Did clockwise rotation of coherent SW Japan case paleomagnetic declinations observed there?

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Paleomagnetic declinations (PDs) observed in rock samples could be caused by various scale and mode of horizontal rotations, such as a coherent rotation of a large tectonic domain, rotations of blocks bounded by faults and shear deformation by strike-slip tectonics. Examinations taking account of geological structures, such as orientations of faults and fold axes, are required to determine the scale and mode of horizontal rotations causing PDs.
Eastward PDs observed in SW Japan are regarded as definite evidence for the double door (DD) model of the opening tectonics of the Japan Sea (Otofuji, 1996). In such a model, geological evidence for the coherent rotation of SW Japan is not adequate. The DD model regards the Paleozoic strata in SW Japan as the extension of the Okchon Belt in the Korean Peninsula. This geological link, however, was criticized as inadequate (Matsumoto, 1967; Ichikawa, 1972). Moreover, the DD model is not consistent with geological relationships between north Kyushu and its tectonic vicinities. NNE-SSW faults are developed in the Cretaceous strata at north Kyushu and SE Korea. NNW-SSE to NW-SE faults are developed in the north Kyushu sedimentary basin and the East China Sea Shelf basin. Foldings and faults oriented to ENE-WSW are developed from northeast Kyushu to the western Chiguoku district, SW Japan. These geological features indicate that SW Japan would not have carried out meaningful horizontal rotation with the respect to the Korean Peninsula and the East China Sea.
Instead, these geological features indicate that eastward PDs observed in SW Japan would have been caused by rotations of faulted blocks. The amount of PDs degreases from the Chugoku district to northwest Kyushu (Ishikawa, 1997). The Philippine Sea Plate gently subducts to the Eurasian Plate at the Chugoku district, whereas it steeply does at Kyushu. These features indicate that the mechanical coupling between the overriding Eurasian Plate and the subducting Philippine Sea Plate would have been caused the horizontal block rotations.

Keywords: paleomagnetic declinations, the Japan Sea opening, Southwest Japan, geological structure, block rotaiton

Reconsideration for motion of Japan since 25Ma, comparison between GPS data and Paleomagnetic data

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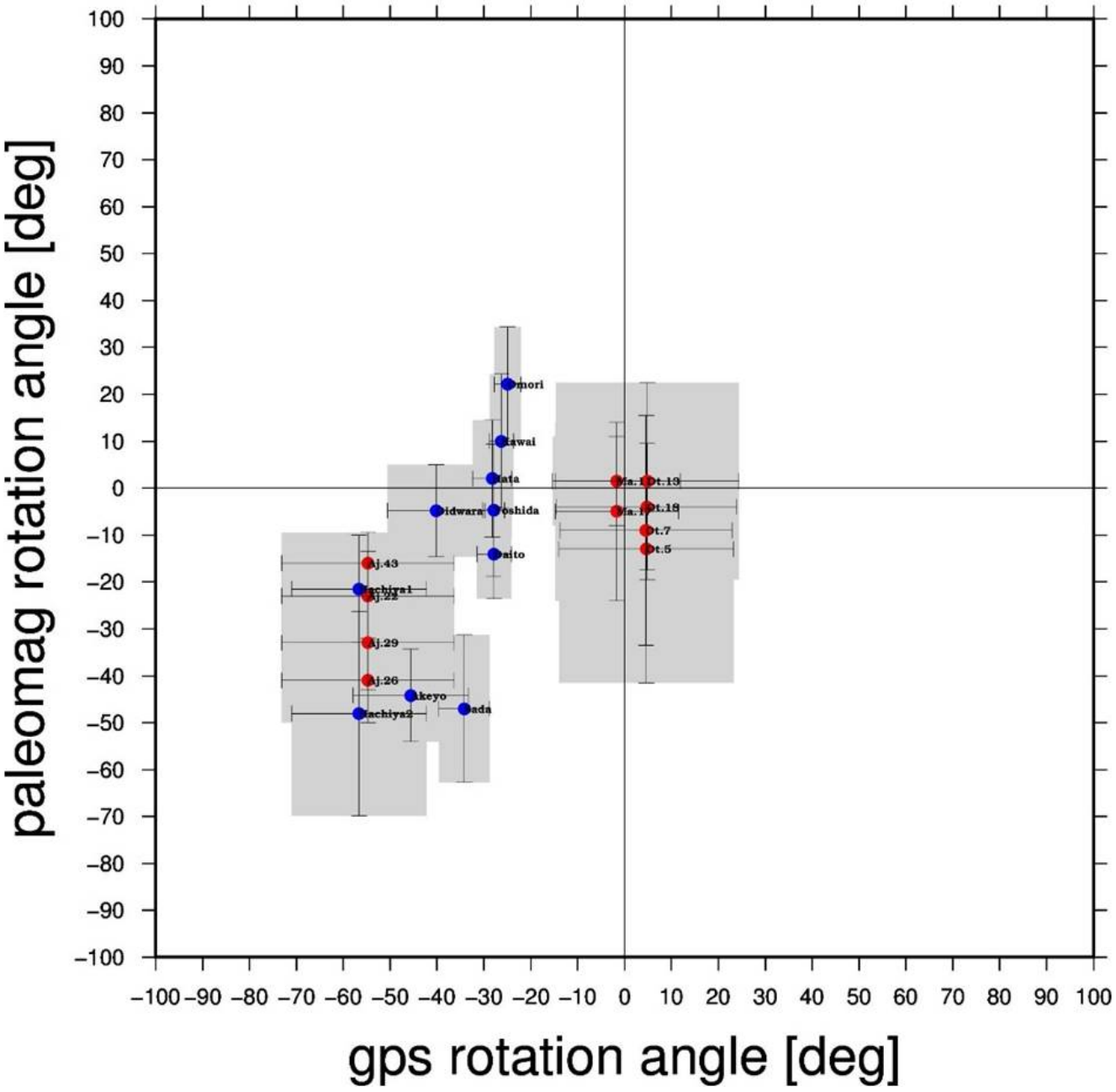
Katsumata et al. (JpGU2016) showed that there are good relation between crustal rotation angles from paleomagnetic data and crustal rotation angles from GPS data on South American continent. The paleomagnetic data are as old as 50Ma, and GPS data holds only 20 years, therefore, this result implies that long term crustal motion for million years is included in yearly GPS data. We did same analysis on Japan and similar results are obtained. We applied Yamazaki, 1988 and Hoshi et al., 2015 for paleomagnetic data, and global IGS GNSS data and GSI F3 solutions for GPS data on Japan.

The results are shown in the Figure. The vertical axis shows the crustal rotation angles from paleomagnetic data and the horizontal axis shows coeval GPS crustal rotation angles at that sites of the paleomagnetic data. The red dots are north-east Japan paleomagnetic data, the blue dots are south-west Japan data. The two independent rotation data are quite in harmony with each other, and this results strongly implies that long term crustal rotations of Japan since about 25Ma are still included in recent GPS data, and the rotation not ceased at about 10Ma (Takahashi and Ando, 2016).

Keywords: GPS data, Paleomagnetic data, Rotations of North-east and South-west Japan



Near-seafloor magnetic mapping for understanding off-axis volcanism hosting the Kairei hydrothermal field in the Central Indian Ridge

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We report the case study of near-seafloor magnetic mapping of the off-axis volcanic knoll, namely the Hakuho knoll, located in the Central Indian Ridge. The Kairei hydrothermal field known as the system related to mafic as well as ultramafic host rocks is distributed on top of the Hakuho knoll [e.g., *Nakamura et al.*, 2009]. Three dive surveys were conducted during the R/V Yokosuka cruises of YK05-16_leg1, YK09-13_leg2, and YK13-03. A three-axes fluxgate-type magnetometer "*Shinkai Miniko*" developed by the AORI, UTokyo, was attached to the submersible *Shinkai 6500* and vector magnetic fields were successfully measured during dives of 6K#918, 6K#1171, and 6K#1332. Submersible tracks cover the Hakuho knoll especially in the western slope at 2,200–3,000 m depth, northern slope at 2,700–3,200 m depth, and the foot of eastern slope at 2,900–3,200 m depth.

The observed data were first corrected for the effects of induced and permanent magnetizations of the submersible to obtain regional magnetic anomalies after subtraction of the International Geomagnetic Reference Field (IGRF) [*Isezaki*, 1986]. Then, two-dimensional forward modeling and inversion technique were applied to estimate absolute and equivalent magnetization under consideration of topography and altitude variation [*Honsho et al.*, 2009; *Fujii et al.*, 2015].

The variation pattern of observed magnetic anomalies above lava flows in the western slope of the Hakuho knoll is in phase with that of synthetic magnetic anomalies calculated for simple assumption with magnetization direction parallel to the IGRF and infinite source layer. This result suggests that these lava flows preserve normal magnetic polarity corresponding to the Brunhes Chron. Estimated absolute magnetization intensity shows up to 20 A/m in this area, which is comparable to crustal magnetization demonstrating the recent volcanic activity [*Honsho et al.*, 2009]. These signatures were certainly observed in both vertical and horizontal components of magnetic anomalies. The Kairei hydrothermal field is characterized by low coherence between observed and modeled anomalies, and low values of magnetization, suggesting that magnetic minerals within basaltic basement were altered into non-magnetic minerals and/or clay minerals due to the oxidative reaction with hydrothermal fluids.

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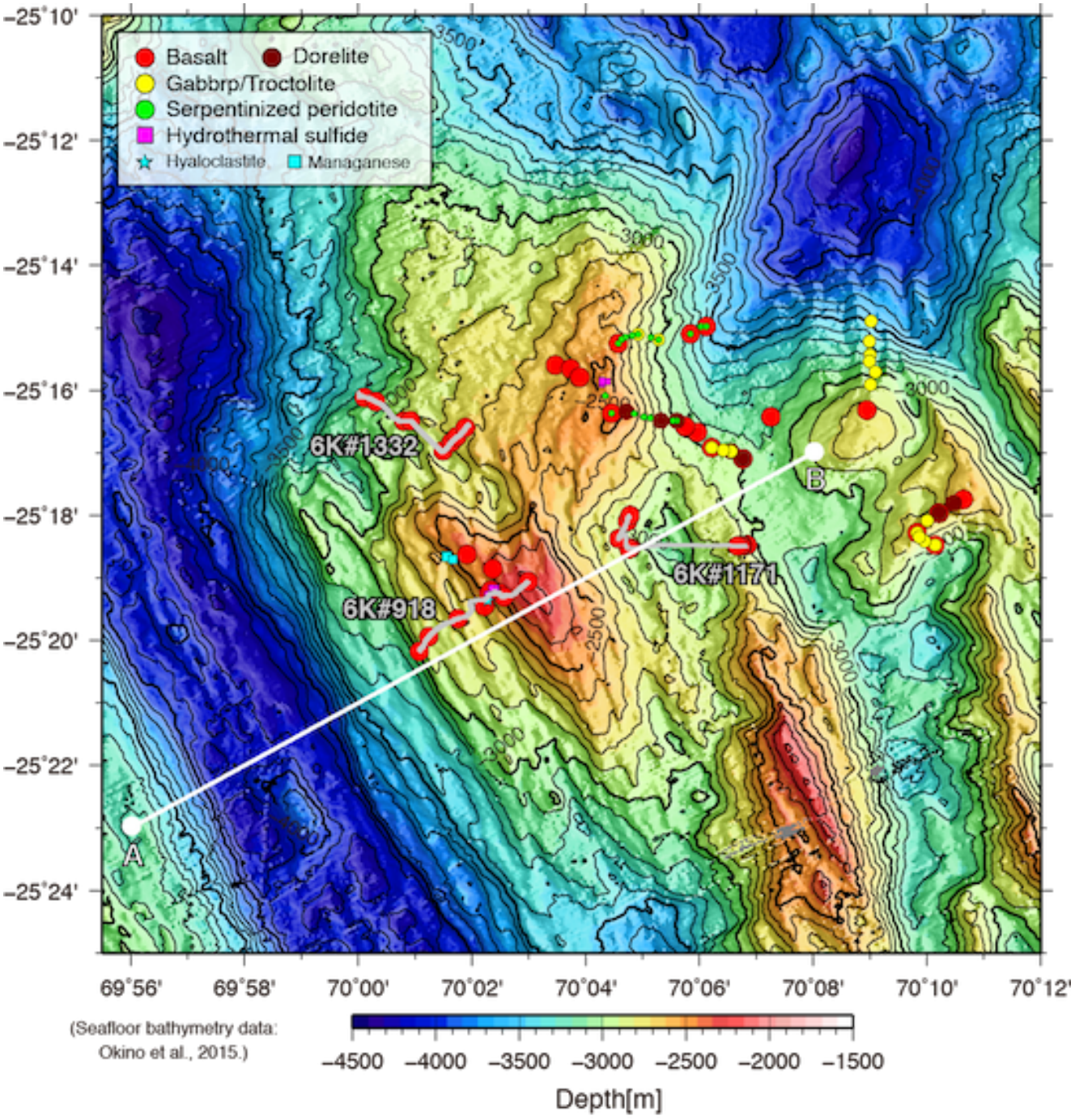
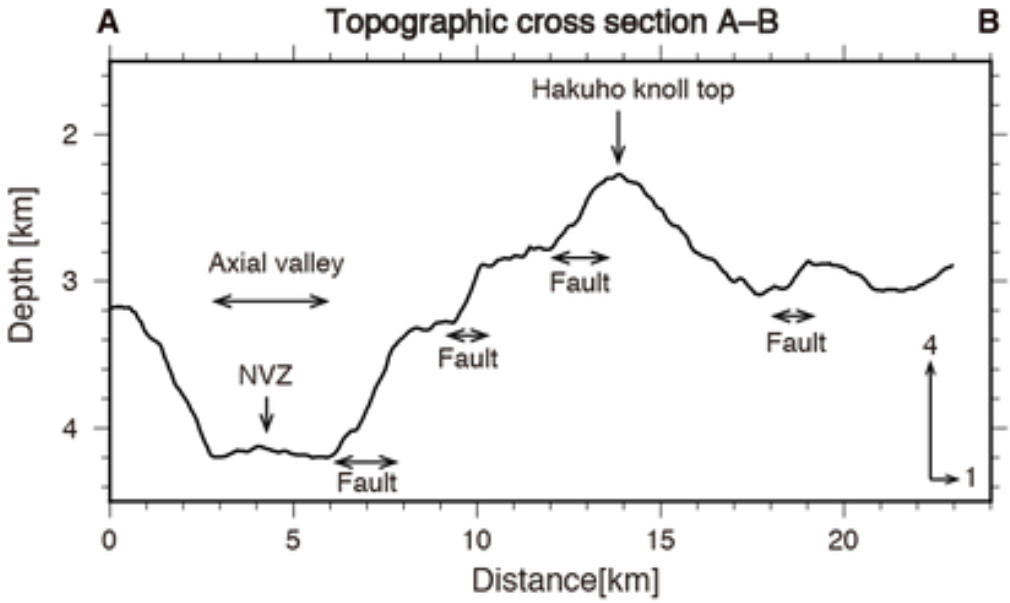
Keywords: Mid-ocean ridge process, Off-axis volcanism, Hydrothermal systems, Magnetic anomaly, Central Indian Ridge, Kairei hydrothermal field





Magnetic anomaly mapping around Antarctica

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Magnetic anomaly data plays an important role in understanding crustal architecture and tectonics in the Antarctic region. Magnetic anomalies obtained in the East Antarctic are used for identification of the tectonic elements and geological structures. Geodynamics and tectonic evolution of the supercontinents such as Rodinia and Gondwana are deduced from those. On the other hand, offshore magnetic anomaly data around the East Antarctic provide information on seafloor spreading history, and the breakup process and mechanism of supercontinent Gondwana are derived from those in consequence. However, magnetic anomaly observation around Antarctica, especially around the East Antarctic, are sill sparse, and the detailed tectonic evolution and fragmentation process of the supercontinents remain unknown. Magnetic anomalies in Antarctica obtained near-surface and satellite magnetic observations have been complied by the Antarctic Digital Magnetic Anomaly Project (ADMAP) working group under the Scientific Committee on Antarctic Research (SCAR). The ADMAP anomaly grid was completed in 2000 and helps to understand the geological and tectonic history around Antarctica. To produce he next generation magnetic anomaly map for the Antarctic, an ADMAP-2 has been started to integrate the new survey data into the database.
As an example of magnetic anomaly observations around the Antarctica, magnetic anomaly observations have been carried out around Syowa Station, the Japanese Antarctic wintering Station in Lützow- Holm Bay, by the shipborne, airborne and ground surveys to elucidate the tectonic evolution and breakup process of Gondwana. The area around Syowa Station is considered to be a junction of Africa, India, Madagascar, and Antarctic continents from the reconstruction model of Gondwana. Therefore, this area is a key to investigate the formation and fragmentation of Gondwana. The shipborne, airborne and ground survey data around Syowa Station made advances in understanding the tectonic evolution in this area. In particular, several characteristic features that may be related to the tectonic evolution of Gondwana were inferred primarily from magnetic anomalies by joint Japanese-German airborne geophysical surveys. A part of those magnetic data have already been used in ADMAP and new data will be incorporated into an ADMAP-2.
The present status of magnetic anomaly map around Antarctica is presented, and the examples of geological structures and the tectonic history deduced from magnetic anomaly map are introduced. Future perspective of magnetic anomaly map in Antarctica is also addressed.

Keywords: magnetic anomaly, Antarctica, geological structure, tectonics

Examination of local geomagnetic jerks using wavelet analysis

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Wavelet analysis can be used to identify singular behavior in time-series by using an appropriate analyzing wavelet. Detection of geomagnetic jerks, sudden variation of secular acceleration of the geomagnetic field components, has been tried using third time-derivative of a Gaussian as the analyzing wavelet and it has been confirmed that geomagnetic jerks occurred globally around 1968 and 1978 (Alexandrescu et al., 1995). Location of extrema lines of the wavelet transform in the time-dilation diagram and the absolute value of the wavelet transform along the extrema lines, ridge functions, were used to identify the geomagnetic jerks and to discuss regularity of them.
Observation of geomagnetic field using satellites allowed identifying local geomagnetic jerks of 2003 and 2007 (e.g. Chulliat et al., 2010), whose signatures are seen strongly in south Atlantic region in secular acceleration map. We attempted to analyze the two local geomagnetic jerks by applying a wavelet analysis on time series of magnetic field at geomagnetic observatories. The analyzing wavelet is the same as that used by Alexandrescu et al. (1995). The two local geomagnetic jerks were successfully identified in wavelet transform at Mbour (MBO, Senegal), but only the one around 2007 was identified in that at Chambon la Foret (CLF, France). The global jerks and local jerk around 2003 at MBO showed similar regularity. However, the regularity of the local jerk around 2007 at MBO and CLF is higher than that of the other jerks. These results might imply that the generation mechanism of the local geomagnetic jerk around 2007 is different from those occurred globally around 1969 and 1978 and locally around 2003.

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Interannual fluctuations of the core angular momentum and the secular acceleration of geomagnetic models

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Recent satellite models for Earth's core magnetic field suggest an existence of interannual core dynamics. Due to the small magnetic signals, however, it is a difficult issue to unambiguously resolve interannual variations of the core flow and the associated oscillation of the core angular momentum (CAM). It has already been shown that the phase of the oscillation is robustly determined, according to numerous CAM computations from diverse core flow models that are all estimated as a result of inverting a single geomagnetic model C^3FM2. Here, we discuss that the phase identification depends on the secular acceleration (SA) of a geomagnetic model, and that a large uncertainty still remains for the pre-satellite era. Estimates of the phase vary clearly with geomagnetic models, C^3FM2, gufm1 and COV-OBS, whose differences are readily specifiable in their SA representations. None of them may be an optimal model for describing the SA. Compared with the SA of a satellite model GRIMM3, C^3FM2 is overdamped in time, while the other two are parametrized inadequately. C^3FM2 may be optimized for better resolving the interannual CAM oscillations by properly modifying its temporal smoothness in reference to satellite SA models.

Keywords: Core, Geomagnetic field, Inverse modelling, Satellite observation, Earth rotation, Interannual variation

Rock magnetic study applied to characterization of back-arc volcanism in the southern Okinawa Trough

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The Okinawa Trough is a back-arc basin located behind the Ryukyu arc-trench system. Its southern part is characterized by active rifting structures and complex arc–back-arc volcanism along the depression and is believed to represent a transition from a rifting stage to initial spreading [e.g., *Sibuet et al.*, 1987]. The southern Okinawa Trough has a unique key to understand the first stage of oceanic lithosphere evolution, however the spatial distribution of the volcanism as well as their magma type remains unclear. It is needed to conduct extensive geophysical mapping such as magnetic anomaly in which signal is sensitive to volcanic edifices due to the rich magnetic minerals (mainly titanomagentite) within volcanic rock. In order to establish a useful benchmark for understanding magnetic anomalies associated with arc–back-arc volcanism, we performed comprehensive rock magnetic analysis and petrological studies of seafloor rock samples collected in the southern Okinawa Trough. The measurements were conducted for basalt from the Yaeyama Ridge (YR) and Irabu knolls (IKs), dacite from the Hatoma knoll (HK), and rhyolite and pumice from the Tarama Knoll (TK).

The natural remanent magnetization intensity shows 0.3–175.2 A/m in the YR, 0.8–214.4 A/m in the IKs, <0.1–3.8 A/m in the HK, and 3.1 A/m for dacite and 0.1–0.2 A/m for pumice in the TK. The magnetic susceptibility of all samples is too low to induce magnetic field under geomagnetic field intensity comparing with NRM intensity; all samples shows Koenigsberger ratio (Q) much higher than 1. The NRM intensity of volcanic rocks may vary in relation to several factors such as the geomagnetic field strength at the timing of remanence acquisition, amount and type of magnetic minerals, grain chemistry such as Ti content of titanomagnetite, magnetic domain state controlled by grain size distribution, and the degree of low-temperature oxidation. Therefore, we carefully examined magnetic properties, petrography, and geochemical signatures for understanding rock-to-rock NRM variation.

Thermomagnetic curves of volcanic rocks with low NRM (<1 A/m) from the YR, IKs, and HK show irreversible and complex Curie temperatures, suggesting these samples have been affected by hydrothermally alteration and/or oxidation which considerably decreases the NRM [e.g., *Gee and Kent*, 1994]. Low NRM of pumice samples from the TK is likely explained by low amount of titanomagneite due to lack of iron oxide minerals. The NRM difference between rhyolite and basalt is certainly explained by difference of iron content, which is diluted by the silica content in magma evolution. A rhyolite sample from the TK (HPD#1109R01) contains titanomagnetite as the magnetic carrier with a Curie temperature of 490˚C (equivalent to $x = 0.15$ in $Fe_{3-x}Ti_xO_4$) and shows coercivity ration (Hcr/Hc) of 2.42 and remanence ration (Mr/Ms) of 0.16, which is regarded as the magnetic domain state of pseudo single domain (PSD). One basaltic rock from the IKs (HPD#1330G02) shows similar Curie temperature of 480˚C (equivalent to $x = 0.16$), and PSD siganture (Hcr/Hc = 2.64 and Mr/Ms = 0.10). In addition, both samples show reversible thermomagnetic curves, suggesting that they have not been affected by low-temperature oxidation (maghemitization); very fresh. Therefore, the acquisition timing of their thermal remanent magnetization is considered to be almost the same, and the effect of geomagnetic field strength as well as the degree of low-temperature oxidation can be ignored for explanation of NRM intensity variations. The titanomagnetite amount of HPD#1109R01, at 0.9 wt.%, is about one-third that of HPD#1330G02, at 3.1 wt.%. This result is consistent with the bulk rock geochemistry showing that iron content of

HPD#1109R01 as Fe2O3 at 3.2% is about one-third that of HPD#1330G02, at 11.2% [T. Nozaki, personal communization]. The NRM intensity of HPD#1109R01, at 3.1 A/m, is also about one-third that of HPD#1330G02, at 9.4 A/m. These results indicate that the lower NRM intensity of rhyolite from the TK was caused mainly by a smaller titanomagnetite content owing to low iron content diluted by the silica content.

Keywords: Back-arc volcanism, Okinawa Trough, Rock magnetism

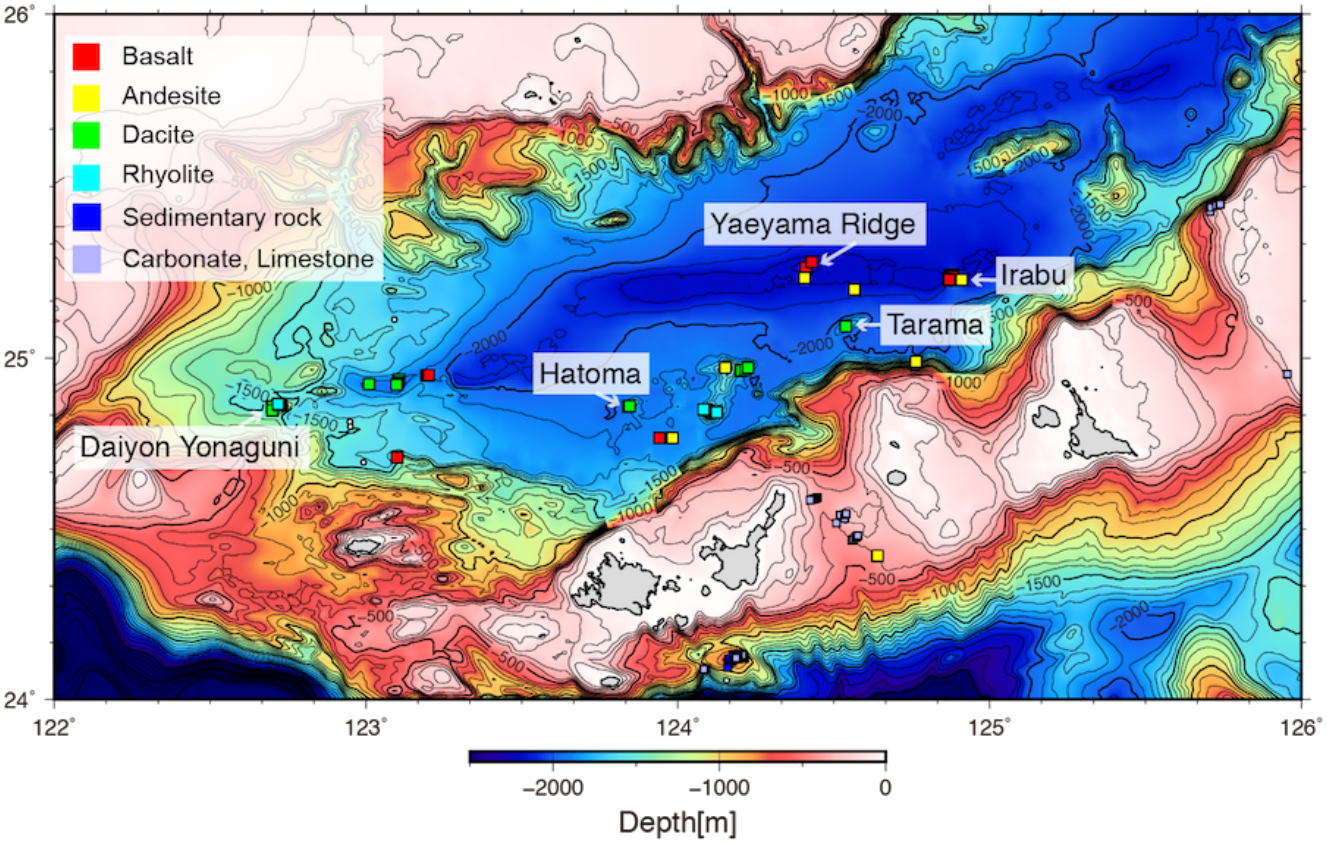

Figure. Seafloor bathymetric map of the southern Okinawa Trough. Squares show rock type of collected samples including basalt (red), andesite (yellow), dacite (green), rhyolite (sky blue), sedimentary rock (blue), and carbonate and limestone (light blue). Data of rock type and location from the GANSEKI database (http://www.godac.jamstec. go.jp/ganseki) managed by JAMSTEC.

Paleomagnetism and rock magnetism of Nishiyama old kilns of Shino old kiln complex

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Sue wares are produced during the 5-10th century in the many part of Japanese islands, which was followed by the posterior and developed potteries. Sue wares were baked in the closed semi-underground or full-underground kilns with high temperature and anoxic environment. Therefore, the main magnetic mineral remaining is magnetite and it is thought to be very suitable for paleomagnetic analyses and there have been many paleomagnetic achievements.
Shino old kiln complex is located in the west of Kyoto old capital and includes over 100 old kilns. They were operated mainly in the 8-11th century, which follows the main period of the Sue-mura and other Sue-were complexes. Paleomagnetic results from Shino kilns are expected to fill the gap between Sue-were period and the new-generation potteries after the 11th century.
Here we report the paleomagnetic results from Nishiyama 1-1 and 1-2 old kilns in the Shino group. The paleodirections from the two kilns show a difference, which indicates the gap of the operated dates. Acctually the archaeological investigations of the pottery morphology and stratigraphy of the ash field also show the same result that the 1-2 kiln is half-of-century newer than the 1-1 kiln.
The age of the kilns estimated by matching of the direction onto the regacy geomagnetic secular variation curve (Hirooka, 1977) is different from the archaoelogical age. However, in case of using our new secular variation model, there is a consistency between paleomagnetic and archaeological ages.

Keywords: Paleomagnetism, Rock magnetism, Archaeology

Archaeointensity of Nishiyama 1st Kiln of Shino Old Kiln Complex –the Attempt for Cross Check by Multi Methods –

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A study about archaeomagnetism in Japan has been processed to be performed toward to recently, and it seems that the interest has been increasing in the community of archaeology. Therefore, most of archaeomagnetic practice is the study for paleodirection. On the other hand, archaeointensity study has not performed except a few cases (e.g. Sakai et al., 2015), because the experiments are very hard and the reference has not constructed. Based on these, we have been carrying out the restoration of the past field intensities using baked earth of ancient kilns since few years ago. Especially, in the case of the remain had non-demagnetized samples, we have been trying to cross check the value of paleointensities obtained by two different methods; Tsunakawa-Shaw method (e.g. Yamamoto et al., 2003) and IZZI-Thellier method (e.g. Yu and Tauxe, 2005) to assess the validity of paleointensity experiment itself. We have done crosscheck for the baked earth samples from Sayama Higashiyama-Oku kiln in Bizen city, Okayama, and confirmed that the value of intensity obtained by two different method consistence each other within the very narrow range as coefficient of variation is less than 10 % (Kitahara et al., SGEPSS 2016 meeting).

In the present, we are carrying out the same experiment using new archaeological materials to support the previous result. The experimental sample is the baked earth from floor surface of Nishiyama 1st kiln of Shino old kiln complex placed Kameoka city, Kyoto. And the measurement of paleodirection of the sample has done, and the results had high reliability, and showed coincidence with archaeological hypothesis have obtained (Hatakeyama et al., JPGU this meeting). Until the present, Tsunakawa-Shaw experiment for three specimens (the cubic specimen processed from block sample) taken in the kiln and one specimen taken from out of the furnace opening, and IZZI-Thellier experiment for the 3+1 specimens taken from the same place like Shaw method’ s one have ended. About Thellier experiment, the straight line was not able to identify on Arai diagram, because all graphs curves downwards. On the other hand, about Shaw experiment, the result as 37.6+/-3.8 uT (coefficient of variation=10.0 %, success rate=100 %) obtained from three specimens of in the kiln. And a value of Shaw method from a specimen from out of the furnace opening is 26.3 uT. It is significantly different from the average of the sample taken from in the kiln. We are going to do the crosscheck among different methods, especially Thellier experiment, as future works.

Keywords: Archaeointensity, Tsunakawa-Shaw Method, IZZI-Thellier Method, Cross Check, Sue Ware Old Kiln

Magnetic separation of diamagnetic grians and paramagnetic grains in general

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Magnetic separation is popularity used to extract materials that are either ferromagnetic, ferrimagnetic or strongly paramagnetic grains from an ensemble of heterogeneous grain. It was believed that dynamic motion (i.e. diamagnetic and paramagnetic) of weak magnetic materials generally require ultra-strong field intensities above 10 Tesla. Field-gradient forces was used to realize levitation of diamagnetic materials at high-field laboratories; the levitation was later realized on a human fingertip by using a small NdFeB block. Field-induced translations were reported recently for single weak particles floated in an area of a monotonically decreasing field [1]. It was proposed that the values of magnetic susceptibility X per unit mass assigned to the grain was obtainable from the translation no mater how small the sample may be [2]. In the present study, the translation was simultaneously performed on multiple grains for the first time, and ensemble of grains composed of weak magnetic materials were successfully separated in a simple manner using a hand magnet (*go to* YouTube “Magnetic separation of general solid particles realized by a permanent magnet” *for movie*) [3]. In order to realize the separation, an apparatus that was previously designed to examine the field-induced translation [2] was modified; the short microgravity condition was produced in a drop box (40 cm ×30 cm ×22 cm) which was used in a short shaft. A monotonically decreasing field distribution along the +x-axis was produced by a small NdFeB circuit . At the edge of the translating areas, 2 collecting plates were added to examine the efficiency of separation. The above setup was sealed in a glass tube (inner pressure˜ 100 Pa) to eliminate the effect of air resistance. The motions of the samples were examined by a high-speed camera that was placed outside of the glass tube. The diamagnetic samples were cut from synthetic blocks with purity higher than 99.99 wt%. The two paramagnetic olivines were products of San Carlos, New Mexico and Mogok, Myanmar . Then a weak magnetic grain is released in a monotonically decreasing field with small initial velocity, it follows a motional equation described as $ma = mXB(dB/dx)$. In a common field distribution, acceleration a of particle is determined by intrinsic X value of the grain material, not by mass m of particle. This property realizes the observed magnetic separation. By using the achieved technique, the extraction of new solid phases from a heterogeneous grain ensemble may, which will lead to important discoveries in inorganic materials. In this sense, the potential of this study as an analytical technique may be comparable to that of chromatography separation. The technique is also applicable in separating rare samples such as the particles recovered from the moon or the asteroids, because in principle, the method is capable of thoroughly separating micron-order grains without sample-loss.

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Keywords: magnetic separation, paramagnetic grain , microgravity, diamagnetic grain

Applying paleomagnetic viscous dating to erratic boulders

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Unblocking temperatures of viscous remanent magnetization (VRM) predict the emplacement age of reworked boulders by Neel's magnetic relaxation theory of single-domain magnetite. If a rock is moved or re-oriented by geological processes, the remagnetization occurs partly and progressively with age, parallel to the present Earth’ s magnetic field. This remagnetization is probably due to natural VRM acquired at low temperature over a long time, disappears at a higher temperature in a short period in the laboratory. By assuming Neel's theory of magnetite, Pullaiah et al. (1975) have reported that an experimental combination of short relaxation time and high temperature for removing VRM can determine the unknown relaxation time (tsunami age) at room temperature. We have been applied the time-temperature relationship to tsunami boulders in several regions of pacific coast (e.g. Ishigaki Island, Japan), but their estimated ages showed anomalously old due to the high unblocking temperatures. It is believed that the presence of high unblocking temperatures yielding older ages is due to a magnetic aggregate including the admixtures of single-domains, pseudo-single-domains, and/or multi-domain grains. Sato et al. (2016) applied an extended time-temperature relationship based on a stretched exponential law to explain the blocking or unblocking in a complex magnetic aggregate. In our study, the extended time-temperature relationship modifies the curvature of unblocking curves of VRM, agreeing with the the old VRM ages. Moreover, we synthetically magnetized partial thermoremanent magnetization (pTRM) to correctly identify the unblocking temperature of VRM. Particularly, the demagnetized samples were first given an pTRM as an original component. After changing set of sample direction to the magnetic field, these pTRMs were remagnetized in progressively higher temperature to generate the secondaly pTRM which is a synthetic VRM. A secondary pTRM was then demagnetized by progressive thermal demagnetization with various hold durations. This new experimental method provides us multiple unblocking temperatures of VRM from a sample. Therefore, we can estimate the curvature of unblocking curves. Our findings show that the VRM has potential as an absolute dating tool for the determination of geologic events.

Keywords: viscous remanent magnetization, erratic boulder, time-temperature relationship

Strong chemical treatment of sediments for environmental magnetic studies on mineral inclusions

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Chemical leaching techniques has been employed in sediment studies to separate components of different origins such as eolian, volcanic, biogenic, or authigenic component. However, in environmental magnetic studies, the use of chemical leaching is limited because aggressive treatment would also affect magnetic minerals. Recently, it is widely recognized that weak magnetic signals of magnetic mineral inclusions in silicate can be precisely measured by modern instruments. Moreover, occurrence of such inclusions in sediments has been reported. Such magnetic mineral inclusions are protected by silicate host, so they could survive strong chemical treatment. To test this idea, we chemically leached out minerals except quartz and feldspar and conducted rock magnetic measurements. The sample was pelagic red clay recovered from Minamitorishima in subtropical Western North Pacific. The magnetic mineralogy of bulk sediment was dominated by biogenic magnetite and oxidized detrital magnetite. The site locality suggests that the quartz in the sample is eolian dust from China, and the feldspar is either from China or the Izu-Mariana volcanic arc.

The intensity of saturation isothermal remanence (SIRM) of quartz and feldspar was on the order of 10^{-4} Am^2/kg. This is about 1-5 % of the SIRM of untreated sample. The signal can be readily measured using cryogenic magnetometers or MPMS. The remanence can also be detected in alternating gradient force magnetometers, but paramagnetic signal from feldspar introduces large background in induced magnetization, making determination of hysteresis difficult. Thermal demagnetization of IRM and low temperature measurements indicate that the magnetic mineral associated with quartz and feldspar is near-stoichiometric magnetite, which is distinct from the more oxidized detrital magnetite. This might reflect magnetite exsolution in feldspar. To check this, a pilot sample was further treated by H_2SiO_6 to isolate quartz. Low temperature measurements indicate that the quartz also contains near-stoichiometric magnetite, suggesting that the magnetite is primary inclusion and not exsolution. If confirmed, the near-stoichiometric magnetite inclusions may be the characteristics of eolian dust from China, and strong chemical treatment is a promising approach to reveal this hidden property. A comparison with sediment from different region is under way.

Keywords: environmental magnetism, magnetic mineral inclusion, eolian dust

Exploration of pedogenic nanoscale particles causing magnetic enhancement in Chinese loess deposits

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Based on magnetic enhancecment in paleosols, magnetic susceptibility (χ) and its frequency dependence (χ_{fd}) are widely accepted as reliable proxies of paleorainfall, and thus often used for estimation of the East Asian Summer Monsoon intensity in the Chinese Loess Plateau (CLP). In spite of its paleoclimatic importance, pedogenic particles causing magnetic enhancement have never been detected. We challenged this problem, using three sets of loess and paleosol samples from Lingtai and Xifeng in the central CLP. Each bulk sample was divided into three subsamples with different detrital grain size ranges (D1: > 10 μm, D2: 10–1 μm, D3: < 1 μm), all of which were subjected to rock magnetic experiments including χ and χ_{fd} measurements, isothermal remanent magnetization (IRM) composition analyses and thermomagnetic analyses. The paleosol bulk samples show high χ values ranging from 116–177 $\times 10^{-8}$ m^3 /kg, which are 4.0–6.1 times higher than loess bulk samples, and 49.6–66.2 % of the magnetic enhancement is contributed by grains in D2 subsamples. Besides, values of χ_{fd} are also increased by 4.0–5.7 times for all paleosol bulk samples, and the enhanced χ_{fd} is dominantly contributed by D2 subsamples (61.0–77.0 %). The rock magnetic experiments reveal that pedogenic particles causing magnetic enhancement are magnetite and maghemite. Based on these results, scanning electron microscope (SEM) and trans electron microscope (TEM) observations were conducted on magnetic extracts from D2 subsamples. As a result, we found nanoscale magnetite inclusions in weathered muscovite particles. These magnetite inclusions are secondarily produced through elution/oxidation of Fe compounds in muscovite during pedogenesis. The inclusions can explain the facts that the magnetic enhancement partly caused by superparamagnetic grains is mostly contributed by D2 size grains, and the main magnetic extracts are not detrital magnetite/maghemite grains but silicate minerals. Hence, we conclude the magnetite inclusions in weathered muscovite particles are the most likely candidate for pedogenic particles causing magnetic enhancement.

Keywords: Chinese loess, Pedogenesis, Magnetic enhancement

Flooding history in Lake Nakaumi of western Japan inferred from sediment records during the last 700 years

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Management of flood risk to local communities located near river mouths can benefit from a knowledge-based approach to flooding history. On some rivers in western Japan, flood events since the 16th century have been well documented in the literature. However, the data of those events are insufficient for an objective evaluation of flooding such as its intensity. Therefore, we analyzed a ^{14}C-dated sediment core recovered from near the Iinashi River mouth in Lake Nakaumi, western Japan, and reconstructed extreme flooding records in the past 700 years from rock magnetism, grain-size distribution and sediment geochemistry. The sediment core contained three black layers, characterized by high magnetic susceptibility (MS), a low anhysteretic remanent magnetization to saturation isothermal remanent magnetization, a high total organic carbon (TOC) to total nitrogen ratio, and coarse mean grain size, that we identified as possible flooding event deposits. In addition, the chemical index of alterlation was low and the TOC to total sulfur ratio was high in these layers, indicating intensified erosion sediments associated with more freshwater inflow due to the flood events. We tentatively correlated the three event deposits with historically documented flooding events along the Iinashi River in AD 1596, 1666, and 1826. The magnitudes of the variations in sedimentary properties relating to rock magnesium and geochemistry suggest that the smallest was the AD 1666 event.

Keywords: Lake Nakaumi, Floods, Sediments

Consistent Matuyama-Brunhes magnetic transition records from depositional detrital and chemical remanent magnetizations from the Chiba Section, central Japan

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A detailed Matuyama-Brunhes (MB) magnetic polarity transition record has been reconstructed from the Chiba Section, central Japan. Oriented samples were collected every 10 cm from an 18-m thick marine sequence along the Yoro River. Rock magnetic and paleomagnetic experiments reveal that all of the sediments were deposited under anoxic environments, and natural remanent magnetizations are carried by magnetite and greigite throughout the sequence. Characteristic remanent magnetizations (ChRMs) isolated by thermal demagnetization (THD) and alternating field demagnetization (AFD) methods basically show consistent directions, except some differences. One of the major differences is the position of the MB boundary. It lies 115±25 cm above the Byk-E tephra in the THD ChRMs, while 50 cm above the Byk-E tephra in the AFD ChRMs. We propose that the ChRM component isolated by THD is a depositional detrital remanent magnetization (DRM), and the component isolated by AFD is a depositional chemical remanent magnetization (CRM) carried by greigite. The latter is probably acquired in the subsurface pyrite formation process under anoxic environments. We found that the vertical paleomagnetic direction changes by the two methods are consistent when the AFD ChRM direction curve is shifted upward by 65 cm. This suggests that the lock-in depth of CRM is about 65 cm below that of DRM, and that the similar condition of remanence acquisition was kept for some time in the bottom of the basin.

Keywords: depositional chemical remanent magnetization, depositional detrital remanent magnetization, Matuyama-Brunhes magnetic reversal, greigite, magnetite

A new constraint for M-B boundary age based on U-Pb zircon dating and a high-resolution oxygen isotope chronology from the most expanded marine sedimentary record from the Chiba composite sectionn, Japan

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The youngest geomagnetic polarity reversal, the Matuyama–Brunhes (M-B) boundary, provides an important datum for sediments, ice cores, and lavas. Its still-frequently cited age of 780 ka is based on orbital tuning of marine sedimentary records, and supported by $^{40}Ar/^{39}Ar$ dating of Hawaiian lavas using a recent age calibration. However, post-depositional
remanent magnetization (PDRM) lock-in of the geomagnetic signal occurs below the sediment-water interface in marine sediments (e.g., Roberts et al., 2013; Suganuma et al., 2011), which then yields ages for geomagnetic events that are too old. This age offset is influenced by sedimentation rate, as records with higher sedimentation rates should minimize the temporal offset caused by PDRM lock-in. Indeed, younger astrochronological M-B boundary ages of 772–773 ka are given for high-sedimentation-rate records (Channell et al., 2010; Valet et al., 2014), with no PDRM lock-in delay being detected by Valet et al. (2014). These MBB ages are consistent with records of cosmogenic nuclides in marine sediments (e.g., Suganuma et al., 2010) and an Antarctic ice core (Dreyfus et al., 2008). Here, we report a newly obtained high-resolution oxygen isotope record from a continuous marine succession of the Chiba composite section of the Kokumoto Formation, Japan to provide a refined chronology for the M-B boundary. Our new chronology indicates that the M-B boundary locates in the middle of Marine Isotope Stage (MIS) 19, and yields an age of 771.7 ka for the boundary. This new M-B boundary age is consistent with those based on the latest orbitally-tuned marine sediment records and on an Antarctic ice core. Furthermore, a high-precision U-Pb zircon age of 772.7 ±7.2 ka from a marine-deposited tephra just below the M-B boundary in the Chiba composite section (Suganuma et a., 2015), coupled with a newly obtained high resolution oxygen isotope chronology yields a highly accurate MBB age of 770.9 ±7.3 ka. Because U-series dating is relatively free from standardization and decay constant issues, this U-Pb zircon age has a distinct advantage over $^{40}Ar/^{39}Ar$ dating. We provide the first direct comparison between orbital tuning, U-Pb dating, and magnetostratigraphy for the M-B boundary, fulfilling a key requirement for calibrating the geological timescales. In addition, there is no clear relationship between geomagnetic field intensity and climate observed in the paleomagnetic and paleoclimatic record from the Chiba composite section.

Reconstruction of the geomagnetic field behavior across the Réunion Subchron

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The Chikura group, covering the Upper Pliocene –Lower Pleistocene, is distributed in the Southernmost part of the Boso Peninsula, Chiba Prefecture, Japan. The group is thought to be a marine deposit filled on the landward slope basin of the paleo-Sagami trouhg. Okada et al. (2012) constructed a paleomagnetic and oxygen isotopic stratigraphies, covering between about 2.3 and 3.5 Ma (MIS G16 to 93), for the Mera and the Minamiasai Formations consisting of the Chikura Group. The tephra bed, seen in the top horizon of the section studied by Okada et al., (2012), can be correlated to a tephra bed found at the bottom horizon of our study section where the Hata Formation laying on and party interfingered with the Minamiasai Formation. This observation indicates that our study section is suitable for reconstruction of stratigraphic records, including the geomagnetic filed variation, for the period younger than 2.3 Ma. For rock-magnetic and paleomagneitc measurements, we collected several mini-cores using a portable engine drill at every 1 - 4 m stratigraphic interval, and collected a mini-core at every 10 cm interval around reversal boundaries associated with the Réunion Subchronozone. The demagnetization methods evaluated in this study are the alternating filed demagnetization (AFD) with 5 mT increments up to 80 mT, the thermal demagnetization (ThD) 50 ˚C increments up to 600 ˚C, a hybrid method consisting of ThD at 250 ˚C and the AFD sequence. Among those methods, only the Hybrid method provided data passing the reversal test. So, we selected the Hybrid method as to provide paleomagentic data from the study section. As the results, the declination of a mean magnetization direction from the whole section without the reversal boundaries is calculated as 11.1 ±5.7˚ indicating a clockwise rotation. Kotake et al. (1995) reported that the average paleomagentic declination indicated a clockwise rotation in the Chikura group due to a tectonic rotation supposed to be caused by a collision of the Izu Massif to the Honshu Island at around 1 Ma. To deduce the virtual geomagnetic poles (VGPs), we corrected our declination data using the average value of -11.1 ˚. We detected the Réunion Subchronozone including a geomagnetic excursion at a horizon of 4.7 m thickness. The VGPs are through the Africa in the lower reversal boundary, and stay on the southern south America in the upper reversal boundary. In addition, the VGPs of the excursion found in the Réunion Subchronozone stay in the East Asia. We compared the VGPs of this study with the results from ODP site 981 (Channell et al.,2003). Although they show different paths, both VGPs seem to pass through the “preferred longitudinal bands” frequently observed during geomagnetic polarity transitions (e.g. Hoffman, 1992) Reference Okada et al., 2012, Jour. Geol. Soc. Japan, 118, 97–108. Kotake et al., 1995, Jour. Geol. Soc. Japan, 101, 515–531. Channell et al., 2003, Earth Planet. Sci. Letters, 215, 1-12.

Keywords: Paleomagnetism, Reunion, polarity transition

Relative paleointensity and inclination anomaly during the last 8 m.y. obtained from eastern equatorial Pacific sediments (IODP Site U1335)

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We conducted a paleomagnetic study of the upper ~55m of IODP Site U1335 cores taken from the eastern equatorial Pacific during the Expedition 320. U-channel samples were taken from the spliced core sections. All magnetic chrons in the geomagnetic polarity time scale down to C4n.2n (~8.1 Ma) are recognized in the magnetostratigraphy, which indicates continuous sedimentation. Rather low sedimentation rates of the cores, 5 to 9 m/m.y., limit resolution of paleomagnetic records. However, the cores are suitable for elucidating long-term geomagnetic-field behaviors such as a relation between geomagnetic-field intensity and polarity length.

Magnetic property measurements and TEM observations showed that magnetic mineral assemblages of the sediments are dominated by oxidized biogenic magnetites. A few degrees of negative inclination anomalies (defined as observed inclination minus the inclination expected from the hypothetical geocentric axial dipole) are observed. This is consistent with the available time-averaged field models showing negative inclination anomalies in Pacific low latitudes. We used ARM as a normalizer of relative paleointensity estimations. An upcore decrease of the ratio of ARM susceptibility to SIRM (k_{ARM}/SIRM) occurs at about 4.2 Ma, which is associated with a decrease of sedimentation rates. Average relative paleointensities increase corresponding to the k_{ARM}/SIRM change. The inverse correlation between relative paleointensity and the k_{ARM}/SIRM ratio indicates that changes in the relative abundance of biogenic to terrigenous magnetic minerals partly contaminated the relative paleointensity record, as pointed out by Yamazaki et al. (2013). We scaled the RPI record so that the average paleointensity younger than 4.2 Ma (the onset of chron C2Ar) equals that of older. The relative paleointensities averaged for individual polarity chrons did not show any correlation with polarity length or polarity during the last 8 m.y.

Keywords: paleointensity, inclination anomaly, IODP

