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

SEM37-01 Room:201B Time:May 22 14:15-14:45

Contribution of magnetotellurics to the study of the Continental Lithospheric Break-up in East Africa

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The breakup of continents and creation of new oceans is a fundamental yet poorly understood plate tectonic process. It is essential not only in terms of fundamental Earth Sciences because it results in the formation of new plate boundaries and ocean basins, but it also has a major social impact, as it will create places of high natural hazards. Its study is yet challenging because most of the ancient margins where breakup occurred are obscured with thick piles of sediments and/or located under deep water. Among still debated topics the rift initiation and the driving forces are burning questions: What controls the strain location? How does the breakup interact with mantle heterogeneities such as plumes and inherited lithospheric fabrics? How do the forces exerted by far-field and mantle processes change during rift evolution? Particularly, the interactions between deep (mantle) and superficial (crustal) processes are controversial and topical subjects. The French project ColiBrea proposes to acquire new field, geophysical, geochemical and petrophysical data in a rifting inception place, the Tanzania rift, to constrain and test 2D and 3D models of continental lithospheric extension associated with repeated episodes of magma intrusion. This combination of data acquisition, novel inversions and models will allow to: (1) map the spatial distribution of strain in space and time using geophysical and geodetic methods; (2) constrain crust and upper mantle structure; (3) characterize the chemistry and spatial distribution of crustal fluids and magma; (4) quantify the volume of magma intruded into the crust through seismic data interpretation combined with InSAR, and (5) distinguish the role of the different processes involved in continental rifting through numerical modelling. The first stage of the project was carried out early this year with a field experiment combining seismological stations installed for 1 years and a series of co-located magnetotelluric (MT) soundings. Further work includes gravity and GPS surveys of the studied area. In this presentation we present the ColiBrea project and report on the preliminary results from the MT experiment.

Keywords: Continental Break up, African rift, geophysics, magnetotelluric, tanzania

SEM37-02 Room:201B Time:May 22 14:45-15:00

First report on electrical conductivity imaging of "Normal Oceanic Mantle"

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Horizontal flow zone between up-welling and down-welling of the mantle convection, which occupies large portion of the ocean floor, is thought to represent "normal" mantle that is away from tectonic activities. The research group of Normal Oceanic Mantle Project consists of researchers in Earthquake Research Institute (ERI), University of Tokyo, and Institute for Research on Earth Evolution (IFREE), Japan Agency for Marine-Earth Science and Technology (JAMSTEC) have investigated normal oceanic mantle by means of marine geophysical observations to elucidate two fundamental questions of the Earth Science; 1) What is the physical condition for the lithosphere-asthenosphere boundary (LAB)? 2) Is the mantle transition zone (MTZ) a major water reservoir of the Earth? We set the target field to two areas, which are northwest (area A) and southeast (area B) of Shatsky Rise in northwestern Pacific, and have carried out seafloor electromagnetic (EM) surveys using ocean bottom electromagnetometers (OBEMs) and electric field observation systems (EFOSs) since 2010. In this presentation, we introduce preliminary result for the estimation of electrical conductivity structure beneath the area A obtained by the data acquired in the pilot survey during June 2010 and August 2012.

The raw time series obtained by the OBEMs at four sites were processed to obtain magnetotelluric (MT) impedance tensor at each site. The MT responses were estimated accurately in the period range from 160 to 122,880 seconds. We first estimated one-dimensional (1-D) conductivity structure model which explains the data of all sites averagely correcting topographic effect on the observed MT responses, as we applied to the previous study for the Philippine Sea and off Bonin Trench in the Pacific Ocean (Baba et al., 2010). The obtained 1-D model shows the resistive upper layer and underling conductive zone, indicating cool oceanic lithosphere and asthenosphere, respectively. Although this kind of feature is common for oceanic upper mantle, there are some differences between the obtained models in this study and the previous study for off-Bonin Trench (Hereafter, we refer it area C). The thickness of the resistive layer is about 150 km, which is thinner than that beneath the area C (~200 km). The conductivity value of the asthenospheric mantle is 0.03-0.1 S/m, which is slightly higher than that for the area C. The seafloor ages are about 130 Ma and 140-155 Ma for the area A and C, respectively. However, the 10-15 Ma difference for old mantle is not likely to produce such difference in conductivity structure. The MT responses predicted from the surface heterogeneity over the 1-D mantle structure fit the observed MT responses imperfectly, especially in terms of splitting between xy and yx elements. This fact suggests that the mantle is laterally heterogeneous and/or anisotropic. These issues should be investigated in the future analysis. Also, we will collect further data in area A and B, and analyze all available data in more detail to achieve the desired purposes.

Keywords: Normal Oceanic Mantle, northwestern Pacific, electrical conductivity, ocean bottom electromagnetometer, magnetotellurics

SEM37-03 Room:201B Time:May 22 15:00-15:15

Electrical conductivity structure beneath the Yasutomi and Kuresaka-touge faults and its relation to fault activity

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The Yamasaki Fault System (YFS) of southwest Japan is a typical strike-slip fault system. The system consists of the Nagisen fault, the main part of the YSF, and the Kusatani fault. The main part of the YFS extends over 80 km and its general trend is WNW-ESE. It can be grouped into the southeast active faults group (Biwako and Miki faults) and the northwest active faults group (Ohara, Hijima, Yasutomi, and Kuresaka-touge faults) according to rrecent fault activity. The latter one bifurcated to the Yasutomi and Kuresaka-touge faults at the eastern end of the Hijima fault . Hyogo (2001) reported that the Yasutomi fault is main one and the Kuresaka-touge fault is a secondary one.

In this paper, we present a two-dimensional conductivity model along three transects (W-, C-, and E-line) across these two faults and discuss relationship between fault activity and subsurface fault structure beneath the two faults.

Audio-frequency magnetotelluric (AMT) surveys were made at 11 points along the W- and C-lines respectively, and 12 points along the E-line. MT responses of the frequency range between 10000 - ~10 Hz were obtained at each station, using remote reference processing (Gamble et al., 1979). We determined dimensionality and strike direction of each line by Phase Tensor analysis (Caldwell et al., 2004). As a result, all of the lines were determined to have dominant two-dimensional nature. The apparent resistivity and phase for both TM and TE modes were inverted simultaneously using the code of Ogawa and Uchida (1996).

Strong conductive zones are recognized benaeth a surface trace of the Yasutomi fault along the W- and C-lines between 2 - 4km in depth, which are located on the north to the surface trace of the Yasutomi fault. Along the C-line this conductive zone slightly extends to the south of the surface trace of the fault. Beneath a surface trace of the Kuresaka-touge fault, characteristic weak conductive zones are recognized between 0.5 - 2 km in depth along three transects. Conductivity of the zones decreases to eastward. We interpret that this feature is caused by decreasing fractures in the damage zone beneath the Kuresaka-touge fault to eastward. This idea is supported by surface feature of the Kuresaka-touge fault. One is horsetail spray structure which is one of the characteristic structure of the tip damage zone is recognized in the eastern half of the fault. Another ones is the proposal of Nakata et al. (1998). They proposed that fault rupture propagates to the end of branching fault, in our case, from west to east. Finally, we interpreted that different conductivity feature between the Yasutomi fault and the Kuresaka-touge fault is caused by different activity of the the two faults as pointed by Hyogo (2001).

Keywords: conductivity structure, active fault, Magnetotellurics, Yamasakii fault

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SEM37-04 Room:201B Time:May 22 15:15-15:30

Three-dimensional resistivity imaging beneath the fold-and-thrust belt, Ishikari-teichi-toen fault zone, Hokkaido

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A magnetotteluric (MT) survey was performed in the Ishikari lowland region in order to clarify the distribution of fluids beneath the Ishikari-Teichi-Toen active fault zone (ITFZ), which is regarded as the most hazardous inland fault zone in northern Japan. Four components of impedance tensor and two components of magnetic transfer function at 16 frequencies between 40 and 0.00012 Hz at 50 measurement stations were inverted to a 3-D resistivity structure with the aid of the WSINV3DMT code. The inverted structure showed at the shallower part that the conductive layer (<10 ohm-m) corresponding to sediments beneath the lowland lies from the surface down to 7 km deep. The resistivity below 7 km shows a regional boundary between the western-northern and southwestern parts. The conductor is found along the ITFZ beneath this boundary in the middle crust. We interpreted this conductor to be a fluid rich zone, acting as a dynamically weakened zone. The conductive body is also found beneath the Shikotsu caldera, implying magmatic fluids ascending from the mantle or a region of partial melt.

Keywords: magnetotellurics, 3-D inversion, active fault, fold and thrust, active volcano

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SEM37-05 Room:201B Time:May 22 15:30-15:45

Effect of induced elctric current in the Earth ongeomagnetic Sq field in the Z component

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Long term variation of geomagnetic Sq field amplitudes in the Y (Sq(Y)) and Z (Sq(Z)) components at some observatories and the ratio of Sq(Z)/Sq(Y) was studied.

Although the varation of both Sq (Y)and Sq (Z) can be basically explained by the solar activity effect, especially varation of Sq (Z) is affetced by the induced current in the Earth, and may be dirrent for each observatory. For example, at Honolulu, although Sq (Y) was increasing through the whole period mostly, Sq (Z) decreased around 1960, Sq(Z)/Sq (Y) fell about to 0.55 from about 0.65. This is a feature peculiar to Honolulu and is considered to be due to the relocation of the observatory in 1960 to have influenced Sq (Z). Although Sq(Z)/Sq (Y) of Kanozan is almost the same as Kakioka reflecting geographical nearness, the ratio becomes alrger at Kanoza than at Kakioka around 1975-1990about all the seasons. This suggests that electrical conductivity distribution of the underground affecting the induced current in the Kanto district may have some change in the period.

Keywords: geomagnetism, daily variation, Z component, induced currents

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SEM37-06 Room:201B Time:May 22 15:45-16:00

Magnetic survey for archaeological old kilns at Sayama area of Bizen city, Okayama

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We have been excavating ancient old kilns of Sueki type potteries in Sayama area of Bizen city, Okayama prefecture. In this area, there are many old kilns buried in forest, which were investigated by the distribution of the archaeological remains such as pottery fragments. In this program, we have had magnetic surveys for searching exact position of buried kilns. Here we report the settings and results of magnetic surveys, presumption of kilns under the ground and the actual properties of the excavated kiln.

There is a back ground noise less than 20 nT in the magnetic observation, so that it is likely that this region is suitable for the magnetic survey. We used an Overhauser type magnetometer GSM-19 (by GEM Systems in Canada).

We observed the magnetic field intensity at 0, 45, 90 cm above the surface and in every 90cm spacing. We discovered a magnetized object below the surface with several tens of nT signal. The signal shows the large positive anomaly regions located narrow negative anomaly band, which indicates that the object was magnetized by northward magnetic field. This feature is typical one generated by a thermoremanent magnetization of baked remains. The size of the anomaly region shows that the object are about 2m width and about 4m length, and the difference between intensity of signals in each height shows that the depth of the object would be less than 1m. Actually we excavated a well baked old kiln floor from 20-50cm depth in this region. The floor at the entrance of the kiln was collapsed and lost so that the exact length of the kiln is unknown. There were some fragment blocks of the roof. This kiln was named ”Sayama Higashiyama-Oku” old kiln and many archaeological samples, potteries, were discovered. Paleomagnetic studies of direction and intensity were also done by Kitahara et al. (detailed in His talk in this meeting).

As stated above, it is likely that magnetic survey is very effective for preliminary investigation of archaeology on silicic or sedimental basement in environs of provincial cities such as the southern area of Okayama prefecture. We have also measured in another location of Sayama area and discovered a similar magnetic anomaly, and will excavate in this spring. We will also give a report of this location in the session.

Keywords: magnetic survey, Old kilns of Sueki potteries, archaeology

SEM37-07 Room:201B Time:May 22 16:15-16:30

Piezomagnetic signals just after the occurrence of seismic events: some examples of 2-D calculation

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Electromagnetic (EM) field observations may detect occurrences of earthquake. Several mechanisms convert seismic waves to variations in EM field. Variations in EM field generated near the seismic sources are possibly detected before the arrival of seismic waves because EM waves propagate the speed of light. This means, observations of EM field potentially improve the usefulness of earthquake early warning systems, which are conventionally based solely on observations of seismic waves.

The piezomagnetic effect is likely an important mechanism in terms of an application to the earthquake early warning by EM observations. The piezomagnetic effect describes changes in the magnetization of ferromagnetic minerals. Mathematical treatments to calculate changes in the magnetic field generated by the piezomagnetic field, referred to as the piezomagnetic field, have been developed [e.g. Sasai, 1991, Bull. Earthq. Res. Inst., Utsugi et al., 2000, GJI] to provide constraints on changes in the stress field accompanying with tectonic events. Although focuses of many studies on the piezomagnetic field are on the static problem, temporal variations in the magnetic field are also considered to be arisen by the piezomagnetic effect. An example of variations in the magnetic field, which likely generated by the piezomagnetic effect at the time of an earthquake but occurred prior to the arrival of the corresponding seismic wave, was reported at the time of the M.7.2 Iwate-Miyagi Nairiku Earthquake in Japan by Okubo et al. [2008, EPSL]. Okubo et al.'s result implies potential use of the geomagnetic observation as an approach to the earthquake early warning.

To promote the feasibility study of the piezomagnetic field observations as a tool of earthquake early warnings, we need to examine temporal variations of the piezomagnetic field corresponding to various kinds of seismic sources, because variations in the magnetic field observed before the seismic wave arrival may be less informative even if they can be detected. To make reliable calculations on this problem, we need to establish a calculation procedure to treat temporal variations both in the stress field and the EM field. Temporal variations in the magnetic field corresponding to time-development of the fault rupture was performed by Okubo et al However, their calculation may somewhat inaccurate. Their calculation was performed in a framework of static piezomagnetic field simulation, in which only near-field term of the displacement field is considered and velocities of seismic waves are assumed to be infinite. In addition, the effect of EM induction was totally ignored. We need to assess how the calculation result is altered when considering finite speed of seismic waves and the electromagnetic induction.

In the present study, we consider a rather simple two dimensional (2D) problem, consisting of an upper half-space representing the air, and a lower half-space representing a solid Earth with a uniform conductivity. The dislocation source is assumed to be two-dimensional, thus the displacement and stress field are also two dimensional. A rigorous solution of the EM field generated by time-varying sources aligned on a line (i.e. line source solution) has already given in the frequency-domain [Yamazaki, 2011, 2012, GJI]. The solutions are further converted to those in the time-domain. Line source solution EM fields generated by time-varying magnetizations with 2-D spatial distributions are obtained by integrating the line source solution.

As examples, two types of rupture and the generated stress fields are considered as the sources of the piezomagnetic field. One is a strike slip at the ground surface, and the other is a dip slip at a buried fault. Displacement fields corresponding to these sources are presented by a textbook in seismology [Aki and Richards, 2002]. Remarks of the results will be shown at the meeting.

Keywords: piezomagnetic effect, seismic wave, detection of earthquakes

SEM37-08 Room:201B Time:May 22 16:30-16:45

Detections of electromagnetic pulses excited by earthquakes

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In order to find electromagnetic (EM) pulses which would be generated due to piezo-electric effect by strong stress impacts to the earth crust when the earthquakes occurred, we have been observing EM pluses using tri-axial electromagnetic sensors installed in a deep borehole (100 m in depth) and on the ground. Detected EM noise has been analyzed on real-time basis by personal computers by means of two methods, one was a continuous display of frequency dynamic spectra (f ? t diagram) in a range from 0 to few kHz for monitoring EM environments in the earth, and another was to estimate arrival direction of EM pulses.

So far, we have detected many EM pulses in the frequency range mainly around few kHz, and have analyzed their waveforms. Almost all of wave polarizations and distant decay rates in the earth have shown clear properties of lightning EM pulses. Therefore, at this stage, we could not detected EM pulses related to earthquakes.

We found the reason why we could not detected EM pulses excited by earthquakes. The reason was wave energy loss during their propagations in the earth due to high electrical conductivity of the earth medium. One of the parameters of wave decay is given by Skin Depth of the earth medium as a function of the EM wave frequency. The Skin Depth is a characteristic distance which is inversely proportional to square root of wave frequency f. Therefore it was expected that extremely low frequency component of the EM pulse excited by earthquakes can propagate for a long distance in the earth. Therefore, we adapted the f-t diagram system to monitor the frequency range 0 ˜ 25 Hz, and started its continuous monitoring from December, 2011.

During the period from Dec. 20, 2011 to Jan. 24, 2013, we detected ten EM pulses surely related to earthquakes among thirteen ones with magnitude greater than M 2 occurred within an area of radius of 40 km centered at the EM observation site. We confirmed that the detected EM pulses were excited by the piezo-electric effect due to stress impact into the earth crust. Now we are going to clarify the time relation between waveforms of seismic waves and of their related EM pulses.

Keywords: electromagnetic pulses in the earth, detections in boreholes, relation with earthquakes

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SEM37-09 Room:201B Time:May 22 16:45-17:00

2-D tsunami dynamo simulations in the northwest Pacific using the finite element method

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Conductive seawater moving in the geomagnetic main field can cause dynamo effects in the ocean. This effect is well-known as "Oceanic Dynamo Effects (e.g., Sanford, 1971)". In recent years, it has been reported that tsunamis also cause Oceanic Dynamo Effects. Hereafter, we call it as tsunami dynamo effects, and tsunami-induced electromagnetic (EM) field variations were observed mainly by seafloor observations so far (Toh et al., 2011; Suetsugu et al., 2011; Manoj, 2011). In the late 1900s, Oceanic Dynamo Effects were mainly attributed to low frequency oceanic current such as tidal currents. This is the reason why most of the preceding studies on Oceanic Dynamo Effects neglected self-induction effects. Tyler (2005) first derived a useful formulation that can be applied to short-period tsunami dynamo studies, considering the self-induction effects. However, Tyler assumed a completely flat seafloor and an insulator beneath the ocean layer. Now that many tsunami-induced EM field variations can be observed on the seafloor as well as on land, it is important to appreciate the effects of bathymetry and conductivity structures beneath the seafloor on EM variations observed on the seafloor.

In this study, we developed a two-dimensional (2-D) tsunami-dynamo simulation code, using the finite element method (FEM). Our code can include actual bathymetry and arbitrary conductivity structures beneath the seafloor with the help of FEM. Our simulation consists of two steps. In the first step, oceanic flows associated with tsunami propagations are calculated. In the second step, using obtained oceanic flows, the induction equation in terms of the vertical magnetic component is first solved to obtain the remaining EM components.

Our research group succeeded in observing tsunami-induced magnetic fields at our seafloor EM observatory in the North-West Pacific (NWP), at the time of the 2011 off the Tohoku earthquake. In this study, we first reproduced the oceanic flows associated with the tsunami by fitting calculated sea surface elevations to seawater column variation data observed at DART21401 and 21419 operated by NOAA. Second, we calculated tsunami-induced magnetic field variations and compared them with the data observed at NWP. As a result, it was found that magnetic field variations observed at NWP were well reproduced by our simulation, and the 3 nT peak of the magnetic downward component is surely due to the effect of the 2011 tsunami, especially for the first wave. In addition, the 2011 tsunami can be regarded as an almost 2-D phenomenon around NWP. In our recent simulation, a homogeneous conductor of 100 Ohm.m is allocated beneath the seafloor. In the presentation, we will also report simulation results with a 1-D conductivity structure inferred at NWP using long EM time-series accumulated so far as well.

Keywords: tsunami, finite element, conductivity structure, The Tohoku earthquake, time domain, self-induction

SEM37-10 Room:201B Time:May 22 17:00-17:15

First seafloor observation of Vector Tsunameter

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We developed a new type of offshore tsunami meter called Vector TsunaMeter (VTM) for the purpose of providing an early and reliable information on the propagation and generation of tsunamis in order to predict the tsunami impact at the coastal area. The VTM observes three components of magnetic fields, two horizontal components of electric fields and tilts, and a differential bottom pressure for more than a year at sea floor up to 6000 m water depth. Based on the observational records, the VTM is designed to detect the temporal variations of sea level change, and particle motion associated with the tsunami passages. Arrival time, arrival direction, and phase velocities of tsunamis can also be calculated from the observed record. These characteristics of tsunamis observed at deep ocean far from the coastline are very useful to forecast the arrival time and the size of tsunamis before the tsunami reaches the coastline. The first seafloor observation of VTM was made during this winter, in which the VTM was installed by KR12-18 cruise of the research vessel KAIREI, JAMSTEC on November 20, 2012 at 25-45.94N, 137-00.48E, Depth=4894m. And the VTM was safely recovered during KR13-03 cruise on February 9, 2013. The VTM continuously records the data sets of, Bx, By, Bz, Ex, Ey, TiltX, TiltY, and Bottom Pressure from Nov. 20, 2012 to the recovery time, i.e. Feb. 9, 2013. Three days before the recovery date, a Mw=8.0 earthquake occurred at the Solomon islands (10.738S, 165.138E) on 2013-02-06 01:12:27UTC. The Solomon islands earthquake generated tsunamis, which hit near Solomon islands and causes damages to human beings and houses. Since the main energy of the tsunami propagates along the north-east to south-west direction from the epicenter of the earthquake, the tsunamis observed at Japanese coast were low. At the observational site of VTM, amplitude of the first wave is as small as 1 cm, but the VTM clearly records the variations of sea level change for more than several hours after the tsunami arrival around 2013-02-06 08:40 UTC. This observation indicates the resolution limit of VTM is less than 1 mm of the sea level change.

Keywords: tsunami, Electromagnetic observation, differential pressure gauge, ocean dynamo effect, Ocean Bottom Electro-Magnetometer

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

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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

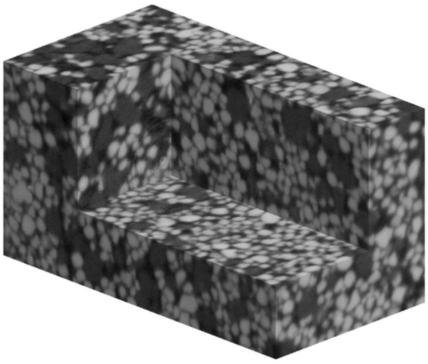

Fig. 1 X-ray microtomographic image of a sandy sediment sample, mixture of quartz (dark) and iron oxide (bright). The image dimension is 400x400x732 voxels = 3.7x3.7x6.8 mm^3.

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Rectifying sulfide minerals and application of geoelectric phenomena

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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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Electromagnetic Wave Propagation through Layered Gouges of Nojima Fault, Japan

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

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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

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

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

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

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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

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

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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