Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-01 Room:102A Time:May 24 10:00-10:15

Development of scanning SQUID microscope and initial results

ODA, Hirokuni[1*] ; KAWAI, Jun[2] ; MIYAMOTO, Masakazu[2] ; MIYAGI, Isoji[1] ; YAMAMOTO, Yuhji[3] ; USUI, Yoichi[4] ; USUI, Akira[3] ; NAKAMURA, Norihiro[5]

[1]Geological Survey of Japan, AIST, [2]Kanazawa Institute of Technology, [3]Kochi University, [4]Japan Agency for Marine-Earth Science and Technology, [5]Tohoku University

Scanning superconducting quantum interference device (SQUID) microscope (SSM) is a useful tool to image very weak magnetic fields with high spatial resolution. Fong et al. (2005) developed an SSM with a monolithic SQUID and applied to scan magnetic field produced by geological thin sections. Oda et al. (2011) succeeded in imaging of the magnetic stripes of hydrogenetic ferromanganese crusts using the SSM at Vanderbilt University developed by Fong et al. (2005) and could provide age model by correlating to the standard geomagnetic polarity timescale. In this project, we have developed an SSM to image vertical magnetic fields over thin sections of various rock samples for geological studies. We designed a hollow-structured cryostat to realize reliable SQUID assembly and repeatable adjustment of the vacuum separation from the sample. The SQUID based on niobium process is a single-washer magnetometer with the pickup area of 200 x 200 square micrometers and the size of the chip is 1 mm x 1mm. The SQUID chip is mounted on a conical sapphire rod and electrically connected to the non-magnetic electrodes with silver paste. The electrodes are patterned on the surface of the sapphire rod using metalization technique. The sapphire rod is connected to a copper block, which is thermally anchored to the liquid helium reservoir with copper bundle wires. The copper block is connected to a rigid shaft through a flexure spring, and the shaft extends through the hollow of the cryostat to the spindle placed on the top flange at room temperature. A 40-micrometer thick sapphire window separating the sample from the vacuum space can be adjusted toward the SQUID using a bellows structure. With this mechanism, we have achieved the separation of ˜250 micrometers between the SQUID and the sample, so far. The field resolution of the SQUID was 1.1 pT/rtHz at 100 Hz in a flux locked loop (FLL) operation. In this talk, we will introduce the development of our SSM project and describe the performance of the system. Further, we will present some initial mapping results conducted on various geological samples, such as volcanic rocks, sediments, etc. The project is supported by JSPS KAKENHI Grant Number 25247073.

Keywords: scanning SQUID microscope, remanent magnetization, geological thin section, liquid He, magnetic shield, XY scanning stage

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-02 Room:102A Time:May 24 10:15-10:30

Proposal of positioning method using a magnetized thin-film dot for scanning SQUID microscopy

KAWAI, Jun[1*] ; ODA, Hirokuni[2] ; MIYAGI, Isoji[2]

[1]Kanazawa Institute of Technology, [2]Geological Survey of Japan, AIST

We have developed a scanning superconducting quantum interference device (SQUID) microscope (SSM) for imaging magnetic field distribution of geological rock samples. The rock sample, which is processed into a thin section and glued on a glass with non-magnetic resin, is placed on a XY table under the SQUID microscope, and is scanned. The distance between the SQUID and the sample can be calibrated with magnetic field generated with a dc-current applied to a thin and long wire. However, the position of the sample for the SQUID must be determined in another way. Positioning the magnetic field image for the structure of the sample is necessary for analysis of the magnetic field distribution. We propose a positioning method using a thin-film magnetized circular dot as a magnetic dipole marker.

Considering expected special resolution of about 200 μm or smaller, we designed four kinds of single circular dots with different diameter, which are 10 μm, 50 μm, 75 μm, 100 μm. We adopted FeCo as a material for the dot. A 500-nm-thick FeCo layer was deposited on a silicon substrate with DC-sputtering and was formed into circular dots with lift-off process. After forming the dots, the Si substrate was diced into square chips with the size of 3.5 mm $\times$ 3.5 mm, where each chip has a single dot. Scanning the 25-μm dot with the SQUID microscope, we obtained dipole-like field of ˜10 nT, which is large enough as a magnetic maker.

We plan to attach this chip with the dot adjacent to the sample on the sample holder. Finally, we can superimpose the magnetic field pattern on an optical image of the sample.

Keywords: SQUID microscope, geological thin section, positioning, magnetized dot, thin film

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-03 Room:102A Time:May 24 10:30-10:45

Deconvolution of continuous paleomagnetic data: Implementation of convenient graphical software based on optimization

XUAN, Chuang[1*] ; ODA, Hirokuni[2]

[1]University of Southampton, [2]Geological Survey of Japan, AIST

Deconvolution effectively overcomes the convolution effect of sensor response and improves the resolution of continuous paleomagnetic data acquired on pass-through superconducting rock magnetometers (SRM). However, the lack of an easy-to-use deconvolution tool has hindered the application of deconvolution for continuous paleomagnetic measurements. Here, we present MATLAB software UDECON with graphical user interface, as a convenient tool to perform realistically optimized deconvolution based on Akaike's Bayesian Information Criterion minimization method (Oda and Xuan, 2014). UDECON directly reads the original paleomagnetic measurement file, and allows the user to view, compare, and save paleomagnetic data before and after the deconvolution. We demonstrate that optimized deconvolution using UDECON can greatly help revealing detailed paleomagnetic information such as excursions that could be smoothed out during pass-through measurements. The application of UDECON to the vast amount of existing and future pass-through paleomagnetic and rock magnetic measurements on sediment archives recovered especially through the ocean drilling programs will contribute to our understanding of the geodynamo and paleo-environment by providing more detailed records of geomagnetic and environmental change through reliable deconvolution.

Keywords: superconducting rock magnetometer, deconvolution, sensor response, u-channel sample, ABIC minimization, MATLAB software

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SEM34-04 Room:102A Time:May 24 11:00-11:15

Measurement of dynamic magnetization in time domain and frequency domain

KODAMA, Kazuto[1*]

[1]Center for Advanced Marine Core Research, Kochi University

Measurement of transient magnetization induced by a pulsed field with duration of ∼10 ms was carried out for a set of synthetic and natural samples with a new instrumentation using a commercial pulse magnetizer. Results from the synthetic samples showed considerable differences from those measured by a quasi-static method using a VSM, due to time-dependent electromagnetic effects, such as magnetic viscosity, eddy current loss, demagnetizing field, shape anisotropy, and magnetic relaxation. Results from the natural samples (volcanic rocks) were characterized by the transient magnetization *vs* field curves that were largely comparable to the corresponding portions of the hysteresis loops. The magnetization remained at the end of a pulse decayed exponentially within 3 ms after a pulse, indicating rapid magnetic relaxation that could be interpreted in terms of domain wall displacement. To better understand such magnetic relaxations, we carried out measurement in the frequency domain that was performed by measuring low-field magnetic susceptibility over a wide band of frequencies. We used the same samples as in the time domain studies. Resulting frequency spectra of susceptibility were converted into the time domain on the basis of linear response theory and computer simulation. Results in the two different domains were mostly consistent, but not identical in detail. We discuss the advantage, disadvantage, and limitations of these two methods, as well as their potential applications to rock magnetism and environmental magnetism.

Keywords: dynamic magnetization, rock magnetism, magnetic relaxation, frequency spectrum, Fourier transfom

Japan Geoscience Union Meeting 2015
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SEM34-05 Room:102A Time:May 24 11:15-11:30

Rock magnetic properties of the September 2014 eruptive products from Ontake volcano, Japan

SAITO, Takeshi[1*] ; KATAOKA, Kyoko S.[2] ; MATSUMOTO, Takane[2] ; SASAKI, Akihiko[3]

[1]Department of Geology, Faculty of Science, Shinshu University, [2]Research Institute for Natural Hazards and Disaster Recovery, Niigata University, [3]Institute of Mountain Science, Shinshu University

Ontake volcano, Japan, erupted unexpectedly on September 27, 2014. Though the eruption was phreatic eruption, which is a relatively small explosion unaccompanied by fresh magma, more than 50 tourists became victims and the eruption is the Japan's deadliest volcanic disaster in more than a century. We start to study eruption process of September 27 eruption and transport and emplacement mechanisms of the eruptive products. This study focuses on magnetic minerals in the eruptive products and carried out rock magnetic measurements.

Thermomagnetic measurements conducted in air showed irreversible curves. Induced magnetization increased remarkably above 400 ℃ and reached about five times of initial values around 470 ℃. Magnetization decayed to almost zero up to 600 ℃. During cooling, only one Tc of about 580 ℃ was obtained. Magnetization after the measurements is less than two times of initial values. Microscopic observation revealed abundant pyrite crystals were contained in the eruptive products. Our thermomagnetic results indicated magnetite was formed during the experiments by the oxidation of pyrite above 400 ℃. This implies that the volcanic materials of this eruption were not heated to about 400 ℃. In addition, thermomagnetic signal of sharp peak around 470 ℃ is observed characteristically in the eruptive products. It can be used as a marker of the eruptive products and we can evaluate how long and how far the eruptive products deposited around the summit of the volcano will transport to the base area.

Keywords: Ontake, phreatic eruption, pyrite, rock magnetism

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SEM34-06 Room:102A Time:May 24 11:30-11:45

Tsunami and seasonal variation records in Senday Bay sediments revealed by rock magnetic and geochemical analyses

ABE, Hirokuni[1] ; KAWAMURA, Noriko[2*] ; ISHIKAWA, Naoto[3]

[1]Takamatsu Office, Japan Coast Guard, [2]Japan Coast Guard Academy, [3]Graduate School of Human and Environmental Studies,Kyoto University

Coastal marine sediments along island arcs have records of the past disaster events like tsunamis and seasonal floods. In order to reconstruct those events from the coastal marine sediments, we need to distinguish between tsunami effects and seasonal variations. Tsunami was occurred in 11 March, 2011, off the Pacific coast of Tohoku by the Earthquake (M 9.0). The earthquake source was located off Sendai city and near the axis of the Japan trench. This study is aimed to sort both past events based on rock magnetic properties and geochemical analysis from the sediments taken in Sendai bay. The sediment samples were collected at five stations in Sendai bay at every season during 2002-2011. The sediment particle size is larger at the offshore stations. It suggests that fine sediment particles are transported by the bottom current. For measurements of carbon, nitrogen and sulfur amounts in the sediments, CHNS analyses were conducted. Results indicated that the amounts of those elements decrease toward offshore stations, and the changes of the values depend on the season in the inner bay. Rock magnetic properties (natural, anhysteretic, and isothermal remanent magnetization, magnetic susceptibility, remanent corecivity, and corecivity) of the sediments were measured. The values also show seasonal variations at the stations in the inner bay. For discriminations between tsunami effects and seasonal variations, we focused on the samples taken in June 2007, 2008, and 2011. The amounts of carbon and sulfur are large in the 2011 samples after the tsunami. Thermo-magnetometric results indicate the presence of magnetite and iron sulfide in all samples. Especially, the 2011 samples at the offshore stations under the bottom current are found to contain iron sulfide as a dominant magnetic mineral. It may be implied that iron combines sulfur after deposition and that are prevented from the transportation of the bottom current.

Keywords: Tsunami deposit, rock magnetism, C/N

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SEM34-07 Room:102A Time:May 24 11:45-12:00

Environmental Rock-Magnetism of Cenozoic Red Clay in the South Pacific Gyre

SHIMONO, Takaya[1*] ; YAMAZAKI, Toshitsugu[2] ; SUZUKI, Katsuhiko[3]

[1]Graduate School of Life and Environmental Sciences, University of Tsukuba, [2]Atmosphere and Ocean Research Institute, University of Tokyo, [3]Research and Development Center for Submarine Resources, JAMSTEC

Red clay occupies about 40 % of the global ocean floor. Paleoceanographic and paleomagnetic studies of red clay were limited so far because red clay does not yield microfossils that can be used for precise age estimation and sedimentation rates were extremely low. However, red clay could be useful for elucidating long-range environmental changes. Recently, red clay has attracted interest because of the discovery that red clay rich in ∑REY (rare-earth elements and yttrium) distributes widely in the Pacific Ocean. We conducted an environmental rock-magnetic study using the Integrated Ocean Drilling Program (IODP) Site U1365 cores (75.5 m long above ~125 Ma basement) taken at the western edge of the South Pacific Gyre (SPG) in order to investigate long-range climatic and paleoceanographic changes during the Cenozoic. This is the first environmental rock-magnetic study in the SPG ever.

Magnetostratigraphy could be established above ~6 meters below the seafloor (mbsf) (~5 Ma). Below ~6 mbsf, the ages of the Site U1365 cores were transferred from published ages of nearby Deep Sea Drilling Project (DSDP) Site 596, which is based mainly on a constant Cobalt flux model, by inter-core correlation using magnetic susceptibility and ∑REY variation patterns. On first-order reversal curve diagrams, a non-interacting single-domain magnetic component, which is a characteristic of biogenic magnetite, was recognized throughout the sediment column. The ratio of anhysteretic remanent magnetization (ARM) susceptibility to saturation isothermal remanent magnetization (IRM) (k_{ARM} /SIRM), a proxy of the biogenic to terrigenous magnetic components, is high, in particular below ~8.0 mbsf (~35 Ma). In the results of IRM component analyses, the middle-coercivity (M) component likely carried by maghemite increased since ~35 Ma, whereas S ratios and k_{ARM}/SIRM values decreased. The increase of the M component accelerated after 5 Ma. These observations suggest increases of the input of terrigenous magnetic minerals, which is inferred to be transported as eolian dust. The Eocene/Oligocene boundary (~34 Ma) is known as the time of a major global cooling, and the increase of eolian dust supply in the South Pacific may have occurred since then. Northward shift of Australia to an arid region in middle latitudes should have also contributed to the increase of eolian dust supply. The second increase of eolian dust flux at ~5 Ma may have been caused by a further growth of the Antarctic glaciation at ~6 Ma.

Keywords: red clay, environmental magnetism, South Pacific Gyre, biogenic magnetite, eolian dust, Cenozoic

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SEM34-08 Room:102A Time:May 24 12:00-12:15

Variation in magnetic properties of serpentinized peridotites from Yokoniwa Rise, Central Indian Ridge

FUJII, Masakazu[1*] ; OKINO, Kyoko[1] ; SATO, Hiroshi[2] ; NAKAMURA, Kentaro[3] ; YAMAZAKI, Toshitsugu[1]

[1]AORI, UTokyo, [2]Senshu University, [3]UTokyo

Serpentinization of ultramafic rocks through hydrothermal alteration changes the physical, rheological, chemical, and magnetic properties of the oceanic lithosphere. Recent discovery of widespread exposures of serpentinized mantle materials on the seafloor in a slow-spreading environment renewed interest for this alteration process. However, we have limited understanding of the serpentinization mechanism because of the lack of data measured from seafloor rocks. Since magnetite is a direct product of serpentinization process, magnetic properties of serpentinized peridotites can be a good indicator to understand the process. We collected 30 peridotite samples of different degrees of serpentinization from the seafloor on the non-transform-offset massif called as the Yokoniwa Rise in the Central Indian Ridge. These 30 samples yielded a wide range (17-100%) of serpentinization degrees and provide us a good data set to evaluate the relationship between serpentinization and magnetic properties. The measured range of magnetic parameters are as follow; natural remanent magnetization (0.2-8.4 A/m), magnetic susceptibility (0.002-0.087 SI), and magnetite amount (0.1-5.5 wt%). The amount of magnetite varies nonlinearly, likely exponentially, as a function of serpentinization degree. Remarkable increase of magnetite amount occurs in samples with high degree of serpentinization (>70%), indicating larger production of magnetite during the late stage of serpentinization process. The results provide key constraints on the serpentinization mechanism, and insights on the potential of serpentinized mantle to contribute to marine magnetic anomalies.

Keywords: serpentinized peridotite, upper mantle, rock magnetics, slow spreading ridge

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SEM34-09 Room:102A Time:May 24 12:15-12:30

Rock-magnetic properties of single zircon crystals sampled from the Tanzawa tonalitic pluton, central Japan

SATO, Masahiko[1*] ; YAMAMOTO, Shinji[2] ; YAMAMOTO, Yuhji[3] ; OHNO, Masao[1] ; TSUNAKAWA, Hideo[4] ; MARUYAMA, Shigenori[4]

[1]Kyushu University, [2]The University of Tokyo, [3]Kochi University, [4]Tokyo Institute of Technology

Geomagnetic field paleointensity data provide critical information about the thermal evolution of the Earth, and the state of the geomagnetic field has been shown to be closely related to the surface environment. While it is pivotal to understand the variations in geomagnetic field intensity throughout the history of the Earth, data are still too scarce to resolve billion-year-scale geomagnetic field variation. This is primary because of the lack of geological samples for older eras, which often result in unsuccessful paleointensity experiments.

This study focuses on a paleointensity experiment using single zircon crystal. Zircon crystals play an important role in paleomagnetic studies because they have several mineralogical advantages: (1) they commonly occur in crustal rocks, (2) precise age determinations with U-Th-Pb and (U-Th)/He analyses are possible, and (3) they have highly resilient responses to alterations and metamorphism. Although rock-magnetic properties of single zircon crystal are essential for establishing the paleointensity method, few rock-magnetic studies have been conducted for single zircon crystals, which is largely because of their small size and weak magnetic moment.

To establish paleointensity method, we conducted systematic rock-magnetic measurements for single zircon crystals. Zircon crystals were sampled from fluvial sands of the Nakagawa River, which crosses the Tanzawa tonalitic plutons in central Japan. Young crystallization ages and the clear thermal history of the Tanzawa zircon crystals made them suitable for evaluating the feasibility of conducting paleointensity experiment using single zircon crystals.

Based on the results of rock-magnetic measurements for 1037 grains of zircon crystals, the zircon crystals can be classified into three groups. The first group contains little or no ferromagnetic minerals. The second group is characterized by low natural remanent magnetization (NRM)/isothermal remanent magnetization (IRM) ratios (0.004-0.02), pseudo-single-domain-like hysteresis parameters, and moderate low-temperature demagnetization (LTD) memory of IRM (20-90%). The third group is characterized by high NRM/IRM ratios (0.02-2), single-domain-like hysteresis parameters, and high LTD memory of IRM (60-140%). Results from low-temperature magnetometry analyses indicate that the main remanence carriers of the second group are nearly pure magnetite. Thermoremanent magnetization (TRM) acquisition experiments were also carried out for the second group zircon crystals. Consequently, the TRM intensity was comparable with that of NRM, and rough estimation of the paleointensity using bulk NRM/TRM ratios show field intensities consistent with the geomagnetic field intensity at the Tanzawa tonalitic pluton for last 5 Myr. A future study using the second group zircon crystals could provide reliable paleointensity data.

Keywords: Zircon, Tanzawa tonalite, Rock-magnetism, Paleointensity

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SEM34-10 Room:102A Time:May 24 12:30-12:45

Magnetic anisotropy of amorphous silicate

UYEDA, Chiaki[1*]

[1]Graduate School of Science, Osaka University

Depth profile of paramagnetic anisotropy was experimentally obtained for the first time on an amorphous sample, namely tektite, with a spatial resolution of 0.5mm. In order to realize the above measurement, quadrangular prism was cut from the amorphous sample with its long axis normal to surface plane, then paramagnetic anisotropy of square plate (2mmx2mmx0.5mm), separated from the above prism, were measured one by one. In order to detect anisotropy of the small square plates, field-induced rotational oscillation of the plates were measured; the plates were released in a micro-gravity area. According to the observed results, the magnetic unstable-axis of the plates was all normal to surface plane, and the magnitude of anisotropy was comparable to the values previously obtained for popular rock forming minerals. Possibility of magnetic alignment by anisotropy has not been considered as yet for an amorphous material, because an amorphous material is generally believed to be isotropic. An anisotropic crystal field assigned to a isolated Fe ion in the material was detected on the above sample plates by ESR measurement, which indicated that anisotropy obtained by micro gravity experiment may derive from a single magnetic ion. According to recent astronomical survey, dust particles in the planet formation area are mainly composed of crystalline silicate and amorphous silica. Hence a model to explain the cause of magnetic dust alignment, commonly observed to estimate the cosmic field direction, may be constructed based on the field-induced anisotropy energy that originates from anisotropy assigned to the dust materials.

Keywords: magnetic alignment, dust alignment, micro gravity, rotational oscillation, paramangetic anisotropy, amorphous silica

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SEM34-11 Room:102A Time:May 24 14:15-14:30

Test of Hotspot Drift Using Recent Paleolatitude Data of Louisville Hotspot

HARADA, Yasushi[1*] ; WESSEL, Paul[2]

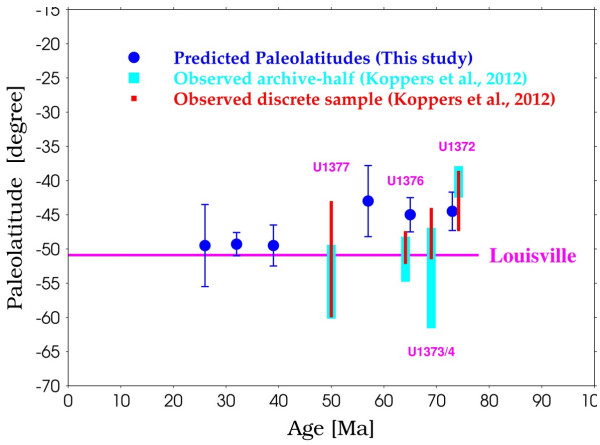
[1]School of Marine Science and Technology, Tokai University, [2]Univ Hawaii

Harada, 2007 JPGU showed that the paleomagnetic data of the Hawaii hotspot track by Turduno et al.,2003 is explainable by a true polar wander path model calculated from the Pacific paleomagnetic skewness data and the absolute motion of the Pacific plate. That is, the paleomagnetic data of the Hawaii hotspot is not proper evidence for inter-hotspot motions.

We did similar analysis for the new paleomagnetic data sets of Louisville hotspot (Koppers et al., 2012). Paleolatitudinal change of Site U1377 (50Ma), U1376 (64.1Ma), U1373 (69.5Ma), and Site U1372 (74.2Ma) is decreasing about 5 to 10 degrees, and that is in harmony with the theoretical paleolatitudinal change by the same true polar wander path model calculated from the Pacific plate data (figure below). The true polar wander path model calculated from the Pacific data is also in harmony with the true polar wander path calculated from paleomagnetic data around the African plate and the absolute motion of the African plate, therefore the new true polar wander model can be regarded as a motion of the paleomagnetic pole relative to the global hotspot reference frame.

We conclude that the paleolatitude data of hotspots above are explainable by true polar wander and are no longer evidence for hotspot drift if any.

Keywords: Hotspot Drift, Louisville Hotspot, Paleolatitude, True Polar Wander Path



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SEM34-12 Room:102A Time:May 24 14:30-14:45

Timing of the clockwise rotation of Southwest Japan: paleomagnetic evidence from Miocene sedimentary rocks

HOSHI, Hiroyuki[1*] ; KATO, Daiki[1] ; ANDO, Yoshikazu[1] ; NAKASHIMA, Kazuo[2]

[1]Aichi University of Education, [2]Yamagata University

The clockwise rotation of Southwest Japan is a textbook example of near-pivot arc rotation associated with back-arc opening. However, its timing is still a matter of debate; earlier studies suggested rapid rotation at about 15 Ma, but this does not seem to be supported by recent paleomagnetic data. To address this problem, we have carried out a paleomagnetic study of biostratigraphically well dated (15.8-15.7 Ma) Miocene sedimentary rocks in the eastern part of Southwest Japan. A total of 288 rock samples of siltstone and felsic fine tuff were collected from a ˜90 m sedimentary sequence. Of these, 142 yielded reverse polarity characteristic remanence directions, resulting in a formation-mean direction that can be used for tectonic discussion. We conclude that about 80% of the entire ˜45^{o} rotation occurred in a period between 17.5 Ma and 15.8 Ma at a rotation rate of ˜21^{o}/Myr, and the remaining ˜20% by 15 Ma. This clockwise rotation happened in the latest stage of the late Paleogene to early Neogene opening of the Japan Sea.

Keywords: paleomagnetism, rock magnetism, Southwest Japan, tectonic rotation, Mizunami area, Oidawara Formation

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SEM34-13 Room:102A Time:May 24 14:45-15:00

Rock magnetism and paleomagnetism of the Nohi Rhyolite in the eastern part of Southwest Japan

SAKO, Kazuki[1] ; HOSHI, Hiroyuki[1*]

[1]Aichi University of Education

The Nohi Rhyolite is a late Cretaceous large volcanic complex in the eastern part of Southwest Japan and has a paleomagnetic record that can be used to infer the tectonic development of the eastern Asian margin. Previous studies have documented two distinct groups of paleomagnetic directions. One has a set of dual polarity antiparallel directions marked by an eastward-deflected declination, which has been reported from the peripheral areas of the Nohi Rhyolite. The eastward deflection suggests a clockwise tectonic rotation. Another is a reverse polarity directional set marked by a southward declination, which has been found in the central part. The southward direction was interpreted in a previous study to be a result of either (1) remagnetization around a fault running in the central part or (2) block rotation occurring in relation to the strike-slip faulting along the fault. To address this problem, we carried out detailed paleomagnetic and rock magnetic experiments and microscopic observations of volcanic and sedimentary rocks collected at 51 sites. We obtained 40 site-mean directions, and our experimental results suggest that they are retained primarily by magnetite and partly by hematite. Positive results of the paleomagnetic baked contact test indicate that the eastward-deflected characteristic remanent magnetization (ChRM) directions were acquired before 68 Ma. Our microscopic observations confirmed the existence of Fe-Ti oxides suffered by high-temperature oxidation in pyroclastic rocks at some sites where the eastward-deflected ChRM directions were detected, implying that the directions are primary thermoremanent magnetization. We obtained 15 reliable site-mean directions that were considered to be a primary magnetization. Basically they are consistent with the directions reported previously, but suggest more complicated crustal deformation in the eastern part of Southwest Japan than has previously been suggested, possibly resulting from the Miocene collision of the Izu-Bonin arc with the Honshu arc. In the central part of the Nohi Rhyolite, we found an outcrop where originally reddish pyroclastic rocks have partly been altered to greenish ones, and detailed magnetic experiments and microscopic observations were carried out for both rocks. Our results indicate that the reddish and greenish rocks possess an eastward-deflected direction and a reverse southward direction, respectively. The greenish rocks contain small secondary magnetite grains within an altered biotite. Therefore, we conclude that the reverse southerly direction is a secondary magnetization.

Keywords: Nohi Rhyolite, paleomagnetism, rock magnetism, tectonic rotation, late Cretaceous

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(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-14 Room:102A Time:May 24 15:00-15:15

Further examination of the geoelectromagnetic jerk hypothesis

SHIMIZU, Hisayoshi[1*] ; UTADA, Hisashi[1]

[1]Earthquake Research Institute, Univ. of Tokyo

Short time-scale geomagnetic main field variations such as a geomagnetic jerk may be influenced by electromagnetic induction and conduction in the lower mantle. Similar variations were seen in long baseline geoelectric field measurements that are in progress in the northwestern Pacific using thousand-kilometer-scale submarine cables. Geoelectric secular variation data from such measurements have potential to discuss the significance of the influence and to clarify the cause of the phenomenon if they are analyzed simultaneously with geomagnetic data. In our previous work, we found a sudden change of the geoelectric field trend at around 2006. By supposing simply that the geoelectric field variation has the same origin with the geomagnetic jerk in 2007 (geoelectromagnetic jerk hypothesis), which was evident in the south Atlantic and Africa, we made a numerical study to understand possible cause and conductivity structure in the mantle. As a result, it was found that the geoelectric and geomagnetic field variations were both explained if the variations were originated from a toroidal magnetic field at the core-mantle boundary. It was also suggested that significant electrical conduction currents existed in the D" layer beneath the area where the geomagnetic field variation was evident. In this presentation, the validity of the geoelectromagnetic jerk hypothesis is discussed by extending the analyses adding more recent geoelectric and geomagnetic field data. Also, we estimate the amplitude of motionally induced electric field variation in the ocean by using a large-scale ocean circulation model, ECCO (Estimating the Circulation and Climate of the Ocean), to confirm that motional induction is not the cause of the observed geoelectric signal.

Keywords: geomagnetic jerk, gelelectric field, electrical conductivity of mantle

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SEM34-15 Room:102A Time:May 24 15:15-15:30

Geomagnetic secular variation due to upwelling and downwelling flows at the core surface

MATSUSHIMA, Masaki[1*]

[1]Tokyo Institute of Technology

Fluid flow near the core surface can be estimated from spatial distribution and secular variation of the geomagnetic field. We have developed a new approach into which the magnetic diffusion is incorporated inside the boundary layer at the core-mantle boundary (CMB), while it is neglected below the boundary layer as in the so-called frozen-flux approximation.

Locations of upwelling and downwelling flows can be derived from the core surface flow thus estimated, and the distribution inside and below the boundary layer provides information on existence of convective columns, which are classified into cyclonic and anti-cyclonic ones; an axial flow component from the CMB to the equator exists in a cyclonic column, whereas that from the equator to the CMB in an anti-cyclonic column. In reality, we have found typical distribution for convective columns in core surface flow below the Indian Ocean for the epoch of 1980.

In many numerical dynamo models, magnetic advection due to downwellings associated with cyclonic vortices is found to be in balance with magnetic diffusion, and cyclonic vortices at the core surface can be responsible for magnetic flux patches. Intense magnetic flux spots seen in equatorial regions might be generated by columnar flows near the equator. Hence we have examined secular variations due to upwelling and downwelling flows at the core surface. It turns out that intense flux spots in equatorial regions do not correspond to downwellings associated with axial flows in cyclonic columns near the equator. This result implies that pairs of intense magnetic flux spots in equatorial regions are produced by flux expulsion due to columnar flows there, and that magnetic diffusion is significant in equatorial regions.

Keywords: core surface flow, secular variation, geomagnetic field

Japan Geoscience Union Meeting 2015
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SEM34-16 Room:102A Time:May 24 15:30-15:45

Propagation of Alfven waves in an outer stable layer excited by MHD thermal convection in a rotating spherical shell

TAKEHIRO, Shin-ichi[1*]

[1]Research Institute for Mathematical Sciences, Kyoto University

Recent seismological observations and their analyses suggest the existence of a stably stratified layer just below the core-mantle boundary of the Earth, whose thickness is O(100km). The extent of penetration of the deep convective motion into the outer stable layer is one of the important key issue for considering magnetic field generation through the dynamo process as well as origin of the magnetic secular variation of the Earth. Takehiro and Lister (2001) theoretically derives the scaling of penetration thickness of the columnar convection into the stable layer in the case of no magnetic field, and show that the penetration thickness is in proportion to the ratio of the angular velocity of the planet to the Brunt-Vaisala frequency of the stable layer and to the horizontal wavenumber of the disturbance. However, the scaling of penetration thickness under the influence of magnetic field is not yet known. Here we theoretically investigate the fluid motions and magnetic field disturbances in the outer stable layer induced by the convective motions below the layer.

We consider MHD version of the theoretical model proposed by Takehiro and Lister (2001). Fluid motion and magnetic field disturbance below the bottom boundary penetrate into a density stratified MHD fluid existing in the semi-infinite region in the vertical direction. The axis of rotation of the system is tilted with respect to the vertical. The basic magnetic field is uniform in the direction of the rotation axis. Neglecting the effects of viscosity and diffusion and assuming that stable stratification is sufficiently large while the magnitude of the basic magnetic field is small, the result of linear analysis shows that MHD fluid motion is classified into two categories of MHD waves. One is the fast mode where the restoring effects of the Coriolis force, buoyancy force and Lorentz force are add up. The other is the slow Alfven waves where the fluid motion is restricted in the horizontal direction. When the frequency of the disturbance given from the bottom boundary is sufficiently small, the fast mode cannot propagate (evanescent) into the stable layer, and its penetration thickness return to that of non-magnetic cases. On the other hand, the slow mode can propagate into the layer however small the frequency is. The propagation (penetration) distance of the slow mode is estimated by the ratio of the Alfven speed to the diffusion coefficient and to the total wavenumber of the disturbance.

In order to validate the theoretical scaling of propagation distance, we perform linear analyses of MHD thermal convection in a rapidly rotating spherical shell with an upper stably stratified layer embedded in the axially uniform basic magnetic field. When the strong stratification of the stable layer is given, the neutral modes of columnar fluid motions and magnetic field disturbances trapped below the stable layer gradually penetrate into the stable layer as the basic magnetic field is strengthened. The penetration distances of the obtained neutral modes are in good agreement with those of the theoretical scaling.

Keywords: Earth’s outer core, Mercury’s outer core, Alfven waves, core mantle boundary, dynamo, secular variation of geomagnetic field

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-17 Room:102A Time:May 24 15:45-16:00

Penetration of MHD disturbances into a strongly stable outer layer caused by MHD dynamo in a rotating spherical shell

SASAKI, Youhei[1*] ; TAKEHIRO, Shin-ichi[2]

[1]Department of Mathematics, Kyoto University, [2]Research Institute for Mathematical Sciences, Kyoto University

Numerical experiments of magneto-hydrodynamic dynamo in a rotating spherical shell with a strongly stable outer layer are performed. Although the estimated values of penetration thickness of the disturbances into the stable layer proposed by Takehiro and Lister (2001) for non-magnetic cases are sufficiently small compared with the thickness of the stable layer, it is observed that vortical fluid motions and toroidal magnetic field disturbances deeply penetrate into the stable layer. These magneto-hydrodynamic disturbances in the stable layer can be interpreted as the Alfven waves whose fluid motions are restricted in the horizontal directions. The proposed theoretical expression of propagation distance

of the Alfven waves suggests that the numerically obtained fields permit the complete propagation of the Alfven waves across the stable layer.

Keywords: Earth’s outer core, Mercury’s outer core, Dynamo, Alfven waves

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-18 Room:102A Time:May 24 16:15-16:30

Axial dipole moment over the past 400 years from single spot archeointensities

FUKUMA, Koji[1*]

[1]Dept. Env. Sys. Sci., Doshisha Univ.

The temporal variation of the axial dipole moment g10 was deduced from the archeointensity data that were obtained from a volcanic island Miyakejima in Japan for the last 400 years, as combined with the field model gufm1. The basaltic lava flows are extremely well dated based on the ancient documents on the eruptions and the detailed field surveys. Essentially no age error is necessary to be considered. Thellier paleointensity experiments gave expected geomagnetic field intensities for the recent volcanic materials that were collected from the upper and lower clinkers and scorias. Volcanic eruptions in Miyakejima occurred intermittently about every 50 years for the last 400 years, providing a reliable past geomagnetic field record both in temporal and intensity variations. Using an automated spinner magnetometer with thermal demagnetizer TSpin, Thellier paleointensity measurements were performed for about 300 specimens. I applied the same method as Gubbins et al. [2006] to the single spot archeointensity variation from Miyakejima, and obtained monotonous decay of the axial dipole over the last 400 years. Contrary to gufm1 that assumes a linear decrease of g10 from 1840 to 1590 by extrapolating the post-1840 instrumental records, Gubbins et al. [2006] argued no definite temporal trend on g10 recognizable from the existing archeointensity database. The scattered archeointensity data should be considerably smeared by both age and intensity errors as resulted from various materials, locations and experimental methods involved. Our single spot archeointensities are free from these problems and suitable to deduce the dipole moment variation.

Keywords: archeointensity, Thellier method, geomagnetism

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-19 Room:102A Time:May 24 16:30-16:45

Reexamination of geomagnetic secular variation in Kinki District using samples from Suemura kilns (II)

SHIBUYA, Hidetoshi[1*] ; MOCHIZUKI, Nobutatsu[2] ; HATAKEYAMA, Tadahiro[3]

[1]Dep't of Earth & Environment, Kumamoto Univ., [2]Priority Organization for Innovation and Excellence, Kumamoto University, [3]Information Processing Center, Okayama University of Science

In 1960s-70s, enormous number of kilns were excavated in Sakai city and its vicinity, Osaka prefecture for a large residential development. Enhanced archeological studies, especially for massive amount of pottery kilns (Sue ware of 5th to 10th century) were carried out by Osaka Prefectural Government. Archeomagnetic researches were also conducted by prof. Kawai and his colleagues of the Osaka University. As the result, the geomagnetic secular variation curve from the 5th century to the 10th century was drawn (e.g. Hirooka 1971; Shibuya 1980). However, there are problems from the present paleomagentic view point. The natural remanent magnetizations (NRM) were measured by astatic magnetometer and demagnetization was not made. Fortunately, those samples are stocked in Osaka Ohtani University, and we moved them to Okayama Science University and Kumamoto University, for conducting systematic remeasurement study of their NRM after alternating magnetic field demagnetization (AFD). We already reported preliminary results in 2012 JpGU meeting. This time, we finished measuring 1992 samples of 215 sites (80% of the remaining sites).

The most of the measurements are carried out in Kumamoto University. One pilot sample is selected for progressive a.f. demagnetization. If the result is understood strait forward, the remaining samples are submitted to blanket demagnetization with the strength determined from zijderveldt diagram. Otherwise, all the samples are progressively demagnetized. Almost all the samples has very stable magnetization as usual as well baked kiln samples, the difference of magnetic direction of different demagnetization strength is minimal. One in a site is reserved undemagnetized for future paleointensity studies.

The problem reported at the previous meeting is the existence of outliers. They are statistically excluded to get the site mean, and draw tentative PSV curve. Besides the same technique, we made the density map of all the sample direction, and draw the PSV curve as the trace of the ridge of the density. This technique has also advantage that it can utilize the sites of unknown age. The PSV curve obtained is similar to the previous works, though the amplitude of inclination variation is slightly larger. The density map seems to show that there are a few gaps in the density map. It may reflect the gap of the pottery production in the area

Keywords: Archeomagnetism, Geomagnetic secular variation

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-20 Room:102A Time:May 24 16:45-17:00

A preliminary paleomagnetic result from Lake Suigetsu 2014 cores

MATSUSHITA, Hayato[1*] ; HYODO, Masayuki[1] ; NAKAGAWA, Takeshi[2] ; HARAGUCHI, Tsuyoshi[3] ; KITAGAWA, Junko[4] ; GOTANDA, Katsuya[5] ; KITABA, Ikuko[2] ; YAMADA, Keitaro[6]

[1]Kobe University, [2]Ritsumeikan University, [3]Osaka City University, [4]Fukui Prefectural Satoyama-Satoumi Research Institute, [5]Chiba University of Commerce, [6]Kyoto Univeristy

Varved sediments were sampled in Lake Suigetsu by Fukui prefectural government in July to September, 2014. Core samples were collected from four bore holes named E, F, G and H near the center of the lake, c. 500 m. to the east of the deepest place. From hole E, 86 sections with a total length of 83.6 m were recovered, and from hole F we obtained 87 sections with a total length of 85.2 m, 28 of which were magnetically oriented. From hole G, we collected 38 sections, 13 of which were magnetically oriented, in order to fill the gaps in holes E and F cores. Sections from hole H are essentially back-ups. Sub-sampling from each core was made using double-L technique (Nakagawa et al. 2012). Sub-samples are 50 to 100 cm long with a cross section of 2 cm by 2 cm. They were all sealed up in Saran (polyvinylidene chloride) film, and vacuum-sealed with deoxidant agents in an aluminum-lined polyethylene bag, before transported to the laboratory. In addition, cubic specimens with a 2.2 cm side were collected from holes F and G cores in the lakeside workshop, and cubic specimens with a 2.0 cm side were re-sampled from LL-channel samples with a cross section of 2 cm by 2 cm in the laboratory of Kobe University.

Firstly, preliminary paleomagnetic analyses were conducted on two double-L channel samples, with progressive alternating field demagnetizations. All characteristic remanent magnetizations measured at 1-cm regular interval have almost constant directions close to the present geomagnetic field. This suggests the remanence of a core is intensively affected by secondary viscous remanent magnetizations (VRM). Next, we performed preliminary paleomagnetic analyses of discrete specimens with progressive thermal demagnetizations (THD). The result shows that secondary VRMs are removed below 350 ℃, and we confirmed that THD was more useful to isolate a primary remanent magnetization than AFD. From preliminary paleomagnetic analyses with progressive THDs for pilot discrete specimens collected from 100 to 10 cm intervals, we have obtained two excursional paleomagnetic directions. One is of an oriented specimen collected at a preliminary composite depth of about 32.50m, having negative inclination and northerly declination, and the other is of an unoriented specimen collected at a preliminary composite depth of 30.25m, having low positive inclination. Both are carried by a component with a temperature range from 400 to 590 ℃, which shows the carrier is magnetite. The Lake Suigetsu varve chronology suggests they are dated at 41 ka and 38 ka, respectively. The former or both may be correlated with the Laschamp excursion.

Keywords: Lake Suigetsu, Varved sediments

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-21 Room:102A Time:May 24 17:00-17:15

Magneto-biostratigraphy of the Upper Triassic bedded chert succession from the Mino Belt, Inuyama area, central Japan

YAMASHITA, Daisuke[1*] ; UNO, Koji[2] ; ONOUE, Tetsuji[1]

[1]Department of Earth and Environmental Sciences, Graduate School of Science and Technology, Kumamoto, [2]Graduate School of Education, Okayama University

Late Triassic magnetostratigraphy and biostratigraphy has recently been investigated in both continental and Tethyan marine sequences (Hounslow and Muttoni, 2010). However, there is no agreed on geomagnetic polarity timescale (GPTS) for the Late Triassic, because of poor age control of many Late Triassic magnetostratigraphic sections, missing or duplicated intervals, and within- section changes in sedimentation rates (Lucas, 2013).

In an attempt to circumvent this problem in the Carnian to Norian, we have established the magnetostratigraphy and biostratigraphy of two bedded chert successions from the Mino Belt, Inuyama area, central Japan.

Paleomagnetic samples from Inuyama area were drilled and oriented in the field at an average sampling interval of ˜20 cm. Chert samples were collected at two localities (Sakahogi and Momotaro sections) where Sugiyama (1997) investigated the radiolarian biostratigraphy. In this study, at Sakahogi section, 93 samples for the biostratigraphy study were collected from ˜30-m-thick early Carnian to late Norian red chert section (Section N; Sugiyama, 1997). We also sampled at Momotaro section where ˜15-m-thick early Carnian to late Norian red chert is well exposed (Section Q; Sugiyama, 1997). 45 samples for the biostratigraphy study and 156 oriented samples for the magnetostratigraphy from 176 beds were collected from this locality. In total, 294 samples were collected from Late Triassic (Carnian to Norian) red cherts of the Inuyama area. All samples were thermally demagnetized and analyzed at the paleomagnetic laboratory of Center for Advanced Marine Core Research, Kochi Univ.

We found many platform conodonts from 81 samples in the section N and Q, where the radiolarian biostratigraphy have previously been investigated (Sugiyama, 1997). These sections are relatively well exposed and continuous. Based on detailed study of the conodont biostratigraphy from the interval of the Carnian and the late Norian in the section N and Q, five conodont zones are recognized. These biozones are calibrated with the radiolarian zone studied in the Upper Triassic bedded chert successions in the Japanese accretionary complex. Thermal demagnetization showed four distinct remanent magnetization components from the cherts. Multiple components of secondary magnetization have been recognized from the red cherts of the Inuyama area (Shibuya and Sasajima 1986; Oda and Suzuki 2000; Ando et al. 2001). The lowest temperature component below 200 ?C (component A) is a present-day viscous overprint. The second component has reversed polarity and unblocking temperatures between 200 ?C to 420 ?C (component B). The third-demagnetized component is removed up to 580 ?C (component C). The first three components are interpreted to be secondary magnetizations. In contrast, the last-removed (highest blocking temperature) component (component D) shows positive reversal tests and is likely primary remanent magnetization. Paleomagnetic polarity reversals observed for the lower Carnian to late Norian are almost correlated with those of other marine sections.

Keywords: Late Triassic, magnetostratigraphy, biostratigraphy, bedded chert, Mino belt, Panthalassa