Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SEM21-P01 Room:Convention Hall Time:May 25 15:30-16:45

Magnetostratigraphy of Upper Cretaceous part of Yezo Group

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A paleomagnetic study of Haborogawa formation of the Yezo group in Kotanbetsu, Hokkaido, is carried out. Although this area is expected to have the Santonian-Campanian (Sn/Cm) stage boundary, its position is not well determined since *Marsupites*, which is one of the most significant index fossils of this boundary, is not yielded. On the other hand, this boundary is very close to the magnetic reversal at the end of the cretaceous normal superchron (CNS). Thus, the magnetostratigraphy is useful to determine the stage boundary.

Samples are collected in 15 sites at Kotanbetsu river and its branches, Kamino-sawa and Nakano-sawa rivers, using a gasoline powered drill. The formation is mostly composed by sandstones and sandstone mudstone alternations. We collect calcareous nodules occur in the formation as the main paleomagnetic samples because The mudstones are fragile to take drill samples.

Rock magnetic studies of IRM acquisition experiments, thermal demagnetization of composite IRM experiments and magnetic hysteresis analyses are performed some representative samples. Rock magnetic analyses suggests that; (1) Main magnetic minerals are magnetites. Pyrrhotites are also seen in some samples. (2) Day plots indicate most samples fall in the pseudo-single-domain (PSD) region.

Superconducting rock magnetometer in Kyushu university is used for NRM measurements. Progressive thermal demagnetization (PTHD) and progressive alternative field demagnetization (PAFD) are performed for pilot samples of all sites. After thermal demagnetization of 300˜400 deg.C, remanent intensity increases significantly in most samples, possibly because of alterations. Hence, characteristic remanent magnetizations (ChRM) are mainly obtained by PAFD.

From 8 sites out of 15, ChRM is retrieved. They show that the end of CNS is situated at the top of Ug unit which is in the middle part of Haborogawa formation. It is confirmed in two sections of Kotanbetsu and Kamino-sawa rivers. Sn/Cm boundary is expected slightly above the level of the reversal.

Keywords: Magnetostratigraphy, Calcareous nodules, Santonian - Campanian stage boundary, Upper Cretaceous Yezo group, Kotanbetsu area

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Paleomagnetic depositional history of Tsunami boulders at Ishigaki Island, Japan

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Boulders at Miyara Bay, Ishigaki Island, Japan consisted of hermatypic coral, *Porites* are known to have deposited due to the 1771 Meiwa Tsunami and/or prehistorical Tsunamis, though some boulders might have been influenced of older Tsunamis and severe storms. At the ancient Tsunami, live *Porites* corals at reef fringes could have transported to the reef and land far beyond the transport limit of storm waves. Then, the corals cease growing and are fossilized. Recent studies have conducted the radiometric dating to Tsunami boulders with fossilized *Porites* and the result indicated that the age distribution is relatively wide range which is greater than the analytical error. Therefore, boulders at Ishigaki Island have had possibilities of the transportation by multiple Tsunami events, resulting in multiple rotations of Tsunami boulders. However, the radiometric dating could only obtain the date of first Tsunami event. Here we propose a paleomagnetic strategy to decide continuous rotation events of multiple Tsunamis from a coral Tsunami boulder. The boulders possess a depositional remanent magnetization of a magnetosome in origin which points to the ancient North pole. If the boulders rotate and stabilize in each new orientation, new magnetic vector component is overprinted to the original magnetization, which parallel to the present Earth's magnetic field. This new magnetization called viscous remanent magnetization (VRM) and increases progressively with age. New and original vector components are not parallel due to boulder rotations by multiple Tsunamis, so this study uses the progressive thermal demagnetization (PTD) to discriminate these new and original components. Furthermore, Neel's theory gives the formula of relationship between temperature and time for VRM acquisition. This formula predicts that natural VRM acquired at low temperature over a long time disappears at a high temperature in a short time in the laboratory. From comparing new magnetization (VRM) and the result of radiometric dating of Tsunami event, the validity of VRM dating is confirmed. If the VRM dating is suitable and the boulders acquire younger magnetization, the record of multiple Tsunami events is visualized from a single boulder. Preliminary experiment show the intensity of remanent magnetization is 2.6mA/m for the live *Porites* and its mean destructive field indicate 26mT, suggesting the presence of fine grain magnetite of magnetsome in origin. In this presentation, we present the paleomagnetic strategy and preliminarily results.

Keywords: boulder, Tsunami boulder, palemagnetic history, viscous remanent magnetization (VRM)

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SEM21-P03 Room:Convention Hall Time:May 25 15:30-16:45

Magnetic properties of surficial sediments of Lake Ogawara, Aomori Prefecture

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Lake Ogawara in Aomori Prefecture is a blackish water lake, which is connected through Takase-gawa River and an artificial sluice to the Pacific Ocean. While the average water depth of the lake is about 11 m, the central part is 15 to 20 m deep. With a year-round halocline layer at a depth around 10 m, the bottom to middle water is in anoxic condition. In 2009, core samples of the Holocene sediments of 20 m long in total were recovered from 3 holes in the central part and subjected to a multi-disciplinary research for reconstruction of paleoenvironment and paleoclimate. When the 2011 off the Pacific coast of Tohoku Earthquake occurred, tsunami waves flooded into the lake through the Takase-gawa River and the sluice. This observation suggests a possibility that the lake sediments have archived tsunami and earthquake events in the past. Then, in order to understand limnological condition of Lake Ogawara, and also aiming detection of the recent tsunami deposits, systematic survey and sampling of lake water and surficial sediments were carried out in August to September, 2011. Here we report a preliminary result of magnetic measurements of the sediment samples dredged with an Ekman-Birge bottom sampler.

We measured weak-field magnetic susceptibility using a Bartington MS3 meter with an MS2C sensor and also on an AGICO KLY-3 KappaBridge to estimate anisotropy of the magnetic susceptibility. The susceptibility values range from 10-5 to 10-3 SI. The higher values were found at the sites around the mouth of the Shichinohe-gawa River entering to the lake and at the sites close to the Takase-gawa River. These data suggest that magnetic minerals of detrital origin were transported into the lake from the watershed in the west and also by erosion of the sandbar along the passway to the Pacific Ocean. Most of the AMS ellipsoids showed oblate shape with horizontal alignment, showing no systematic directional trends of the sediment supply.

Keywords: Lake Ogawara, environmental magnetism, magnetic susceptibility, tsunami deposit

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Regional variation in magnetic properties of topmost sediments in the first depression of the Northern Lake Biwa

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Rock-magnetic analyses have been performed on topmost sediments cored at the deepest part (91m water depth) of the first depression in North Basin of Lake Biwa for clarifying effects of early diagenesis on magnetic properties of the sediments and for investigating response of the magnetic properties to seasonal variation of dissolved oxygen (DO) content in bottom water, which is one of factors controlling early diagensis. The following results have been obtained (Asami et al., in preparation): (1) the downcore decrease of magnetic coercivity occurs in uppermost sediments above about 10 cm below sediment surface (bss), and the content and grain size of magnetic minerals (magnetite or maghemitized magnetite) subsequently decreases and increases downcore, respectively, (2) in uppermost sediments above 10 cmbss magnetic coercivity and the presence of magnetic minerals with characteristic low-temperature magnetic property, as mentioned later, change seasonally associated with seasonal variation of DO content in the bottom water. In order to reveal these magnetic features in detail, we further conducted rock-magnetic analyses of topmost sediments cored at ten sites with different water depth in the first depression in Northern Lake Biwa. The DO content of bottom water at the ten sites changes seasonally. The Do value becomes lower than 4 mg/L in winter (November and December) at seven sites with the water depth deeper than 80 m among the ten site. Sediments cores of about 30 cm long were taken in summer (June-July) and winter (November-December), 2009.

Low-temperature magnetometric results from surface sediments above about 1 cmbss of all sites indicated the presence of magnetite or maghemitized magnetite. Warning curves from 6 to 300K of isothermal remanence (IRM) imparted at 6K in 1T after zero-field cooling showed a remarkable decrease of IRM between 90 and 120K, which may be regarded as a suppressed Verway transition of magnetite. Magntite or maghemitized magnetite is considered to be the principal magnetic mineral controlling magnetic properties in room temperature in Northern Lake Biwa. The warning curves of the samples at the deeper seven sites also showed another IRM decrease between 20 and 30K with the inflection point at about 29K. The IRM drop was detected more clearly in the samples taken in winter, when the bottom water showed the lowest DO value. It seems that the magnetic mineral with the characteristic low-temperature magnetic behavior exists at the deeper part with low DO bottom water in the first depression, and that the occurrence of the mineral is influenced by seasonal change of the DO values. Frederichs et al. (2003) reported low-temperature IRM decay curves of Fe-bearing rhodochrosite similar to those of our samples. A ferro-rhodochrosite may be a possible candidate as a magnetic mineral showing the IRM transition at about 29 K in our samples although the presence of ferro-rhodochrosite has not been reported from topmost sediments in Lake Biwa (e.g., Kawashima, 1985).

Keywords: Lake Biwa, sediments, magnetic property, rock magnetism, early diagenesis

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Rock magnetic study on sediments of non-marine and marine clay (Ma5) in the Osaka Group cored at Kyoto Basin

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Rock magnetic analyses were performed on sediments of non-marine and marine clay in the Osaka Group cored at Kyoto Basin in order to investigate magnetic variations corresponding to environmental changes between freshwater and marine. The Osaka Group is the Pleistcene sequence formed related to sea-level changes in the glacial-interglacial cycles, and consists of alternating beds of non-marine sediment and marine clay. In a core drilled at Kyoto Basin, the Osaka Group is observed above 223.17 m in depth, and five beds of marine clay are recognized. The Ma5 bed of marine clay exists between 150.00 and 141.35 m in depth. The lower and upper boundaries of the Ma5 bed have been determined mainly based on the sediment facies and color. Analyzed samples in this study were collected in 20 cm intervals from two parts between 140.60 and 153.82 m in depth, including the Ma5 bed, and between 155.80 and 157.75 m in depth. We measured initial magnetic susceptibility (X), ARM susceptibility (Xarm), IRM intensity (IRM) and hysteresis parameters, and performed thermomagnetic analyses and progressive thermal demagnetizations of IRM (IRM-PThD). Electristic conductivity (EC) and pH of clayey water stirring the sediment samples were also measured.

EC values showed a remarkable change between 151.41 and 151.21 m in depth. The EC values were lower (3.03-54.7 mS/s) in a zone between 157.75 and 151.41 m in depth (low EC zone: LEC), and were higher (142-278 mS/s) in a zone between 151.21 and 142.40 m in depth (high EC zone: HEC). The EC values were 45.6-133mS/s in a zone between 142.20 and 140.60 m in depth (intermediate EC zone: IEC). A drastic change of pH was also observed at the LEC-HEC boundary. The LEC and HEC zones showed stable pH values of 3.26-3.80 and 5.92-7.07, respectively. In the IEC zone, the pH values fluctuated between 3.37 and 4.41. According to Yokoyama and Sato (1987), sediments in the LEC, HEC and IEC zones were regarded as freshwater, marine and blackish sediments, respectively.

Values of rock magnetic parameters, X, Xarm and IRM, changed at the LEC-HEC boundary. These values extremely stable in the HEC zone, while the values fluctuated in the LEC and IEC zones. On the other hand, magnetic coercivity (Hc) showed no remarkable change at the LEC-HEC boundary. In the HEC zone, Hc were 30-43 mT with a maximum value at the middle part of the zone. Decay curves of IRM in IRM-PThD showed inflections at about 300-400^{o}C and 580^{o}C, and IRMs were completely demagnetized at about 700^{o}C. The IRM behaviors at about 580^{o}C and 700^{o}C indicated the presence of magnetite and hematite, respectively. The inflection at 300-400^{o}C implies the presence of iron sulfides such as pyrrhotite and greigite or titanomagnetite. The IRM decay curves of samples in the HEC zone resembled, suggesting that the composition of magnetic minerals is constant in the HEC zone. Decay curves of induced magnetization in the heating process of thermomagnetic analysis were similar to those of IRM in IRM-PThD. In the cooling process, magnetization of samples in the HEC zone increased below 200-250^{o}C, indicating the formation of magnetic minerals with the curie temperature of 200-250^{o}C during the heating treatment in air.

The HEC zone showing characteristic variations of pH, EC and rock magnetic parameters excluding Hc is not corresponded to the Ma5 bed. The lower and upper boundaries of the HEC zone are about 1.21 m and 1.05 m lower than those of the Ma5 bed, respectively. The difference in the depth of the boundaries between the Ma5 bed and HEC zone implies two alternative possibilities as follows: (1) the boundary estimation for the Ma5 bed is wrong, and the HEC zone is the sequence of marine sediments, or (2) magnetic properties, as well as pH and EC, of the sediments below the lower and upper boundaries of the Ma5 bed had been altered related to chemical condition changes between freshwater and marine.

Keywords: Rock magnetism, The Osaka Group, marine clay

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Seasonal variations of iron sulfide and oxide in the Hiroshima bay

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Frequent outbreaks of red tide have been reported since 1970 in the Hiroshima bay, and the red tide is caused by the bloom of dinoflagellates. Iron is an essential element for dinoflagellates. Iron is supplied as bivalent or trivalent ions, or as oxides and sulfides from lands to sea. For damage predictions of red tide, it is important to research the iron distribution in the bay. Therefore we investigated iron sulfide and oxide in the sediments and seawater in this study. Sediments of 5 cm in depth and surface and bottom waters were taken from three sites in the Hiroshima Bay during 2011. We performed rock magnetic analyses on the sediments and suspended solids in surface water, and also measured the concentrations of carbon, nitrogen and sulfur. Measurements of dissolved iron concentration in bottom water were conducted. The SIRM of suspended solids varied with pH in the surface water, and showed the minimum value during summer. It is implied that iron in the liquid phase is richer in the surface water during this season. The presence of magnetite ($Fe_3 3O_4$) and hematite (Fe_2O_3) were recognized in all analyzed sediment samples, whereas greigite (Fe_3S_4) appeared at the sites with rich in sulfur in the sediments. The decrease of magnetization from 280 to 320 Celsius degree was unclear in the sediments taken in August. Magnetic grain size in the sediments decreased and iron concentration increased in the bottom waters in August. It is inferred that iron oxides were dissolved and greigite was replaced to pyrite (FeS_2) under an anoxic condition.

Keywords: iron oxide, iron sulfide, rock magnetism, C/N ratio, marine sediments, suspended solids

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Coexistent titanohematite and titanomagnetite in obsidian from Takanoobane lava of Aso Volcano, Japan

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Volcanic glass contains abundant superparamagnetic and single-domain grains carrying stable remanence and has been served as an accurate paleomagnetic field recorder. Obsidian, a sort of volcanic glass of rhyolitic composition, is potentially a rich source of reliable paleomagnetic information. Also rock magnetic properties of volcanic glass provide key clues to identify and correlate a particular tephra layer related to an explosive volcanic eruption.

Here we report magnetic characterization of both titanohematite and titanomagnetite from borehole cores penetrated into Takanoobane rhyolitic lava of Aso Volcano, Japan. Crystalline rhyolite comprises a inner part of the lava and is bounded by upper and lower obsidian layers. We collected samples from an upper obsidian layer of one hole and from lower obsidian layers of three holes. Collected obsidian blocks are often mixtures of cloudy glass and crystalline spherules so that we carefully picked up glassy grains and rinsed with a ultrasonic cleaning. We performed high-temperature thermomagnetic analyses, low-temperature AC susceptibility measurements and low-temperature demagnetizations.

Most remarkable feature in these measurement results is ubiquitous 160 K peaks in AC susceptibility variations seen for almost all samples. This points to the Neel temperature of titanium-rich titanohematite (y = 0.9). On the other hand, Curie temperatures above 500degC are always observed from high-temperature measurements. Sometimes two Curie points (>500degC) can be seen in a single single, suggesting that dual low-titanium titanomagnetite phases ($x < 0.1$) are present. In addition, we found a kink at about 50 K in low-temperature demagnetization curves and also frequency dependence of AC susceptibility around 50 K in both in-phase and out-of-phase components. This indicates extremely fine grains are contained in obsidians. Low-temperature frequency dependence was most obviously seen for a lowermost part of a lower obsidian layer, where clear glassy obsidian can be seen.

We could identify a complex mineralogy and grain-size distribution of iron-titanium oxides. Titanomagnetite is a common oxide in igneous rocks and readily recognized by using room- or high-temperature techniques like three-axis IRM demagnetization. In contrast high-titanium titanohematite is usually missed in ordinary magnetic measurements because of its low Neel temperature, whereas low-temperature magnetic measurement is able to detect a very low concentration of titanohematite. Detailed grain-size distribution can give a clue to resolve cooling history of a rhyolitic lava.

Keywords: rock magnetism, obsidian, superparamagnetic grains, low-temperature magnetometry, frequency dependence of susceptibility

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Magnetic property of the Oshima 1986 lava based on mapping of the coercivity - blocking temperature diagram

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Magnetic properties depend strongly on composition, size and shape. Dunlop and West (1969), they carried out mapping of grain size vs coercivity using pTRM. The problem is that their mapping cannot be applied to the natural rocks including PSD and/or MD grains as well as SD grains, since the grain size data are based on the single domain theory. In addition, thermal alteration due to the laboratory heating cannot be checked in their experiment. In the present study, we use ARM and combine thermal demagnetization and alternating field demagnetization to make ARM spectra against blocking temperature (Tb) and coercivity (Hc). This mapping is applied to Oshima basaltic lavas extruded in 1986. We will report Hc-Tb maps and discuss those characteristic features.

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Paleointensity determination of welded tuffs correlated with widespread tephras

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In order to calibrate relative paleointensity (RPIs) variation curve to absolute values, Takai et al. (2002) proposed to use absolute paleointensities from pyroclastic flows which are correlated with widespread tephras. Using to the oxygen isotope age estimate of the widespread tephra, absolute paleointensity from the welded tuff can be compared with RPIs.

In the JpGU 2011 Meeting, we reported paleointensities of welded tuffs of Aso-1, Aso-2, Aso-3, and Aso-4 using the LTD-DHT Shaw method. In this study, we are measuring paleointensities of welded tuffs of Funakura, Ito, Imaichi, and Yabakei. These welded tuffs have been correlated with widespread tephras of K-Ah, AT, Ss-Az, and Ss-Pnk, respectively. Two to six paleointensities have been obtained and average paleointensities are calculated as 30.9 +/-5.6 micro T for Funakura, 14.9 +/-0.6 micro T for Ito, 32.2 +/-1.3 micro T for Imaichi, and 30.7 +/-1.2 micro T for Yabakei.

We compare our LTD-DHT Shaw data with the Thellier data of Takai et al. (2002). Four of the 6 average paleointensities determined by the Thellier method are 10-50% highler than those by LTD-DHT Shaw method. Also, we will compare the paleointensity results with a relative paleointensity stack (PISO-1500) using the ages of widespread tephras based on the oxygen isotope stratigraphy. PISO-1500 is 5-100% higher than all paleointensities.

Keywords: paleointensity, pyroclastic flow, widespread tephra, PISO-1500, LTD-DHT Shaw method

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Paleointensity experiments on baked clay samples taken from the reconstructed ancient kiln

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In 1960-1970s systematic oriented-sample collections were made from baked clay at many archeological sites in Japan. Paleomagnetic directions had been intensively measured from these samples and databases reporting the results have been constructed (e.g. Hirooka et al., 2006). As a next step, we plan paleointensity measurements from these samples. To test how reliable paleointensity results we can obtain, we have conducted paleointensity experiments on baked clay samples taken from the reconstructed ancient kiln, which was completely imitated to that of an excavated kiln of the 7th century (Nakajima et al., 1974).

The reconstruction experiment was conducted on January 1972 (Nakajima et al., 1974). Prior to the reconstruction, in-situ geomagnetic field was measured by a magnetometer: D=-5.63 deg, I=46.78 deg and F=46.350 micro-T. During the experiment, thermocouples were set at several points in the kiln. It was recognized that temperature reached to 1000 C at the floor surface, 630 C at the level 10 cm below the floor, and 350 C at the level 20 cm below the floor. After the experiment, baked clay was taken from (1) the floor surface and (2) the level 20 cm below the floor, with orientation using plaster. Nakajima et al. (1974) conducted partial alternating field (AF) demagnetization up to 20-40 mT on the baked clay samples and reported mean paleomagnetic directions as D=-5.03, I=43.36 and a95=2.41 (N=10) for the samples from (1) and D=-4.80, I=43.52 and a95=3.38 (N=5) for the samples from (2). These are generally consistent with the in-situ geomagnetic field measured prior to the reconstruction.

Tsunakawa-Shaw paleointensity method (Shaw 1974; Rolph and Shaw 1985; Tsunakawa and Shaw, 1994; Yamamoto et al., 2003) mainly utilizes AF demagnetization and it can be applicable to partially AF demagnetized samples in previous. Mini specimens (about 1.7cm cube) cut from 12 baked clay samples were subjected to the Tsunakawa-Shaw paleointensity experiment. Nine results passed selection criteria and they give mean paleointensity and its standard deviation as 45.9 +/- 7.4 micro-T (N=9). The mean paleointensity coincides with the in-situ geomagnetic field measured prior to the reconstruction, but the standard deviation beyond 10 per cent of the mean.

The mini specimens giving nine successful results consist of seven red-colored ones taken from (1) and two gray-colored ones taken from (2). The gray-colored specimens show one order of magnitude smaller anhysteretic remanent magnetization (ARM) intensities than the red-colored ones. If we exclude results from the two gray-colored specimens, mean paleointensity and its standard deviation results in 46.1 +/- 3.5 micro-T (N=7). The standard deviation becomes smaller. It implies that archeointensity can be estimated by the accuracy within 10 per cent of the mean using red-colored baked clay specimens taken from a kiln surface, with the application of the Tsunakawa-Shaw method.

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

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In 1960's-70', enormous number of kilns were excavated in Sakai city and its vicinity, Osaka prefecture for a large residential development. The enhanced archeological studies were carried out by Osaka Prefecture. The archeomagnetic researches were also conducted under prof. Kawai of Osaka University. As the result, the geomagnetic secular variation curve from the 5th century to the 10th century was drawn. 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 are conducting remeasurement study of their NRM after alternating magnetic field demagnetization (AFD). Number of samples stocked amounts to about 4000, and 1000 of them were moved to Kumamoto University for this study. This report describes remeasured NRM using spinner magnetometer and results of AFD for 213 samples of 19 sites.

After AFD, precision parameter of each site generally improved from the previous results in the initial reports, about 4 times on average, 21 times at most.

Those improvements seems due both better measurement accuracy and stable magnetization component found by AFD. The degree of concentration of average magnetic directions in each age group is also improved. However the resultant secular variation curve has still some problem in smoothness, which shall be attributed to reasons other than the accuracy of magnetic measurements.

Keywords: Suemura kilns, Archeomagnetism, Geomagnetic secular variation

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Paleomagnetic results from andesite dikes in Toki, Gifu Prefecture: implications for dike emplacement and rotation

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High-magnesium andesite dikes of latest Cretaceous or Paleocene age (dated at 70-60 Ma by K-Ar dating) were samples from the Toki area, central Japan, to reveal a paleomagnetic direction and to discuss its implications for volcanic dike emplacement and regional tectonics. More than 100 oriented core samples were taken from a total of 17 dikes. Stepwise demagnetization (AF, thermal) was carried out for all samples, and principal component analysis was performed on demagnetization results to obtain characteristic remanent magnetization (ChRM) components. We determined ENE and down site-mean ChRM directions for 11 dikes. (Titano-)magnetite is the main carrier of ChRM. Small directional dispersion characterizes the site-mean directions, which suggests that the dikes were all emplaced probably within a short period of time compared to the general timescale of paleosecular variation. The ENE deflection of the ChRM directions indicates clockwise tectonic rotation in the study area. Clockwise rotation of the southwestern Japan arc associated with Paleogene to Miocene opening of the Japan Sea is the most likely cause of the observed paleomagnetic deflection. The angle of deflection is, however, larger than that of the Early Miocene direction in the same area, suggesting possible small clockwise rotation prior to the Early to Middle Miocene major rotation.

Keywords: paleomagnetism, rock magnetism, dike emplacement, tectonic rotation, central Japan, Japan Sea opening

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Preliminary paleomagnetic results from 1.32 Ga diabase sills from Northern China Craton

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We report new paleomagneic results from diabase sills within the Mesoproterozoic meta-sedimentary rocks in the northern North China Craton. The age of the sills is assigned to 1320 Ma by U-Pb method (Li et al, 2009). We collected oriented block samples from ten sills for paleomagnetic investigation. Host rock samples were also collected for the baked contact test.

Preliminary paleomagnetic analyses were done on three or four diabase samples per site where two or three were demagnetized by thermal techniques while one complementary sample was demagnetized by an alternating field. We obtained stable paleomagnetic components from six sills. Two or three magnetic components are revealed during the experiments. The characteristic high temperature component is isolated between about 400 degrees and 600 degrees after removing low-temperature component with present field direction. The unblocking temperature of about 600 degrees indicates the main magnetic carrier of magnetite. During alternating field experiments, the high temperature component is exhibited as a high coercivity component.

Both normal and reversed directions and smaller scatter after tilt correction indicate likely primary origin of the magnetization. The characteristic components have northerly direction with shallow inclination after tilt correction. The preliminary paleomagnetic results indicate the low latitude position of North China Craton at about 1.3 Ga.

Keywords: Paleomagnetism, North China Craton, Proterozoic

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A new technique for probing thermal alteration by using comparison of AF demagnetization curves of AMS parameters

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We report our new findings that anisotropy magnetic susceptibility (AMS) parameters during stepwise alternating-field (AF) demagnetization can be used for probing thermal alteration that often occur in paleointensity experiments. It is generally recognized that changes in thermal remanent magnetization (TRM) due to thermal alteration of magnetic grains during laboratory heating are the main reasons to result in failure in paleointensity determination experiments. We wander whether there is a quick and simple mean that allow us to detect this kind of changes and thus better selecting proper samples for paleointensity experiments which is time-consuming and lab-intensive. Based on results from Zheng et al (2005, 2006, 2007) that it is magnetostatic interaction between grains, rather than domain interaction, could seriously affect on the properties of TRM and generate the non-ideal behavior in the Thellier-Coe method even in the case of mixture of MD and PSD grains, we recently identified that anisotropy magnetic susceptibility (AMS) parameters such as shape parameter (T) and mean susceptibility (K) are also significantly affected by the grains interacting field. Thus, AF demagnetization curve of AMS parameters is also a function of grains interacting field and magnetic mineralogy of grains, which can potentially probe the thermal changes in TRM as well. To enforce the effect of grains interacting field we charge sample with greatest magnetization of saturation isothermal remanent magnetism (SIRM) before running of AF demagnetization. After every AF demagnetization step, AMS parameters are measured to obtain the stepwise AF demagnetization curves of shape parameter (T) and mean susceptibility (K). By comparison of the curves obtained from raw sample and heated sample, it is possible to check whether thermal alteration has occurred in view of both magnetic mineralogy and magnetostatic interacting field. We will illustrate the effectiveness of this method with true rock examples from the Northeastern China Tertiary - Cretaceous basalt sequences.

Keywords: probing thermal alteration, AMS parameters, paleointensity experiment, magnetostatic interacting field, SIRM, AF demagnetization

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Saturated Magnetization of Single Grain Obtained from Field-Induced-Translation in a Chamber Type Micro-G System

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A new technique to obtain precise value of saturated magnetization Ms of a single small particle is required in various field of magnetic science. For example, the magnetic structure of pre-solar magnetite, recently indentified form the IDP samples, are expected to provide information on the magnetic field structure at the time of super-nova explosion. Magnetization data of individual micron-sized Fe-Ni grain embedded in the primitive meteorites may preserve information of the field intensity at the stage of their formation.

A method to detect Ms of small grain is newly proposed and experimentally examined; the method is based on field-induced translation of the grain which was released in diffused (about 100 Pa) microgravity space. The released samples translated in the direction of monotonously increasing field by field-gradient force.The sum of kinetic and magnetic energy is conserved between any two different positions, denoted as position-i and ?j. The above-mentioned conservation is described as $(1/2)mv_i^2$-$mMsH_i$=$(1/2)mv_j^2$-$mMsH_j$. Here v_j, and H_j denote sample velocity and field intensity at position-j, respectively; m and Ms denote mass and saturated magnetization per unit mass of the grain, respectively. The Ms value was obtained from the gradient of a linear correlation between many sets of (v_i^2-v_j^2, H_i-H_j) data obtained between two different sample positions -i and -j. The MS values obtained by the above manner agreed fairly well with the published values for millimeter sized grains of Fe and Ni metal. It was also confirmed from the observation that amount of various energy losses caused, for example, by viscous drag from the gas medium was negligibly small compared to kinetic and magnetic energies.

In previous reports we have observed field-translation of various diamagnetic and paramagnetic grains, confirmed that their kinetic energy and magnetic energy were preserved as well during the translation [1]. Accordingly the present result on ferromagnetic materials indicated that the energy conservation rule is confirmed throughout the major 3 types of magnetic materials. It is noted that the above translations are all independent to mass m of particle, because the translations are driven by a magnetic volume force originating from individual atoms(or molecules) that compose a material. If the translation of particle is observable, its magnetization is obtainable irrespective of sample size. Using a conventional apparatus, detection of magnetization becomes difficult for a single small sample, because of the difficulty of mass measurement and because of interference of sample holder (noise signal etc).

Conventional micro-G facilities are not suitable for a routine analyzing process because they require a long machine time and high running feet for a single turn of experiment. In the present work, a chamber type drop shaft was introduced to apply a short duration of micro-G ($t < 0.5s$). Accordingly, the above-mentioned translation was observable in an ordinary laboratory chamber. In order to realize the compact system, the size of the measuring system was reduced to ˜25cm in diameter (30kg in weight) by introducing a coupleof NdFeB magnetic plate as a field generator. Because of its simplicity, the compact drop shaft was recently adopted in an educational program at a senior high school; here residual-G was diminished by introducing a 2 fold capsule[2].

[1] C.Uyeda et al: Jpn. Phys. Soc. Jpn. 79, 064709 (2010)

[2] Kasugaoka Senior High School(Osaka pref). Presented at public session for senior high school. JpGU meeting 2011 & 2012.

Keywords: chamber type micro-gravity system, saturated magnetization, single grain, field gradient force, field induced translation, material identification

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Influence of electrical conductivity heterogeneity in the D" layer on geomagnetic jerks

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Geomagnetic jerks are known to have occurred globally around 1969, 1978 and 1991 and they are called as global jerks. Also, those occurred around 1999, 2003 and 2007 are identified as local jerks. One of the most prominent features of the 1969 geomagnetic jerk is the differential delay time of its appearance at the Earth's surface: the sudden change of the first derivatives was observed earlier in Europe compared with that in southern Africa. The cause of the difference as large as two years was attributed to the effect of conductivity anomaly in the D" layer. Here we assume the locality of the jerk appearance to be simply due to the shape and intensity of the anomaly, and a set of 3-d numerical modeling of electromagnetic induction in the mantle was performed to clarify whether features of the geomagnetic jerks can be reproduced by the effect of mantle heterogeneity and magnetic field of a single spherical harmonic mode, both poloidal and toroidal, at the CMB. Numerical results suggest that even an extremely high conductive body in the D" layer cannot generate differential delay time as large as two years at the surface of Earth by either the poloidal or the toroidal magnetic field at the CMB. On the other hand, it is demonstrated that a geomagnetic jerk originated from the toroidal magnetic field at the CMB is possibly observed as a local jerk. We consider that fast torsional oscillation in the core may produce the toroidal field variation by the omega effect. Global scale geoelectric field observed by transoceanic submarine cables in the north western Pacific may show possible contribution of the toroidal magnetic field on 2007 local geomagnetic jerk.

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Time spectra of the geomagnetic field at the CMB and MHD flow in the core

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The flow of electrically conducting fluid in the outer core is responsible to generate and sustain the geomagnetic field. The flow in the core is expected to contain wide range of spatial spectrum, from planetary to turbulent scale. In this study, we made an attempt to extract information of the turbulence in the core from the geomagnetic field time spectra of decadal time scale.

The kinetic energy density of turbulence depends on power law with respect to the wave number in the inertial range and the power law also holds for certain frequency range according to Taylor's hypothesis. The exponent or the slope of the power spectral density (psd) in log space depends on the characteristics of the flow. Theoretical and numerical studies of MHD turbulence suggest that the exponents of the kinetic and magnetic energy are related with each other by magnetic induction. Therefore, if the exponent of the magnetic energy is obtained, it is possible to discuss the turbulent flow in the core by using the relationship between the two exponents.

Previous studies of the geomagnetic field spectra of decadal time scales employed magnetic field variation at the Earth's surface (Consolini et al., 2002) or the dipole moment (Sakuraba and Hamano, 2007). However, it would be more appropriate to analyze the magnetic field variation closer to the core for the discussion of the turbulent flow in the core. In this study, we used global geomagnetic main field model ufm1 (Bloxham and Jackson, 1992) to calculate the magnetic field time series and the psd of magnetic energy at the CMB. Average exponent of the psd is obtained as -5.8 when the spherical harmonic expansion is truncated at degree 10. It is confirmed that the exponent converges by increasing the truncation degree. The obtained value of exponent is significantly different from -11/3, which was obtained by previous studies of the surface magnetic field or the dipole moment.

The magnetic field calculated by a recent geodynamo (Sakuraba and Roberts, 2009) is also analyzed to compare the characteristics of the exponents. The obtained exponent is -5.3 and its variation with respect to increasing truncation degree is similar to that of ufm1. Similarity of the exponent value and the truncation behavior imply that the MHD dynamo model may reflect the dynamics of the Earth's core well.

In addition to the magnetic field, calculated flow by the geodynamo model was analyzed to compare the slopes of the magnetic and kinetic energy. The obtained exponent near the CMB was -3.1. The difference of the magnetic and kinetic energy exponents, about two, is consistent with the result of order estimate using the induction equation by assuming quantities expected in the core. The kinetic energy exponent in the core is estimated as about -3.3 when the same relationship between the magnetic and kinetic energy exponents holds. The value is smaller than the Kolmogorov exponent of -5/3. The strong magnetic field in the core, coordinate rotation and vigorous convection by high Rayleigh number are the possible causes of the steeper slope.

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Bifurcation analysis of an extended disk dynamo model incorporating effects of viscosity and variable mutual inductance

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In recent years, a subcritical regime has been found in numerical models of MHD dynamo in a rapidly rotating spherical shell [1]. Under an influence of strong magnetic field, the critical Rayleigh number required for sustaining dynamo action is often lowered. Such kind of dynamo action is classified as subcritical. Subcritical dynamo may be important to understand dynamics and thermal history of planetary cores, such as Mars. However, fundamental physical processes of the subcritical dynamo are not well understood. Moreover, it is not easy to find a basic physics in a three-dimensional MHD dynamo model, which shows spatially and temporally complicated structure. Therefore, it is good as a first step to analyze a simpler model. Here we use a disk dynamo model, extended from the original by Bullard [2] to examine the essentials giving rise to the subcritical dynamo regime.

We extended the Bullard model by taking two effects into account. First, we add a viscous term proportional to the angular velocity of the disk to the equation of motion, where there is no viscous term incase of the Bullard model. Another effect is excitation of different mode of the velocity field modulated by the magnetic field. The mode of the volocity field is varied in a MHD dynamo model, whereas that is fixed to one in the Bullard model. In a MHD dynamo model, dynamo action is likely to be efficient by excitation of different mode of the volocity field modulated by the magnetic field. Therefore, we consider a feedback effect represented by the mutual inductance of the coil, which varies in response to the induced electric current. This effect is added to the equations of motion and dynamo action. We have analyzed the dynamical system governed by the equations with the effects given above. Equations are non-dimensionalized adopting a proper scaling.

We have examined behavior of the extended disk dynamo using a bifurcation theory and numerical simulation. We first investigate the model involving the viscosity with a constant mutual inductance. As a result, it is found that there is a region in parameter space, where dynamo action fails. Then, the model with viscosity and the variable mutual inductance is studied. Consequently, subcritical bifurcation is found in case of two different parameter values describing variability of the mutual inductance. The results suggest that parameter region that can not sustain dynamo action in a MHD dynamo model is due to the viscous force, and that emergence of the subcritical dynamo regime in a MHD dynamo model is due to excitation of different mode of the velocity field modulated by the magnetic field.

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Keywords: Dynamo theory, planetary magnetism, subcritical dynamo, disk dynamo

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Magma flow direction of basaltic rocks in the King George Island, Antarctica

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The magmatic arc along South Shetland Islands, East Antarctica is considered to have been formed by back arc spreading related to the subduction along the South Shetland Trench, north of the Antarctic Peninsula during the late Cretaceous and middle Miocene. This magmatism consists of lava flows with subordinate pyroclastic deposites, intrusive dykes and sills and plutons, displaying a typical subduction-related calc-alkaline volcanic association. Moreover, radiometric dating indicated an apparent westward migration of the magmatic centers with time along the length of arcs (Birkenmajer 1994). The King George Island is represented by mainly Eocene basaltic to basaltic-andestic lavas, dacitic lavas, tuff and diorite?dolerite plutons. These magmatisms may have corresponded to major plate tectonic events of the area, such as the break-up of Gondwana land and the opening of Drake Passage. It is known that the flow direction of magma is directly connected to the mode and rates of a back arc spreading. There has been no data for the flow direction in this area, although magmatic flow direction of these volcanisms determines whether the intrusive volcanic rocks are fed by vertical injection of magma from deep seated magma chambers or by lateral injection from crustal magma chambers. In this presentation, we report the flow structure of basaltic rocks and diorite around the Marian cove in King George Island, Antarctica. We sampled 12 basaltic lavas, 8 plutons, 6 basaltic-andestic dykes, all located within 4 kilometer radius from the Korean Antarctic research station (King Sejong station) in the western side of King George Island. The plutonic rocks of diorite and dolerite are only found along the Marian cove, where is corresponding to the strong surface positive magnetic anomaly regions taken by ship-borne and foot-borne surveys. We measured a preferred alignment of magnetic minerals along framework-forming plagioclases in these rocks using anisotropy of magnetic susceptibility (AMS) with the verification of petrofabrics and source minerals by a field-emission gun electron microscope. The result reveals that plutonic rocks have high value of magnetic susceptibility and their anisotropy represents the vertical intrusion from the deep seated magma, being the possible origin of surface magnetic anomaly. The basalt dykes at Weaver and Barton Peninsula or along the Potter Cove are associated with steep plunge direction of the Kmax AMS axes, which gives support to notice that vertical magma flow may be related to a higher buoyancy of the magma during dyke intrution. The magnetic lineation of some basaltic rocks are mainly within 30? from the horizontal plane, suggesting the presence of lava flows along the topography. Moreover, the basaltic lavas in the center of Barton Peninsula show a high value of magmatic susceptibility, being corresponding to the surface negative magnetic anomaly.

Keywords: Antarctica, anisotropy of magnetic susceptibility, magnetic anomalies, volcanic activity, back arc spreading

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Analyzing the early 19th century's geomagnetic declination in Japan from Santou-Houi-Ki The 5th report

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Santou-Houi-Ki Japan national treasure is the survey data book comprised of 67 volumes consist of magnetic compass azimuth of approximately 200,000 data in 1800 to 1816, cover nearly whole of Japanese mainland cartographic survey, written by cartographer Tadataka Inoh. We continue the work of analysis that stopped after only analysis in 1918, which done about the survey data at Inoh retirement home Fukagawa in Edo (Tokyo) in 1802-1803.

(1)If we analyze the data of Santou-Houi-Ki, we can change Japan as one of the most concentrated area of accurate geomagnetic declination data in the world, back to early 19th century, from insufficient area of data, and supply new data to northeast Asia.The total Number of analyzed points is exceeded by 130, and the outline of the distribution of declination in Japan archipelago in early 19th century begun to appear.

(2)Comparison of Santou-Houi-Ki with Gauss and Weber isogonic Atlas which published in 1840, consisted of observational data roughly at the time of 1830(1828-1832), it foundational structure of isogonic lines in Japan archipelago is roughly similar to the result of analysis from Santou-Houi-Ki, But we can recognize the contradiction to reverse with secular variation in Northern Kyushuu area and Tsushima Island, or the local differences in eastern Hokkaido in Gauss and Weber isogonic Atlas, The observational data in Japan archipelago did not described in the table supplemented with Gauss isogonic Atlas. The described observational data in East Asia were from Pekin. Monggol, Baykal, Yakutsk Ohotsk Kamchatka etc. The isogonic line of declination in western pacific coast in Gauss and weber Atlas including Japan had to drawn by calculated estimates. The Gauss and Weber Atlas was drawn to understand the general conditions of geomagnetism of the entire world. The declination data in the table were calculated on a matrix of 5 degree of latitude and 10 degree of longitude, One cell of this matrix is 500km long in the vicinity of Hokkaido Isl. Therefore the analysis of Santou-Houi-Ki becomes very important.

(3)Advantage to use the data described in Santu-Houi-Ki.

1.Huge number of survey data. 2. Minute standard of analysis. 3. The Data are concentrated in 1800 to 1816. 4. Data cover nearly whole of Japan Mainland. 5. It include the ability of local abnormality, if there is a remarkable differences between Gauss Atlas and the value of analysis from Santou-Houi-Ki. 6. We can restore the precise position of Tadataka Ino reference point in less than second unit in latitude and longitude from Santou-Houi-Ki, valuable for both geomagnetism and local history.

(4) The development and improvement in analysis method and application.

1.Calculate the average of remainder as the declination, to deduct the magnetic azimuth recorded in Santu-houi-Ki from the true azimuth.

2.The important point in deciding the precise position of the reference point should be adjusted to that all of the declination values are calculated from the azimuth to different target at the reference point are approximately equal to each other. 3. Use GPS transmitter at the reference point for investigation of longitude and latitude. 4. By the request of Motohiro Tsujimoto to make the consecutive formula use Excel for speed up his process in the above, Akitoshi Omotani realizes this important improvement. Akitoshi Omotani continues to analysis both in Shimane and Tottori Pref. 5.Takaaki Inui apply the result of analysis to education of local history in Matsue city. 6.This method and formula is available for the analysis of magnetic survey azimuth data in the world. 7. The result of analysis is useful for global model of geomagnetisism.

Keywords: geomagnetic declination, Tadataka Inoh, Santou-Houi-Ki, Isogonic Atlas by Gauss and Weber, Secular variation of geomagnetic declination, Restoration of precise position of survey point