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

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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

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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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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]

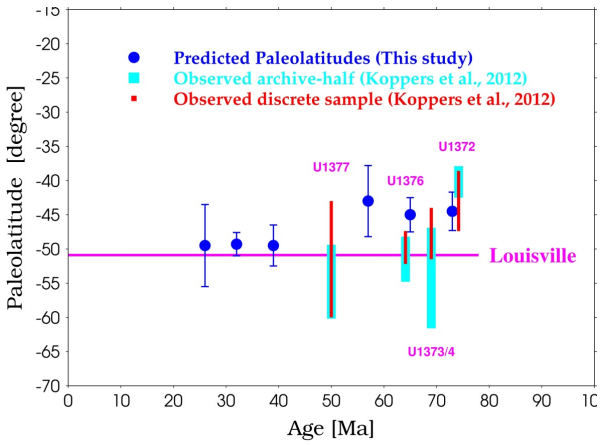
[1]School of Marine Science and Technology, Tokai University, [2]Univ Hawaii

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



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

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

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

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

Japan Geoscience Union Meeting 2015
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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

Japan Geoscience Union Meeting 2015
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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

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

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

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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

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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

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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
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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
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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

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SEM34-P01 Room:Convention Hall Time:May 24 18:15-19:30

Paleomagnetism of a lithological contact of granophyre dikes with bedrock granites at Vredefort dome, South Africa

NAKAMURA, Norihiro[1*]

[1]Dep. Earth Sci., Tohoku Univ.

The Vredefort dome is known as the largest and oldest (2023 ± 4 Ma) terrestrial impact structures, which is the deeply-exhumed remanent of the central uplift zone (~10km) of an originally ca. 250-km diameter crater. The Vredefort impact structure contains a suite of granophyric dykes, referred to as the Vredefort Granophyre, occurring within and at the edge of the Archaean basement core. This unique melt rock occurs as vertical ring dikes along the contact between sedimentary collar and core of Archaean granites, and as vertical dikes extending northwest-southeast and northeast-southwest in the granitic core. Although there have been a lot of mineralogical and isotopic studies, the lithological contact has not been observed due to the lack of the outcrop. During our field survey, we found the lithological contact of the Vredefort granophyre with bedrock granites near the Kopjeskraal Country Lodge, Vredefort, South Africa. In this presentation, we report the presence of a distinct chilled margin from a cooperative study of petrology and rock magnetism of the contact and also a micro-paleomagnetic consideration across a transection of the chilled margin.

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

SEM34-P02 Room:Convention Hall Time:May 24 18:15-19:30

Archeointensity study on baked clay from the reconstructed kiln: implication for validity of the Tsunakawa-Shaw method

YAMAMOTO, Yuhji[1*] ; TORII, Masayuki[2] ; NATSUHARA, Nobuyoshi[3]

[1]Kochi University, [2]Okayama University of Science, [3]Natsuhara Giken

A reconstruction experiment of a kiln had been done to imitate completely that of an excavated kiln of the 7th century in Japan. Baked clay samples were taken from floor surface and -20 cm level, and they have been stored after determinations of the paleomagnetic directions by partial alternating field demagnetizations. A suite of the rock magnetic experiments and the scanning electron microprobe observations elucidate that dominant magnetic carriers of the floor surface samples are Ti-poor titanomagnetite grains in ˜10 nm size with single-domain and/or super-paramagnetic states, whereas contributions of multi-domain grains seem to be relatively large for the -20 cm level samples. We applied the Tsunakawa-Shaw method to the samples to assess how reliable archeointensity results are obtained from the samples. From the floor surface samples, six out of the eight successful results were discriminated and they give an average of 47.3 microT with a standard deviation of 2.2 microT. This is fairly consistent with the in-situ geomagnetic field of 46.4 microT at the timing of the reconstruction. They are obtained with a built-in anisotropy correction using anhysteretic remanent magnetization, and without any cooling rate corrections. In contrast, only one out of the four successful result was obtained from the -20 cm level samples. It yields an archeointensity of 31.6 microT, which is inconsistent with the in-situ geomagnetic field. Considering from the in-situ temperature record during the firing of the kiln, the floor surface samples acquired full thermoremanent magnetizations (TRMs) as their natural remanent magnetizations whereas the -20 cm level samples only acquired partial TRMs, and these differences probably cause the difference in the archeointensity results between the two sample groups. For archeointensity researches, baked clay samples from a kiln floor are considered to be ideal materials.

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

SEM34-P03 Room:Convention Hall Time:May 24 18:15-19:30

Archeointensity trend between 7th and 10th century in Japan

KITAHARA, Yu[1*] ; YAMAMOTO, Yuhji[2] ; HATAKEYAMA, Tadahiro[3] ; TORII, Masayuki[4] ; KAMEDA, Shuichi[5]

[1]Graduate School of Integrated Arts and Sciences, Kochi University, [2]Center for Advanced Marine Core Research, Kochi University, [3]Information Processing Center, Okayama University of Science, [4]department of Informatics, Okayama University of Science, [5]department of Biosphere-Geosphere Science, Okayama University of Science

Earth's magnetic field is known to show complicated, and irregular variations in time. It is important to investigate a paleomagnetic secular variation to deepen our understanding of the geodynamo. An approach based on the paleomagnetism is a powerful tool to obtain the information of geomagnetic variation before the 16th century when modern observations started. Especially, a technique based on the archeomagnetism is expected to provide high quality information. There has been much progress in archeomagnetism in Europe recently: for example, Donadini et al. (2009) complied the published direction and intensity data for the past 2,000 years, and Korte et al. (2009) proposed a global field model.

In Japan, archeomagnetic directions have been studied activery since 1960's, and the resultant 'master curve' has been utilized in scientific studies in cultural properties (e.g. Hirooka et al., 2006). In contrast, archeointensity data have been published only in the four papers (Nagata et al., 1963; Sasajima and Maenaka, 1966; Sakai and Hirooka, 1986; Yoshihara et al., 2003). Considering a set of statistical selection criteria, they provide only 43 high quality data which were also obtained by the Thellier method without a pTRM check. It is thus necessary to obtain new data by modern experimental techniques with modern selection criteria. This study presents new archeointensity data between 7th and 10th century which are obtained from backed-clay samples taken from the Oku kilns in Okayama prefecture and the Sue-Mura kilns in Osaka prefecture. The experimental techniques used in this study are the IZZI-Thellier method (Tauxe and Staudigel, 2004) and the Tsunakawa-Shaw method (Tsunakawa and Shaw, 1994; Yamamoto et al., 2003).

Various rock magnetic experiments revealed that (1) the samples are generally resistant to laboratory heating, (2) main magnetic carriers are non-interactiving SD-like Ti-poor titanomagnetite, and (3) blocking temperatures distributed widely between 100 and 600 ^{o}C. It is considered that the IZZI-Thellier method and the Tsunakawa-Shaw method are applicable to the samples. We obtained 41 successful results by the IZZI-Thellier method and 23 successful ones by the Tsunakawa-Shaw method. We screened these data by selection criteria as follows: (1) at least three successful results are obtained from a site, (2) a standerd deviation of these results is less than 20 %. The screening resulted in seven reliable site-mean archeointensities: (1) 48.0 +/- 9.6 uT for KM-11 kiln (A.D. 630 +/- 10), (2) 45.4 +/- 2.0 uT for TG-38-III kiln (A.D. 720 +/- 10), (3) 55.3 +/- 8.4 uT for KM-102 kiln (A.D. 750 +/- 10), (4) 50.0 +/- 4.3 uT for KM-38-II kiln (A.D. 770 +/- 10), (5) 55.9 +/- 8.4 uT for Sayama Shin-Ike 1st kiln (A.D. 775 +/- 25), (6) 48.9 +/- 7.4 uT for Sayama Higashiyama kiln (A.D. 775 +/- 25), (7) 49.4 +/- 4.5 uT for Sayama Higashiyama-Oku kiln (A.D. 900 +/- 50).

The former published high-quality archeointensity data in Japan indicated a decreasing trend approximatery from 70 uT at A.D. 600 to 50 uT at A.D. 900. In contrast, the presently obtained data rather suggested a constant trend about 50 uT for the same period. This constant trend appeared to be consistent with the recently reported archeointensity data from Korea and China by the IZZI-Thellier method (Hong et al., 2013; Cai et al., 2014). New data also appeared to be consistent with the world VADM data extracted from the GEOMAGIA50 database (Donadini et al., 2006; Korhonen et al., 2008), showing a decreasing trend approximately from $11*10^{22}$ Am^2 at A.D. 0 to $8*10^{22}$ Am^2 at present.

Keywords: archeointensity, secular variation, climbing kiln of Sue ware, high-quality data, IZZI-Thellier method, Tsunakawa-Shaw method

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

SEM34-P04 Room:Convention Hall Time:May 24 18:15-19:30

Archeomagnetic study of Takabatake ruins and Wada-taishido ruins in Matsumoto city

HEMMI, Ryo[1*] ; SAITO, Takeshi[1]

[1]Department of Geology, Faculty of Science, Shinshu University

This study presents some archaeomagnetic directions from burnt sediments at Takabatake ruins (site TK2˜4) and Wada-taishido ruins (site W1) in Matsumoto city, Japan. Compared with the secular variation curve in Japan (Hatakeyama et al., in prep.), archaeomagnetic dating and local magnetic anomaly will be discussed.

As a result of our study, reliable archaeomagnetic directions were obtained. The abandonment of TK2, TK3, TK4 and W1 has been dated to 1025±25 AD, 1015±15 AD, 1075±50 AD and 850±50 AD, respectively. Declination values of our data were almost one or two degrees smaller than those of the secular variation curve in Japan. The present field around the studied area show smaller declination (GSI, 2010.0). Local magnetic anomaly resulted from non-dipole component around the studied area possibly continue in the past several thousand years.

Keywords: Archeomagnetism, Geomagnetic secular variations, non-dipole component, thermal remanent magnetization, depositional remanent magnetization, ruins

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SEM34-P05 Room:Convention Hall Time:May 24 18:15-19:30

Anallyzing the early 19th century's Geomagnetic declination in Japan from Tadataka Inoh's Santou-Houi-Ki The 9th report

TSUJIMOTO, Motohiro[1*] ; OMOTANI, Akitoshi[2] ; MIYAUTI, Satoshi[3]

[1]Japan Cartographers Association, [2]Sannin System Consultant, [3]Geopark Choushi

The Santou-Houi-Ki is a national treasure of Japan recorded by cartographer Tadataka Inoh in 1800-1816, is 67 volumes survey ledger consist of approximately 200,000 magnetic compass land survey azimuth data accuracy of 5 min, from the coast of eastern Hokkaido to Yakushima Island in western Japan.

We continue the work of analysis that stopped after only one analysis in 1917, which done about the magnetic compass survey azimuth data at known position of the retirement home of Tadataka Inoh at Fukagawa in Edo (Tokyo) in 1802-1803.

From this interdisciplinary simultaneous analysis across geomagnetism, survey science, historical cartography and local history and human sciences, we can increase precise evidence to verify the real azimuth, geomagnetic declination and short description of the reference point where magnetic compass survey was executed or the historical place name of survey target points recorded in The Santou-Houi-Ki, than the traditional way of study separated in each field.

(1) The short description of survey reference point where Tadataka Inoh executed magnetic compass survey, the place name of each survey target points, and magnetic compass survey azimuth in accuracy 5min were recorded inThe Santou-Houi-Ki.

(2)Procedure of analysis.

Use the recreation software of scenery and digital map of GSI Japan Denshi Kokudo to know the latitude and the longitude of particular survey target points in accuracy 1 second, and the latitude and longitude at the outline position of survey reference point, to grasp the outline of each real azimuth from the survey reference point to survey target points.

Geomagnetic declination= Real azimuth - Magnetic compass survey azimuth recoded in The Santou-Houi-Ki

Calculate backward the precise position of the survey reference point should be adjusted to the position in accuracy 1 second in latitude and longitude, where all of geomagnetic declination values unit of 1 second,calculate from the magnetic compass survey azimuth to each different targets at the reference point are approximately equal to each other.

Calculate the average value of each geomagnetic declination unit of 1 second, and express it as the geomagnetic declination unit of 1 second on the day Tadataka Inoh's magnetic compass survey was executed. To use the consecutive formula of Excel for speed up and keep accuracy. If it possible to go to the field of the survey reference point, confirm the real scenery at the reference point and use GPS transmitter to confirm the longitude and the latitude, and recalculate the value of geomagnetic declination.

(3)It is able to change Japan as one of the most concentrated area of accurate geomagnetic declination data in the world, in early 19th century, from insufficient area of data, and supply new data to northeast Asia by analysis of The Santou-Houi-Ki. The total number of analyzed points exceeded 183 and the outline of isogonic line in Japan archipelago and the distribution of the declination in every 15 minutes in western Japan coast in those days, began to appear. The analysis is developed from the coast area of Japanese archipelago to the inland area of Honnshuu Island.

(4)Compare the isogonic line of declination in those year's Japanese Archipelago by analysis of The Santou Houi Ki, with the Historical Magnetic Declination -Map-by NOAA (1800,1805,1810,1815) is almost similar. The difference is the NOAA's pace of variation west is almost 5 years later than the analysis of The Santou-Houi-Ki.

(5)However, from the analysis of Santou-Houi-Ki, we can recognise the magnetic declination supposed as the local geomagnetic anomaly in southern coast of eastern Hokkaido, some part of Noto Peninsula, Mt.Asama in Ise, Nobeoka city in Kyuushuu Island etc, can not drow in Historical Magnetic Declination -Map-by NOAA. . Therefore the analysis of THe Santou-Houi-Ki becomes more important.

Keywords: geomagnetic declination, Tadataka Inoh, Santou-Houi-Ki, Survey reference point, Survey Target point, interdisciplinary

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Remanent magnetization observed in core sediments from the Ichinomegata Maar, Akita Prefecture

ANRAKU, Kazuhiro[1*] ; HAYASHIDA, Akira[2] ; YAMADA, Kazuyoshi[3] ; SHINOZUKA, Yoshitsugu[4] ; YONENOBU, Hitoshi[5] ; GOTANDA, Katsuya[6] ; HARAGUCHI, Tsuyoshi[7]

[1]Graduate School of Science and Engineering, Doshisha University, [2]Department of Environmental Systems Science, Doshisha University, [3]Museum of Natural and Environmental history, Shizuoka, [4]Faculty of Environmental Earth Science, Hokkaido University, [5]Graduate School of Education, Naruto University of Education, [6]Faculty of Polycy Informatics, Chiba University of Commerce, [7]Department of Geosciences,Graduate School of Science,Osaka City University

The Ichi-no-megata is a maar lake with a maximum water depth about 45 m, located in the Oga Peninsula on the Japan Sea coast. A piston-core sample (IMG13P) obtained in 2013 provided a Holocene paleomagnetic secular variation (PSV) record through measurements of natural remanent magnetization (NRM) of 7cm^3 cubic samples. Also, we collected Mackereth core samples (IMG13M-1 and IMG13M-2) at the center of the lake, and measured magnetic susceptibility, anisotropy of magnetic susceptibility (AMS) and NRM of 7cm^3 cubic samples.

The core sediments are mostly composed of laminated clay or silt intercalating sandy turbidite layers. According to correlation between the Mackereth cores and the piston cores based on lithological and magnetic susceptibility data, it is revealed that uppermost parts of the piston cores were missed. Inclinations of minimum axis and shape parameters q of AMS ellipsoids indicate that turbidite layers of upper parts have not preserved primary sedimentary fabric. Stepwise AF demagnetization of the NRM showed that remanence of the laminated layer is more stable than turbidite layers. Therefore, we argue that the turbidite sediment is not suitable for preservation of NRM.

Keywords: Remanent magnetization, magnetic susceptibility, Ichi-no-megata Maar

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Remanent magnetization of a sediment core from Haneji-naikai, Okinawa : Diagenetic modification of magnetic mineral

TAKANASHI, Yutaro[1*] ; HAYASHIDA, Akira[2] ; YAMADA, Kazuyoshi[3] ; GOTANDA, Katsuya[4] ; YONENOBU, Hitoshi[5]

[1]Doshisha Univ., Grad. School Sci. & Engineer., [2]Department of Environmental Systems Science, Doshisha University, [3]Museum of Natural and Environmental history, Shizuoka, [4]Faculty of Polycy Informatics, Chiba University of Commerce, [5]Graduate School of Education, Naruto University of Education

We have studied magnetic properties of sediment core samples from the Haneji Inner Bay and the Shioya Bay on the northwest coast of Okinawa Island in order to investigate runoff of red soils associated with environmental changes in the watershed. Here we present results of measurements of natural remanent magnetization (NRM) of the core sample from Haneji-naikai Bay.

Pass-through measurement of the u-channel samples revealed that NRM above 120 cmbsf (cm below sea floor) has a stable component, which shows linear decay toward the origin (MAD $<$10 degree). By contrast, NRM intensity below 130 cmbsf is only 2% of the upper interval and no characteristic magnetic component was isolated (MAD $\geq$ 10 degree). While low-field magnetic susceptibility shows gradual down-core decrease of at 100-150 cmbsf, anhysteretic remanent magnetization (ARM) decreases sharply at 140-160 cmbsf. Isothermal remanent magnetization (IRM), which was measured for discrete cubic specimens of 1 cm^3 subsampled from the u-channels, showed consistent variation with the ARM. It was also found that proportion of low-coercivity ($<$0.3 T) magnetic minerals (S-ratio) decreases at 140-160 cmbsf. Thermal demagnetizations of three-component IRM made for selected specimens suggest abundance of titanomagnetite and magnetite at the upper interval, but such medium to low coercivity minerals were not observed in the lower part. It is suggested that a loss of fine-grained magnetite have occurred due to reductive diagenesis, resulting destruction of stable NRM signals below 130 cmbsf.

Keywords: paleomagnetism, natural remanent magnetization, diagenesis, sediment, red soil, Okinawa

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Rock magnetic property of the marine sediment cores recovered from IODP Site U1403 in the Northwest Atlantic

FUKAMI, Hiroto[1*] ; YAMAMOTO, Yuhji[2]

[1]Graduate School of Integrated Arts and Sciences, Kochi University, [2]Center for Advanced Marine Core Research, Kochi University

Marine sediment is an important recorder of the past environmental changes. It can provide important information to investigate the environmental change continuously back in time, once a high-resolution age model is constructed by multiple techniques. Integrated Ocean Drilling Program (IODP) Expedition 342 recovered marine sediment cores from the Northwest Atlantic, off Newfoundland, to investigate the environmental change from the Paleocene to the Eocene. Our objective is to estimate relative paleointnsity variation for that period. In order to achieve this, we need to find out relatively homogeneous intervals in rock magnetic properties. In this study, we conduct preliminary rock magnetic measurements on the 88 discrete samples taken from Hole A in Site U1403 at every ˜1.5 m interval (25-160 mcd: meter composite depth).

Low temperature magnetometry failed to detect, the Verwey transition except some horizons. We therefore, think that Ti-poor titanomagnetite is not much included in the present samples. Below about 117 mcd, the samples showed a distinct phase transition at about 25 K. It is probably due to an existence of rhodochrosite.

In the thermomagnet experiments, slight increase in magnetization at about 400 ℃ and Curie temperatures at about 580 ℃ and/or about 670 ℃ were recognized throughout the studied interval. Because the Verwey transition was not detected except some horizons ,the Curie temperature at about 580 ℃ is probably originated from a breakdown of titano-maghemite upon heating. These results indicate that the present samples contain titano-maghemite and titano-hematite.

Anhysteretic remanent magnetization (ARM) was imparted by a DC field of 100

μT and AF of 80 mT. The samples from the 50-90 mcd interval showed a relatively constant high ARM intensity of 3-5X10^{-4} (A/m). Except this interval, the ARM intensity varied a lot, as low as 1X10^{-6} (A/m). Isothermal remanent magnetization (IRM) imparted by a DC field of 2.5 T exhibited a similar tendency. The samples from the 50-90 mcd interval showed a relatively constant high IRM intensity of 1-3X10^{-3} (A/m). Except this interval, the IRM intensity varied a lot, as low as 1X10^{-5} (A/m).

Ratios of ARM to IRM (ARM/IRM), which are often used as parameters of magnetic grain size and/or degree of magnetostatic interaction, resulted in either about 0.15 or 0.05 for the studied interval. The interval of 50-90 mcd showed a constant ratio of 0.15. S-ratio (-0.1T and, -0.3T) which stands for a remanence fraction according to a coercivity resulted in constant values of 0.97 (-0.1T) and, 0.98 (-0.3T) for the 50-90 mcd interval.

In summary, the 50-90 mcd interval is considered to be little affected by a diagenesis and have relatively homogeneous rock magnetic property, because of the relatively strong ARM and IRM intensities and constant values of several rock magnetic parameters. We think that, this interval is suitable for an estimate of relatively paleointensity variation.

Keywords: geomagnetic field, paleointensity, marine sediments

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Relative paleointensity during the last 3 m.y. from sediments in the western equatorial Pacific

SAKURAMOTO, Yukihiro[1*] ; YAMAZAKI, Toshitsugu[1] ; KIMOTO, Katsunori[2]

[1]The University of Tokyo, [2]Japan Agency for Marine-Earth Science and Technology

It is important to determine the strength of the past geomagnetic field for better understanding of the geodynamo. This study aims to estimate relative paleointensity of the geomagnetic field (RPI) back to about 3 Ma. Marine sediments can preserve temporally continuous paleomagnetic records. Piston core samples obtained from the West Caroline Basin (R/V MIRAI MR14-02 cruise, core PC01) were used. This area is empirically known for yielding good paleomagnetic records. Alternating field demagnetization of the natural remanent magnetization (NRM) enabled to estimate directions of the past geomagnetic field. Ages of the sediments were estimated from the magnetic polarity reversal sequence. We are also trying age estimations based on the oxygen isotope stratigraphy. The anhysteretic remanent magnetization (ARM) and the saturation isothermal remanent magnetization (sIRM) were imparted to normalize the NRM intensity for obtaining RPI. Here, the ARM was chosen for the normalizer. The result generally agrees with the previous RPI stacked curves of the last 2 m.y.. However, the RPI record seems to correlate with the ARM/sIRM ratio, which may reflect the variation in the sedimentary environment. Thus the RPI record may be influenced by environmental changes. We need to evaluate this influence for more reliable RPI estimation.

Keywords: paleomagnetic intensity, marine sediments

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Origin of magnetic remanence in coral skeletons in Ishigaki Island, Japan

KUMAGAI, Yuho[1*] ; NAKAMURA, Norihiro[1] ; SATO, Tetsuro[1]

[1]Department of Earth Science, Tohoku University

Coral skeletons have an attractive potential as high-resolution recorders of the Earth's ancient geomagnetic field for the last several hundreds of years due to their long-lived and annual growth rate, but they have a general problem: 1) the magnetization of corals is very weak and 2) its origin has not been understood. Some of the corals appear to carry an excellent record of the field. Sato et al. (2014) succeeded, even using a conventional spinner magnetometer, to measure enough magnetizations of deceased coral tsunami boulders along the shorelines of Ishigaki Island where the coral reefs are grown on bedrock of Ryukyu limestone and Jurassic schist. Therefore, the in-situ coral skeleton of this Island would provide us a high-resolution paleomagnetic record if we could determine what magnetic minerals and their domain structures. However, our understanding of the magnetic mineral assemblages within coral frameworks is not well developed, because of rare abundance of magnetic particle. Previous rock-magnetic studies have reported two different results of both biogenic magnetite and abiogenic detrital titanomagnetite in late Cenozoic shallow-water carbonate platforms as the main remanence carriers at Bahamas (McNeil et al., 1988) and Tahiti (Ménabréaz et al., 2010), respectively. To determine the remanence carriers for our corals, we conducted petrologic observations of acid-treated residuals of corals by a field-emission type scanning electron microscope (FE-SEM) and revealed the presence of c.a. 80˜100 nanometer rectangular-shaped individual iron oxide grains with a very short chain of them, implying the origin of biogenic magnetite. We also found some titanium iron oxides from detrital deposits transported from bedrock schist. A first order reversal curves (FORC) measurements are also conducted to confirm the magnetic mineralogy. FORC diagrams have a narrow ridge along the H_c axis with little vertical spread. The FMR spectra represent a similar form with those of magnetosome-bearing carbonates. Our results indicate that the main magnetic carriers of coral frameworks are from both bacterial and detrital fine-grained magnetite.

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A new magnetic relaxation dating reveals tsunami ages from individual tsunamigenic coral boulders on Ishigaki Island

SATO, Tetsuro[1*] ; NAKAMURA, Norihiro[1] ; GOTO, Kazuhisa[2] ; KUMAGAI, Yuho[1] ; MINOURA, Koji[1] ; NAGAHAMA, Hiroyuki[1]

[1]Department of Earth Science, Tohoku University, [2]International Research Institute of Disaster Science (IRIDeS),Tohoku University

Information about past tsunami hazards, such as their recurrence interval and magnitude, is needed for future disaster prevention and mitigation. Tsunamigenic boulders could estimate a magnitude of tsunami waves to transport them to coastlines, but no information for recurrence intervals has been obtained. In the Ishigaki Island, Japan, there are tsunamigenic boulders consisted of the hermatypic corals. The distributions of large numbers of radiocarbon dating for these boulders determined the timing of past tsunamis. Although the radiocarbon dating is a powerful tool for estimating tsunami age for corals including radiocarbon, information for subsequent transportations of individual coral boulders and for ages of tsunamigenic igneous boulders without any trace of radiocarbon. Paleomagnetic viscous dating could overcome this problem because time-dependent viscous remanent magnetization is acquired parallel to the Earth's magnetic field after the transportation. Furthermore, Neel's thermal relaxation theory on single domain magnetite particles predicts the time-temperature relation for the viscous relaxation. Following Pullaiah et al. (1975), we can derive a time-temperature nomogram for single domain nanoparticle ensembles describing that a remanence acquired during a time at a room temperature in nature can unblock during shorter heating step at higher temperature in a laboratory. We have been applying this relation to the coral boulders in Ishigaki Island, but their emplacement ages determined from this time-temperature relation showed an older age than radiocarbon dating for the same boulders. Here, we revisited the Neel's exponential relaxation model of magnetic relaxation in order to determine the same age as radiocarbon dating by extending the previous time-temperature relation. It is considered that magnetic viscous relaxation of fine-grained magnetite is following an exponential or logarithmic function of time, but the reexamination of previously published viscous relaxation data suggested that magnetic viscous data is fit by a stretched exponential function of time. Using this stretched exponential function, we obtained a new time-temperature relation for estimating accurate tsunami ages. Combined this new relation and statistical data measured by the repeated thermal demagnetizations with a varied duration time, we succeeded to determine the same ages as radiocarbon dating for our coral boulders.

Keywords: tsunamigenic boulder, viscous remanence, time-temperature relation, stretched exponential

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Precise determination of Fe species in plagioclase crystals: a preliminary study

SATO, Masahiko[1*] ; USHIODA, Masashi[2] ; NAKADA, Ryoichi[2]

[1]Kyushu University, [2]Tokyo Institute of Technology

Silicate minerals such as plagioclase and pyroxene sometimes contain fine-grained magnetite crystals; such silicates are called magnetic silicates. Magnetic silicates are ubiquitous in mafic and intermediate plutonic rocks [Dunlop and Ozdemir, 1997; Gee and Kent, 2007]. As the middle and lower crust have greater mafic composition than the upper crust [Rudnick and Gao, 2004], magnetic silicates should play an important role in controlling the magnetic properties of deep crustal rocks. For understanding the sources of magnetic anomalies, which are often originated from thick magnetized layers within the crust [Shive et al., 1992 and reference therein], it is crucial to investigate the condition of exsolution of magnetite in silicate minerals.

In this study, to precisely determine the chemical species of Fe in the plagioclase crystals, magnetic measurements combined with microscopic observation and synchrotron radiation study were conducted for single grain plagioclase crystals. We prepared the two types of plagioclase crystals from (1) the basalt (Ofunato scoria) from the Miyakejima volcano [Ushioda et al., 2014] and (2) the gabbro from the Oman ophiolite [Sato et al., submitted]. The plagioclase crystals were collected under a stereoscopic microscope and used for the measurements after a hydrochloric acid (HCl) leaching for several days.

The main series of measurements for the single grain plagioclase crystals were as follows. (1) To estimate a content of magnetic mineral in the plagioclase crystals, magnetic hysteresis loop was measured using an Alternating Gradient Magnetometer (Micro-Mag 2900, Princeton Measurements Corporation) and magnetic hysteresis parameters (saturation magnetization M_s, saturation remanence M_{rs}, coercivity B_c, and coercivity of remanence B_{cr}) were calculated. (2) To investigate chemical compositions of the plagioclase crystals, microscopic observation was conducted using a field emission electron microprobe (JXA-8530, JEOL). (3) To investigate valence state of Fe, K-edge X-ray absorption near edge structure (XANES) spectra were measured at BL-4A of Photon Factory (PF).

The M_s value for the plagioclase crystals of the basalt and gabbro samples were $<5 \times 10^{-4}$ Am^2/kg and ca. 1×10^{-2} Am^2/kg, respectively. Therefore, the plagioclase crystal of the gabbro contained substantial amount of magnetic minerals, while that of the basalt contained no or little magnetic mineral. Taking into account the Curie temperature of 548 ^oC [Sato et al., submitted], the ulvospinel content for the plagioclase crystal of the gabbro was estimated to be x = 0.047 [Hunt et al., 1995] and the magnetite content was estimated to be 0.011wt%.

The microscopic observation showed that the FeO contents for the plagioclase crystals of the basalt and gabbro samples were 0.45wt% and 0.18wt%, respectively. The XANES analysis showed that the valence state of Fe for the plagioclase crystals of the basalt and gabbro samples were ca. 2.54 (Fe^{3+}/Fe^{2+} = 1.17) and ca. 2.59 (Fe^{3+}/Fe^{2+} = 1.44), respectively. In the case of the basalt sample, all Fe was contained in the plagioclase crystal, which is consistent with the thermal history of the Miyakejima basalt [Ushioda et al., 2014]. In the case of the gabbro sample, about 95% of Fe was contained in the plagioclase crystal and the remaining 5% of Fe was exsolved as magnetite crystals. The presence of magnetite was also suggested by the linear combination fitting of XANES spectra.

Now, our plan is to conduct high temperature heating experiment for the plagioclase crystals with varying the oxygen fugacity. On the basis of the measurements results for the samples before and after heating, we will discuss the high temperature heating effect on the Fe chemical species in the plagioclase crystals.

Keywords: Plagioclase, Magnetic silicate, Rock-magnetism, XANES

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The magnetic structure in Taiwan

CHEN, Chun-rong[1*] ; YEN, Horng-yuan[1] ; CHEN, Chieh-hung[2]

[1]Department of Earth Sciences, National Central University, Taiwan, [2]Department of Earth and Environmental Sciences, National Chung Cheng University, Taiwan

In this study, the main focus is to construct a magnetic structure model for Taiwan. The well covered total-field geomagnetic anomaly map in Taiwan was calculated by the observed data during a series of survey at 2003-2004. A new 3D forward modeling of total-field magnetic anomaly method was applied to our calculation. We assign the susceptibility to the particular rectangular prism from the reference studies, which had defined the susceptibility from the result of Geological survey. Two profiles in West-East direction and one in North-South direction has been studied. The modeling total-field magnetic anomaly along these profiles are used to compare with the observed data and further discuss the magnetic structure along with it.

Keywords: geomagnetic, Taiwan, magnetic structure