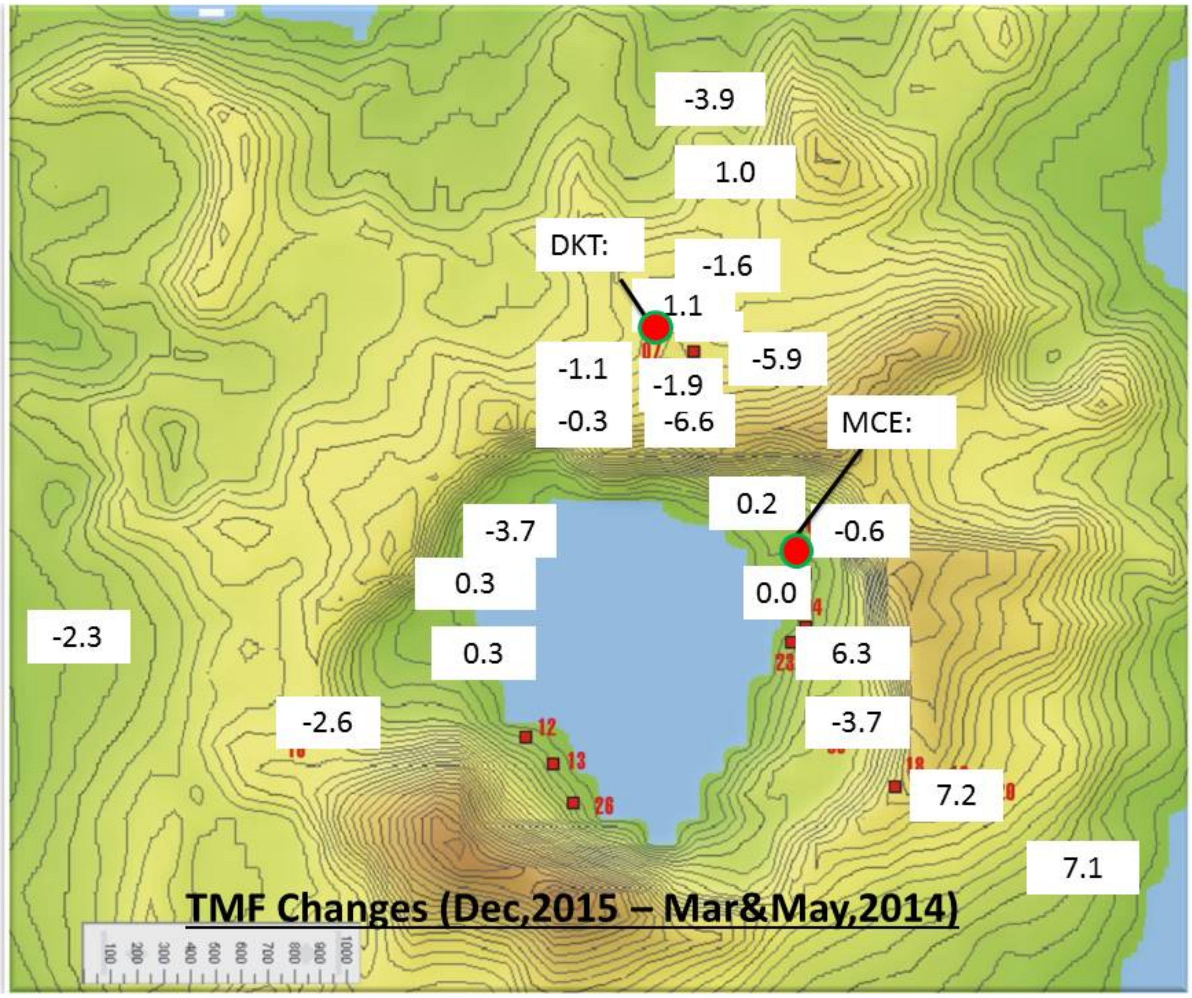
New activity occurring on Taal Volcano, Philippines? - Indications from Electromagnetic (EM) observations

*Yoichi Sasai[1], Paul Alanis[2], Toshiyasu Nagao[1], Jacques Zlotnicki[3], Malcolm Johnston[4]

1.Earthquake Prediction Research Center, Institute of Oceanic Research and Development, Tokai University, 2.Philippine Institute of Volcanology and Seismology, 3.National Scientific Research Center, 4.United States Geological Survey

We have conducted EM observations on Taal Volcano, Philippines, in the central part of Luzon Island since 2005. The seismic and volcanic activity abruptly increased in January 2005 and in June 2010, leading to totally evacuation of the inhabitants of Volcano Island near the center of Taal Lake. Remarkable changes in the total magnetic field (TMF) and self potential (SP) were observed during both the 2005-2006 and the 2010-2011 seismovolcanic crises. Magnetotelluric (MT) surveys on Volcano Island revealed a large resistive block of about 3 km radius (Yamaya et al., 2013; Alanis et al., 2014), which was interpreted to be a hydrothermal reservoir filled with two-phase fluids (gas and liquids). A shallow block adjacent to the hydrothermal reservoir shows strong attenuation of seismic S-waves. This was suggested to be an active magmatic body (Kumagai et al., 2014). From 2013 to present, Taal volcano has been apparently quiescent. In particular, the geothermal area along the NE shoreline of the Main Crater Lake (MCL), which is now exposed above the lake surface owing to the lack of rainfall during the year 2015, shows no enhancement of geothermal activity. However, we conducted repeat TMF surveys in December 2015 and found that remarkable changes in TMF have occurred since March and May 2014, as shown in Fig. 1. The anomaly pattern of the TMF shows negative changes largely occurred in the north and positive changes largely occurred in the south as would be expected from piezomagnetic effects generated by a simple Mogi model of a pressure source at about 2.5 km depth under the MCL. This suggested that, although the surface activity appears quiescent, the hydrothermal reservoir is most likely inflating right now. Owing to the lack of data at the reference station, we could not identify when such changes in TMF took place during the period from May 2014 till December 2015.

Keywords: Taal Volcano, Hydrothermal reservoir, TMF changes, Piezomagnetic effect


-3.9
1.0
DKT:
-1.6
1.1
-5.9
-1.1
-1.9
-0.3
-6.6
MCE:
0.2
-3.7
-0.6
0.3
0.0
-2.3
0.3
6.3
-2.6
-3.7
12
13
26
7.2
7.1
TMF Changes (Dec,2015 – Mar&May,2014)

Analytical Investigations of the Magnetotelluric Directionality Responses in 1-D Anisotropic Media

*Tomohisa Okazaki[1], Naoto Oshiman[2], Ryokei Yoshimura[2]

1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University

Electrical anisotropy is discussed in the interpretation of electrical structures of the earth in magnetotelluric observations. It is then of fundamental interest to infer the properties of anisotropy at a site from data, so as to select an appropriate method for modeling or inversion. As for isotropic media, dimensionality tools are established which estimate geoelectric structures such as dimensionality (1D, 2D or 3D) and directionality (strike directions for a 2D case) from the impedance tensor. Although satisfactory criteria including anisotropic media have been unavailable yet, several studies were performed trying to extend the criteria to distinguish anisotropic media. Among them, Marti et al. (2010) examined using numerical code the responses of anisotropic media in the dimensionality analysis based on a set of rotational invariants (WAL invariants) established by Weaver et al. (2000), and proposed an extended criteria including anisotropic media. They dealt with synthetic models of anisotropic 1D and 2D media, and confirm their results in half-space using analytical expressions. In this talk, we present the results of analytical investigation of the strike estimation of the WAL method for 1D anisotropic layered media for which only numerical results were shown in Marti et al. (2010), with a generalization to arbitrary number of layers.

We first show that if anisotropy axes are identical in all anisotropic layers, the strike direction generally coincides with the axis. The exception is an indeterminate value, which in practice corresponds to unstable behavior. We reveal the condition of it for two types of strike estimations. One always has a definite value as long as anisotropy exists, while the other is indeterminate if conductivity contrast is absent as half-space because it relies only on phases.

We then deal with general anisotropic layers to evaluate the impedance tensor at long periods. The method is expansion of the impedance tensor with respect to (the square root of) frequency at the first order. It gives an analytical formula of the strike direction at the long period limit. This shows that the strike points to the azimuth where the conductance integrated along depth takes a maximum value. We further examine behavior of the phase tensor (Caldwell et al. 2004). At the long period limit, it reduces to the unit tensor corresponding to half-space as expected. The leading part in frequency consists of two parts. One changes the radius of the tensor circle as ordinary phase responses by vertical conductivity contrast. The other distorts the tensor ellipse reflecting anisotropy in total. The major axis points to the maximum conductance direction as the strike does.

We finally compare our analytical results with the results of numerical researches. Applying the obtained formula to the models treated in Marti et al. (2010), we found that the strike angles are different by about 3 degrees. This seems to be because the numerical calculations are evaluated at finite periods. Then electromagnetic fields damp in depth, so the impedance would capture the structure of upper layers more than that of lower layers. The numerical results are more close to the anisotropy axis of the upper layer than the theoretical ones, which supports this expectation.

Caldwell, T.G., Bibby, H.M., Brown, C., 2004. The magnetotelluric phase tensor. Geophys. J. int. 158, 457-469.

Marti, A., Queralt, P., Ledo, J., Farquharson, C., 2010. Dimensionality imprint of electrical anisotropy in magnetotelluric responses. Phys. Earth Planet. Inter. 182, 139-151.

Weaver, J.T., Agarwal, A.K., Lilley, F.E.M., 2000. Characterization of the magnetotelluric tensor in terms of its invariants. Geophys. J. Int. 141, 321-336.

Electrical resistivity structure beneath the fault segment gap: A case study of the Yamasaki fault zone, southwest Japan

Yusuke Oda[1], *Satoru Yamaguchi[1], Hideki Murakami[2], Shigehiro Katoh[3], Shuhei Ito[1], Yuhei Ouchi[1], Makoto Uyeshima[4]

1.Department of Geosciences, Graduate School of Science, Osaka City University, 2.Natural Sciences Cluster - Science Unit, Kochi University, 3.The Museum of Nature and Human Activities, Hyogo , 4.ERI, The University of Tokyo

The relationship between the earthquake magnitude and the displacement accompanying an earthquake was proposed by Matsuda (1975) for Japanese inland earthquake and this formula is widely used to estimate the magnitude which will occur at a given fault-segment. However, many papers which pointed out the larger earthquake magnitude was observed than the estimated ones, have been published. Revealing subsurface structure of an active fault is important to overcome the problem (The Earthquake Research Committee, 2010) and, furthermore, is an interesting academic theme. Clear electrical resistivity variation is expected to be identifiable in the vicinity of an active fault as a result of enriched and interconnected fluid (meteoric waters and/or groundwater) in fractures and/or uneven fluid distribution across the fault because of impeded cross-fault fluid flow (e.g., Electromagnetic Research Group for the Active Fault, 1982). The electrical resistivity distribution can provide a new image of the subsurface structure of an active fault.
We have made an audio-frequency magnetotelluric (AMT) survey along many lines across the Yamasaki Fault System (FZC) and the Gomura Fault System. The characteristic conductive zones (Fault Zone Conductor: FZC) have been commonly found beneath the surface traces of them, and we recognize the FZC is a good sign to identify a hidden active fault.
The Yamasaki Fault Zone (YFZ) is a ~120 km long, typical left-lateral strike-slip fault. According to the Earthquake Research Committee (2013) and Okada (1987), The YFZ consists of the Nagisen Fault Zone, the main part of the YFZ, and the Kusadani Fault. The main part of the YFZ is further divided into the northwestern (NW) group (consisting of the Ohara, Hijima, Yasutomi, and Kuresakatouge faults) and the southeastern (SE) group (consisting of the Biwako and Miki faults) based on their latest faulting events and mean slip rates.
We made an AMT survey along the line across two regions where no surface trace of active faults are observed: one is a clear gap between two fault-segments of the Yasutomi fault and the Biwako fault (Region I) and another is a region where is eastern extension of the Kuresakatouge fault (Region II). We obtained the two-dimensional resistivity model along the line (FKS model) and is characterized by three conductive areas and two of them are located near the points where hidden faults are expected to exist.
In this paper we show the FKS model and its feature, then discuss relationship between the FKS model and two adjacent resistivity models: one is the model along the line across both the Yasutomi and Kuresakatouge faults (Kubota, 2012) and another is the model across the Biwako fault (Ito, 2015).

Keywords: conductivity structure, active fault, Yamasaki fault zone, Magnetotellurics

Improving horizontal magnetic components in MT data using independent component analysis

*Mao Okuda[1], Toru Mogi[1]

1.Graduate School of Science, Hokkaido University

We carried out a MT survey in the Boso peninsula to investigate the resistivity structure of the area where the slow slip event have occurred at least five times within 20 years. Large artificial noise contaminated in the MT data and the resistivity and phase showed near field effect at the frequency band below 1Hz. To avoid the local noise, usually, we use the remote reference technique (Gamble et al., 1979), but the method was not so effective to eliminate the larger noise in this area. The remote reference method is based on the correlation between local horizontal magnetic field and the reference field. To apply a stronger technique, we attempted to use the independent component analysis (ICA). The ICA is stronger mathematical tool to extract the signal from the mixed data than the correlation.

ICA is one of the multivariate analysis methods and in which complicated data sets can be separated into all underlying sources without knowing these sources or the way that they are mixed. It assume that the mixing is liner, and yields the relation $x(t)=As(t)$ with input signals $x(t)$, mixing matrix A and source signal $s(t)$. In this study, to determine the matrix $W(=A^{-1})$, we used FastICA algorithm which was introduced by Aapo Hyvärinen (2000). It is based on a fixed-point iteration scheme for finding maximum of the nongaussianity of $W^{T}x(t)$.

We applied the ICA method to improve horizontal magnetic components in MT data using both the data observed in Boso area and the noise free magnetic data observed in Esashi (Iwate) or Memanbetsu (Hokkaido). After applying ICA, each component is not defined intensity scale. To extract noise free data in original data scale, kept the noise free components, and other component set to 0. (i.e. $x(t)=W^{-1}u'(t)$ Where u': components vector after ICA, x(t): the original data vector.) Finally we calculated the apparent resistivity and phases using the horizontal magnetic data processed as above.

In comparison between before and after the ICA processing, the noise components were removed. The apparent resistivity and phase improved by ICA were free from the influence of near-field phenomenon. These results revealed that ICA has the potential to handle noisy data. However we must more improve MT data to reveal the deep area, we also need to remove the noise of electric data.

Keywords: MT methods, independent component analysis

