Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SEM36-01 Room:413 Time:April 30 15:15-15:30

Development of analysis strategy for continuous total geomagnetic field data around Mt. Fuji

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Geospatial Information Authority of Japan (GSI) has conducted continuous total geomagnetic field observation at Fuji Yoshida observation station (FUJ), which is located the northeast mountainside of Mt. Fuji, and Fuji-City observation station (FJI), which is located at the southern bottom of Mt. Fuji, since 2000. These stations were established in order to enhance observation infrastructure to monitor low-frequency earthquakes underneath Mt. Fuji which had rapidly increased since October 2000. Additional continuous observation in the northwest mountainside of Mt. Fuji had also been started by utilizing electrical power and communication line of Remote GNSS Monitoring System (REGMOS) at Fuji Oniwa. Furthermore, Earthquake Research Institute, the University of Tokyo has conducted continuous total geomagnetic field observation at Fuji Yoshida (FJ1) and continuous geomagnetic observation at Yatsugatake (YAT). These data are also available and useful to monitor and understand geomagnetic variation around the Mt. Fuji.

Although GSI has been monitoring total geomagnetic field difference between the station at the bottom, FJI, and the stations at the mountainside, FUJ and REGMOS, it is almost impossible to identify variation truly caused by volcanic activities because total geomagnetic field around volcanoes can be fluctuated by both volcanic activities and locally unique geomagnetic variation as well as earth's main magnetic field and external magnetic field variation. Therefore, GSI tries to extract volcano-induced total geomagnetic field variation from the observation data around Mt. Fuji by principal component analysis, and develop monitoring strategy by principal component analysis of total geomagnetic fields around Mt. Fuji.

Keywords: Total geomagnetic filed, Mt.Fuji, principal component analysis

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SEM36-02 Room:413 Time:April 30 15:30-15:45

Classification of tsunami dynamo phenomena in terms of ocean depths

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Conductive seawater moving in the geomagnetic main field drives an electromotive force and induces secondary electromagnetic (EM) fields. This effect is well known as "oceanic dynamo effect" and has been investigated for many years, especially for low-frequency phenomena such as tides and steady oceanic flows. However, it was recently found that tsunamis are also significant sources of the oceanic dynamo effect. Toh et al. (2011) reported tsunami-induced EM field data observed at the northwest Pacific seafloor EM station (NWP) at the time of the 2006/2007 Krill tsunamigenic earthquakes. Ever since, many events associated with the oceanic dynamo effect by tsunamis, hereafter called "tsunami dynamo effect", have been reported (e.g., Manoj et al. 2011; Suetsugu et al., 2012; Ichihara et al., 2013). To explain the tsunami dynamo effect, most of the preceding studies adopted analytical approaches in the frequency domain (e.g., Tyler, 2005). However, it is difficult to understand how EM fields are generated by tsunami propagations, although analytical solutions are very useful and handy.

In order to understand the tsunami dynamo effect more physically, we compared analytical solutions and results of numerical simulations using solitary waves, and revealed that tsunami dynamo phenomena can be classified according to the influence of the diffusion term in the induction equation for the magnetic field. In tsunami dynamo phenomena, the ocean depth has a dominant influence on the diffusion term. When the ocean depth is shallow enough, the diffusion term is large and comparable with the source term, while the self-induction term is small. In this case, the self-induction effect cannot attenuate the magnetic field induced by the coupling of the oceanic flows (v) and the geomagnetic main field (F), namely $v \times F$. We can understand this case mostly by the Ampere's Law. On the other hand, when the ocean depth becomes deeper, the self-induction effect gets larger and reduces the amplitude and causes delay in phase of the magnetic field induced by $v \times F$. Especially for the ocean depth deeper than 5000 m, the amplitude is attenuated to approximately 70 percent and the phase is delayed by more than 70 degrees compared with the magnetic field due to $v \times F$, which can be understood by analogy with "Frozen Flux". As for the case of the tsunami dynamo phenomena reported by Toh et al. (2011) as well as Minami and Toh (2013), we can regard the phenomena as the self-induction dominant case because the ocean depth at the observation site, NWP, is approximately 5600m. This is consistent with the fact that sea level changes observed at the two DART sites in the vicinity of NWP are in phase with that of the vertical component of the magnetic field observed at NWP. In addition, our analysis using analytical solutions revealed that magnitudes of the tsunami-induced magnetic field have maximum peaks around the ocean depth of 2000m, when the tsunami height is fixed to 1m. This is because the self-induction and the diffusion effect, which vary differently according to the ocean depth, balances around that specific depth. These results are important because they enable us to predict how EM fields are induced by tsunamis in a variety of ocean depths, even though the number of observed examples of tsunami dynamo phenomena is limited at present. It is possible that our results are applied to tsunami early warning or mitigation of tsunami hazards in the future.

In the presentation, we will report the methodology of our classification of tsunami dynamo phenomena and discuss how tsunami-induced EM fields vary according to the ocean depth. We will also discuss how the ocean depth influences on the recently found initial rise (Minami and Toh, 2013) in the horizontal magnetic component observed prior to tsunami arrivals.

Keywords: tsunami, dynamo, solitary wave, seafloor observation, finite element method

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SEM36-03 Room:413 Time:April 30 15:45-16:00

Electric conductivity of earth's medium derived from earthquake-excited electromagneic siganals

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We have been observing electromagnetic (EM) pluses excited by earthquakes, using tri-axial electromagnetic sensors installed in a deep borehole of 100 m in depth. We simultaneously captured waveforms of EM pulses in the borehole and of seismic waves installed near the borehole. We have confirmed that the detected EM waves were co-seismic ones readily generated by piezo-electric effect in earth's crusts [1].

We detected an EM pulse in the borehole when an earthquake of M3.0 occurred at 10 km depth and at 5.4 km north of the EM observation site at 03:57 on Dec. 25, 2013. Figure 1 shows waveforms of (a) east-west component (S_{ew}) of the seismic wave, and of (b) east- west component (H_{ew}) of magnetic field of the EM pulse. The waveform of the S_{ew} wave shows an impulsive amplitude at the arrival of its S-wave, which is because the earthquake hypocenter was close to the EM observation site. On the other hand, the waveform of H_{ew} shows that its amplitude was increasing from about 1 sec prior to the S-wave arrival, and after that it was decreasing.

The amplitude change of H_{ew} can be explained as follows: Since the electronic conductivity of the earth's medium is large, the amplitude of an EM wave shows an exponential decrease as a function of the distance, in which the decay rate is so-called Skin depth. Since the source of EM pulse was propagating with the S-wave velocity, the amplitude of the EM wave measured at the EM observation site is exponentially increasing as time goes on, and after the S-wave arrival it is exponentially decreasing. Therefore we obtained the Skin depth ?for the frequency of 20 Hz and the electronic conductivity as 850 m and 0.0175 S/m, respectively.

[1] M. Tsutsui, submitted to IEEE Geoscience, Letters, 2014.

Keywords: seismic wave, electromagnetic wave, observation in the earth, skin depth, electric conductivity

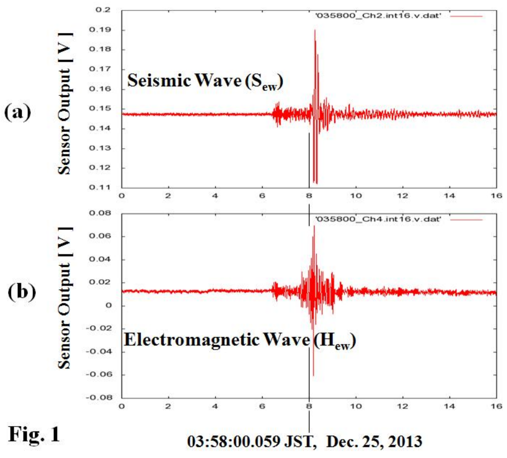

Fig. 1

SEM36-04 Room:413 Time:April 30 16:15-16:45

Electrical conductivity structures of volcanic areas: a proxy for volcanic gas fluxes

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The efficiency of degassing of volcanic gases in magma is one of the key parameters controlling the explosive potentiality of the eruption and the diversity of the volcanic activity. Therefore, to evaluate the mass flux of volcanic gases is important in considering the constraint conditions of the activity. When volcanic gases are dissolved into the pore water of an aquifer, the aquifer has a high electrical conductivity (E.C.); this is because that the pore water conductivity is increased due to the high-salinity and temperature, and that the surface conductivity of rock matrices is also increased due to hydrothermal alteration. Therefore, the spatial extent of the high E.C. region could be related to the abundance of the mass flux of volcanic gases. We have developed the method to estimate the mass flux of volcanic gases using the E.C. structure of volcanic areas as follows.

[Effect of exposure temperatures on the surface conductivity of rock matrices]

There has already been some quantitative formula about the effect of temperature and salinity on the E.C. of the pore water. On the other hand, it has been known that temperatures are closely related to the generation/stability of smectite, which makes a great contribution to the increase of E.C. However, their effect on the surface conductivity has not been understood quantitatively. We performed the E.C. measurements using drillcore samples obtained from drilling projects, to estimate the surface conductivity. Results showed that the relation between surface conductivities and the temperatures to which the rock matrices have been exposed well corresponds to generation/stable condition of smectite. Thus, the surface conductivity could be represented as relatively simple function of exposure temperatures, and the formula could be incorporated into the modeling of dissipation of volcanic gases (Komori et al., 2010, 2013).

[Simplified model for the dissipation of volcanic gases and its application to Unzen volcanic area]

In Unzen volcanic area, there are various geophysical and geochemical studies to understand the formation process of hot springs associated with magma degassing and the magmatic activity. Ohba et al. (2008) proposed three-stage magma degassing; the first magma degassing occurs at the depths of 4-6 km. Correspondingly, the pressure sources are estimated at the similar depths (Kohno et al., 2008). In addition, the high temperature region greater than 200 ℃ are present above the sources (NEDO, 1988), which corresponds to the high E.C. region inferred from TDEM surveys (Srigutomo et al., 2008).

Based on the above background, we developed the simple model of volcanic gases dissipation into the aquifer at the area, to estimate the mass flux of volcanic gases. The model assumes the isotopic physical properties and the simple geometry of the aquifer. The temperatures and salinity of the pore water are distributed by the simulated flow regime, which is the consequent of the injection of the thermal waters formed by the mixing between volcanic gases and groundwater. Their distributions are converted to the pore water and surface conductivities; which are then converted to the bulk E.C. Results showed that the spatial extent of the high E.C. region is essentially controlled by the volcanic gases flux and rainfall recharge (Komori et al., under review).

[Possibility of effective magma degassing]

The above model was applied to the E.C. structure of the area. The estimated volcanic gas flux was 10ˆ4.8$\pm$0.5 t/yr, yielding the CO_2 flux (10ˆ3.1$\pm$0.5 t/yr) and the magma input rate (10ˆ0.1$\pm$0.5 million t/yr). These values are consistent with other petrology, geochemical and geophysical evidences. Our result suggests that the magma is steadily releasing the volcanic fluids into the aquifer. This effective degassing might lead to the decrease of water content of magma, and be one of the reason of the recent effusive volcanism like dome-forming eruptions (Komori et al., under review).

Keywords: Bulk electrical conductivity, Pore water conductivity, Surface conductivity, Volcanic gas fluxes, Unzen volcanic area

Japan Geoscience Union Meeting 2014
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SEM36-05 Room:413 Time:April 30 16:45-17:00

Audio frequency magnetotelluric imaging and tectonic activity evaluation of the Cimandiri Faullt, West Java, Indonesia

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The tectonic activity around the Cimandiri fault zone, Pelabuhan Ratu, West Java, Indonesia, has been analyzed for 30 years (1973-2013). The subsurface electrical resistivity structure close to the Cimandiri fault has been also investigated by twenty five audio-magnetotelluric (AMT) sites. The AMT exploration was carried out during two weeks, from July 27, 2009 to August 8, 2009. The sites were distributed on two lines along about 13 km x 6.5 km profile. There are two profiles of the AMT: (1) the A-A' line of the AMT which is perpendicular to the fault (2) the B-B' line of the AMT which is parallel to the fault. Two-dimensional modelling using the code developed by Ogawa and Uchida 2-D inversion has been applied in the AMT data. The result of tectonic activity analysis shows that the Cimandiri fault is the active fault. The subsurface electrical resistivity structure of the Cimandiri fault zone is characterized by (1) the A-A' and B-B' lines present a conductive zone (1-100 Ωm) from the surface up to the depth of 1 km, which is possibly associated with quarternary volcanics. At the surface, there are also some very conductive spots (1-5 Ωm) which are indicating the existence of the marine sediments in the study area. (2) The gradual conductive-resistive (500-1,000 Ωm) zone at the depth of 1-3.5 km overlays above a low resistivity zone (10-100 Ωm). This low resistivity zone may reflect the combined influences of a fluid network and the presence of the young and less compact sediments with the 500-1,000 Ωm zone as a cap rock that defines the upper boundary of the low resistivity zone (10-100 Ωm). Finally, the result of both methods presents that the Cimandiri fault is the strike-slip fault.

Keywords: audio frequency magnetotelluric, subsurface electrical resistivity structure, 2-D inversion, Cimandiri Fault, Indonesia

Japan Geoscience Union Meeting 2014
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SEM36-06 Room:413 Time:April 30 17:00-17:15

Robust magnetotelluric inversion

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A robust magnetotelluric (MT) inversion algorithm has been developed on the basis of quantile-quantile (q-q) plotting with confidence band and statistical modelling of inversion residuals for the MT response function (apparent resistivity and phase). Once outliers in the inversion residuals are detected in the q-q plot with the confidence band and the statistical modelling with the Akaike information criterion, they are excluded from the inversion data set and a subsequent inversion is implemented with the culled data set. The exclusion of outliers and the subsequent inversion is repeated until the q-q plot is substantially linear within the confidence band, outliers predicted by the statistical modelling are unchanged from the prior inversion, and the misfit statistic is unchanged at a target level. The robust inversion algorithm was applied to synthetic data generated from a simple 2-D model and observational data from a 2-D transect in southern Africa. Outliers in the synthetic data, which come from extreme values added to the synthetic responses, produced spurious features in inversion models, but were detected by the robust algorithm and excluded to retrieve the true model. An application of the robust inversion algorithm to the field data demonstrates that the method is useful for data clean-up of outliers, which could include model as well as data inconsistency (for example, inability to fit a 2-D model to a 3-D data set), during inversion and for objectively obtaining a robust and optimal model. The present statistical method is available irrespective of the dimensionality of target structures (hence 2-D and 3-D structures) and of isotropy or anisotropy, and can operate as an external process to any inversion algorithm without modifications to the inversion program.

Keywords: Inversion, Probability distribution, Magnetotellurics

SEM36-07 Room:413 Time:April 30 17:15-17:30

Preliminary report of self-potential observation during a water injection experiment at 1800 m depth in Nojima fault

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We report self-potential variations during 2013 water injection experiment at 1800 depth in Nojima fault, which is a surface earthquake fault of the 1995 Hyougoken-nanbu earthquake (Mw6.9). The 2013 water injection test started in 15 September and ended in 29 September. Fresh water was injected into the fault system through the open hole part of the borehole (1800m depth). Average injection rate was 20 litter/min and pressure was 5 MPa. Self-potential variations around the 1800m borehole were very smaller than those in the previous water injection experiments (1997, 2000, 2003, 2004, 2006, and 2008) at 540m depth and self-potential variations did not appear clearly to correspond to the operation of the water injection. The previous water injection experiments have been repeated in the same conditions. The observed variations during the experiments have the following features: 1) self-potential variations appeared to correspond to the operation of water injections; 2) the negative voltage appeared around the water injection borehole, and 3) the magnitude of self-potential variations decreased with increasing distance from the borehole. And the self-potential variations in the previous experiments have become larger every experiment. These features suggest that the observed variations were caused by the streaming potential and the permeability around the open hole part of the borehole (540m depth) has decreased. If the line source model to explain the self-potential variations associated with the water injection is correct, the small self-potential variations observed this experiment may suggest that the permeability of the fault fracture zone at 1800m depth is larger than that around the fault at 540m depth.

Keywords: Nojima fault, 1995 Hyogoken-nanbu earthquake, self-potential, water injection experiment, streaming potential

SEM36-P01 Room:Poster Time:April 30 18:15-19:30

Long-term variation of geomagnetic transfer function in Japan

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Time variation of geomagnetic transfer function in Japan was studied for long period of since 1985. Most of the long-term variation is common at most observatories, and some of then are due to the solar activity. However, different behavior of the variation was found at some observatories, which may be caused by time variation of the local conductivity structure in the earth.

Keywords: geomagnetism, transfer function, long-term variation, induced current, locality

SEM36-P02 Room:Poster Time:April 30 18:15-19:30

Numerical simulations for the electrical prospecting of the rock samples

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For the purposes of oil explorations and surveys of active faults, electrical and electromagnetic methods are powerful tools to reveal the underground properties, since the resistivity images have high sensitivity to the existences of the fluid. Obtained resistivity images are interpreted in relation to the porosity of rock and its connectivity with several mixing lows. In order to verify the applicability of such interpretations, we plan to carry out high-density electrical soundings for hand size rock samples whose other geological characteristics are well known.

As the first step of laboratory experiments, we made numerical simulations to estimate the optimal electrode arrangement and the scale of detectable anomalies. In this presentation, we will report the results of numerical simulations and the future plans of laboratory experiments.

Keywords: rock experiments, electrical conductivity, numerical simulations

Japan Geoscience Union Meeting 2014
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SEM36-P03 Room:Poster Time:April 30 18:15-19:30

Volcano-Loop observation at Kusatsu-Shirane volcano

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We have made successful measurement of time domain electromagnetic signals using transmitting and receiving loops at the same location. This system is being planned to work for monitoring the volcano vent.

The test measurement was conducted in the Kusatsu-Shirane volcano where detailed resistivity structure is known by audio-magnetotelluric method. The stepwise waveform was used and off-time response was measured using a transmitting and receiving loop both with 33m radius. The induced voltage was measured from the 0.1ms to 30ms. The observed voltages as a function of time in logarithm were inverted using Occam's algorithm and the model resistivity and resolution of the model were investigated. We also compared the result with those obtained by magnetotelluric method and found that the upper surface layers which have 1d structure are consistent with volcano loop results. We plant to use the system for repeated measurements or continuous monitoring the volcano in the future.

Keywords: Electromagnetic induction, time domain, loop, volcano, monitoring

Japan Geoscience Union Meeting 2014
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SEM36-P04 Room:Poster Time:April 30 18:15-19:30

Electrical conductivity structure beneath the Gomura Fault (Kyotango, Kyoto)

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Fault zone architecture and related permeability structures form primary controls on fluid flow in upper-crustal, brittle fault zone. As the electrical resistivity of rocks is sensitive to distributions of fluids, the magnetotelluric (MT) method can be a powerful tool in investigating the fault zone architecture.

The Yamada Fault is located in Kyoto, Japan. The Yamada Fault zone consists of the main part of the Yamada Fault zone and the Gomura Fault zone. The Gomura Fault zone extends over 34 km and can be grouped into the Gomura Fault, the Chuzenji Fault and so on. The Gomura Fault appeared as a result of 1927 Tango earthquake.

In oreder to delineate subsurface structure of the fault, we made an audio-frequency magnetotelluric survey at 12 stations along the transect (4 km) across the surface trace of the Gomura Fault. The MT response function was obtained at each station, using remote reference processing. After dimensionality analysis by Phase Tensor method (Caldwell et al., 2004; Bibby et al., 2005), two-dimensional inversions for TE and TM modes were carried out, using the code of Ogawa and Uchida (1996).

The model is characterized by two resistive zones and four conductive zones. The most significant conductive zone is recognized beneath the surface trace of Gomura Fault with a width of more than 650 m and located in a depth range of 0.45-1 km. It is noteworthy that the conductive zone beneath the Gomura Fault is comparable in width to the damage zone determined by geological survey.

Keywords: The Gomura Fault, electrical resistivity structure, Magnetotelluric(MT), Damage zone

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SEM36-P05 Room:Poster Time:April 30 18:15-19:30

A Summary report on the investigations of an electrical resitivity structure beneath Chugoku and Shikoku regions, south

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The purpose of this study is to estimate crossing and longitudinal electrical resistivity structure sections in the southwest Japan arc in order to clarify the relation between the deep crustal low resistivity region and seismic activities. Therefore, based on the investigation research of the electrical resistivity structures in Japan arc and the southwest Japan arc, in Sanin region, it is important to clarify the relation between earthquake occurrences out of the strain concentration zone, volcanoes not having eruption records for a long time and crustal fluid, and to find the structural heterogeneity in the inland earthquake occurrence area, the inland seismic gap (beneath the third class and quaternary volcano) and deep low frequency earthquakes. In Shikoku region, it is also important to find the relation between the occurrence pattern and structural locality of crustal earthquakes and deep low frequency earthquakes and the fluid supposed to be supplied from ocean plate subduction.

Our research group has shown that there is a clear relationship between resistivity and seismicity in the Sanin and Shikoku regions. We investigated deep crustal resistivity structures in the measurement lines that traverse a linear seismic activity area along with the coastal part of Japan Sea. As the result, in the eastern part of San-in region, it was found that a conductive area exists in the deep crust part under the seismic region, which is a resistive area, along with the seismic activity area stretching nearly in the east and west direction

However, Ozaki et al.(2011) showed that the crust has generally a high resistivity 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 the author that has studied electrical resistivity in Sanin region. That is, there is a possibility that the deep low resistivity area beneath the Sanin region does not exist in series. Assuming that inland earthquakes occur because of local stress concentration caused by heterogeneity beneath a seismic activity band (Iio, 2009), the heterogeneity should be clarified by a spatial and structure analysis, and a more detailed surfacial structure data should be completed hereafter.

On the other hand, in the Shikoku region, the same investigation was carried out mainly in the outer zone, the south side of MTL and the result suggested that a remarkable conductive area should exist in the upper crust of the outer zone, and that the conductive area in the central and western part should have a clear relation with the non-seismic area.

These studies suggest that high conductivity(low resitivity) is possibly caused by the existence of deep crustal fluids, which probably play an important role in the inland earthquake occurrence mechanism of these regions. As one of the possible interpretations of water supply system, it is thought that the fluids in the deep crust are supplied from the subducting Philippine Sea plate by means of the dehydration processes. However, the existence of the plate is not thoroughly identified in the geological inner zone of the southwestern Japan Arc. Therefore, in order to grasp a whole tectonic setting, from the fore to the back arc side in the southwestern Arc, quantitative discussions based on the wideband MT survey covering whole these regions should be required. Consequently, for making the island arc crossing structure section in the southwest Japan arc, an additional structure investigation in the unmeasured area, the area of Setouchi as the main area is required to clear the northern edge of Philippine Sea plate.

In this presentation, the summary report on joint structure analysis result in Chugoku and Shikoku regions and key features of spatial resistivity distributions in these regions, using the recent data acquired in the Seouchi area incorporated in the existing data, will be shown.

Keywords: electrical resistivity, Chugoku and Shikoku regions, heterogeniety

SEM36-P06 Room:Poster Time:April 30 18:15-19:30

Electrical resistivity features of the back-arc areas in the NE Japan subduction zone

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Electrical resistivity in the crust and upper mantle depends on the pore-fluid distribution, salinity, and connectivity of fluid-filled rock pores. Thus imaging of resistivity distribution based on magnetotelluric surveys gives us fundamental information about fluid distribution of subduction zones. Marine magnetotelluric survey is important to understand dynamics of the NE Japan subduction zone because dehydration of subducting Pacific plate occurs under the Japan Sea. In this study, we discuss resistivity distribution around back-arc areas in the NE Japan subduction zone based on the marine MT data.

We collected natural EM signals with ocean bottom electro-magnetometers (OBEMs) in the eastern Japan sea area between April and August 2013 by MR13-02A and NT13-18 JAMSTEC scientific cruises. In addition, 3 land MT stations were settled in islands in the Japan Sea (Tobishima, Awashima and Sado islands) between April and October 2013. These recorded time-series data were converted to a frequency-domain impedance tensor based on the BIRRP program [1]. The remote reference technique [2] was applied in the data processing using horizontal magnetic field data from Kakioka Station in the period range between 10 and 20000 seconds. As results, high-quality MT responses and geomagnetic tippers in both the trench and back-arc areas.

We calculated phase tensors [3] based on MT impedances by this and previous studies [4] to discuss re-sistivity distribution beneath the back-arc area. The phase tensor ellipse indicates high Φ_{max} (>65 degrees) and Φ_{min} (>50 degrees) in the long periods (>8000 seconds). Large β of phase tensor and large amplitude of geomagnetic transfer function are also shown. These features cannot be explained with bathymetry and sediment effects based on the 3-D forward modeling [5]. Thus strong three-dimensionality and deep conductor possibly distributed beneath the Japan sea. In order to discuss detailed resistivity structure, 3-D inversion approaches are required by using a newly developed 3-D MT inversion code for marine data to treat complicated ocean bottom and land topography [6].

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Keywords: back arc, NE Japan subduction zone, magnetotelluric, OBEM, phase tensor

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SEM36-P07 Room:Poster Time:April 30 18:15-19:30

Conductivity structure beneath the fault segment gap in the Yamasaki fault zone, southwest Japan (2)

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Abstract

The Yamasaki fault zone (YFZ) of southwest Japan is a typical strike-slip fault system consisting of the Nagisen fault, the main strand of YFZ, and the Kusadani fault. The main strand of YFZ extends for over 79km and is divided into northwestern (NW) and southeastern (SE) groups based on their latest seismic activity. The NW group consists of the Ohara, Hijima, Yasutomi and Kuresaka-touge faults, and the SE group consists of the Biwako and Miki faults. The maximum magnitudes of the earthquakes generated by the NW and SE groups are estimated to be 7.7 and 7.3, respectively. Simultaneous activation of both fault groups is also pointed out to be as large as M = ~8.0 (The Headquarters for Earthquake Research Promotion, 2013).

The subsurface structure beneath the fault segment gap between both groups will be the key information for assessing the possibility of such large earthquake.

To infer the structure, we carried out Audio-frequency Magnetotelluric (AMT) survey at 11 sites along a transect between the NW group and the SE group and showed the two-dimensional resistivity model along the transect based on MT impedances. This model is characterized by three conductive zones. They locate beneath the points where the transect crosses the extension lines of the surface trace of the Yasutomi, Kuresaka-touge, and Biwako fault. We thus concluded that the Yasutomi and Kuresaka-touge faults are extended to southeast and the Biwako fault is extended to northwest further than the recognized terminals of their surface trace.

In this presentation, we show the improved resistivity model which is determined by not only MT impedance but tipper vectors.

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

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Electrical Resistivity Imaging at Western Turkey by Wideband Magnetotelluric Method

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The westward migration of large magnitude earthquakes along the North Anatolian Fault Zone indicates that a major event may take place at and around the Marmara region, following the Izmit (Mw7.4) and Duzce (Mw7.2) earthquakes that took place in 1999 in northwest Turkey. For this reason many studies were conducted around Marmara sea, west of these events. These studies focused mostly on the northern part of this area because of the high damage risk near Istanbul, but the similar potential is also present for the southern Marmara. In order to investigate the upper crustal electrical resistivity structure at this location, wide-band magnetotelluric data were collected at sixteen sites forming two parallel profiles. These profiles were constructed to cross the southern branches the North Anatolian Fault. Following the application of Groom and Bailey decomposition that has been applied to remove the surplus features and to deduce the appropriate geo-electric strike direction which is an important requirement for two-dimensional interpretation, an inversion algorithm developed by Ogawa and Uchida (1996) was utilized to develop electrical resistivity models. These models pointed out a relatively complicated shallow (surface-to-5 km) structure which may be associated with the presence of crustal fluids, but below these depths the electrical resistivity is more uniform with only a deep conductor appearing beneath the northern ends of the two profiles. The known faults in the survey area correlate well with the features characterized in the final geo-electric models. A resistive-conductive boundary between Manyas - Karacabey basin and Bandirma-Karadag uplift on the western and Uluabat uplift and Mudanya uplift on the eastern profiles may be associated with the South Marmara Fault.

Keywords: North Anatolian Fault, Fluids, Electrical resistivitiy, Magnetotellurics, geo-electric models

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Installation of a Vector Magnetometer for a Ground-based Tsunami Early Warning

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Conductive sea water moving in the geomagnetic main field generates electromagnetic variations by a physical process called the oceanic dynamo effect. This effect at the time of tsunami passages was recently detected on the seafloor in the northwest Pacific (Toh et al., 2011) and on Easter Island (Manoj et al., 2011). The tsunami-induced electromagnetic field is expected to contribute to existing global tsunami warning systems.

We are carrying out a project that aims to observe geomagnetic variations associated with tsunami passages by ground-based real-time observations. This project requires a pair of geomagnetic observation sites for clear detection of tsunami events. The geomagnetic coast effect and the external field due to ionospheric and/or magnetospheric disturbances can be removed by taking real-time differences between a coastal and an inland geomagnetic sites. We installed a vector magnetometer at Umaji located in the middle of Muroto Peninsula, where artificial electromagnetic noises are very small. This location is selected as a counterpart of the existing observation site at Muroto located at the tip of the peninsula, which is operated by Geospatial Information Authority of Japan (GSI).

In this presentation, we will make a progress report on our ground-based tsunami warning system consisting of a pair of vector magnetometers. This system is intended to detect the geomagnetic field variations induced by tsunamis at the time of Nankai/Tonankai earthquakes.

Keywords: Geomagnetism, Tsunami

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The several Records of tsunami induced magnetic field obtained by the JMA Chichijima observation station(CBI).

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Through the geomagnetic field, electrically conducting seawater movement generates electric fields and currents in generally. Furthermore, the current induces secondary magnetic fields. Our Chichijima geomagnetic observation station (CBI) is located on the solitary island in the Pacific Ocean. Addition this, located the tsunami observation station (Futami tide gauge) that is subject to the JMA. We are able to obtain concurrent tsunami and magnetic data because the distance between these observation points is only 1 km. So, this Chichijima Island is suitable in order to research tsunami induced magnetic fields research. We have investigated in CBI data (samples taken every 1 second) and Chichijima Futami tide gauge data (every 15 seconds) from 1995 to 2013, finally obtained 9events tsunami induced phenomena. The many of the signal of these events is small, but three of them has clear record, the 2011 off the Pacific coast of Tohoku Earthquake Tsunami (2001/3/11 M9.0), The 2010 Chile earthquake (2010/2/27 M8.8) and 1996 the Irian Jaya Earthquake Tsunami (1996/2/17 M8.1). The other events are week, but their magnetic signals are detectable enough. it may be worth worldwide renown that so many induced magnetic phenomena have been fund in one observation station Chichijima (CBI). In the low solar activity periods, the induced magnetic signal may be detectable, if the half tsunami amplitude is 20cm or over. Some of these events might have been disturbed and dismissed due to magnetosphere substorm, even though the induced magnetic field was enough to detect. Each of above-mentioned three examples has over 1 m tsunami height, and clear induced magnetic record. Especially, in spite of weak magnetosphere substorm, the record of the 2011 off the Pacific coast of Tohoku Earthquake Tsunami is very clear. So, on 1 m or more-high tsunamis, it is safely said that the induced magnetic fields is detectable definitely. These induced magnetic field records will be one of mediation between the geomagnetic science and the tsunami disaster prevention science.

Keywords: tsunami, Induced magnetic effects, chichijima

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SEM36-P11 Room:Poster Time:April 30 18:15-19:30

Geomagnetic total intensity variations associated with vertical crustal movement in the eastern part of Izu Peninsula

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In order to detect geomagnetic changes associated with the earthquake swarm and anomalous crustal activities, continuous observations of the geomagnetic total intensity have been conducted in the eastern part of Izu Peninsula. The continuous data of the geomagnetic total intensity were utilized after an analysis of removing the effect of external magnetic field from those data during 2010 - 2012. An association between the geomagnetic field variation and the vertical crustal movement was examined comparing the day-to-day variation of the geomagnetic total intensity with that of the geodetic height measured by GPS (Global Positioning System). It is found that the day-to-day variation in the geomagnetic total intensity shows each seasonal change on the quiet seismic period during 2010 and on the relatively active seismic period during 2011 and shows no significant change on the quiet seismic period during 2012, though the day-to-day variation in the vertical crustal movement shows seasonal changes during 2010 - 2012. It is inferred that the hydrothermal activity related to the Dec. 2009 earthquake swarm caused by magma injection had been lasting up to less than two years and the hydrothermal movement associated with the vertical crustal movement had caused the seasonal changes in the geomagnetic total intensity during 2010 - 2011. This suggests the observed variations of the geomagnetic total intensity were not directly associated with seismic faulting. The continuous observation of the geomagnetic total intensity is expected to have a monitoring advantage in predicting the course of the earthquake swarm activity in the eastern part of Izu Peninsula.

Keywords: eastern part of Izu Peninsula, geomagnetic total intensity, crustal movement, hydrothermal activity

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Validity of using space approximation in calculating EM variations generated by the piezomagnetic effect

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Variations in the magnetic field generated by the piezomagnetic effect, which is referred to as the piezomagnetic field, has been discussed in a framework of magneto-statics, in which temporal variations are totally ignored. This treatment is valid for quasi-static processes, but possibly invalid for dynamic processes including fault ruptures. The earlier works by the author has demonstrated that, when the temporal variations in the EM field is considered, finite conductivity of the Earth's crust alters the feature of the piezomagnetic field. However, consideration of the temporal variations in the EM field makes estimation of the piezomagnetic field complicated, even in a simple two-layered model which consists of the Earth's ground with finite conductivity and the air as a perfect resister.

The problem will be largely simplified if the situation is approximated by a finite space model with a uniform electrical conductivity.

In the present work, variations in the EM field generated by the piezomagnetic effect are compared for two situations: finite space and semi-finite space models with finite conductivity, assuming the source of the piezomagnetic field is two-dimensional. It is demonstrated that, for some situations, the simpler model provides a good approximation of the expected piezomagnetic field.

Keywords: piezomagnetic effect, electromagnetic field, electrical conductivity, infinite space, semi-infinite space