**R004-01**
**C 会場 ：11/6　AM1 （9:00-10:30）**
**09:00〜09:15**

# ベトナム中部の考古遺物を用いた考古地磁気学・岩石磁気学 －予察的分析－

#北原　優 [1)], 畠山　唯達 [1)], 山形　眞理子 [2)]
([1] 岡山理大・フロンティア理工学研,[2] 立教大・学校社会教育講座

# Archaeomagnetism and rock magnetism using archaeological artifacts from central Vietnam: a preliminary analysis

#Yu Kitahara[1)], Tadahiro Hatakeyama[1)], Mariko Yamagata[2)]
([1]Frontier Science and Technology, Okayama Univ. Sci,[2]Curator Course, Certification Programs, Rikkyo Univ.

Archaeomagnetism is the field of research that reconstructs geomagnetic information (intensity and direction) in the Holocene from baked archaeological materials. On the other hand, rock magnetism is the field of research that investigates the magnetic properties of various materials such as rocks and archaeological materials. Archaeomagnetic studies in Southeast Asia have been reported on the direction by Barbetti & Hein (1989, Thailand) and Hirooka (2009; 2011, Cambodia), and on intensity by Cai et al. (2021, Vietnam), but the number of data and the ages covered are very limited. On the other hand, rock magnetic studies have been reported a study by Proske et al. (2009) that consider how to use a type of briquetage based on the results of stepwise thermal demagnetization but no systematic rock magnetic study has been reported to the present. Based on the above, this study aimed to obtain basic knowledge for conducting archaeomagnetic and rock magnetic studies using archaeological artifacts in Southeast Asia, especially in Vietnam. And (1) IRM acquisition experiments, (2) stepwise thermal demagnetization, and (3) archaeointensity experiments using the Tsunakawa-Shaw method and IZZI-Thellier method using pottery fragments excavated from 13 remains at the Hoa Diem site, located on the west coast of Cam Ranh Bay, Khanh Hoa Province, central Vietnam were carried out preliminarily.

The results of the IRM acquisition experiments indicated that there is diversity in the excavated pottery fragments, which can be roughly classified into three types: (1) those containing a single low-coercivity component, (2) those containing two low-coercivity components, and (3) those containing both low-coercivity and high-coercivity components. The cause of this diversity can be attributed to differences in the source of the clay and the firing atmosphere. The results of stepwise thermal demagnetization indicated that the pottery fragments could be classified into two types: (1) those with a single component of remanent magnetization and (2) those with a distinctive secondary magnetization component. The latter is estimated to have been baked at a temperature of 600 oC or higher during the initial pottery production and then secondarily baked at a temperature of 400-500 oC, or to have been overturned during the initial pottery production. The results of the archaeointensity experiments at the present also obtained two mean archaeointensities: 34.3 ± 5.2 μ T (n=2) by the Tsunakawa-Shaw method and 42.0 ± 9.6 μ T (n=3) by the IZZI-Thellier method. The mean intensities obtained by the different methods are consistent within 1 σ and are expected to provide a basis for further archaeointensity studies in the future.

In addition, the possibility of using brick samples from the My Son site in Quang Nam Province, central Vietnam, will also be presented.

考古地磁気学は被熱した考古試料から人類史スケールでの地磁気情報（強度・方位）の復元を行う研究分野であり、岩石磁気学は岩石や考古試料など様々な物質の磁気的性質を調べる研究分野である。東南アジアにおける考古地磁気学的研究は、現在までに Barbetti & Hein（1989、タイ) や広岡（2009; 2011、カンボジア）による方位に関する研究事例や Cai et al.（2021、ベトナム）による強度に関する研究事例が報告されているが、データ数およびその網羅年代は非常に限定的である。また岩石磁気学的研究に関しては、現状として、Proske et al.（2009）によるベトナム出土の製塩土器の使用方法を段階熱消磁結果から考察した研究が一例存在するが、体系的に行われた研究事例は未だ報告されていない。本研究では上記の現状を踏まえ、東南アジア、特にベトナムの考古遺物を用いた考古地磁気学・岩石磁気学的研究を実施する上での基礎的知見を得ることを目的とし、ベトナム中部・カインホア省カムラン湾西岸に位置するホアジェム遺跡の 13 遺構から出土した土器片を用いて、(1)IRM 獲得実験、(2) 段階熱消磁、(3) 綱川－ショー法と IZZI －テリエ法による考古地磁気強度実験を予察的に実施した。

IRM 獲得実験の結果、ホアジェム遺跡の土器群は (1) 一成分の低保磁力成分が含まれているもの、(2) 二成分の低保磁力成分が含まれているもの、(3) 低保磁力成分と高保磁力成分が含まれているものの 3 種類に大別され、出土土器群に多様性があることが確認された。これらの多様性の原因は、胎土の供給源の違いと焼成雰囲気の違いによるものであることが考えられる。段階熱消磁の結果、同土器片は (1) 一成分の残留磁化を持つものと、(2) 顕著な二次磁化成分が観察されるものの 2 種類に大別されることが分かった。後者は土器製作時に 600 ℃以上の温度で焼成された後、400〜500 ℃程度の温度で二次的に焼成された、もしくは最初の土器製作時に転倒したことが推定される。また、現時点の考古地磁気強度実験の結果、綱川－ショー法による 34.3 ± 5.2 μ T（n=2)、および IZZI －テリエ法による 42.0 ± 9.6 μ T（n=3）という 2 つの平均考古地磁気強度値が得られた。異なる手法によって得られた平均強度値は標準偏差の範囲で一致しており、今後、考古地磁気強度研究を進める上での基礎となり得ると期待される。

本発表ではこの他に、ベトナム中部クアンナム省に位置するミーソン遺跡のレンガ試料を用いた研究の可能性についても紹介する予定である。

**R004-02**
**C 会場 ：11/6　AM1 （9:00-10:30）**
**09:15〜09:30**

#加藤　千恵 [1)], 望月　伸竜 [2)], 劉　浩田 [2)],Kidane　Tesfaye[3,4)],Muluneh　Ameha A.[3,5)], 石川　尚人 [6)], 加々島　慎一 [7)], 吉村　令慧 [8)]
([1] 九大・比文・地球変動講座,[2] 熊本大学,[3] アディスアベバ大,[4] クワズール・ナタール大,[5]GFZ ドイツ地球科学研究所,[6] 地球システム・富山大,[7] 山形大,[8] 京大・防災研

# Absolute paleointensity study of lava flows from Tendaho Graben, Afar depression, Ethiopia

#Chie Kato[1)], Nobutatsu Mochizuki[2)], Haotian Liu[2)], Tesfaye Kidane[3,4)], Ameha A. Muluneh[3,5)], Naoto Ishikawa[6)], Shinichi Kagashima[7)], Ryokei Yoshimura[8)]
([1]Division of Earth Sciences, SCS, Kyushu Univ.,[2]Kumamoto University,[3]Addis Ababa Univ.,[4]University of KwaZulu-Natal,[5]GFZ German Research Centre for Geosciences,[6]Earth System Science, Toyama Univ.,[7]Yamagata Univ.,[8]DPRI, Kyoto Univ.

Variation of the geomagnetic field in the latest geologic era is a fundamental subject of research in paleomagnetism. Field strength of the Quaternary have been studied using volcanic rocks, but even the average and dispersion have not been well constrained, obstructing our understanding on the global feature of the geomagnetic field variation. In this study, we conduct absolute paleointensity experiments on lavas in the Tendaho Graben (Afar depression, Ethiopia) to investigate the variation of the geomagnetic field strength over the past million years in East Africa. The Afar depression is located at the rift-rift-rift triple junction between Nubian, Somalian and Arabian Plates, and the Tendaho Graben in the central Afar is one of grabens formed by the spreading process at the divergent plate boundary. Basaltic lava flows with ages ranging from a few thousand to about one million years are widely distributed and are good targets of research to investigate the variation of Quaternary geomagnetic field.

We conducted paleomagnetic, absolute paleointensity, and rock-magnetic measurements on lava samples collected from 54 sites distributed in the Tendaho Graben. Paleointensity experiments by the Tsunakawa-Shaw method were carried out at both Kumamoto University and Kyushu University. First, one pilot specimen for each site was measured at Kumamoto University. For the sites that the pilot specimen passed the selection criteria, one to four additional measurements were conducted at Kumamoto University and/or Kyushu University. Results obtained at both laboratories are in good agreement, except for the samples from site SA08, which are highly scattered. In total, 89 out of 114 results passed the selection criteria. Most of the rejected results are from samples with reversed polarity. At 16 sites, three or more successful results were obtained. Mean paleointensities of those sites range from 11.8 to 39.5 micro T, corresponding to virtual dipole moment of 2.9 to 9.8 $*10^{22}$ $Am^2$. Thermomagnetic analysis in vacuum is also conducted on selected samples using the Curie balance at Kyushu University. For all samples, the thermomagnetic curves are reversible in general, with the cooling curves more or less below the heating curves. First derivatives of the thermomagnetic curves indicate single component magnetic mineralogy with a Curie point of about 550 ℃.

To the best of our knowledge, this is the first study to report the absolute paleointensity during the past 1 million years from the East Africa, which will contribute to our better understanding of the global pattern of the geomagnetic field variation. In the presentation, comparison with coeval data from different areas and results from older ages of the same area (Ahn et al., 2016; Yoshimura et al., 2020) will be discussed.

**R004-03**
**C 会場 ：11/6　AM1 （9:00-10:30）**
**09:30〜09:45**

#望月　伸竜 [1)], 長谷川　健 [2)], 穴井　千里 [3)], 中川　光弘 [4)], 渋谷　秀敏 [5)]
([1] 熊本大学,[2] 茨城大・地球環境,[3] 高知コアセンター,[4] 北大・理・地惑システム,[5] 同志社大・文化遺産

# Paleomagnetic directional change observed for nonwelded pyroclastic flow deposits of the 46 ka Shikotsu caldera-forming eruption

#Nobutatsu Mochizuki[1)], Takeshi Hasegawa[2)], Chisato Anai[3)], Mitsuhiro Nakagawa[4)], Hidetoshi Shibuya[5)]
([1]Kumamoto University,[2]Earth Science Course, Ibaraki Univ.,[3]KCC,[4]Hokkaido Univ.,[5]Doshisha University

We report paleomagnetic results obtained from multiple units of pyroclastic deposits at the type locality section of the 46 ka Shikotsu caldera-forming eruption. Geological observation of the previous study indicated that these deposits were classified into six units in the section and two possible temporal intervals. In order to obtain temporal information from these units, we conducted paleomagnetic measurements on successive five units of nonwelded pyroclastic density current (PDC) deposit and a unit of surge deposit in the section. These nonwelded pyroclastic deposits were carefully sampled into aluminum and plastic cubes where the cubes were precisely oriented using an improved procedure. Thermal/alternating field demagnetizations on the samples in the aluminum/plastic cubes give well-clustered characteristic remanent magnetization directions for individual sites except for a site. Paleomagnetic directions with confidence limits of a few deg. determined from seven sites on the five units show a continuous directional change of more than 15 deg., which is regarded as paleomagnetic secular variation of the order of 100 years. These paleomagnetic data provide a high temporal resolution history of the 46 ka Shikotsu caldera-forming eruption.

**R004-04**
**C 会場 ：11/6　AM1 （9:00-10:30）**
**09:45〜10:00**

#小田　啓邦 [1)], 下司 信夫 [1)],Pengxiang Hu[1,2)], 佐藤 哲郎 [1,3)], 江島 圭祐 [1,4)], 本橋 銀太 [1,5)], 谷元 瞭太 [6)],Andrew Roberts[1,2)],David Heslop[1,2)], Xiang Zhao[1,2)]
([1] 産総研・地質情報,[2] オーストラリア国立大学,[3] 早稲田大学,[4] 山口大学,[5] 筑波大学,[6] 茨城大学

# Paleomagnetism of pyroclastic deposits of Futatsudake eruptions from the younger Haruna Volcano, Japan during the 5-7th century

#Hirokuni Oda[1)], Nobuo Geshi[1)], Pengxiang Hu[1,2)], Tetsuro Sato[1,3)], Keisuke Eshima[1,4)], Ginta MOTOHASHI[1,5)], Akihiro Tanimoto[6)], Andrew Roberts[1,2)], David Heslop[1,2)], Xiang Zhao[1,2)]
([1]IGG,GSJ,AIST,[2]Australian National University,[3]Waseda University,[4]Yamaguchi University,[5]University of Tsukuba,[6]Ibaraki University

Paleomagnetic studies were conducted on the two sites of the pyroclastic deposits of the Futatsudake eruptions of the younger Haruna Volcano, central Japan. One of the objectives of the studies is the dating of pyroclastic deposits using paleomagnetic secular variations. Haruna volcano is considered to have erupted twice around the 6th century from the Futatsudake crater (Souda, 1989). There have been reports of 14C ages ranging from 1540 to 1640 yr BP from the Haruna Futatsudake Shibukawa tephra suggesting the eruption age of the late 5th century – early 6th century. On the other hand, the four samples obtained from the Haruna Futatsudake Ikaho tephra shows same 14C ages of 1480 yr BP suggesting

the eruption age of the Ikaho tephra is considered as between the late 6th century and the beginning of the 7th century (Geshi and Oishi, 2011). It is expected that the paleomagnetic dating could provide ages for the pyroclastic deposits enabling to associate with the above-mentioned tephra layers.

Paleomagnetic samples were taken both from essential lithics and pumice in the pyroclastic deposits for the two sites. It is well known that self-reversed magnetization was recognized in the pumice from the Haruna Volcano (e.g. Nagata et al., 1953), which is expected to provide an opportunity to compare and normal magnetizaion recoded by essential lithics and self-reversed magnetization recorded by pumice fragments. In total, 20 and 17 oriented cores were taken from sites 1 and 2, respectively. A preliminary results of stepwise AF demagnetization for eight essential lithics of site 1 based on 8 specimens provide paleomagnetic direction of (dec, inc, alpha95) = (-11.4deg, 52.6deg, 5.5deg). The comparison of the paleomagnetic direction with the paleomagnetic secular variation for the studied area (Hatakeyama, 2022) suggest the age range of around 500-600 AD.

Further investigation including results of pumice fragments and thermal demagnetization of site 1, and the results of site 2 will be presented.

References

Geshi, M. and Oishi, M. (2011) Geological Survey Reports, 62, 177-183. (in Japanese with English abstract)
Hatakeyama, T. (2022) JRFM2K.1, http://mag.center.ous.ac.jp/reduction/cal.cgi.
Nagata, T., Akimoto, S., and Uyeda, S. (1953) Nature, 172, 630-631.
Souda, T. (1989) Quaternary Research, 27, 297-312. (in Japanese with English abstract)

**R004-05**
**C 会場 ：11/6　AM1 （9:00-10:30）**
**10:00〜10:15**

#李　嘉熙 [1)], 山崎　俊嗣 [1)], 佐藤　雅彦 [2)], 黒田　潤一郎 [1)]
([1 東大大気海洋研,([2 東大・地惑

# Unmixing magnetic mineral assemblages of a western equatorial Pacific sediment core subjected to reductive diagenesis

#Jiaxi Li[1)], Toshitsugu Yamazaki[1)], Masahiko Sato[2)], Junichiro Kuroda[1)]
([1AORI, Univ. Tokyo,([2Dept. EPS, Univ. Tokyo

Diagenesis is ubiquitous in marine sediments, causing sedimentary iron-bearing minerals to undergo a series of redox reactions until they reach equilibrium with reactive chemical components in sediments. Paleomagnetic records in sediments subjected to severe diagenesis may be distorted or lost due to iron mineral dissolution. Some magnetic minerals like silicate-hosted magnetic inclusions can survive the diagenetic iron mineral dissolution and are widely found in marine sediments. Thus they provide the possibility of preserving paleomagnetic records in sediments subjected to reductive diagenesis. To better understand this issue, we studied on a sediment core from the Ontong Java Plateau, western equatorial Pacific Ocean. Magnetic susceptibility has a sudden about 90% decrease at about 6 m in depth, which indicates a magnetic mineral concentration decrease due to diagenetic iron-mineral dissolution. A coeval drop of the ratio between anhysteretic remanent magnetization susceptibility and saturation isothermal remanent magnetization (SIRM) can be explained by loss of magnetofossils. However, information on paleomagnetic declination and paleointensity could still be recovered. Silicate-hosted magnetic inclusions were separated from bulk sediments by chemical procedures. They contribute about 45% or more of SIRM in the reduced sediments. Hence the contribution of silicate-hosted magnetic inclusions to paleomagnetic recording is confirmed in the studied sediment core. High coercivity hematite may be another major remanence carrier in the reduced sediments. Superparamagnetic greigite formation under sulphate-reducing diagenetic environments was estimated from first-order reversal curve diagrams and SIRM decay behaviors of bulk sediments.

**R004-06**
**C 会場 ：11/6　AM1 （9:00-10:30）**
**10:15〜10:30**

#藤井　昌和 [1,2)
([1 国立極地研究所,([2 総合研究大学院大学

# Rock magnetic study of exposed oceanic crust and mantle

#Masakazu Fujii[1,2)
([1National Institute of Polar Research,([2SOKENDAI

Marine magnetic anomalies have been utilized to understand geomagnetic field reversals and fluctuations recorded in spreading seafloor since the 1960s. Recent advances in dense sea-surface and high-resolution near-bottom surveys provide further information on oceanic lithosphere processes such as lava accretion, hydrothermal circulation, and complex faulting. However, the relationship between the anomaly signal and geological ground truth still remains poorly understood. In particular, rock magnetic data of deeper sources and temporal variation are essentially limited because of sampling difficulty. Here, we newly demonstrate a more comprehensive dataset of rock magnetic analysis studied on serpentinized peridotites and gabbroic rocks as well as basaltic rocks with a variety of localities on the global scale.

The samples were collected from several abyssal geological outcrops during mainly Japanese research expeditions of the R/V Yokosuka, R/V Hakuho-maru, and R/V Kairei; Yokoniwa Rise, Central Indian Ridge; Near Rodrigues Triple Junction, Central Indian Ridge; Vulcan Fracture Zone, Mid Atlantic Ridge; Cape Verde Fracture Zone, Mid Atlantic Ridge; Rainbow Massif, Mid Atlantic Ridge; Atlantis Bank, Southwest Indian Ridge; Gakkel Ridge, Arctic Ocean; Seamount B (Antarctic rift margin), Southern Ocean; Mado Megamullion, Philippine Sea; Suishin Megamullion, Philippine Sea; Mariana Forearc slopes close to the Challenger Deep; Shinkai Seep Field, Mariana Forearc.

Results of serpentinized peridotite show a negative correlation between grain density and magnetic properties are commonly observed in different geological settings of mid-ocean ridge, back-arc basin, wedge mantle, and continental margins. Furthermore, it is clear that highly serpentinized rocks with low density are mainly magnetic, but also include a variety of weak to intermediate properties. Results of the gabbroic rock show that the oxide gabbro has high magnetic susceptibility, and its induced magnetization may contribute significantly to marine magnetic anomalies. Extensive data of basaltic rocks from different areas and ages demonstrate that time-dependent change (e.g., reaction with seawater), as well as initial magma composition and grain size distribution (cooling rate), could be the main cause for controlling remanent magnetization intensities.

**R004-07**
**C 会場 ：11/6　AM2 （10:45-12:30）**
**10:45〜11:00**

#佐藤　雅彦 [1)], 黒澤　耕介 [2)], 長谷川　直 [3)], 高橋　太 [4)]
([1] 東京大学,[2] 千葉工業大学,[3] 宇宙航空研究開発機構,[4] 九州大学

# Shock remanence distribution of single-domain titanomagnetite-bearing basalt sample

#Masahiko Sato[1)], Kosuke Kurosawa[2)], Sunao Hasegawa[3)], Futoshi Takahashi[4)]
([1]The University of Tokyo,[2]Chiba Institute of Technology,[3]Japan Aerospace Exploration Agency,[4]Kyushu University,

Knowledge of a three-dimensional distribution of the shock remanent magnetization (SRM) intensity is crucial for interpreting the spatial change in magnetic anomalies observed over the crater and reconstructing the paleo-planetary field based on the anomaly data. However, the distribution of SRM properties have not been fully understood owing to the lack of subsample magnetization measurements for the experimental SRM-imparted samples. Here we report the results of newly designed SRM acquisition experiments using a magnetically well-characterized basalt sample bearing fine-grained single-domain titanomagnetite and remanence measurements for cube-shaped subsamples cut from the SRM-imparted samples, to investigate the SRM intensity and stability structures. Additionally, the pressure and temperature changes during the shock wave propagation were estimated from the impact simulations. In one series of experiments, the magnetic field was fixed at 100 μ T and the impact velocities were set to 1.3 (polycarbonate), 2.7, 4.0, 5.3, and 7.0 km/s (aluminum). The SRM intensity increases with increasing pressure value, and it deviates from the increasing trend near the impact point due to the significant temperature rise for each sample. In the other series of experiments, the shock experiments were conducted under the magnetic fields of 100, 150, 200, and 400 μ T with the constant impact velocity of approximately 5.5 km/s. The SRM intensities normalized by applied field intensity shows the similar values in whole pressure range, and thus, the SRM intensity is confirmed to be proportional to apple field intensity up to 400 μ T. On the basis of SRM experiments, remanence measurements, and impact simulations, we will discuss the empirical relationship between SRM intensity and pressure/temperature changes during the shock wave propagation and discuss the magnetic anomaly distribution over impact craters.

**R004-08**
**C 会場 ：11/6　AM2 （10:45-12:30）**
**11:00〜11:15**

#高橋　太 [1)], 兵藤　史 [2)], 金嶋　聰 [1)], 清水　久芳 [3)], 綱川　秀夫 [4)]
([1] 九大・理・地惑,[2] 九大・理・地惑,[3] 東大・地震研,[4] 東工大・理・地惑

# A long-term evolution of a compositionally-driven dynamo: implications for a sudden decline in lunar paleointensity

#Futoshi Takahashi[1)], Fumi Hyodo[2)], Satoshi Kaneshima[1)], Hisayoshi Shimizu[3)], Hideo Tsunakawa[4)]
([1]Kyushu Univ.,[2]Earth and Planetary Sciences, Kyushu Univ.,[3]ERI, University of Tokyo,[4]Dept. Earth Planet. Sci., Tokyo TECH,

At present, the Moon does not possess its own magnetic field by a dynamo action, which worked in the ancient era [e.g., Garrick-Bethell et al., 2009]. It is thought that the lunar dynamo had a long lifetime (hundreds of millions of years) from the lunar paleointensity records. A long-lived dynamo hypothesis is also supported by a study of the magnetic anomalies on the Moon [Takahashi et al., 2014]. On the other hand, a recent study suggests that the lunar dynamo was shut down by 4.19 Ga and supports a short-lived dynamo hypothesis [Tarduno et al., 2021]. A sudden decline in lunar paleointensity by at least an order of magnitude by 3.3 Ga is an important issue to understand the evolution history of the Moon. This sudden paleointensity variation may corresponds to either the cessation of the lunar dynamo or a shift to a different dynamo mechanism [Tikoo et al. 2014]. Here we examine a long-term lunar dynamo evolution focusing on sudden decline in paleointensity. In order to elucidate the issue, we perform numerical dynamo simulations combined with thermal history calculations.

Among various lunar dynamo mechanisms proposed so far, we adopt a compositionally-driven dynamo because it is believed to be long-lived [Laneuville et al., 2014 ; Scheinberg et al., 2015]. We made thermal history calculations to obtain the inner core size as well as its growth rate as a function of time. Guided by the information, core geometry and compositional buoyancy source (i.e. Rayleigh number, Ra) are consistently determined as input parameters for dynamo runs. The inner to outer core radius ratio, $\chi$, is varied discretely. Individual simulation results at each $\chi$ are connected to trace an evolution curve in the $\chi$-Ra space.

We found two cases consistent with the decline in lunar paleointensity, where the dynamos are maintained in a range of $\chi$=0.2 - 0.5 corresponding to 4.25 - 3.81 Ga. Afterward, they terminate in different fashions. Two ways of interpretation for the drop in lunar paleointensity are suggested: dynamo shutdown or a transition to a different dynamo regime. Our results demonstrate that a long-lived lunar dynamo with a sudden intensity drop is reproduced by a single mechanism of compositionally-driven dynamo.

This work was supported by JSPS KAKENHI Grant Number JP21K03725.

**R004-09**
**C 会場 ：11/6　AM2 （10:45-12:30）**
**11:15〜11:30**

# スパース磁気インバージョン解析におけるペナルティ項の検討

#伊藤　良介 [1)], 宇津木　充 [2)]
([1] 京大,[(2] 京大・理・火山研究センター

# The study on the penalty terms in sparse magnetic inversion analysis

#Ryosuke Ito[1)], Mitsuru Utsugi[2)]
([1]KU,[(2]Aso Vol. Lab., Kyoto Univ

When determining the subsurface structure from total magnetic the geomagnetic total force data obtained at the surface on the ground, the number of the unknown parameters is generally larger than that of the observed data, and the equations to be solved are usually ill-posed. For this reason, it is widely used to constrain the solution when performing inversion, but the properties of the solution obtained will differ greatly depending on the conditions of the constraint, or the penalty terms . When we use the smoothing condition (L2 penalty), which has been commonly used in the pastprevious studies, we can usually get an unfocused solution that blurs the actual structure, and it is pointed out that the interpretation of the structure is difficult. In contrast, a sparse regularization method represented bycalled Lasso (Tibshirani, 1995) has recently attracted attention and is sometimes used in magnetic inversion analysis. This method is an optimization method that imposes a constraint to minimize the L1 norm (sum of absolute values of each component) of the solution vector, and it is known that sparse solutions can be obtained.

Sparse regularization can be classified into several methods depending on the penalty term: Lasso uses the L1 norm of the solution vector as the penalty term, while Generalized generalized Lasso uses the L1 norm of the solution vector multiplied by a differential operator matrix, as the penalty term. Other possible methods include are Elastic Net (L1-L2 inversion), which combines the L1 and L2 norms, and Generalized the combination of the generalized Lasso penalty and the -L2 norm penaltyinversion.

The objective of this study is to characterize the estimated model by performing sparse magnetic inversion analysis based on various kinds of the penalty term. For this purpose, we plan to performed a resolution test using the point-spread function. We also plan to apply applied the model to the aeromagnetic survey data measured in 2004 at Kuju volcano. In this our presentation, we will report the progress of the projectthese works.

地表において観測された全磁力データから地下構造を求める場合、一般にデータよりも未知パラメータの数の方が多く、解くべき方程式は ill-posed な線形方程式となる。このため、インバージョンを行う際に解に制約を与える事が広く行われるが、その条件によって得られる解の性質は大きく異なる。従来より一般的に使用されてきた平滑化条件（L2 ペナルティ）を課した場合、実際の構造をぼかした unfocused な解が得られてしまい、構造の解釈が難しいことが指摘されている。それに対して、近年 Lasso（Tibshirani, 1995）を代表とするスパース正則化が注目され、磁気インバージョン解析においても積極的に使用されている。この手法は解ベクトルの L1 ノルム （各成分の絶対値の和） が最小となる制約を課した最適化法で、スパースな解が得られることが知られている。

スパース正則化はペナルティ項によって複数の手法に分類される。Lasso は解ベクトルの L1 ノルムをそのままペナルティ項とする手法であるのに対し、Generalized Lasso（一般化 Lasso）は、解ベクトルに微分演算子行列などをかけたものの L1 ノルムをペナルティ項とする手法である。その他には、L1 ノルムと L2 ノルムを組み合わせた Elastic Net（L1-L2 inversion）や、一般化 Lasso と L2 ノルムを組み合わせる手法などが考えられる。

本研究では、さまざまな種類のペナルティ項に基づくスパース磁気インバージョン解析を行い、推定モデルの特徴を把握することを目的とする。そのために、point-spread function を用いた解像度テストを行う予定である。また、九重火山で 2004 年に計測された空中磁気測量データへの適用を考えている。本発表では、研究の途中経過を報告する。

**R004-10**
**C 会場 ：11/6　AM2 （10:45-12:30）**
**11:30〜11:45**

# 四元数による古地磁気学における回転操作

#福間　浩司 [1)]
(1 同志社大・理工

# Quaternions for rotations in paleomagnetism

#Koji Fukuma[1)]
(1Dept. Env. Sys. Sci., Doshisha Univ.

A variety of rotation operations are needed in paleomagnetism. These include transformations to the geographic coordinate system, tilt correction, finding virtual geomagnetic poles, and drawing demagnetization paths. Different methods have been used for each rotation operation - graphical manipulations on a stereonet, matrix calculations, and spherical trigonometry - and computer software has been developed based on these methods. Quaternions, which are commonly used in three-dimensional computer graphics, can handle rotations about arbitrary axes and provide descriptions of various rotation operations in paleomagnetism in a unified manner. Conversion from a sample coordinate system to the geographic coordinate system depends on orientation methods that vary by sample type and laboratory. Conventionally, coordinate transformations have been calculated using rotation matrices by Euler angles based on stereonet manipulations, but quaternions can flexibly accommodate samples oriented by different conventions. Tilt correction can be expressed as a single rotation about the strike direction of the formation. Virtual geomagnetic poles can be obtained by two-step rotations using quaternions. Furthermore, spherical linear interpolation for drawing demagnetization paths can be performed using quaternion rotation. Python functions are included for all of the rotation operations discussed in this paper, therefore the readers can incorporate these functions into their own programs to perform rotations using quaternions.

古地磁気学では様々な回転操作が必要とされます。地理座標系への変換、傾動補正、仮想地磁気極を求める、消磁経路の描画などです。それぞれの回転操作には、ステレオネット上での図形操作、行列計算、球面三角法などの方法がもちいられ、これらの方法に基づいたコンピュータソフトウェアが開発されてきました。三次元コンピュータグラフィックスでよく使われる四元数 (クォータニオン) は、任意の軸に関する回転を扱うことができ、古地磁気学における様々な回転操作を統一的に記述することができます。試料座標系から地理座標系への変換は、試料の種類や研究室によって異なる方位づけに依存します。従来、この座標変換はステレオネットでの操作に基づき，オイラー角による回転行列を用いて計算されてきましたが、四元数を使えば異なる方法で方位づけされた試料にも柔軟に対応することができます。傾動補正は地層の走向方向まわりの１回の回転で表すことができます。仮想地磁気極は、オイラー角による回転では直接扱えませんが，四元数を用いて２段階の回転で得ることができます。さらに、消磁経路を描くための球面線形補間は、四元数による回転がもっとも適しています。今回取り上げたすべての回転操作について用意された Python の関数を使えば、自分のプログラムに組み込んで、四元数を用いた回転を実行することができます。

**R004-11**
**C 会場 ：11/6　AM2 （10:45-12:30）**
**11:45〜12:00**

#川村　紀子 [1)], 松下　拓哉 [1)], 板宮　裕実 [2)], 杉田　律子 [2)], 山崎　俊嗣 [3)]
([1] 海上保安庁海上保安大学校,[2] 科学警察研究所,[3] 東京大学大気海洋研究所

# Forensic research of beach sand collected from Aomori in Japan: an application of rock magnetic and chemical analyses

#Noriko Kawamura[1)], Matsuhita Takuya[1)], Hiromi Itamiya[2)], Ritsuko Sugita[2)], Toshitsugu Yamazaki[3)]
([1]JCG,[2]National Research Institute of Police Science,[3]Atmosphere and Ocean Research Institute, The University of Tokyo

When concealments and smugglings have occurred on beaches, it is essential to physically and chemically investigate beach sediments to lead a successful criminal conviction. Previous studies indicate that the microtextural analysis of quartz is useful for characterizing beach sediments (Itamiya et al., 2019; 2020; 2022). In order to suggest a new method to characterize the particle of beach sediments, we applied chemical and magnetic analyses to the samples collected at nine sites (from 1M-1 to 1M-9) from Shimokita peninsula in Aomori, the northernmost part of the main island in Japan. Sites 1M-1, 1M-2, 1M-3, 1M-4, 1M-5, and 1M-6 are located at the eastern coast of the peninsula, the Pacific Ocean side. While the other sites 1M-7, 1M-8, and 1M-9 are located in the western coast, which faces Mutsu Bay. The sedimentary rocks which were formed from Pleistocene to Holocene are distributed, while Osore (andesitic) and Towada (basaltic) volcanoes are located near the sampling sites. Rock magnetic and chemical analyses of the samples were performed. The results indicate that the beach sediments vary depending on the lithology. Concentration-dependent magnetic parameters increase southward. The direction of the coastal drift is from the south to the north, suggesting that basaltic ash of Towada volcano rich in magnetic minerals was supplied to the sampling sites. The sample collected at 1M-4 where is near Sabishiro Mine indicates the maximum value of anhysteresis remanent magnetization among the samples. Magnetic grain size parameters, Mrs/Ms and Hcr/Hc, values are also reflected to the result of grain size analysis. High temperature magnetometry results suggest that goethite ( α FeOOH), magnetite (Fe3O4), and (titano) maghemite (rFe2O3) are common in the samples at the Pacific side sites. Low temperature magnetometry indicates the drastic decrease from 5 K to 30 K in Pacific side samples which contain Na, Ca, and Al. The microtextural analysis of quartz also shows that the ratio of “silica precipitation” and “oriented etch pits” types were relatively high values (Itamiya et al., 2020). The results of magnetic properties and chemical analyses of the beach sediments indicate that the origin of sand particles can be characterized as andesite and/or basalt. We can suggest these approaches as useful methods for forensic investigations.

**R004-12**
**C 会場 ：11/6　AM2 （10:45-12:30）**
**12:00〜12:15**

# 岩石・古地磁気研究のための計測機器の最新動向

#クリチュカ　プシェミスワフ [1)],Roud Sophie[1)]
([1]Mag-Instruments

# Latest developments in instrumentation for rock- and paleo-magnetic research

#Przemyslaw Kryczka[1)], Sophie Roud[1)]
([1]Mag-Instruments

Mag-Instruments is a young company developing state-of-the-art solutions for magnetic measurements by combining expertise in geophysics, robotics, and mechatronics. Here we will introduce our latest developments oriented towards research in paleo-, rock and environmental magnetism: the Triaxe 2.0 for fully integrated full-vector magnetic measurements during thermal demagnetization and a new generation of ultra-sensitive spinning magnetometers (USM).

The Triaxe 2.0 is a three-in-one tabletop device combining a three-axis vibrating-sample magnetometer (VSM) with a dynamic range of $1x10^{-8}$-0.1 $Am^2$, thermal demagnetization up to 800C and 3D Helmholtz coils to impart thermomagnetic remanence in homogenous fields up to 1.7 mT. Precise feedback control of sample temperature and feed-forward control of the applied magnetic field together with automatic measurement sequences facilitate user-friendly, rapid paleomagnetic measurements and make the Triaxe particularly useful for absolute paleointensity experiments. Apart from explaining the instruments capabilities we will present experimental data to demonstrate applications in paleomagnetism.

We will also report on current developments bringing together spinning magnetometry and state-of-the-art sensing technologies to deliver a low-maintenance, affordable alternative for SQUID based cryogenic rock magnetometers. Our Ultra-sensitive Spinner Magnetometer (USM) will bring the ultra-low level magnetic measurements with sensitivity levels $<1x10^{-12}$ $Am^2$ into regular laboratories, which previously could not afford instrumentation at this sensitivity level.

**R004-P01**
**ポスター 2 ：11/5　AM1/AM2 （9:00-12:30）**

# 中央インド洋海嶺玄武岩を用いた絶対古地磁気強度の推定

#吉村　由多加 [1)], 藤井　昌和 [2)]
([1 九大,([2 極地研

# Estimation of absolute paleointensity from Central Indian Ridge basalts

#Yutaka Yoshimura[1)], Masakazu Fujii[2)]
([1KU,([2NIPR

Volcanism at the mid-ocean ridge (MOR) plays a fundamental role in the Earth system. Because eruption intervals in MORs could be very short and hydrothermal activities are complicated, high-resolution dating of the seafloor is essential to estimate seafloor spreading rate and resolve hydrothermal activities. Previous studies have been conducted to distinguish between new and old lava flows using structural observations and chemical composition analysis, but their information provides just relative ages, not absolute ages. In addition, it is difficult obtain certain eruption age if rock samples have a large heterogeneity or general chemical composition. In order to solve these problems, a paleomagnetic method has been proposed to measure absolute paleomagnetic intensities (paleointensities) of submarine lava to detect the unique pattern of each age as an age indicator. However, previously measured absolute paleointensities derived from submarine basaltic glasses of the East Pacific Rise measured in a previous study are highly variable, which potentially indicate a problem with the sample properties and/or the paleointensity estimation method. Here, we conducted absolute paleointensity measurement experiments for submarine basalts using the Tsunakawa-Shaw method, a technique that is expected to provide more accurate absolute paleointensities than conventional methods. Studied basaltic rock samples were collected from the Central Indian Ridge by the SHINKAI 6500 dives 926 and 927 operated during the R/V Yokosuka YK05-16 cruise. Only two samples from one lava site passed the statistical acceptance criteria of the Tsunakawa-Shaw method, showing absolute paleointensities of 31.4 μ T and 33.7 μ T. Their mean value is 32.6 ± 1.6 μ T (1 σ), with a standard deviation of 4.9% of the mean. In other words, highly accurate absolute paleointensities were obtained. The mean value is 0.7 times weaker than the geomagnetic intensity at the current sampling site (45.8 μ T, IGRF-13). It is also significantly different from the current geomagnetic intensity even when the standard deviation is considered. Therefore, we conclude that the results of this study can be a useful indicator for high-resolution seafloor dating. The acceptance rate of the absolute paleointensity measurement in this study is 14%. This is significantly lower than the pass rate for volcanic rocks from terrestrial eruptions, which is usually around 60%. All rejected specimens had significantly stronger experimental thermal remanent magnetization from the first heating than from the second, but no thermal alteration occurred. Thermomagnetic analysis of the pieces of the accepted and one rejected specimen fragment showed that titanomagnetite includes high titanium in both cases. From these results, we inferred that the first heating caused the ilmenite lamellae to exsolve from the titanomagnetite (i.e., high-temperature oxidation) and that the specimens acquired thermochemical remanent magnetization, which was the cause of rejection. However, the difference in the experimental conditions between the accepted and rejected specimens is currently unknown.

海底拡大に伴う中央海嶺の火山活動は、地球システムの基礎的な役割を担う。特に、非常に速い可能性のある海底拡大の速度の推定や、複雑なマグマ熱水活動の実態把握には、高分解能な年代測定が必要である。これまで溶岩流の構造観察や化学組成の違いを用いて溶岩流の新旧を判別する研究が行われてきたが、相対年代を示唆する情報が得られる一方で絶対年代は不明である。また、岩石試料内の不均質性が大きい場合や、組成に違いがない場合には正確な年代を判別できない。それを踏まえ、海底の溶岩から絶対古地磁気強度を測定し、その時代ごとにユニークなパターンを年代指標として用いる方法が提案されている。しかし、先行研究で測定された東太平洋海膨の海底玄武岩ガラス由来の絶対古地磁気強度にはバラツキが多いため、試料や手法に問題がある可能性がある。そこで、本研究では、従来の手法よりも正確な絶対古地磁気強度が得られると期待される手法「綱川-ショー法」を用いて、海底玄武岩を用いて絶対古地磁気強度測定実験を行なった。研究試料には、「よこすか」YK05-16 航海中に実施された「しんかい 6500」926 潜航と 927 潜航で採取された中央インド洋海嶺玄武岩を利用した。7 箇所の溶岩から 2 個ずつ、計 14 個の試料片に対して実験を行ったところ、1 箇所の溶岩の 2 個の試料片のみが綱川-ショー法の統計的な実験合格基準に合格し、31.4 μ T と 33.7 μ T という絶対古地磁気強度を示した。これらの平均値は 32.6 ± 1.6 μ T(1 σ) であり、標準偏差は平均値の 4.9% である。したがって高精度な絶対古地磁気強度が得られたと言える。この値は現在の採取地点の地磁気強度 (45.8 μ T, IGRF-13) の 0.7 倍である。また、標準偏差を考慮しても、現在の地磁気強度と有意に異なる。そのため、本研究の結果は海底の年代測定の有力な指標になり得る。一方で、本研究の絶対古地磁気強度測定は合格率が 14% であった。これは、陸上噴火の火山岩が通常 60% 前後の合格率であることと比べて顕著に低い。全ての不合格試料片は、2 回目よりも 1 回目の加熱による人工熱残留磁化が有意に強いが、熱変質を起こさなかった。合格試料片と不合格試料片 1 個ずつの破片を用いて熱磁気分析を行なったところ、どちらもチタンの多いチタノマグネタイトが磁化を担う磁性鉱物であると分かった。これらの結果から、1 回目の加熱でチタノマグネタイトからイルメナイトラメラが離溶し (高温酸化)、試料片が熱化学残留磁化を獲得したことが不合格の原因だと推察した。しかし、合格と不合格を分ける実験条件の違いは現時点で不明である。

**R004-P02**
**ポスター 2 ：11/5　AM1/AM2 （9:00-12:30）**

# 北西大西洋の IODP Site U1403 および U1408 の海底堆積物から推定された約 3800 〜5000 万年前の期間における古地磁気強度相対値変動

#山本　裕二 [1)], 深見　洋仁 [1,2)], リッパート　ピーター [3)]
(1 高知大,(2 三洋テクノマリン株式会社,(3 ユタ大学

# Relative paleointensity variation for about 38-50 Ma deduced from IODP Sites U1403 and U1408 sediments in the northwest Atlantic

#Yuhji Yamamoto[1)], Hiroto Fukami[1,2)], Peter C. Lippert[3)]
(1Kochi Univ,(2Sanyo Techno Marine Co. Ltd,(3University of Utah

Rock magnetic and paleomagnetic measurements have been conducted on Eocene marine sediments recovered at Integrated Ocean Drilling Program (IODP) Sites U1403 and U1408 in the northwest Atlantic. Various rock magnetic measurements indicate that the main remanence carrier is single domain biogenic magnetite. Paleomagnetic measurements gave RPI records for Chrons C18 – C21 and C22n, which correlates to ~ 38.4 – 49.6 Ma, after excluding a few short intervals with inhomogeneous rock magnetic properties. The records show that RPI minima always occur at chron boundaries and that RPI fluctuates between highs and lows within each chron. This record is the first to show that these characteristics persist at least since the onset of Chron C22n at ~ 49.3 Ma, and it is concluded that these are intrinsic and fundamental features of the geomagnetic field regardless of the polarity reversal rate.

A stacked RPI curve for Chron 18, named PIS-C18, is produced on the basis of the RPI records obtained in this study and those from IODP Sites U1331 and U1332 in the equatorial Pacific. The PIS-C18 RPI of the stack is generally high with no prominent lows during Chron C18n.2n, whereas it is not as high and has several prominent lows almost equivalent to the RPI minima at the chron boundaries during Chrons C18n.1n and C18r. A histogram of RPI during Chron 18 is slightly skewed to the right, and the ratio of the standard deviation to the mean paleointensity is 0.38. These characteristics are resembled to a histogram of the RPI stack for the last 1.5 million years. It is implied that character of the geodynamo for $10^4$ – $10^6$ years timescales has been unchanged since the Eocene.

**R004-P03**
**ポスター 2 ：11/5　AM1/AM2 （9:00-12:30）**

# 四国北東部高松地域の中期中新世瀬戸内火山岩類の古地磁気学情報（再考）

#石川　尚人 [1)], 中村　幹人 [1)]
(1 地球システム・富山大

# Reanalyzed paleomagnetic information from Middle Miocene Setouchi volcanic rocks at Takamatsu area in NE Shikoku region

#Naoto Ishikawa[1)], Mikito Nakamura[1)]
(1Earth System Science, Toyama Univ.

A short-lived volcanic activity of the Setouchi volcanic rocks (SVR) in the middle Miocene time in Southwest (SW) Japan arc has been considered to occur related to the opening process of the Japan Sea back-arc basin accompanied with a rapid clockwise (CW) rotation of the SW Japan block at about 15 Ma. Paleomagnetic data form SVR has been regarded as key data for documenting the rotational motion of the SW Japan block and for investigating the relationship among the activity of the SVR, the rotation of the SW Japan block and the Japan Sea opening. We reanalyzed the SVR at Takamatsu area in the NE Shikoku region paleomagnetically in order to confirm a paleomagnetic direction of the rocks at the area. Paleomagnetic samples were collected at 16 sites from eight rock bodies. A mean-age calculated from K-Ar age data at eight sites (Tatsumi et al., 2001) out of the 16 sites was 13.4 +/- 0.3 Ma.

Progressive thermal and alternating-field demagnetization experiments revealed the presence of one to three stable magnetic components in natural remanent magnetizations of samples at 14 sites. The components isolated at high demagnetization steps between 440ºC and 580ºC and/or between 30-40 mT and 100-180mT were shown as linear trends of vector end-points decaying toward the origin of the vector demagnetization diagrams. Directions of the components were well grouped at 13 out of the 14 sites, of which site-mean directions had alpha-95 below 10º. Three site-mean directions with normal polarity and 10 directions with reverse one showed an antipodal relationship in a N-S trend. An angular standard deviation of virtual geomagnetic poles calculated from the 13 site-means indicated that a directional variation in the site-means was reflected by the geomagnetic secular variation. A mean direction of the 13 site-means, D=7.5º, I=48.4º and alpha-95=7.9º, were thus considered as a paleomagnetic direction at Takamatsu area at 13.4 Ma.

The paleomagnetic direction suggested no significant tectonic motions at Takamatsu area before 13.4 Ma. As suggested by Hoshi (2018), compiled paleomagnetic and age data from the SVR except for the data from the Muro volcanic rocks and the Takanawa Peninsula in the NW Shikoku region suggested no rotational motion of the SW Japan block, indicating the initiation of the SVR activity just after the CW rotation of the SW Japan block.

西南日本孤で中期中新世に起こった特異的な火山活動により産した瀬戸内火山岩類の古地磁気情報は日本海の拡大形成に伴う西南日本ブロックの時計回り回転運動，また，瀬戸内火山岩類の活動と日本海の拡大・西南日本の回転運動の関連性を考える際の重要な情報とされてきた．そこで，四国北東部の高松地域に分布する瀬戸内火山岩類の古地磁気方位を確定するために，その古地磁気情報の再解析を行った．高松地域の 8 岩体から計 16 地点で試料を採取した．そのうち 8 地点から報告されている K-Ar 放射年代値 (Tatsumi et al., 2001) の平均は 13.4 ± 0.3Ma である．

段階的熱消磁また交流消磁実験により自然残留磁化の安定性を検討したところ，各試料において 1 成分から 3 成分の安定な磁化成分が検出された．14 地点において高消磁段階（400 から 580ºC または 30-40mT から 100-180mT）で分離される成分（H 成分）は直交面投影図上で原点向かって直線的に減衰する成分として認められた．熱磁気分析と人工残留磁化の消磁実験の結果，H 成分はマグネタイトまたはチタノマグネタイト（x=0.2~0.3）に担われていることが分かった．14 地点のうち 13 地点において，H 成分の地点平均方位はよく集中し，そのα $_{95}$ は 10º 未満であった．その 13 地点のうち，3 地点の方向は正極性，10 地点は逆極性でそれらは N-S 方向で反平行であった．またその 13 地点の方位から求めた仮想的地磁気極の角度の分散から，H 成分の方向は地磁気永年変化を反映していることが確認された．

13 地点から得られた H 成分の平均方位は D=7.5º，I=48.4º，α $_{95}$ ＝ 7.9º となり，これを高松地域の約 13.4Ma の古地磁気方位とみなした．この古地磁気方位は約 13.4Ma 以降，高松地域には有意な構造運動が無かったことを示す．また，西南日本に分布する瀬戸内火山岩類からの古地磁気データと年代データを再検討すると，室生火山と四国北西部・高縄半島からの古地磁気データ以外については，星（2018）が指摘した通り，瀬戸内火山岩類の活動開始以降，西南日本の有意な構造運動はなかったことが確認された．

**R004-P04**
**ポスター 2 ：11/5　AM1/AM2 （9:00-12:30）**

# 北西太平洋の堆積物中の二種類の風成塵成分

#臼井　洋一 [1)], 山崎　俊嗣 [2)]
[(1] 金沢大学,[(2] 東大大気海洋研

# Two eolian components from sediment magnetism in the wesetern North Pacific

#Yoichi Usui[1)], Toshitsugu Yamazaki[2)]
[(1]Kanazawa University,[(2]AORI, Univ. Tokyo

North Pacific sediments contain long-range transported eolian dust. They record the paleoenvironment in Asia and atmospheric circulation. The environmental magnetism of oxic pelagic clay is particularly useful for decoding the records because the effects of fluvial components and early diagenesis are minimal. Previous studies have demonstrated the increased eolian flux since c. 3 Ma (Yamazaki and Ioka, 1997; Rea et al., 1998; Zhang et al., 2020). Recently, multiple eolian components have been suggested based on coercivity distributions (Shin et al., 2020; Yamazaki and Kanamatsu, 2007), which may reflect changing source locations or their environments. However, possible spatial variation has not been considered because of the small number of reports. This presentation provides paleomagnetism and rock magnetism of a core obtained around Minamitorishima Island during the cruise MR13-E02_leg2.

The core consists of brown diatom-rich silty clay. Regional acoustic and geochemical stratigraphy suggest relatively young ages. Paleomagnetic polarities are obtained by progressive alternating field demagnetization (AFD) of natural remanence (NRM). We correlate the base of Oldvai chron (2.078 Ma) at 12.7 m. A nearby site provides almost the same pattern (Yamazaki et al., 2020). Further age constraints are obtained by relative paleointensity (RPI). RPI proxy was calculated by comparing progressive AFD of NRM and anhysteretic remanence (ARM). Age estimates were based on a graphical comparison with the PADM2m model (Ziegler et al., 2011).

S-ratio obtained by a 100 mT backfield ($S_{-0.1}$) decreases from around 0.8 Ma to present, while ARM and saturation isothermal remanence (SIRM) do not show much depth trend. When plotted as a cross plot for $S_{-0.1}$ v.s. kARM/SIRM, the data show a linear trend. The trend does not extend toward a biogenic magnetite component, which would show ($S_{-0.1}$, kARM/SIRM) ≈ (1.0, 3.0). Therefore, the coercivity variation as indicated by $S_{-0.1}$ mainly reflects the mixing of two eolian components. This trend matches quantitatively the one from ODP Site 777 which is southwest from the study site (Usui and Yamazaki, 2021). It is also similar to the northwestern site NPGP1401-2A (Shin et al., 2020), but this site shows systematically higher kARM/SIRM. So, it is still unclear if all the variation can be explained by single cause. Besides, RPI proxy is lower for older sediments with higher $S_{-0.1}$, implying different efficiency of detrital remanence acquisition.

Yamazaki and Ioka, 1997, https://doi.org/10.1029/96PA02757
Rea et al., 1998, https://doi.org/10.1029/98pa00123
Zhang et al., 2020, https://doi.org/10.1130/g46862.1
Shin et al., 2020, https://doi.org/10.3389/feart.2021.789584
Yamazaki and Kanamatsu, 2007, https://doi.org/10.1186/BF03352741
Yamazaki et al., 2020, https://doi.org/10.1186/s40623-020-01248-5
Ziegler et al., 2011, https://doi.org/10.1111/j.1365-246X.2010.04905.x
Usui and Yamazaki, 2021, https://doi.org/10.1029/2021GC009770

北太平洋の堆積物は長距離輸送された風成塵を含んでおり、陸域の環境や大気循環の手がかりとなる。特に遠洋粘土においては、河川による鉱物供給が少なく初期続成も激しくないため風成塵由来の磁性鉱物が比較的保存されており、環境磁気学による特徴づけが行われている。これまでの研究では主に風成塵フラックスの変化が見積もられ、地球化学的な方法と合わせ 3 Ma 付近からフラックスが増加したことが示されている（Yamazaki and Ioka, 1997; Rea et al., 1998; Zhang et al., 2020）。最近では保磁力分布の解析に基づき複数の風成塵成分が提案されている (Shin et al., 2020; Yamazaki and Kanamatsu, 2007)。これらは異なった供給地に対応する可能性があるが、報告例が少なく地理的な変動は明らかではない。本発表では、MR13-E02_leg2 航海により南鳥島周辺で採取されたコア（MR13-E02_leg2 PC02）について、古地磁気年代と岩石磁気特性を報告する。

対象としたコアは茶色の diatom-rich silty clay よりなる。音響探査や地域的な化学層序から、比較的若い堆積物であることが予想される。NRM の交流消磁により容易に極性が判別でき、12.7 m で Oldvai クロンの基底までが見られた。近隣の MR13-E02_leg2 PC01 でもほぼ同じ極性パターンが報告されている（Yamazaki et al., 2020）。さらに年代制約を得るために、ARM の交流消磁を行い NRM-ARM 図の傾きから相対古地磁気強度変化を推定し、PADM2m モデル (Ziegler et al., 2011) と対比した。

ARM や SIRM はあまり深度変化を示さない一方、100 mT のバックフィールドによる S 比 ($S_{-0.1}$) はおよそ 0.8 Ma から現在に向かい減少する傾向が見られた。これらの変動は $S_{-0.1}$ と kARM/SIRM とのクロスプロット上でほぼ直線状に変化するが、そのトレンドの延長は生物源磁鉄鉱に期待される値 ($S_{-0.1}$, kARM/SIRM) ≈ (1.0, 3.0) と比べ、kARM/SIRM

が著しく低い。したがって、$S_{-0.1}$ の変化に表れている保磁力の増加は生物源磁鉄鉱の相対的増減とはほぼ関係なく、陸源成分の変化を見ていると考えられる。この変化は、より南西のマリアナ海盆に位置する ODP Site 777 の結果（Usui and Yamazaki, 2021) と定量的に一致する。より北東のサイト NPGP1401-2A (Shin et al., 2020）の結果とも定性的には一致するが、このサイトは kARM/SIRM がやや高い傾向にあり、同一の原因で説明できるかは不明である。また、相対古地磁気強度の値は S 比が高い堆積物のほうが低くなる傾向があり、堆積残留磁化の獲得効率の系統的な違いを示唆する。


Yamazaki and Ioka, 1997, https://doi.org/10.1029/96PA02757
Rea et al., 1998, https://doi.org/10.1029/98pa00123
Zhang et al., 2020, https://doi.org/10.1130/g46862.1
Shin et al., 2020, https://doi.org/10.3389/feart.2021.789584
Yamazaki and Kanamatsu, 2007, https://doi.org/10.1186/BF03352741
Yamazaki et al., 2020, https://doi.org/10.1186/s40623-020-01248-5
Ziegler et al., 2011, https://doi.org/10.1111/j.1365-246X.2010.04905.x
Usui and Yamazaki, 2021, https://doi.org/10.1029/2021GC009770

**R004-P05**
**ポスター 2 ：11/5　AM1/AM2 （9:00-12:30）**

#佐藤　哲郎 [1)], 佐藤　雅彦 [2)], 山田　昌樹 [3)], 斉藤　央岳 [3)], 佐竹　健治 [4)], 中村　教博 [5)], 後藤　和久 [2)], 宮入　陽介 [6)], 横山　祐典 [6)]
([1] 早稲田大学,([2] 東大・地惑,([3] 信州大学理学部理学科地球学コース,([4] 東京大学地震研究所,([5] 東北大・高教機構,([6] 東大・大海研

# Viscous remanent magnetization and radiocarbon dating reveal the multiple movements of tsunami boulders on Ishigaki Island

#Tetsuro Sato[1)], Masahiko Sato[2)], Masaki Yamada[3)], Hirotake Saito[3)], Kenji Satake[4)], Norihiro Nakamura[5)], Kazuhisa Goto[2)], Yosuke Miyairi[6)], Yusuke Yokoyama[6)]
([1]Waseda Univ.,([2]Dept. EPS, UTokyo,([3]Shinshu Univ.,([4]ERI, UTokyo,([5]IEHE, Tohoku Univ,([6]AORI, Univ. Tokyo

Massive tsunami boulders on the coastal regions are prominent geomorphic features. Tracking their movement history is important for reconstructing past tsunami events; however, the reworking movements of massive tsunami boulders remain unresolved. The boulder field on the Ishigaki Island was formed by repeated tsunamis. Although the individual movement histories of tsunami boulders contribute to retrodict the history of different magnitude tsunamis, their radiocarbon ages only correspond to the tsunamis that detached boulders from the reef. Viscous remanent magnetization dating methods have been applied in reworking movements. These methods reveal signals associated with remanent magnetization that gradually grew since the reworking event, which helps to determine the passage of time. The methods were verified by comparison to the radiocarbon ages of un-reworked boulders detached by the recent Meiwa tsunami, while the estimated ages of such two boulders based on the classical relaxation theory contradicted the radiocarbon ages. Here, we show that a method based on the stretched exponential function addressed this contradiction. The reworking movement was estimated using an additional boulder, whose, using our method, radiocarbon age indicated that an older AD 800 tsunami moved it onshore, whereas the remanent magnetization age unveiled a reworking of the boulder attributed to the Meiwa tsunami.

**R004-P06**
**ポスター 2 ：11/5　AM1/AM2 （9:00-12:30）**

## 伊能忠敬から 19 世紀初頭の日本の地磁気偏角を解析する。

#辻本　元博 [1)]
(1 日本地図学会

## Analyzing the early 19th century's geomagnetic declination in Japan from Tadataka Inoh.

#Motohiro Tsujimoto[1)]
([1]Japan Cartographers Association

The Santou-Houi-Ki is a national treasure of Japan consist of 67volumes ledger of approximately 200,000 Azimuth by 0 deg,5 min unit in 1816 cover from eastern Hokkaido to Yakushima Island recorded by cartographic surveyor Tadataka Inoh. We execute interdisciplinary and simultaneous analysis of real azimuth, magnetic declination, magnetic compass survey azimuth, the target points in latitude and longitude and the survey reference point in latitude and longitude where the value of declination to any targets are similar or proximate. It is necessary to introduce the geomagnetic declination data analyzed from the San-Tou-Houi-Ki, to Andrew Jackson's GUFM1 or NOAA's Historical Declination Viewer, because the lack of declination　data in Japan from mid 17 century to mid19 century equal to term of national isolation of Japan. The analyzed position of survey reference point in latitude and longitude will be further detailed by referring to the old and new maps created by the Geospatial information Authority of Japan and the old and new maps registered by the Ministry of Justice . It can be used detailed positions in local history which was impossible with the research methods of liberal arts of each University.

国宝「山島方位記」は地図測量家伊能忠敬により 1800 年から 1816 年に記録された北海道東部から屋久島迄の 67 巻の磁針測量方位角原簿である。「山島方位記」から測量対象地点と測量実施地点の各緯度経度、真方位、地磁気偏角を同時解析する。測量実施地点からいずれの測量対象地点への磁針測量方位角にも含まれる地磁気偏角が一定或いは極めて近似になる測量実施地点を逆算解析をする。「山島方位記」から解析した地磁気偏角を 17 世紀中期から 19 世紀中期迄の日本の鎖国期地磁気偏角データが不足する Andrew Jackson k の GUFM1 及び NOAA の HIstorical Declination Viewer と比較検討しドゥ乳する必要がある。解析された測量実施地点の緯度経度位置は国土地理院の゜新旧地図、法務省の登記図により更に詳細になる。従来はどの大学の文系での研究方法では不可能であった郷土史上の詳細地点の研究で活用可能である。

**R004-P07**
**ポスター 2 ：11/5　AM1/AM2 （9:00-12:30）**

## 窯跡から出土する土器片に対する岩石磁気学的測定

#畠山　唯達 [1)], 森本　蓮 [2)], 白石　純 [2)]
([1] 岡山理大・フロンティア理工学研,[2] 岡山理大・生物地球

## Rock magnetic properties of ancient pottery pieces from buried old kiln

#Tadahiro Hatakeyama[1)], Ren Morimoto[2)], Jun Shiraishi[2)]
([1]IFST, Okayama University of Science,[2]BIG, Okayama University of Science

The ceramic potteries excavated from ancient kilns contain minerals refrecting the clay elements. They were dehydrated and transformed into other stable minerals in the high-temperature and oxic or anoxic environments. The status of the baking, temperature, oxidation, are very complicated and widely variated even in a kiln, so that they create greater variation in colors, porosity and other characteristics of the ceramics. We focus on the iron-baring minerals, mainly iron oxides like magnetite and hematite, in the ancient ceramics to estimate the characteristics of the kiln and manufacturing works of them. Here we have a preliminary report of rock magnetic measurements on the pottery pieces obtained from 'Subetto old kiln' in the Tokameyama kiln sites, central Kagawa prefecture. Although the colors of the pottery pieces are rich in variety, from dark grey to reddish brown via white, the variation of the rock magnetic properties does not spread widely as well as colors. We will show the comparison of the rock magnetic and chemical properties between Subetto and Shoda-Kuden reported former SGEPSS meeting in the presentation.

**R004-P08**
**ポスター 2 ：11/5　AM1/AM2 （9:00-12:30）**

#穴井　千里 [1)], 大倉　敬宏 [2)], 吉川　慎 [2)], 望月　伸竜 [3)]
[(1] 高知大学海洋コア総合研究センター,[(2] 京都大学火山研究センター,[(3] 熊本大学

# Temporal change with rock magnetic properties of volcanic ashes: A case study on the Aso Nakadake 2019 – 2020 eruption

#Chisato Anai[1)], Takahiro Ohkura[2)], Shin Yoshikawa[2)], Nobutatsu Mochizuki[3)]
[(1]Center for Advanced Marine Core Res. Kochi Univ.,[(2]Aso Volcanological Laboratory, Kyoto Univ.,[(3]Kumamoto University

We investigated temporal changes in the magnetic properties of volcanic ash ejected from the Aso Nakadake volcano during a sequence of ash eruptions from 2019 to 2020. Volcanic ash was continuously collected during the time series of the ash eruptions. We performed detailed measurements on these samples to investigate temporal changes in the rock magnetic properties of volcanic ash and their possible relationship to the eruption processes. Volcanic ash was collected from eight sites that were included in the observation points of the Aso Volcanological Laboratory, Kyoto University. This study focused on the volcanic ashes at four sampling sites, Kako-fuchi (KAF), Hondo observatory (HOND), Sakanashi (SAK), and National Aso Youth Friendship Center (AYFC), whose distances and directions from the first crater of the Nakadake volcano are approximately 250 m WSW, 1000 m SW, 7000 m NE, and 4400 m NNE, respectively. Titanium-rich titanomagnetite and titanium-poor titanomagnetite were the dominant magnetic minerals in the samples where titanium-rich titanomagnetite was more dominant. From the rock magnetic measurements, parameters such as the saturation remanent magnetization ($M_{rs}$), saturation magnetization ($M_s$), coercivity ($B_c$), and titanium content estimated from the Curie temperature ($T_c$) were extracted and checked for their temporal changes. The magnetic behavior of the magnetic minerals was confirmed by the increasing values of $M_{rs}/M_s$ and $B_c$ at several periods. The samples with higher values of $M_{rs}/M_s$ and $B_c$ included titanomagnetite with a low $T_c$ (high titanium content). The clear increase in $M_{rs}/M_s$ and $B_c$ suggests that the ratio of the single-domain volume fraction increased, indicating that the titanomagnetite particles became finer in size. Interestingly, the periods of high $M_{rs}/M_s$ and $B_c$ were synchronized with observations of the volcanic glow. These results suggest that changes in the magnetic properties of volcanic ash reflect changes in physical and/or thermal conditions from the vent to the conduit.