High-resolution paleomagnetic and environmental reconstruction from sediments using scanning magnetic microscopy

*Chuang Xuan[1], Hirokuni Oda[2]

1.University of Southampton, 2.Institute of Geology and Geoinformation, Geological Survey of Japan, AIST

High-resolution paleomagnetic and environmental magnetic records from marine and lacustrine sediments play fundamental roles in our understanding of the geomagnetic field and climate change. These data make it possible to reconstruct past changes in Earth's magnetic field and environment on centennial to decadal scales. High-resolution records are often acquired through study of sediments accumulated at high rates (e.g. tens of centimeters to meters per thousand year). In this presentation, we use scanning magnetic microscopy equipped with superconducting quantum interference device (SQUID) to reconstruct high-resolution paleomagnetic records from sediments accumulated at moderate to low rates (e.g. few centimeters per thousand year), taking advantage of the few hundred-micron spatial resolution permitted by the SQUID microscopy. We study the natural remanent magnetization (NRM) of thin sections of sediments from lakes in the UK and Japan as well as from the Japan Sea. NRM of the samples is typically scanned at 100-micron spacing along the surface of thin sections before and after stepwise alternating field (AF) demagnetization. NRM measurements are followed by measurements of laboratory-induced magnetizations including anhysteretic remanent magnetization (ARM) and isothermal remanent magnetization (IRM) before and after the same AF demagnetization steps used for NRM. We will compare the SQUID microscopy-acquired paleomagnetic and environmental magnetic data with those obtained from deconvolved u-channel sample measurements. We will also discuss the potentials and challenges of ultra-high resolution paleomagnetic reconstruction from sediments using SQUID microscopy.

Keywords: scanning SQUID microscopy, paleomagnetism, environmental magnetism, high resolution records

New Palaeosecular Variation Master Records for New Zealand –Applications for Dating and Field Modelling

*Gillian M Turner[1], Gino de Gelder[2], Jamie Howarth[3], Annika Greve[1], Rimpy Kinger[1], Ruth Corkill[1], Andreas Nilsson[4], Sean Fitzsimons[5]

1.Victoria University of Wellington, New Zealand, 2.Institut de Physique du Globe, Paris , 3.Geological and Nuclear Sciences, New Zealand, 4.Lund University, Sweden, 5.Otago University, New Zealand

We present new palaeosecular variation master records for New Zealand on both archaeological and Holocene timescales. These have been compiled using continuous data from the detrital remanent magnetization of lake sediment cores with high-resolution C-14 based chronology, and are constrained and calibrated using directions and absolute palaeointensities obtained from the thermoremanent magnetizations of archaeological materials and volcanic rocks. All data has been “relocated” to a standard geographical location (40°S, 175°E) using a virtual geomagnetic pole (VGP) transformation. By a reciprocal VGP process, the master records can be used to calculate accurate palaeosecular variation records for all locations within the New Zealand region. The geomagnetic field alternates between active periods of high amplitude swings from 12000 to 8000 BP and over the past 4000 years, and a relatively inactive period between 8000 and 4000 BP. The current field (Dec = 21.5° E, Inc = - 65.4°, F = 55.4 micro T at 40°S, 175°E) represents a rare steep and easterly extreme in direction, but is close to average in intensity. The palaeointensity record mirrors to some extent the variation of the virtual axial geomagnetic moment seen in the global dataset, but shows some notable differences. We also investigate the effect of including the Holocene record in global spherical harmonic-based and regional field models.

Keywords: Palaeomagnetism, Secular variation, New Zealand

Secular variation of inclination with a timescale of tens of thousand years

*Toshitsugu Yamazaki[1], Takaya Shimono[2,3], Seiko Inoue[2]

1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Graduate School of Life and Environmental Sciences, The Univerisity of Tsukuba, 3.Gas Hydrate Research Laboratory, Meiji University

Relative paleointensity records of marine sediments revealed that geomagnetic field fluctuations between polarity reversals contain variations with a timescale of tens of thousand years and longer. However, discussion on directional secular variations has been limited for timescale of tens to a few thousand years in general. This is probably because directional variations of the timescale of tens of thousand years are not easy to be detected due to the small amplitude of variations, often close to measurement errors, and difficulty in precise inter-core correlations. Exceptionally, inclination variations of the timescale of tens of thousand years were discussed using sediments from the western equatorial Pacific in terms of possible relations with persistent non-dipole components and orbital forcing (Yamazaki and Ioka, 1994; Yamazaki and Oda, 2002; Yamazaki et al., 2008). We revisited the problem of the long-term inclination secular variations using sediments from the Okhotsk Sea; three piston cores and nine gravity cores adjacent to each other were available. The sediments are of late Pleistocene age, and relative paleointensity was used for the age control. Inclination variations with the timescale of several to tens of thousand years are visible. Further accumulation of datasets for better spatial and temporal distribution is expected for elucidating geomagnetic field behavior of this timescale. For tectonic application of paleomagnetism assuming the virtual geocentric axial dipole field, a period of order of 100 kyr is required to average out secular variations to detect differences of several degrees in paleolatitudes.

Keywords: geomagnetic secular variaiton, inclination, Okhotsk Sea

Paleomagnetic secular variation of deep-sea sediment in Northeast Japan: challenge of dating of sedimentary sequence below CCD for paleoseismology in the rupture zone of 2011 Tohoku-oki earthquake

*Toshiya Kanamatsu[1], Kazuko Usami[2], Cecilia McHugh[3], Ken Ikehara[2]

1.Japan Agency for Marine-Earth Science and Technology, 2.Institute of Geology and Geoinformation, National Institute of Advanced Industrial Science and Technology, 3.Earth and Environmental Sciences, Queens College, City University of New York Earth and Environmental Sciences, Queens College, City University of New York

We examined the potential for obtaining detailed ages from the turbidites sequences recovered from deep-sea basins close to the rupture zones of the 2011 and past earthquakes off Tohoku, Japan using paleomagnetic secular variation records. Although it is generally difficult to obtain a detailed stratigraphy from deep-sea sediments below Calcium Compensation Depth (CCD), we found the sediments possess excellent paleomagnetic secular variation records. Sediment cores were recovered from a slope break at 4000-6000 m water depth, off Tohoku. The cores are mainly composed of diatomaceous clay-silt intercalated with sand layers of various thicknesses. The thickness of the coarse beds and laminae are generally a few cm, and rarely more than 10 cm. Occasionally the cores involve tephra layers spreading in historical time from the Japan Island, which are used for tie-points for establishing the stratigraphy. Samples for paleomagnetic study were collected continuously using standard paleomagnetic plastic cubes without gap. Natural remanent magnetization (NRM) intensities of samples before alternating field demagnetization (AFD) ranges from 10^{-5} to 10^{-6} kA/m. Maximum angular deviation (MAD) angles calculated from NRM vectors in AFD steps show that NRM vectors are stable single components, which are generally less than 2°. Major magnetic carrier is recognized as magnetite by themo-magnetic analysis. The ages obtained from the tephra layers, and the core tops calibrated with excess 210Pb permit to correlate our data to the references such as an archaeomagnetic field model, and a lacustrine data set back to ca. 9,000 ka. Variations in magnetic records obtained show systematic changes in the cores with remarkable similarity in all the studied cores in spite of a wide distribution with 200 km. Especially their declination patterns are similar to those of the references, while obtained inclination profiles seem to be less amplified in various degree than that of references. We infer the shorter frequency in the obtained inclination is subject to the filtering effects of post-depositional remanent magnetization. Paleomagnetic pattern matching with tephra tie points of well defined age reveal offsets in depth between our data and those of references. We consider these are corresponding to “lock-in depth” of post-depositional remanent magnetization process. These facts suggest age determinations by the pattern matching will produce some time offsets. We can estimate those offsets using depth of tephra horizons and geomagnetic directional variations. Measured offsets are in the range of a few tens of cm’s. Our study reveals that more detailed age control is possible by taking into consideration the lock-in depth, and this information is useful to understand the detailed recurrence of earthquake in Tohoku and can potentially be applied to sediments from other subduction boundaries located below the CCD.

Keywords: Paleomagnetic secular variation, 2011 Tohoku earthquake, Lock-in depth, deep sea-sediment

Archaeomagnetism in Japan: a historical review and new perspectives

*Tadahiro Hatakeyama[1], Hidetoshi Shibuya[2]

1.Information Processing Center, Okayama University of Science, 2.Department of Earth and Environmental Sciences, Graduate School of Science and Technology, Kumamoto University

Archaeomagnetism, a branch of paleomagnetism aimed at archaeological relics and antiquities, provides the highest-precision geomagnetic data in all paleomagnetic targets. In Japan, researches of archaeomagnetism for paleodirection and paleointensity would begin in 1940s and have achieved a certain goal in 1970s and 1980s. Although for a quarter century after that a lot of measurements of archaeomagnetic direction have been conducted to give date estimates to few thousand baked earth sites such as old kilns, archaeomagnetic results in Japan brought out almost no new contribution and feedback to geomagnetic secular variation study. Here we refer the history and the current status of archaeomagnetism in Japan, and we also introduce our recent efforts to build a new archaeomagnetic database and secular variation curve in Japan and recent measurements carried out by the Japanese paleomagnetic community.

Keywords: Archaeomagnetism, Paleomagnetism, Geomagnetic Secular Variation, Geochronology

Paleomagnetic Study of Four Geomagnetic Records of the last 15,000 years: Insights From Hawaiian Lavas, Ecuadorian Archaeomagnetic Artefacts and Soft Sediments From the Baltic Sea

*Emilio Herrero-Bervera[1]

1.University of Hawaii at Manoa

Paleomagnetic data are the unique source of observations to understand the geomagnetic variations and hence the geodynamo processes involved in field generation. During the last three decades, great interest has been concentrated on the investigation of the Secular Variation (SV) of the Earth's magnetic field in different parts of the world. Several reference SV curves have been constructed at the local and/or the regional level mainly based on the paleomagnetic data from lava flows, soft sediments and archaeological artifacts. Such reference curves are particularly important for improving our knowledge about the non-dipole variations of the geomagnetic field, the geodynamo processes and the particular characteristics of the field behavior. Based on these secular variation records, particular interest has been recently concentrated on the short-term variations of the direction and intensity of the Earth's magnetic field evidenced from local SV curves. Recent archaeomagnetic and geomagnetic observations from studies in western Europe, the eastern Mediterranean, South America and Hawaii indicate that periodic changes of ~500 to 1000 years in the secular variation of the geomagnetic field over the last 1000 to 15000 years have been truncated by sudden so-called “archaeomagnetic jerks,” which apparently have taken place at irregular intervals of time. Here, we present results of 15000 years of PSV investigations derived from Hawaiian lavas and from two widely separated archaeological sites in Ecuador spanning ~3000 years of PSV, from Valdivia coastal Ecuador spanning ~6000 years of PSV, and two sites from IODP Expedition 347 Sites M0059 and M0060 in the Baltic Sea that cover ~9000 years and 510-15145 years of PSV. We will show correlations of all these PSV results with the regional and global geomagnetic field models.

Keywords: Paleosecular Variation, Hawaiian Lavas, Ecuadorian archaeomagnetic artefacts

A Power Spectrum for the Geomagnetic Dipole Moment

Bruce A. Buffett[2], *Hiroaki Matsui[1]

1.Dept. of Earth and Planetary Sciences, University of California, Davis, 2.Dept. of Earth and Planetary Science, University of California, Berkeley

Fluctuations in the geomagnetic field offer insights into convective processes deep inside the liquid outer core. We show that quantitative information can be recovered from a time series of fluctuations in the dipole moment when the underlying process is represented by a stochastic differential equation. Slow changes in the dipole moment are described by a deterministic term (sometimes called the drift term), whereas short-period fluctuations are represented by a random noise term. Our description of the dipole moment in terms of a stochastic differential equation provides a framework for evaluating the power spectrum in frequency. We show that the power spectrum has the form A f^{-n}, where the exponent n takes even integer values n = 0, 2, and 4, over a prescribed range of frequency, f. The low frequency behavior (n = 0) changes to n = 2 at intermediate frequencies. The transition frequency corresponds to the average decay time of dipole fluctuations. Numerical geodynamo simulations suggest that dipole fluctuations inside the core can be represented by the first few dipole decay modes, so the appropriate decay time for the power spectrum is a weighed average of the eigenvalues for the decay modes. A second transition from n = 2 to n = 4 at higher frequency is set by the correlation time of the noise term. When the correlation times are recovered from a geodynamo model we obtain values that are consistently less than the convective overturn time. However, changes in the relative amount of heat flow across the top and bottom boundaries can produce systematic variations in the correlation time. Similarly, a change in the style of convection can affect the spatial structure of dipole fluctuations, which alters the first transition frequency. Consequently, the transition frequencies in the power spectra contain quantitative information about the underlying convection. We use these results to interpret recent paleomagnetic estimates of the power spectrum.

Keywords: geodynamo simulation, spectrum analysis

Long-term secular variation in dynamo simulations

*Futoshi Takahashi[1]

1.Faculty of Sciences, Kyushu University

Geomagnetic secular variation provides a way to characterize dynamo processes in the Earth's outer core. Thanks to recent developments in paleomagnetic and rock magnetic measurement technique, some models of global paleosecular variation have been constructed, although uneven distribution of data in terms of location and age should be kept in mind. In contrast, numerical dynamo simulation has advantages regarding such matters. Here we use numerical dynamo modeling to offer interpretation of geomagnetic paleosecular variation and its connections with dynamo action in the core. Since we primarily focus on statistical behavior of paleosecular variation, long-term (typically longer than 1 Myrs) dynamo simulations are required. However, it is extremely difficult and time-consuming to carry out such a long-term dynamo simulation with state-of-the-art parameters. To handle this problem, we have to adopt a higher value of Ekman number (E) by compromise. Some of the parameter values used in this study are fixed at E = 3.25 x 10^{-3}, Pr (Prandtl number) = 1, Pm (magnetic Prandtl number) = 20, whereas Ra (Rayleigh number) is varied to see effects of flow vigor. We will report our preliminary analysis of secular variation in numerical dynamos.

Keywords: secular variation, dynamo, core

Vector archeomagnetic secular variation for the past 400 years from Miyakejima volcanic rocks in Japan

*Koji Fukuma[1]

1.Department of Environmental System Science, Faculty of Science and Engineering, Doshisha University

Full vector archeomagnetic secular variation for the past 400 years was obtained from volcanic rocks in Miyakajima, Japan. Recent archeomagnetic studies have revealed the temporal variation of geomagnetic direction and intensity for the several thousands years. The archeomagnetic variation for the past centuries, which is closely related to the directly measured geomagnetic variation, is rather difficult to be obtained due to poor age constraints. Volcanic eruptions in Miyakejima occurred intermittently about every 50 years for the last 400 years. The basaltic lava flows are extremely well dated based on the ancient documents, therefore essentially no age error is needed to be considered. We collected drilled cores oriented with several azimuthal methods by using back-sighting and magnetic, sun and GPS compasses. The archeomagnetic directions were obtained based on the cross-checked azimuth so that the orientation error should be minimized. Thellier paleointensity measurements were performed for primarily the clinker and scoria samples that give much more reliable paleointensities than the solid part of lavas. An automated spinner magnetometer with thermal demagnetizer *TSpin* was utilized for all the Thellier measurements. We will discuss our archeomagnetic direction and intensity results by comparing with the geomagnetic field model *gufm1.*

Keywords: archeointensity, Thellier method, paleomagnetism

Paleointensity study on lava flows of Fuji Volcano and implications for the atmospheric ^{14}C variation for the last 30 kyr

*Nobutatsu Mochizuki[1], Masahiko Sato[2]

1.Priority Organization for Innovation and Excellence, Kumamoto University, 2.Geological Survey of Japan, AIST

The atmospheric ^{14}C production rate is considered to be controlled by the solar activity and geomagnetic field intensity. The ^{14}C variation of timescale of the order of 10-100 years is mainly caused by the solar activity, while the ^{14}C variation of longer timescales is probably related to the geomagnetic field intensity change. We can recognize a decreasing trend in the atmospheric ^{14}C for the last 30 kyr and an increasing trend in paleointensity data in the database for the same period. However, a quantitative evaluation on the relationship between the geomagnetic dipole moment and the atmospheric ^{14}C has been difficult, because the paleointensity database shows a very large scatter. The present study attempts to obtain reliable paleointensities from ^{14}C dated lava flows and then discuss the relationship between absolute paleointensity and the atmospheric ^{14}C. We sampled seven lava flows of 4-30 ka ^{14}C ages of Fuji and Aso Volcanoes in Japan. These ages were reported from the charred material in/below the lava flows or organic sediment below the lava flows in previous studies. Sixty-three samples were subjected to the LTD-DHT Shaw paleointensty experiment (Tsunakawa-Shaw experiment), and forty-six of them passed the selection criteria. These paleointensity data and the ^{14}C data reported for the same lava flows give a constraint on the relationship between virtual axial dipole moment and the atmospheric ^{14}C.

Keywords: paleointensity, 14C, Fuji Volcano

A preliminary paleomagnetic secular variation from varved sediments of Lake Suigetsu, central Japan

*Kosuke Tsumura[1], Masayuki Hyodo[1,2], Hayato Matsushita[1], Takeshi Nakagawa[3], Ikuko Kitaba[3], Suigetsu 2006/2014 project members

1.Department of Planetology, Graduate School of Science, Kobe University, 2.Research Center for Inland Seas, Kobe University, 3.Research Centre for Palaleoclimatology, Ritsumeikan University

Studies of paleomagnetic secular variation (PSV) are important to reveal the mechanism of geodynamo acting in the outer core, and in addition PSV can be used as a tool of dating of hundreds to thousands yr resolution. Sediments from Lake Suigetsu, Fukui prefectural, central Japan, have annual layers (varves), and thus precise varve chronology has been established, with small errors, e.g. ±58 years for 20000 years. In addition, the Lake Suigetsu varved sediments have a high accumulation rate of 99 cm/kyr for the last 20000 years. Therefore, high resolution secular variation records can be obtained. The aim of this study is to obtain high-resolution PSV records from Lake Suigetsu varved sediments, and assess the previous PSV records, focusing on the timing of secular variation features.
Varved sediments of Lake Suigetsu were sampled in July to September, 2014, and a total of 274 cores of 1 m length were collected from four holes on the bottom of the lake. In this study, we used 1cm x2cm x2cm double-L channel sub-samples collected from each core. Paleomagnetic analyses were conducted on 43 double-L channel samples, and 16 of 43 are originate samples.
For all samples, we conducted demagnetizations with progressive alternating field up to 80mT and measured magnetizations at 1-cm regular interval. Characteristic remanent magnetization (ChRM) was calculated by principal component analysis. As a preliminary result, inclination and declination variations for last 20000 years were obtained. The PSV of Lake Suigetsu shows many features commonly observed in the Japanese archeomagnetic secular variation for last 2000 years, and also in the Holocene PSV from Japanese lake sediments.

Keywords: paleomagnetic secular variation, varved sediments, Lake Suigetsu, the Holocene

Sedimentary record of the Holocene paleomagnetic secular variation from Beppu Bay, Southwest Japan

*Akira Hayashida[1], Kazuhiro Anraku[2], Masao Ohno[3], Michinobu Kuwae[4], Keiji Takemura[5]

1.Department of Environmental Systems Science, Doshisha University, 2.Graduate School of Science and Engineering, Doshisha University, 3.Department of Environmental Changes, Kyushu University, 4.Center for Marine Environmental Studies, Ehime University, 5.Institute for Geothermal Sciences, Kyoto University

Although considerable efforts have been made for global data compilation and geomagnetic field modeling for paleomagnetic secular variation (PSV), it is desired to further improve the data distribution and quality in the Asia-Pacific region. We have investigated the Holocene PSV records from marine sediments of Beppu Bay, which is a tectonic basin adjacent to active volcanic fields of Kyushu Island in Southwest Japan. Previous studies utilizing multiple piston-core samples from northwestern part showed that the sediments of the Beppu Bay have preserved stable remanent magnetizations suitable for reconstruction of the Holocene PSV. Recently, an age-depth model was developed for the late Holocene sediments in the southwestern part through detailed sedimentologial analysis and AMS radiocarbon dating, particularly for the last 3,000 years. We hence made pass-through measurements of natural remanent magnetizations of u-channel samples from newly obtained piston cores. Although our declination record was discontinued at section boundaries, relative variation within a u-channel sample was comparable with paleomagnetic records from the northwestern part. The inclination records showed consistent variation between the two areas and also correlative to a PSV record from Lake Biwa. It is thus suggested that the paleomagnetic data from Beppu Bay play a key role in synthesizing sedeimentary and archeomagnetic PSV records in Southwest Japan.

Keywords: paleomagnetic secular variation, remanent magnetization, Beppu Bay

Orbital Influences on Geomagnetic field in the Matuyama and the Gauss Chron at IODP site U1314 in the North Atlantic

*Masao Ohno[1], Meng Zhao[1]

1.Faculty of Social and Cultural Studies, Kyushu University

We have investigated the detailed geomagnetic field variation during the Matuyama and the Gauss Chron from a sediment core (IODP Site U1314) with high sedimentation rate (≥ 10 cm/kyr) and good age control. Characteristic remanent magnetization directions were well resolved by stepwise alternating field demagnetization. As a proxy of relative paleointensity, natural remanent magnetization (NRM) normalized by anhysteretic remanent magnetization (ARM) was used after testing that the influence of magnetic interaction in ARM is negligible. We discuss the variation of the geomagnetic field with the period close to those of the Earth's orbital elements.

Keywords: geomagnetic excursion, Milankovitch cycle

Archeomagnetic direction and intensity of ancient settlements at Koushin district, central Japan

*Ryo Hemmi[1], Takeshi Saito[2]

1.Geosphere and Biosphere Science, Graduate school of Science and Technology, Shinshu University, 2.Department of Science, Faculty of Science, Shinshu University

Archeomagnetic direction and intensity were estimated from baked soils obtained at four archaeological sites (Idegawa-minami site of the 6th century, Wada-taishido site of 9th century and Takabatake site of 11th-12th century in Matsumoto city and Kamihara site of 9th-10th century in Hokuto city), Koushin district, central Japan. 62 baked soil samples were obtained from heated ground at the ancient housings. These soils are reddened and consolidated because of heating during cooking. It is expected that these soils recorded stable TRM, though these baked soils from ancient kitchens were hardly experienced so high temperature as to those from pottery kilns and furnaces used in iron smelting (studies of Sue ware; Shibuya et al., 2015, JpGU).
As a result of PAFD and PThD, 47 samples from 12 ancient housings had stable TRMs whose directions were parallel to the earth magnetic field at the time when TRM was acquired. Directions from some samples which showed lower NRM intensity and susceptibility were not concentrated to the past magnetic field. Our site-mean directions are almost identical with those from the secular variation curve in Japan (Hatakeyama et al., in prep.) with a few exceptions. Archeomagnetic directions obtained from Matsumoto city are plotted on right side of the secular variation curve, suggesting that declination become higher due to local magnetic anomaly. According to present distribution of earth's magnetic field, declination is slightly higher of about 1-2 degree around Koushin district than surrounding region (GSI, 2010). This may result in eastward distribution of archeomagnetic data from Matsumoto city.
Using Thelier-Coe method (Coe, 1967), archeomagnetic intensities were estimated from 20 specimens with high magnetic susceptibility at Kamihara site. Obtained intensities showed wide range of 16.7~73.9μT. Excluded data from specimens with low magnetic susceptibility and NRM intensity, mean intensities are estimated as follows: 51.9±2.1μT (A.D. 850~900), 57.3±4.4μT (A.D. 850~950). These values are consistent with the values from previous study in Japan (e.g. Sakai, 1980; Yoshihara et al., 2003).

Keywords: secular variation, archeomagnetism, archeomagnetic direction, archeointensity, archaeological site

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

*Hidetoshi Shibuya[1], Tadahiro Hatakeyama[2], Nobutatsu Mochizuki[3]

1.Department of Earth and Environmental Sciences, Graduate School of Science and Technology, Kumamoto University, 2.Information Processing Center, Okayama University of Science, 3.Priority Organization for Innovation and Excellence, Kumamoto University

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 the results in 2012, 2015 JpGU meeting. The preliminary secular variation curve for 5^{th} and 10^{th} century were also reported in 2015 SGEPSS meeting, and 2015 AGU fall meeting. However, the curve has some conflicts with archeological dates in the later part of the interval. This time, we reexamined the archeological age and its reliability of each kiln, and tried redrawing the secular variation curve. The discrepancy between the Sueki typological ages and the archeomagnetic ages inferred from the secular variation curve is smaller for the redrawn one. It is interesting that Hajiki (another category of earthen wares in Japan, which does not have secular typological change, thus hard to be dated by archeology) kilns have magnetic direction aligned in a line after the youngest Sueki kilns. It may indicates that those Hajiki kilns were used for producing earthen wares of daily life after the technique of Sueki had been lost. If it is correct, the secular variation curve can be extended to 12 CE. The density of the kilns and a couple of gaps in age may also be suggestive to the rise and fall of the craftsmen groups of Suemura.

Keywords: Archaeomagnetism, Geomagnetic secular variations, Pottery kilns

A paleointensity study on historical and ^{14}C dated lavas in Hawaii Island using the Tsunakawa-Shaw method

*Yuhji Yamamoto[1], Yamaoka Ryo[1]

1.Center for Advanced Marine Core Research, Kochi University

In 1987 and 1991, historical and ^{14}C dated lava flows distributed in Hawaii Island were collected from 37 sites by Masaru Kono, Hidefumi Tanaka and others. Tanaka and Kono (1991) and Tanaka et al. (1995) reported absolute paleointensities determined for samples from the 7 sites using the Thellier-type method, but many samples have been stored and reserved for a further analysis. We have conducted absolute paleointensity measurements on 172 samples at 36 sites using the Tsunakawa-Shaw method, and obtained 149 successful results. Applying the site-level selection criteria with (1) minimum of three successful results for a site (N >= 3) and (2) the successful results giving site mean paleointensities with their standard deviations less than 15 percent (stdev =< 15 percent), 24 well-defined site mean paleointensities are discriminated. They range between 16.8 and 67.8 microT for a period from -21890 to 1960 yr AD (last 0-24 kyr), and associate with Q_{PI} (Biggin and Paterson, 2144) of 4/5 (AGE=1, STAT=0/1, TRM=1, ALT=1 and MD=1).
For that period, 72 site-mean Hawaiian paleointensities obtained by the Thellier-type method with pTRM checks can be selected from the GEOMAGIA50.v3 database (Brown et al., 2015), applying the same site-level selection criteria. 48 site-means of them are from surface lavas mainly covering the last 5 kyr (4 data, Coe et al. (1978); 5 data, Tanaka and Kono (1991); 12 data, Mankinen et al. (1993); 1 data, Cottrell and Tarduno (1999); 1 data, Chauvin et al. (2005); 18 data, Pressling et al. (2006); 7 data, Pressling et al. (2007)) while the other 24 site-means are from the Hawaiian Scientific Drilling Project (HSDP) cores mainly spanning the last 5-24 kyr (12 data, Teanby et al. (1991); 1 data, Laj and Kissel (1999); 11 data, Laj et al. (2002)). They show a general increasing trend from about 25 microT at around -22000 yr AD toward about 60 microT at around -3000 yr AD, and a high intensity period of the last 5 kyr with the average of 57.2 microT (standard deviation of 12.3 microT). Our new data appear to confirm basically this trend as well as this high intensity period, but to result in somewhat lower paleointensities as is evidenced by the average intensity of 45.8 microT (standard deviation of 10.0 microT) for the last 5 kyr.

Keywords: Paleointensity, Hawaii, lava

Volcanic records of the Laschamp geomagnetic excursion from Mt Ruapehu, New Zealand

Elizabeth M Ingham[2], *Gillian M Turner[1], David Helsop[2], Andrew P Roberts[2], Christopher Conway[1], Graham Leonard[3], Dougal Townsend[3], Andrew Calvert[4]

1.Victoria University of Wellington, 2.Research School of Earth Sciences, Australian National University, 3.Geological and Nuclear Sciences, New Zealand, 4.US Geological Survey, USA

We present palaeodirectional records of the Laschamp excursion from the thermoremanent magnetization of lavas on Mt Ruapehu, New Zealand. Fourteen lava flows on the western and southern flanks of Mt Ruapehu, for which $^{40}Ar/^{39}Ar$ dating yields ages between 39.1 ±1.4 and 45.4 ±2.0 ka, were studied. The youngest and older flows have normal polarity magnetizations; however, six flows, dated between 41.8 ±1.8 and 45.4 ±2.0 ka, record excursional field directions. The palaeomagnetic directions of three flows have southerly declinations and inclinations of about -40°, in good agreement with a previously published Laschamp record from the Auckland Volcanic Field (AVF). Together, the AVF and Mt Ruapehu lavas represent the only current volcanic records of the Laschamp excursion outside the Chaîne des Puys region of France. They, thus, provide a vital contribution to the global studies of the Laschamp excursion. Comparison of virtual geomagnetic pole (VGP) positions determined from the New Zealand and French excursion records suggest the dominance of an equatorial dipole dominated field in the early phase of the Laschamp excursion. Meanwhile, differing VGPs for the younger excursional flows from France and New Zealand suggests that either the field lost its predominantly dipole-dominated morphology in the later phase of the excursion, or that the two records are not synchronous. Compatible features of volcanic and sedimentary records of the Laschamp excursion are explored, including the possibility of a precursory palaeodirectional anomaly before the main excursion phase. Overall, $^{40}Ar/^{39}Ar$ ages for the Mt Ruapehu excursion records are slightly older than recently published ages from the northern hemisphere. Although the difference is not significant at the 2s level, if real, it could result from such a precursory phase, or from non-synchroneity of anomalous field directions at near-antipodal locations, or it could indicate a longer overall excursion duration than the currently accepted 1500 years.

Keywords: Geomagnetic excursion, palaeomagnetism, Laschamp

Palaeomagnetic field strength variations suggest a Mesoproterozoic age of inner core nucleation

*Greig A Paterson[1], Andrew Biggin[2], Elisa Piispa[3], Lauri Pesonen[4], Richard Holme[2], Toni Veikkolainen[4], Lisa Tauxe[5]

1.Institute of Geology and Geophysics, Chinese Academy of Sciences, 2.University of Liverpool, 3.Michigan Technological University, 4.University of Helsinki, 5.Scripps Institution of Oceanography, University of California San Diego

The Earth's inner core grows by the freezing of liquid iron at its surface. The point in history at which this process initiated marks a step-change in the thermal evolution of the planet. Recent computational and experimental studies have presented radically differing estimates of the thermal conductivity of the Earth's core with resulting widely ranged dates of inner core nucleation (from less than 0.5 to nearly 2 billion years). Some of these raise serious challenges to explaining how the dynamo responsible for generating the geomagnetic field has been sustained over the whole of observed Earth history. The nucleation of the core leads to a different convective regime, and might be expected to produce different magnetic field structures, producing an observable signal in the palaeomagnetic record and allowing the date of inner-core nucleation to be estimated directly. Previous studies searching for this signature have been hampered by the paucity of palaeomagnetic intensity measurements, by the lack of an effective means of assessing their reliability, and by shorter timescale geomagnetic variations. Here we examine results from an expanded Precambrian database of palaeomagnetic intensity measurements selected using a new set of reliability criteria. Our analysis provides the first intensity-based support for the dominant dipolarity of the time-averaged Precambrian field, a crucial requirement for palaeomagnetic reconstructions of continents. We also present the first firm evidence for the existence of very long-term variations in geomagnetic strength. The most prominent and robust transition in the record is an increase in both average field strength and variability observed to occur between 1 and 1.5 billion years ago. This observation is most readily explained by the nucleation of the inner core occurring during this interval; the timing would tend to favour a modest value of core thermal conductivity and a more conventional thermal evolution of the Earth.

Keywords: inner core, paleointensity

