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

SEM37-P01 Room:Convention Hall Time:May 22 18:15-19:30

Grain-scale simulations of the formation factors of sandy sediments containing conductive iron oxides

Yoshito Nakashima[1]*

[1]AIST

The formation factors of geo-samples are important when interpreting data obtained by geophysical exploration. Geo-samples often contain conductive solid minerals such as iron oxide (sandy sediment from Niijima Island, Fig. 1). The formation factor value depends on the two quantities: volume fraction and three-dimensional connectivity of the conductive mineral. The computer simulations were performed according to Nakashima and Nakano (2012) for the synthetic grain-scale images of sandy sediments (mixture of quartz and iron oxide saturated with seawater) to show the dependence of the two quantities on the formation factors.
This study was partly supported by JSPS KAKENHI (No. 23241012).

Ref: Nakashima and Nakano (2012) Transport in Porous Media, 93, 657-673. http://dx.doi.org/10.1007/s11242-012-9976-1

Keywords: sediment, X-ray microtomography, computer simulation, geophysical exploration, resistivity, iron oxide mineral

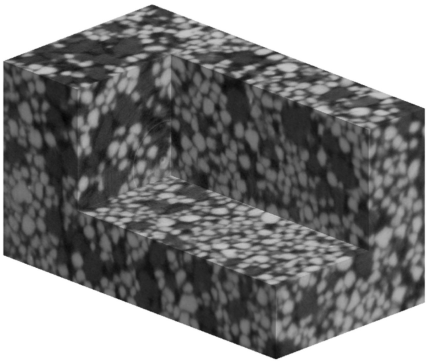

Fig. 1 X-ray microtomographic image of a sandy sediment sample, mixture of quartz (dark) and iron oxide (bright). The image dimension is 400x400x732 voxels = 3.7x3.7x6.8 mm^3.

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SEM37-P02 Room:Convention Hall Time:May 22 18:15-19:30

Rectifying sulfide minerals and application of geoelectric phenomena

Mitsuyuki Ozawa[1*], Jun Muto[1], Hiroyuki Nagahama[1], Toshiro Nagase[2]

[1]Department of Geoenviromental Sceinces, Graduate School of Science, Tohoku University,, [2]The Tohoku University Museum

Various geoelectric phenomena, such as self-potential anomalies and electromagnetic radiation induced by volcanic eruptions and earthquakes have been known. Although various models have been proposed as a mechanism of electromagnetic phenomena, its origin is not fully understood. Recent research proposes that semiconductor minerals are involved in electromagnetic phenomena (e.g. Sobolev et al., 1982). For example, negative self-potential anomaly is observed in the upper ore body, and the radio wave (30 kHz - 3 MHz) is triggered at the ore body by seismic wave. Semiconductor minerals are divided into n- or p-type and form p-n junctions. Rectifying property of the junction would particularly affect the geoelectric phenomena. Natural ore body contains a lot of micro p-n junctions which connect in parallel or in series and they can be equivalent to a single p-n junction at large scale. Therefore clarifying the electric property of micro p-n junction leads to the understanding of semiconductor property of natural ore body. However, due to the defect and trace elements, the composition and electric properties of natural semiconductor minerals are heterogeneous. For this reason, a quantitative understanding of electric properties of semiconductor minerals is not clear yet.

In this research, we measure the electrical properties of the pyrite to discuss the relation between geoelectric phenomena and semiconductor minerals. In order to understand heterogeneity of the mineral surface we apply the electrolytic etching method. We also use the indentation method to reveal electric characteristics of a given small region. Natural pyrites from Waga-Sennin ore were used. Its area of cross section is 1.4 cm^2 and thickness of 0.38 cm.

In the electrolytic etching method, pyrite is reduced. As a result, pyrite surface shows macro-etching patterns attributed to the difference in solubility and some macro-etching patterns show zonal structures. The variation in solubility is due to the difference in conduction mechanism. P-type regions have a higher solubility than n-type regions. In the zonal structure, the properties of p- or n-type alternately change at narrow range (several dozen to several hundred millimeters). Electrical conductivity of the p-type region is greater than of the n-type region, so electric current preferentially flows into n-type region about ten times larger than p-type region. At the p-n junction region, rectifying property is observed. By eliminating to the effect of internal resistances in the sample, we can get semiconductor properties, such as forward and reverse break down voltages of p-n junction.

The reverse breakdown voltage of the p-n junction is close to the maximum voltage for the generation of radio waves when voltages were applied to the ore body in the laboratory experiment (Maibuk, 2006). It is considered that the radio wave is generated by discharge at p-n junction which is triggered by electric pulses. Our result supports this trigger mechanism. Further, it suggests that the electric pulses generated by elastic waves during earthquake can be triggered to radio waves radiation. Negative self-potential anomaly is observed above the ore body, due to the geothermal gradient or redox potentials difference in groundwater. It makes galvanization system: top and bottom ore body act as a cathode and anode respectively, and ground water behave as an electrolyte. If the ore body is regard as a single large p-n junction, the breakdown forward voltage of the p-n junction of the ore body corresponds to the electromotive force generated by galvanization process. Therefore the amplitude of the self-potential anomaly in an ore body could be estimated by investigating the properties of various semiconductor minerals.

In conclusions, it became clear that semiconductor minerals play an important role in geoelectric phenomena and we need further research on electric properties of semiconductor minerals.

Keywords: semiconductor minerals, rectification, geoelectric phenomena, pyrite

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SEM37-P03 Room:Convention Hall Time:May 22 18:15-19:30

Electromagnetic Wave Propagation through Layered Gouges of Nojima Fault, Japan

Shiori Mikuniya[1*], Norihiro Nakamura[1], Hiroyuki Nagahama[1]

[1]Graduate School of Science, Tohoku Univ.

The attenuation and scattering of electromagnetic (EM) wave propagating through geological media are represented by skin depth which is the penetration length decaying to 1/e from the initial intensity of EM wave. The transmission and reflection of EM waves depend on continuous internal structures beneath the ground, such as changes in density (Robin et al. 1969, Ono et al. 2009), conductivity (Paren and Robin 1975) and changes in crystal orientation fabric (Harrison 1973, Muto and Nagahama, 2005). Given the appropriate frequencies of EM waves, the magnetotelluric exploration and the ground-probing radar detect the underground structures in the Earth's crust. Some researchers have reported, prior to earthquake, the detection of ultralow frequency (ULF) band electromagnetic waves (Loma-Prieta earthquake: Fraser-Smith et al. 1990) as well as direct currents (DC) (Hyogo-ken Nanbu earthquake: Enomoto and Zhang 1998). It appears that the EM waves should be transmitted from an in-depth focal region or nearby stressed region through highly damaged fault zones. Takahara et al. (2010) revealed from fractal skin depth theory that the skin depth decreases as the crustal media is fractured in a homogeneous crust, suggesting that highly damaged fault zones heavily attenuate the EM waves from hypocenter or nearby deep stressed region. Here we show this contradiction is solved by considering the internal layered structure of fault zones. The skin depth of bianisotropic layered Nojima fault gouges is measured in different lithology at different orientations. The Nojima fault is an active fault and is separating the Osaka formation of silt and protolith granite. The fault gouge samples consist of bianisotropic layered structures of comminuted siltstone, granitic gouge and pseudotachylyte. Previous paleomagnetic studies of layered fault gouges showed that stable remanence oriented parallel to the fault foliation, suggesting that coseismic direct currents magnetized the pseudotachylyte. This anomalous remanence can be interpreted as a remanence acquisition by direct currents perpendicular to the fault foliation. Our laboratory measurements of dielectric constant and loss tangent of siltstone, granite and pseudotachylyte revealed that pseudotachylyte have the longest skin depth in the ULF-DC band. Moreover, the results suggest that ULF band wave penetrates pseudotachylyte perpendicular to the fault foliation more deeply than paralle. These results agree well with the paleomagnetic implication. This bianisotropic transmission of EM waves explains why some earthquakes have accompanied EM wave radiations at the surface and others don't have done.

Keywords: Nojima Fault, skin depth, electromagnetic wave, bianisotropy

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SEM37-P04 Room:Convention Hall Time:May 22 18:15-19:30

Preprocessing of Network-MT data contaminated by leak currents to obtain the accurate MT response functions (4)

Hideki Murakami[1*]

[1]Faculty of Science, Kochi University

We have reported preprocessing methods of Network-MT electric field data contaminated by railway leak currents for estimating the accurate MT response functions. In previous studies we show that preprocessing methods using multiple classification analyses (PCA and ICA) were effective to reduce large railway leak current noise and improve the accuracy of MT response functions. Howerver, some problems have been left unresolved; the selection method of components corresponding to railway leak currents, azimuthal dependence of the effect of noise reductione, and etc. In this study we will report results of a noise reduction method using median filter, which is a nonlinear digital filter and preserves step-like changes that are characters of railway leak currents.

Keywords: Network-MT electric field data, Noise reduction, railway leak currents, multivariable analysis, median filter

SEM37-P05 Room:Convention Hall Time:May 22 18:15-19:30

Investigations on crustal resistivity structures in the middle-western part of Tottori and the eatern part of Hiroshima

Ichiro Shiozaki[1*], Naoto Koide[1], Yojiro Yasuda[1], Tatsuya Noguchi[1], shinji Yamamoto[2], Yasuo Ikezoe[2], Ryokei Yoshimura[3], Naoto Oshiman[3]

[1]Graduate School of Engineering, Tottori University, [2]Faculty of Engineering, Tottori University, [3]Disaster Prevention Research Institute, Kyoto University

The purpose of this study is to estimate electrical resistivity structure sections across and along the southwest Japan arc in order to clarify the relationship between the deep crustal conductive region and seismic activities. In this report, the general description of the resistivity structure investigation in 2012 by using a wide band MT method (the measurement line of the middle-western part in Tottori pref. and the east part in Hiroshima pref.) is given.

Ozaki et al(2011) showed that the crust has generally a resistive, as a feature of the resistivity model estimated from the south-north crossing measurement line in the earthquake occurrence region in the middle-west part of Tottori pref. (2002, Mj5.3). This observation fact conflicts with the model advocated by the group including authors that have studied electrical resistivity in Sanin region: A conductive area exists in the deep crustal part where inland earthquakes occur. And characteristic seismic activities including hypocenters of big earthquakes are found in the border between a conductive area and the above resistive area or on a resistive area side. That is, there is a possibility that the deep conductive area less than 10ohm-m beneath the Sanin region pointed by the existing study in the adjacent area in the east-west direction is not found and a deep crustal area in Sanin region does not exist in series. Assuming that inland earthquakes occur because of local stress concentration caused by inhomogeneous structure beneath a seismic activity band (Iio, 2009), the reliability of this information should be confirmed. To clear a continuity of a deep conductive structure clarified in the existing study is important to find the mechanism of the zonal seismic activity in this area.

Under the background mentioned above, after the autumn in 2012, a supplemental MT observation of resistivity structure was done in the middle-west part of Tottori pref. The investigation points are 6 places including that of the supplemental observation. As the result, both data obtained from the supplemental observation on the two points (Shitsu and Oka) close to the Tottori middle-west part earthquake occurrence area shows the same feature that apparent resistivity curve decreases for the frequency range below 1 Hz. This is a new feature that was not found in the former observation data. There is a difference in the configuration of the investigation curve between the points very close each other with several Km distance. This difference should be clarified by a structure analysis and a more detailed surfacial structure data should be completed hereafter.

On the other hand, as for the investigation research crossing the southwest Japan arc, the first 2-dimensional resistivity structure sections of the eastern part of Shikoku and Chugoku region obtained and the detailed earthquake reflection wave section found by Sato et al. (2005) and Ito et al.(2009) were compared and examined. However, for making the second island arc crossing structure section from the southwest Japan arc, an additional investigation in the unmeasured area, the eastern part of Hiroshima as the main area, is required to clear the northern edge of subducting Philippines plate. The MT investigation in the eastern part of Hiroshima has just started to make the second island arc crossing structure section. At the writing time of this report, the five points are being investigated.

We would like to express sincere gratitude for the Nittetsu Mining Consultants Co. Ltd. kindly let us use their continuous geomagnetic records of Sawauchi-mura of Iwate pref. as remote references. This study was supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, under its Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions.

Keywords: Chugoku region, electrical resistivity, heterogeniety

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SEM37-P06 Room:Convention Hall Time:May 22 18:15-19:30

Electrical conductivity structure beneath the eastern end of the Ohara and Hijima faults,

Yusuke Oda[1*], Satoru Yamaguchi[2], Takahiro Kubota[2], Hideki Murakami[3], Shigehiro Katoh[4], Toshiaki Mishima[2], Makoto Uyeshima[5]

[1]Geosciences,Osaka City Univ., [2]Geosciences,Graduate School of Osaka City Univ., [3]Natural Sciences Cluster-Science Unit,Kochi Univ., [4]Hyogo Museum of Nature and Human Activities, [5]ERI,University of Tokyo

Yamasaki fault system (YFS) of southwest Japan is a typical left-lateral strike-slip fault system and consists of the Nagisen fault, the main part of YFS, and the Kusatani fault.The main part of YFS extends for over 80km and its general trend is N60W-S60E. The northwest part of this fault system consists of the Ohara, Hijima, Yasutomi and Kuresaka-touge faults, and the southeast part consists of the Biwako and Miki faults. The maximum magnitude of the earthquake which will occur at northwest part of YFS is estimated to be 7.7 and that at southeast part is estimated to be 7.3. (The Headquarters for Earthquake Research Promotion, 2003)

These estimation as stated above was made by the result of surveys of surface structure, trenching, and boring. However, the surface fault structure does not always reflect correctly the subsurface fault structure. Therefore, it is important to reveal the subsurface fault structure, especially, the area near the end -point of a surface fault trace is thought to be the key area.

In this paper, we report the result of Audio-frequency Magnetotelluric (AMT) survey at 11 sites along a transect across near the east end of Ohara fault. A two-dimensional resistivity model along the transect was made based on these MT responses.

We interpreted the model as follows.

1. The Ohara and Hijima faults are not connected each other to the depth of at least 2km.
2. Highly conducive zone on the surface trace of the Hijima fault which was reported by Yamaguchi et al. (2010) , is recognized in our model, too.
3. Subsurface structure of the Ohara fault may extend eastward than the eastern end-point of the surface trace of the fault, because characteristic conductivity structure which is found by Ueda (2011) along two transects across the clear segment of the Ohara fault is recognized in our model.

Keywords: conductivity structure, active fault, Magnetotelluric, Yamasaki fault

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SEM37-P07 Room:Convention Hall Time:May 22 18:15-19:30

Two-dimensional Inversion Analysis of Magnetotelluric (MT) Data in Pelabuhan Ratu, West Java, Indonesia

Febty Febriani[1*], Peng Han[1], Katsumi Hattori[1]

[1]Chiba University

To identify the underground electrical structure close to Cimandiri fault, Pelabuhan Ratu, West Java, Indonesia, the subsurface structure near Cimandiri fault has been investigated by magnetotelluric (MT). This research is a advanced research of the previous research which was done by LIPI team in June-July 1999 and June 2000. The previous research have been analyzed by using two-dimensional inversion revealed the relative location of Cimandiri fault zone. This MT exploration was carried out during two weeks, from July 27, 2009 to August 8, 2009. There were forty eight MT sites which distributed on two line, A line and B line, along about 13 km x 6.5 km profile. The first line, A line, is perpendicular to Cimandiri river and the second one is parallel to Cimandiri river. The preliminary analysis by using one-dimensional Bostick inversion show that there are high resistivity structure between 8 km length and 13 km length underneath A line. The structure starts appearing from 3 km depth until 6 km depth. The analysis result of B line shows high resistivity body in two location. The first on is between 0 km and 2 km length. The second one is between 4 km and 6.5 km length. The high resistivity body in B line appears from 1.25 km depth. In the next analysis, we would like to apply two-dimensional modeling using the Ogawa and Uchida 2-D inversion to get more detail of the underground electrical structure close to Cimandiri fault. The data analysis of 2D inversion is now going on and details will be given in our presentation.

Keywords: magnetotelluric, two-dimesional inversion, Cimandiri fault, Indonesia

SEM37-P08 Room:Convention Hall Time:May 22 18:15-19:30

3D resistivity structure around a high strain rate zone of the Tohoku back-arc

Hideaki Hase[1*], Koki Aizawa[2], Takayuki Sugano[1], Takao Koyama[1], Yusuke Yamaya[3], Tsutomu Ogawa[1], Makoto Uyeshima[1], Shin'ya Sakanaka[4], Tadashi Nishitani[4], Takemichi Nojiri[4], Masayuki Ohmoto[4], Teruki Kohno[4], Hiroshi Ichihara[5], Shinichi Takakura[3], Ryokei Yoshimura[6]

[1]Earthquake Research Institute, the University of Tokyo, [2]Graduate School of Sciences, Kyushu University, [3]AIST, [4]Graduate School of Engineering and Resource Science, Akita University, [5]JAMSTEC, [6]DPRI, Kyoto University

The dehydrated fluid from a subducted oceanic plate is estimated to be localized in the crust and the upper mantle in the tectonic zone. To clarify the image and the mechanism of the tectonic zone, our electromagnetic group in the Hizumi project conducted wideband magnetotelluric (MT) surveys in the northeastern margin of Japan sea tectonic zone since 2008. We performed 6 survey lines and 82 sites (CHK line: 11 sites, SKT line: 8 sites, SNJ line: 11 sites, TRK line: 9 sites, GSS line: 16 sites, YNZ line: 27 sites) from east to west in the southwestern part of Tohoku region. We estimated 2D resistivity structures till last year by using a 2D inversion code (Ogawa and Uchida, 1996). The 2D models from TE and TM modes show characteristic conductive part above -5km ASL in the Shonai plane, and beneath -10km ASL at the eastern part of Mt Gassan. However, strike directions estimated from phase tensor analysis (Caldwell et al., 2004) are different in the upper and lower part, and some of induction allows estimated by tipper responses did not imply 2D structure. Therefore, we should evaluate the resistivity structures whether they are plausible or not. In this study, we performed 3D analysis by using the inversion code of WSINV3DMT (Siripunvaraporn and Egbert, 2009). We will discuss the difference of structures between 2D and 3D inversion analysis, and also will discuss the mechanism of the tectonic zone.

Keywords: Magnetotellurics, high strain rate zone, Shonai plane, resistivity structure