Preliminary study of detecting jerk-like magnetic secular variation in a numerical dynamo model

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The geomagnetic field, which is generated by the geodynamo, varies in a wide range of time scale. Focusing on short time scale variation, it is well known that a sudden and abrupt change in the first time derivative of the magnetic field (a V-shape-like change) occurs in typically one-year time scale. This abrupt change is called the geomagnetic jerk. Although we don’ t fully understand the mechanism of the geomagnetic jerk, Malin and Hodder (1982) show that internal sources can generate the geomagnetic jerk. Subsequent spherical harmonic analysis and wavelet analysis (Alexandrescu et al. 1995; Le Huy et al. 1998; Bloxham et al. 2002) establish that the geomagnetic jerk is an internal origin in a broad sense.
In this study, we examine magnetic field variation using a result of numerical dynamo simulation in order to see whether or not any jerk-like variation could be observed in the numerical model. The adopted values of the Ekman number in the model is 3x10^{-5}, which is not state-of-the-art but considerably low, and therefore, seems suitable for a pilot study. As a first step, we investigate the radial component of the magnetic field at the core-mantle boundary truncated at spherical harmonic degree 12. With a second order centered finite differencing, the first and second time derivatives are evaluated globally at every time step. According to the procedure utilized in observations, we calculate jerk-amplitude to find jerk-like discontinuous change in the second time derivative. As a result, jerk-like variation is found at some point in the first time derivative, whereas it is not evident in the second time derivative. In conclusion, our preliminary study suggests a possible detection of jerk-like behavior in a numerical dynamo model. More careful analysis is required to confirm first detection of magnetic jerk in numerical dynamos.

Keywords: geomagnetic jerk, dynamo, numerical simulation

Geomagnetic Anomaly Survey at the Divergent Plate Boundary in Afar Depression, Ethiopia

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In order to expand our knowledge about magnetic structures under a sea-floor spreading center and the formation process of magnetic stripes, we are proceeding an on-land geo-electromagentic research plan at the divergent plate boundary in Afar Depression, Ethiopia, where we can directly investigate into a sea-floor spreading center on land. We will introduce our plan and report the progress of geomagnetic and geological surveys we have performed.

Keywords: divergent plate boudary, sea-floor spreading center, Afar depression, geomagnetic anomaly survey

Variation of geomagnetic field intensity at about 30 Ma recorded in the Ethiopian flood basalt

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We conducted a paleointensity study on samples from lava sequences of the Ethiopian flood basalt in order to clarify geomagnetic field variation at about 30 Ma. We obtained 24 absolute paleointensities by using the double heating technique of the Shaw method combined with low-temperature demagnetization, and 45 relative paleointensities estimated from intensity ratios of natural remanent magnetization to anhysteretic remanent one (NRM/ARM). Based on highly positive correlation of NRM/ARM with absolute paleointensity data, we calculated paleointensity values of samples that did not yielded absolute paleointensities. Finally, we determined paleointensities for 46 specimens from 45 flows of the lava sequences.
An overall mean of the paleointensity data is 13.2±10.9 μT and an averaged virtual dipole moment (VDM) is 2.7±2.3 10^{22} Am^2, indicating a weak intensity at about 30 Ma in the past 10 million years. Among seven polarity zones recorded in the lave sequences, a normal polarity one shows very low intensity (4.5± 2.7 μT) with smaller variation of intensity, and the VDM variation shows a tendency that the VDM was weaker in normal polarity zones than reverse polarity ones. In a period when polarity changes occurred in short intervals, a larger variation of VDM is observed, and higher values of VDM are detected from samples with large co-latitude of VGP from a mean paleomagnetic pole of the lava sequences.

Keywords: paleointensity, Ethiopian flood basalt

Updated magnetostratigraphy for IODP Sites U1409 and U1410

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The Integrated Ocean Drilling Program (IODP) Expedition 342 recovered ~5.4 km of hemipelagic sediment drifts from the Northwest Atlantic. Routine onboard measurements resulted in shipbaord magneto- and biostratigraphic age models (Norris et al., 2014). The shipboard magnetostratigraphies were based on the measurement of natural remanent magnetization (NRM) of the split-half cores after 20 mT alternating field (AF) demagnetization. In the present study, we performed detailed shore-based paleomagnetic measurements on the sedimentary sections recovered at Sites U1409 and U1410 to improve the shipboard magnetostratigraphies.

U-channel samples (typically 1.5 m in length with a 2 ×2 cm cross-section) were taken from the central part of the split half cores along the stratigraphic splice described in Norris et al. (2014): 6-142 mcd (meter composite depth) for U1409 and 0-165 mcd for U1410. We conducted progressive AF demagnetizations on NRMs of the samples up to 80 mT in approximately 10-12 treatment steps with remanence measurements at each AF step with a stratigraphic resolution of 1 cm. Characteristic remanent magnetization (ChRM) directions of the samples were typically resolved after AF demagnetization of 20-40 mT. The maximum angle of deviation (MAD) was less than 10˚ for most intervals of the samples.

The results show that intervals with negative inclinations are more manifested in shore-based results than they are in the shipboard results. It allowed us to locate chron boundary depths more precisely than those determined shipboard. In most cases the depths determined in the present study are not much different from those determined shipboard (less than ~1 m), but there are some boundaries which resulted in large differences. We could locate also some of new boundaries which had not been identified shipboard.

Deconvolution of pass-through paleomagnetic measurements of whole- and half-round cores for improved magnetostratigraphy

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Pass-through superconducting rock magnetometers (SRM) offer rapid and high-precision remanence measurements of continuous samples for paleomagnetism studies. Continuous SRM measurements are smoothed and distorted due to the convolution effect of SRM sensor response. Thus, deconvolution is necessary to restore accurate magnetization from pass-through SRM measurements. Robust deconvolution requires reliable estimate of SRM sensor response. Recent studies (Oda and Xuan, 2014; Xuan and Oda, 2015; Oda et al., 2016) have demonstrated that optimized deconvolution through ABIC minimization using a proper measurement of the SRM sensor response can restore geomagnetic and environmental information, and reveal short “excursion” event that is not recognizable before deconvolution. Here, we present sensor response functions of three SRMs with larger bores onboard D/V *Joides Resolution*, *D/V Chikyu*, and at the Geological Survey of Japan, AIST, as well as the tools and procedures used to measure the SRM sensor response. We also plan to demonstrate the ability to extract information of short “excursion” event associated with a significant magnetization intensity drop.

Keywords: deconvolution, superconducting rock magnetometer, sensor response, IODP

High-sensitivity multifunctional spinner magnetometer using a magneto-impedance sensor

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A novel spinner magnetometer was developed with a wide dynamic range from 10^{-10}–10^{-4} Am^2 and a resolution of 10^{-11} Am^2. High sensitivity was achieved with the use of a magneto-impedance (MI) sensor, which is a compact, sensitive magnetic sensor used industrially. Its slow spinning rate (5 Hz) and the incorporation of a unique mechanism for adjusting the spacing between the sensing unit and the spinning axis allows the measurement of fragile samples sized 10–50 mm. The sensor configuration, in which a pair of MI sensors is connected in opposite serial, along with an amplification circuit with a programmable low-pass filter, reduces the problems of external noise and sensor drift. The signal, with reference to the spinning frequency, is detected with a lock-in amplifier. The MI spinner has two selectable measurement modes: the fundamental mode (F mode) and the harmonic mode (H mode). Measurements in the F mode detect signals of the fundamental frequency (5 Hz), in the same way as conventional spinner magnetometers. In the H mode, the second (10 Hz) and the third (15 Hz) harmonic components are measured, in addition to the fundamental component. Tests in the H mode were performed using a small coil and a natural sample to simulate dipoles with various degrees of offset. The results revealed that the magnitude of the fundamental component of the offset dipole was systematically larger (by several percent) than that of the non-offset dipole. These findings suggest that this novel MI spinner will be useful in estimating the inhomogeneity of the magnetization of a sample that can equivalently be described by an offset dipole.

Keywords: spinner magnetometer, magneto-impedance sensor, dipole moment, nondipole moment

Rock magnetic properties of single grains extracted from fall-out tephra deposits in western Kochi

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There are many widespread tephra around Japan. In usual paleomagnetic and rock magnetic studies, analyses are typically made on an assemblage of tephra grains to investigate macroscopic remanent magnetizations. In this study we have extracted single grains from fall-out tephra deposits taken from an outcrop in western Kochi, and performed paleomagnetic and rock magnetic measurements on the grains. We will report these results.

Characterizations of fault slip zones in Nojima fault gouge by scanning magnetic microscopes

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Microscopic billow-like wavy folds and frictional slip zones have been observed along slip planes of the Nojima active fault, southwest Japan. The folds are similar in form to Kelvin Helmholtz (KH)-instabilities occurring in fluids, which suggests that the slip zone underwent "lubrication" such as frictional melting or fluidization of fault gouge materials. Since the folds and frictional slip zones are consisted of fine-grained granular materials, the driving mechanism of faulting might be fluidization induced by fault rupture and frictional heating. If the temperature range for generation of the billow-like wavy folds and slip zones can be determined, we can constrain the physical properties of fault gouge materials during seismic slip. In this presentation, we report on rock magnetic studies that identify seismic slip zones associated with the folds and slip zones, and their temperature rises during ancient seismic slips of the Nojima active fault. Using a scanning magneto-impedance (MI) magnetic microscope and a scanning superconducting quantum interference device (SQUID) microscope (SSM), we observed that such folds and slip zones are magnetized. Our heating experiments suggested that this magnetization is due to the production of magnetite through thermal decomposition of antiferromagnetic or paramagnetic minerals in the gouge at temperatures over 350˚C. Considering rock magnetic results and microtextural records with fluid mechanical method, the existence of KH-type billow-like wavy folds prefers the fluidization model to frictional melting, suggesting that the existence of such low viscosity fluid induced by fluidization and frictional heating decreased the frictional strength of the fault slip zone.

Emplacement age of a debris-flow deposit by using viscous remanent magnetization: a case study on granite porphyry boulders from Kii Peninsula, Japan

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Elucidation of occurrence age and periodicity of debris flows is one of the most important examinations to prevent debris disasters. We investigated an emplacement age of boulders from an old debris-flow deposit by using the palaeomagnetic method of stepwise thermal demagnetization (ThD) for viscous remanent magnetization (VRM) in Nachikatsuura town, Wakayama Prefecture, Japan. The old debris-flow deposit outcropped by debris flows occurred by the Typhoon Talas on September 2011 in the Kanayama valley of the Nachi River basin. The estimated depositional age was 3,650±30 yBP (2,057-1,943 calBC, 2 σ) by the ^{14}C analysis for a buried wood piece (Nishiyama and Wakatsuki, 2014). Some granite-porphyry boulders near the wood piece were sampled and shaped into cubic test pieces of 2.23 cm on a side. We examined heating durations and placements of the test pieces for the stepwise ThD experiment by measuring the temperature change inside the test piece by heating in the ThD equipment. In order to minimize the effect of multi-domain magnetic grains, low-temperature demagnetization was applied prior to the stepwise ThD. The stepwise ThD was applied at 5˚C steps, and demagnetization temperature of VRM was recognized as a bending point on the vector diagram and Schmidt net. In the presentation, we estimate the emplacement ages by applying theoretical time-temperature curve of VRM on the acquired temperatures.

Keywords: Granite porphyry, Thermal demagnetization, Viscous remanent magnetization

Ferromagnetic resonance spectroscopy and rock magnetism of coral skeletons

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Deceased coral skeletons, especially annual banded skeletons of hermatipic corals (e.g., *Porites*), possess an enormous potential as environmental proxies if they show an enough magnetization above sensitivity limits of magnetometers. Sato et al. (2014) found that coral boulders reworked from reef edge by tsunamis showed a measurable remanent magnetization with spinner magnetometer. However, the origin of magnetic minerals in coral skeletons is poorly constrained between detrital and biogenic magnetic minerals. To determine the magnetic mineralogy of coral skeletons, we conducted ferromagnetic resonance (FMR) spectroscopy, first-order reversal curve (FORC) measurements, and scanning electron microscopy observations of acid-treated residuals of coral skeletons collected from Ishigaki Island, Miyako Island, and Tonga. FORC diagrams of the boulders with coral skeletons and microbial mats showed a narrow ridge along the *H*c axis with negligible vertical spread, being called as “central ridge” which indicates the presence of intact magnetosomes (Egli et al., 2010). FMR spectra of the same boulders represented an obvious secondary absorption peak on lower field side of main peak, which are explained as result from uniaxial anisotropy of magnetosome (e.g., Weiss et al., 2004; Charilaou et al., 2011). Although the FORC diagrams from single *Porites* skeletons also had the central ridge feature, the FMR spectra represented multiple lower field absorption peaks which is different from the signature of magnetosome-bearing coral skeletons. This suggests that coral boulders with microbial mats showed the presence of magnetites aligned in magnetosome chain structures like those produced by the magnetotactic bacteria, whreas single *Porites* coral skeletons showed the higher contribution of detrital magnetite with trace amount of biogenic magnetites.

Keywords: Ferromagnetic resonance, Rockmagnetism, Coral skeleton

Reexamination of historical eruptions of Fuji volcano based on paleomagnetism

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Eruption age of the products of Fuji volcano were recently determined using ^{14}C datings and tephrochronology. However, those of some units differ in dating from historical records. Therefore, we investigated paleomagnetic study in order to reexam eruption age of historical eruption of Fuji volcano. Paleomagnetic age determination is based upon similarity to secular variation model of the Japan Archeomagnetism Database (JRFM2k.1) reconstructed from archeological sites in southwestern Japan. Samples for paleomagnetic measurements were collected from 32 units of lavas and pyroclastic deposits. At each site, we collected 6 to 12 samples using core-drill. The samples were oriented by a sun compass to eliminate local magnetic anomalies.
Based on eruptive sequence and historical records, Koyama (2007) identified that Hoei pyroclastic cone, Kenmarubi 1 lava flow, Aokigaharamarubi lava flow and Takamarubi lava flow were eruption products in A.D.1707, A.D.937, A.D.864-866 and A.D.800-802, respectively. As a result of our study, paleomagnetic directions of Hoei pyroclastic cone fit for the expected age deduced from the secular variation curve. The directions of Kenmarubi 1 lava flow imply age range of 1000-1030 A.D. indicating simultaneous eruption with Fudosawa lava flow. It requires careful consideration for the result of Aokigaharamarubi lava flow, which shows unexpected directions. The directions of Takamarubi lava flow imply age range of 600-640 A.D. Our findings suggest that paleomagnetic method can improve eruption history of Fuji volcano.

Keywords: Fuji volcano, historical eruptions, dating

Analyzing the early 19th century's geomagnetic declination in Japan from Tadataka Inoh's Santou-Houi-Ki The 11th report.

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The Santou-Houi-Ki is a national treasure of Japan 67 volumes magnetic survey ledger recorded by cartographer Tadataka Inoh in 1800 to 1816,consist of approximately 200,000 magnetic compass land survey azimuth data accuracy of 0 degree 5 min, from the coast of eastern Hokkaido to Yakushima Island in Western Japan. I restarted the analysis 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, by interdisciplinary simultaneous analysis across geomagnetism, survey science, historical cartography and local history. (1) Interdisciplinary simultaneous analysis. We can increase precise evidence to verify the real azimuth, geomagnetic declination and the reference point where magnetic compass survey was executed, or survey target points recorded in the Santou-Houi-Ki,than traditional way of study separated in each field. (2) Procedure of analysis. Use the recreation software of scenery and digital map of GSI Japan Chiriin Chizu to know the latitude and longitude accuracy sec of particular survey target points, and 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 recorded in the Santou-Houi-Ki. Calculate backward the precise position of the survey reference point should be adjusted to the position in accuracy 0.001sec.in latitude and longitude, where all of geomagnetic declination unit of 0.01sec. 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 declination unit of 0.001sec.and express it as the geomagnetic declination unit of 1min.on the day and point Tadataka Inoh's magnetic compass survey was executed. To use the consecutive formula of Excell for speed up and Keep accuracy. If it possible to go to the field of the survey reference point, confirm the real scenery and the longitude and latitude by GPS transmitter and recalculate the value of geomagnetic declination. (3) The outline of isogonic line in Japan archipelago and the distribution of the declination in every 15 min in western Japan coast in those days, begun to appear. 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 the NOAA's pace of variation West is almost 5 years later than the analysis of the Santou-Houi-Ki in western Japan. (4)However, from the analysis of Santou-Houi-Ki, we can recognize the magnetic declination supposed as the local geomagnetic declination anomaly in southern coast of eastern Hokkaido, some part of Noto Peninsula, Mt. Asama in Ise, Nobeoka city in Kyushu Island etc., impossible to drew in Historical Magnetic Declination map by NOAA. The analysis is developed from the coast area of Japanese archipelago to the inland area of Honshu island. (5)It is able to restore the precise position of survey reference points where Tadataka Inoh's magnetic compass survey was executed the accuracy of less than sec in latitude and longitude ,valuable in local history. It is so accurate as impossible to achieve by other way of study. (6)It is able to change Japan as the concentrated area of data in early 19th century from insufficient area of data and supply data to north east Asia. Total number of analyzed points exceeded 203. (7)We started the discussion to compile those analysis to the data base available to Japan Archeomagnetism Data base, or NOAA’ s Historical Magnetic Declination Map.

Keywords: geomagnetic declination, Santou-Houi-Ki, interdisciplinary

The Design of Excavation Information Sharing Tool for Communication between Archaeomagnetism and Archaeology

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In Archaeomagnetism as a methodology to restore the ancient geomagnetic field from baked archaeological materials, the strengthening joint collaboration with archaeological community is indispensable to devise the expanding the dataset. On the other hand, the scientific analysis like archaeomagnetic age estimation seems to be receiving focus as a useful tool to do an independent crosscheck for archaeological chronology in recent. However, the joint research have not done actively among the both academic regions under the present situation. This reason is conceivable that it does not have much interaction between the member of both communities, and it is very difficult to meet the appropriate researchers.

We have been developing the tools to do the efficient information searching and the personnel matching by unifying the management of (1) the information of excavations (academic excavation and emergency one) is carried out all over Japan and (2) the information of human resource of various fields, on a server. Specifically, we are going to realize the function by customization of “Kataribe Cloud” provided by Network Application Engineering Laboratories Ltd. (the platform to synchronize a weblog page of every user and Google Map based on the location information of photos), and additional implement of SNS plug-in of WordPress. Generally, such a sharing site has a problem of cold-start, so we are considering some solution for this problem.

In the present, the first prototype (smartphone app) implemented some functions for “Kataribe Cloud” platform, and designed GUI has been completed.

In this presentation, we introduce this real app and discuss about validation of app design, policy for next version up, and future developments, etc.

Keywords: Excavation Information Sharing Tool, Smartphone App, Kataribe Cloud, Archaeomagnetism, Archaeology

Multi-platform applications generated from MATLAB codes for viewing and analyzing demagnetization and directional data

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Directional paleomagnetic data are now processed through a routine workflow, and many kinds of on- or off-line softwares have been provided for viewing and analyzing paleomagnetic data (e.g., PuffinPlot [Lurcock and Wilson, 2012], Paleomagnetism.org [Koymans et al., 2016], PmagPy [Tauxe et al., 2016]) . However, some of these softwares were left unuqdated in spite of continually updated operating systems (OS). Each analyzing software requires a particular data format that needs to be converted from exported data of measuring softwares. Among paleomagnetists in Japan, a simple data format has been shared for more than 30 years along with DOS or Macintosh applications “Progress” and “Direction” developed by Prof. Shibuya at Kumamoto University. In order to succeed these established applications, we developed multi-platform applications with graphic user interface (GUI) based on a MATLAB code UPmag for analyzing U-channel data [Xuan and Channell, 2009].

There are two separate applications available: for viewing and fitting stepwise demagnetization data on Zijderveld and equal-area plots, and for viewing directional data on an equal-area plot and calculating the Fisher statistics. The data format remains simple; for demagnetization data it just needs three parameters in a polar coordinate of declination, inclination and intensity at each demagnetization level. For directional data only declination and inclination are necessary for each specimen or site. Users can confirm demagnetization intervals to be fitted on Zijderveld and equal-area plots before performing the fitting. Fitted data can be exported to a text file and handed out to the direction application. Fisher statistics parameters can be stored in a text file. You can save drawings in a variety of format such as pdf, jpeg, tiff, bmp etc. Later you can process the drawings for presentation or manuscript preparation with graphic softwares.

Both applications run on Windows (32 and 64 bits), Macintosh OS X, and Linux. Any MATLAB license is not needed to use the applications, just download a software package at http://mpms.doshisha.ac.jp/pd16/pd16top.html and MATLAB Runtime will be automatically installed. The MATLAB source code is also available, so if you prefer you can run the MATLAB programs and also modify them on your own right. Future update of the applications adapted to updated OS will be easily carried out by ourselves or others using updated MATLAB.

Keywords: paleomagnetism, software, demagnetization, MATLAB

