R004-01
D 会場 ：11/25　PM2 （15:00-18:00）
15:00〜15:15

拡張カルマンフィルタ法で訓練された再帰的ニューラルネットによる地磁気永年変化の予測 (IGRF-14 候補モデル)

#佐藤 匠 [1)], 藤 浩明 [1)]
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Using recurrent neural networks trained by the Kalman filter to produce geomagnetic secular variation forecasts for the IGRF-14

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This study presents a machine-learning-based approach for predicting geomagnetic secular variation. The International Geomagnetic Reference Field (IGRF) is a standardized model that provides a comprehensive description of the Earth's magnetic field, updated every five years. The IGRF model includes a five-year linear prediction of the secular variation. Traditional forecasting methods heavily rely on complex geodynamo simulations, which are computationally expensive and may result in large forecasting errors when sudden changes occur.

In our research, we adopted an EKF-RNN model, where a Recurrent Neural Network (RNN) is trained using the extended Kalman filter (EKF) to predict the five-year changes in the geomagnetic main field. Among machine learning methods, RNNs (Elman, 1990) offer a data-driven approach to modeling temporal sequences with lower computational cost, making them suitable for predicting time-dependent phenomena such as geomagnetic variations. The EKF is an efficient data assimilation algorithm widely used in the geosciences. The EKF algorithm dynamically updates the RNN weights using the error covariance of the training data, improving the learning process and mitigating overfitting, a common issue with standard Backpropagation methods.

To verify the prediction accuracy of the EKF-RNN model, we conducted a five-year hindcast experiment for the training period from 2004.50 to 2014.25, using the datasets derived from the MCM model (Ropp et al., 2023). The MCM model is based on geomagnetic field snapshots obtained from hourly means collected at geomagnetic observatories worldwide, and CHAMP and Swarm-A Low-Earth-Orbit satellite data (Ropp et al., 2020).

The results showed that the short-term predictions of the EKF-RNN model had reduced errors compared to traditional simulation-based methods. This suggests that the EKF-RNN could serve as a superior alternative for predicting geomagnetic secular variation, potentially contributing to the accuracy and reliability of the 14th-generation IGRF.

本研究は、機械学習を用いて地磁気の永年変化を予測するための新しいアプローチを提示する。国際標準地球磁場 (International Geomagnetic Reference Field, IGRF) は、地球主磁場を包括的に記述する最も標準化されたモデルのひとつであり、5 年ごとに更新される。IGRF として提供されるモデルには、永年変化の 5 年線形予測が含まれる。

従来の予測手法は、複雑なジオダイナモ・シミュレーションに大きく依存している。従来の手法では計算コストが高く、突発的な変化が起こった際に予測誤差が大きくなる場合がある。我々の研究では、地磁気主磁場の 5 年間の変化を予測するために、拡張カルマンフィルタ (extended Kalman filter, EKF) を用いて再帰的ニューラルネットワーク (Recurrent Neural Network, RNN) を学習させる EKF-RNN モデルを採用した。

機械学習の中でも RNN (Elman, 1990) は計算コストが小さく、時間的シーケンスをモデル化するためのデータドリブンなアプローチを提供する。RNN は地磁気変動のような時間依存現象の予測に適しており、シミュレーションよりも計算コストが小さい。EKF は地球科学の分野で広く使われている効率的なデータ同化アルゴリズムである。EKF アルゴリズムは、教師データの誤差共分散を利用して RNN の重みを動的に更新している。これによって学習プロセスが改善され、予報誤差共分散の推定が可能になると同時に、標準的な誤差逆伝搬法でよく見られる過学習の問題が軽減される。

EKF-RNN モデルの予測精度を検証するために、2004.50 から 2014.25 までの学習期間を設定して、5 年間の再予報実験を行った。訓練と検証のためのデータセットには、MCM モデル (Ropp et al., 2023) を用いた。MCM モデルは世界中の地磁気観測所で収集された毎時の平均値から得られた地磁気スナップショット、及び CHAMP と Swarm-A の低軌道衛星データを元に作成されている (Ropp et al., 2020)。

その結果、EKF-RNN モデルの短期予測結果は、シミュレーションに基づく従来の手法と比較して、誤差が減少することが示された。このことは、EKF-RNN が地磁気の経年変化を予測するための優れた代替手段となり、第 14 世代 IGRF の精度と信頼性に貢献する可能性を示唆している。

R004-02
D 会場 ：11/25　PM2 （15:00-18:00）
15:15〜15:30

上部鮮新統，千倉層群布良層におけるカエナ逆磁極亜帯上部境界の高時間分解能の古地磁気記録

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(1 茨城大

A paleomagnetic record across the upper boundary of the Kaena reversed subchron from the Pliocene Mera Formation, Chikura Group

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Reconstruction of the geomagnetic field behavior during geomagnetic reversals is important for providing implications into the dynamics of Earth's internal fluids and advancing our understanding of the dynamo mechanism that drives the geomagnetic field. Many studies have reported geomagnetic reversal events since the Pleistocene (e.g., Okada et al., 2017; Konishi and Okada, 2020). However, there are relatively few reports on geomagnetic reversal events before the Pliocene (e.g., Van Hoof and Langereis, 1992; Haneda and Okada, 2022).

The Chikura Group is the Late Pliocene to the Early Pleistocene distributed at the southernmost part of the Boso Peninsula, central Japan. This Group is a marine deposit that filled deep-sea trenches and trench slope basins, with an estimated average sedimentation rate of 70 cm/kyr. Therefore, we can reconstruct paleomagnetic variations with an exceptionally high-temporal resolution of several decades to several hundred years. Okada et al. (2012) established a composite stratigraphy based on paleomagnetic and oxygen isotope records in the Mera Formation of the Chikura Group, demonstrating the existence of a reversed chronozone, interpreted as the Kaena reversed subchron. In this study, we present the results of measurements conducted on samples collected at approximately 10 cm intervals in thickness to clear the paleomagnetic behavior at the upper boundary of the Kaena reversed subchron within the Mera Formation of the Chikura Group.

So far, paleomagnetic samples have been collected from 58 horizons, with measurements completed on 26 horizons. The results indicate that nearly all strata exhibit reversed polarity, with a gradual relative paleointensity decay. The virtual geomagnetic pole (VGP) form a cluster extending from southeastern Antarctica to the Indian Ocean. This pattern is consistent with records obtained from marls in southern Sicily (Van Hoof and Langereis, 1992). This suggests that the early stages of polarity reversal during the upper Kaena event have been captured. However, because only the minimum number of measurements required for statistical processing were conducted, the number of stratigraphic levels yielding stable magnetization orientations is limited, and the detailed VGP path could not be reconstructed. Therefore, it is necessary to increase the number of measurement specimens in future studies.

Acknowledgment

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地磁気逆転時の地磁気の詳細な振る舞いを復元することは，地球内部流体の運動についての情報を与え，地磁気を駆動するダイナモの性質を理解する上で重要である．これまで，更新世以降の地磁気逆転イベントに対しては多くの報告が行われてきた（たとえば，Channell 2016; Haneda et al., 2020; Channell et al.,2003; Konishi and Okada, 2020）．しかし，鮮新世以前の地磁気逆転イベントについて報告された例は少ない（たとえば，Van Hoof and Langereis, 1992; Haneda and Okada, 2022）．

千葉県房総半島南端地域には，上部鮮新-下部更新統である千倉層群が分布している．千倉層群は海溝陸側斜面に形成された小海盆を埋積した海成層であり，その平均堆積速度は 70cm/kyr と推定されている．このため，数十年から数百年という非常に高い時間分解能で古地磁気変動を復元することができる．岡田ほか（2012）は，千倉層群布良層における古地磁気-酸素同位体複合層序を確立し，カエナ逆磁極亜帯の上部・下部境界と解釈される逆磁極亜帯が存在することを

示した．そこで本研究では，千倉層群布良層において，カエナ逆磁極亜帯の上部境界における地磁気の振る舞いを明らかにすることを目的とし，層厚間隔約 10cm 間隔で採取した試料の測定を行った結果を報告する．

これまでのところ，古地磁気測定用試料を計 58 層準から採取し，26 層準の測定を行った．その結果，ほぼすべての層準が逆極性を示し，相対古地磁気強度が緩やかに減衰する傾向が確認された．仮想地磁気極（VPG）は，南極大陸南東部からインド洋上にかけてのクラスターを形成しており，シチリア島南部の泥灰岩層から得られた記録（Van Hoof and Langereis , 1992）と共通する特徴をもつ．したがって，上部カエナイベントにおける極性反転初期の振る舞いを捉えたものであると考えられる．しかし，統計的処理を行うために最低限度の測定しか行っていないため，安定的な磁化方位が得られた層準が少なく，詳細な VGP 経路の復元ができていない．このため，今後は測定数を増やす必要があると考えられる．

謝辞

本研究は，東京地学協会調査・研究助成（研究課題：房総半島南端地域に分布する海成堆積層を用いた後期鮮新世の連続古地磁気変動復元）および藤原ナチュラルヒストリー振興財団第 32 回学術研究助成（研究課題：中期鮮新世温暖期に発生した地磁気極性反転イベントの高時間分解能復元）の一部を使用して行われた．

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R004-03
D 会場 ：11/25　PM2 （15:00-18:00）
15:30〜15:45

IODP Expedition 392 でアガラス海台にて掘削された玄武岩コアの古地磁気強度研究

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Paleointensity study on basalt cores from the Agulhas Plateau drilled during IODP Expedition 392

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The Agulhas plateau in the Southeast Indian Ocean had been formed during breakup of Africa and East Antarctica in the Late Cretaceous. Owing to its locality and period of activity, it is expected that the igneous basement of the Agulhas Plateau records absolute paleointensities during the Cretaceous Normal Superchron (CNS) at southern mid to high latitudes. During International Ocean Discovery Program Expedition 392, three sites (U1579, U1580, and U1582) were drilled on the Agulhas Plateau. Two units of basaltic sills with various thicknesses were recovered at Site U1579, while six at Site U1580, and a unit of pillow basalt was recovered at Site U1582.

For absolute paleointensity experiments, less-altered portions of the basaltic cores were searched based on the results of on-board measurements by the superconducting rock magnetometer (SRM) and off-shore rock-magnetic studies. Paleomagnetic cube specimens taken from depths which showed relatively high ($>$10 mT) median destructive field (MDF) of the natural remanent magnetization (NRM) in the on-board SRM measurements were selected for off-shore studies. Magnetic hysteresis measurements and thermomagnetic analysis were conducted on small chips cut from the cube specimens. All studied samples showed pseudo-single domain (PSD) and/or mixture of single domain (SD) and multi domain (MD) behavior upon magnetic hysteresis measurements by an alternating gradient magnetometer. Js-T curves were obtained in a DC field of 300 mT at ˜50 to 700 C in vacuum (˜1 Pa) by a Curie balance, and samples which showed reversible heating and cooling curves were chosen for paleointensity experiments. Tsunakawa-Shaw paleointensity experiments were conducted on the selected specimens using an automated spinner magnetometer with an AF demagnetizer. The obtained paleointensity ranged from 52 to 103 micro T (7.3×10^{22} to 15.2×10^{22} Am^2 in virtual dipole moment). These results suggest that the strength of the geomagnetic field was variable during the CNS.

R004-04
D 会場 ：11/25　PM2 （15:00-18:00）
15:45〜16:00

紀元前 250 年から紀元 50 年の弥生時代中期〜後期に作成された土器から推定される日本の考古地磁気強度の増加

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Archeointensity increase in Japan estimated from Middle and Late Yayoi potteries of 250 BCE to 50 CE

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The Earth's magnetic field is known to fluctuate significantly over various time scales. The reference curve of secular variations of geomagnetic intensity over the past few thousand years in Japan, as well as the standard curve of geomagnetic direction, provides fundamental data to understand the Earth's core dynamics. Also, the reference curve over the past several thousand years is important because it can be used as a reference to estimate the making age of baked archeological artifacts, whose ages are unknown. Recent previous studies show an archeomagnetic field intensity (archeointensity) trend of a decrease from about 300 CE to 600 CE and an increase from about 600 CE to 700 CE. However, archeointensity data prior to 300 CE are scarce. In this study, we conducted experiments to estimate archeointensity using Yayoi pottery samples of about 250 BCE (Middle Yayoi) to 50 CE (Late Yayoi) collected at the Gokuden site in Kasuga, Fukuoka, Japan. We conducted thermomagnetic analysis for 45 pottery samples in vacuum and in air. The reversibility of thermomagnetic curves were higher in air than in vacuum. Based on the results, the Tsunakawa-Shaw method was performed in air to estimate the archeointensity. As a result, 17 out of 23 specimens from seven out of eight pottery samples passed the acceptance criteria of the Tsunakawa-Shaw method. In order to ensure the reliability of these samples, we set a selection criterion of "archeointensity obtained from at least two specimens per pottery sample and their standard deviation meets 15% or less" and selected the four sample-level archeointensities (36.9 - 46.2 μ T). When we arrange the archeointensities from Gokuden site in chronological order with the results of previous studies, we can observe that the archeointensity increased from -250 CE to 50 CE, and the increasing trend may have continued until 300 CE. These results suggest that the geomagnetic field intensity at the Yayoi period increased within 300 years. Thus, the Yayoi period may be suitable for the dating of baked archeological artifacts by archeointensity.

日本における過去数千年の地磁気強度の永年変化の標準曲線は、方位の標準曲線とともに地球外核のダイナミクスを探る基礎的データとして重要である。また、地磁気強度が大きく変化する時代であれば、年代不明の考古遺物の焼成年代を推定する手がかりとなる。近年の先行研究によると、約 300 CE から 600 CE にかけての減少、約 600 CE から 700 CE にかけての増加という傾向が確認されている（Kitahara et al., 2018, 2021; Tema te al., 2023）。しかし、300 CE 以前の考古地磁気強度データは少ない。そこで本研究では、福岡県春日市の御供田遺跡で採取された約 250 BCE〜50 CE の弥生土器片を用いて考古地磁気強度の推定実験を行った。45 個の土器サンプルから一つずつ真空中と空気中で熱磁気分析を行ったところ、真空中よりも空気中の方が加熱と冷却の誘導磁化曲線が可逆的であった。そこで、綱川・ショー法を空気中加熱によって絶対古地磁気強度を推定した結果、8 個中 7 個の土器サンプルにおける 23 個中 17 個のスペシメンが綱川・ショー法の合格基準に合格した。信頼性を担保するため、「1 個の土器サンプルにつきスペシメン 2 個以上から考古地磁気強度が得られていて、それらの標準偏差が 15% の選択基準を満たすもの」という選別基準を設定したところ、4 個の考古地磁気強度の土器サンプルレベル平均（36.9〜46.2 μ T）が選別された。本研究の考古地磁気強度と、御供田遺跡から復元した考古地磁気強度を本研究の結果と合わせて年代順に並べると、考古地磁気強度は-250 CE から 50 CE まで増加したことが示され、その増加傾向は 300 CE まで続いた可能性がある。これらの結果から、弥生時代は 300 年という短期間で地磁気強度が増加し、考古地磁気強度による焼成考古遺物の年代推定が可能な時代である可能性があると結論づけられる。

R004-05
D 会場 ：11/25　PM2 （15:00-18:00）
16:00〜16:15

アイスランド西部ボルガルフィヨルズル地域のルンダルレイキャダルールバレーから採取した溶岩試料群の岩石磁気特性

#山本 裕二 [1)], 星 博幸 [2)], ブラウン マクスウエル [3)]
[(1] 高知大, [(2] 愛知教育大, [(3] ミネソタ大

Rock magnetic properties of the lava samples from Lundarreykjadalur valley in the Borgarfjordur region of western Iceland

#Yuhji YAMAMOTO[1)], Hiroyuki HOSHI[2)], Maxwell BROWN[3)]
[(1]Kochi University, [(2]Department of Earth Sciences, Aichi University of Education, [(3]Institute for Rock Magnetism, University of Minnesota

Iceland is a volcanic island with thousands of plateau lava flows emplaced sequentially in piles over the past ~16 Ma. These lava sequences are a unique data source for investigating quasi-continuous time variations in the past geomagnetic field. To investigate quasi-continuous time variations in absolute paleointensity (API) during the Gauss normal polarity chron and the upper Gilbert reversed polarity chron, we have targeted ~390 lavas spanning 21 sections located in Lundarreykjadalur valley in the Borgarfjordur region of western Iceland. The results of the API obtained so far by the Tsunakawa-Shaw method, from ~2.6 Ma to ~4.3 Ma, have been reported in Yamamoto et al. (2024 JpGU). According to this, the API during the stable polarity period generally fluctuates between 15 and 50 microT, and decreases to around 5 microT at chrono boundaries. In addition, the timing of the minima in the quasi-continuous API records obtained as a result could be compared with the timing of the minima in the relative paleointensity records of the sediments of the same period.

In order to assess the quality and fidelity of the API results, systematic rock magnetic measurements were carried out on chip samples cut from the specimens before they were used in the Tsunakawa-Shaw experiment. The measurements include hysteresis measurements at room temperature with a strong magnetic field up to 1 T, and thermomagnetic experiments in vacuum at temperatures ranging from room temperature to high temperatures with a DC magnetic field of 300 mT applied. We will report on the hysteresis parameters and thermomagnetic properties, and discuss whether there is any relationship between these rock magnetic properties and the API results.

R004-06
D 会場 ：11/25　PM2 （15:00-18:00）
16:15〜16:30

開聞岳仁和噴火火山灰の残留磁化：　古地磁気記録としての信頼性

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Remanent magnetization of volcanic ash from the Ninna eruption of Kaimondake volcano: Reliability as a paleomagnetic record

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Paleomagnetism has generally been studied by measuring the natural remanent magnetization of volcanic rocks and marine and lake sediments. Some studies on the widespread tephra reported that a widespread tephra accurately records the paleomagnetic direction at the time of the deposition of the widespread tephra. On the other hand, few paleomagnetic studies have been conducted using volcanic ash layers ejected by relatively small eruptions in the vicinity of volcanoes. In this study, we evaluated the reliability of the volcanic ash from the Ninna eruption of Kaimondake as a paleomagnetic record. We applied alternating field demagnetization and thermal demagnetization to samples collected from two sites of the volcanic ash and one site from the pyroclastic flow deposit, which were ejected at the Ninna eruption occurred at CE 885. We also conducted redeposition and magnetization acquisition experiments of the volcanic ash samples to study the remanent magnetization acquisition process of the volcanic ash.

R004-07
D 会場 ：11/25　PM2 （15:00-18:00）
16:45〜17:00

十勝岳から噴出した火山岩塊における残留磁化獲得の過程

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([1] 同志社大・理工, [2] 大阪公立大・理

Process of acquiring remanent magnetization in volcanic rock masses ejected from Tokachi-dake volcano

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Subaerial volcanic rocks are irreplaceable recorders of the Earth's past magnetic field, and how they acquire magnetization during cooling is important for deciphering the paleomagnetic record. Basalt/andesite lavas usually contain titanomagnetite and magnetite, which have different Curie points. However, since lavas do not rotate greatly during cooling, it is not possible to reproduce the cooling and magnetization acquisition process from the direction of remanent magnetization. In this study, several relatively large (approximately 10 x 10 x 15 cm) blocks were collected from a volcanic rock mass ejected into the air from Tokachi-dake volcano in 1989, and slab samples were cut to determine the change in the direction of natural remanent magnetization as a function of distance from the surface. Curie point and magnetic hysteresis property variations from the surface to the interior were also obtained. Furthermore, Raman microscopy was used to determine how the composition of titanomagnetite changes from the surface to the interior.

The direction of natural remanent magnetization before demagnetization deviates significantly from the direction of the 1989 earth field on the surface, but approaches the 1989 direction toward the interior. On the other hand, the intensity of natural remanent magnetization increases sharply by several times at a distance of 5 to 10 cm from the surface. Thermal demagnetization yields characteristic remanent magnetizations parallel to the 1989 earth field with unblocking temperatures of about 300° C or higher, except for a few cm from the surface. Thermomagnetic analyses show titanomagnetites with Curie points of about 200° C and 300° C regardless of the distance from the surface, and a small amount of magnetite with a Curie point of 580° C inside a few centimeters from the surface. The hysteresis parameters do not change significantly with depth, and the saturation remanent magnetization / saturation magnetization ratio (Mr/Ms) is low (less than 0.1), but the trend on the Day plot shifts to the right at depths where magnetite also appears. Raman microscopy reveals titanomagnetite crystals of several hundred microns as phenocrysts and in groundmass of about 10 microns, regardless of the distance from the surface. Magnetite is seen only around voids in the interior of the rock mass, deeper than a few centimeters.

The volcanic mass contained only titanomagnetite before eruption, and a few centimeters of the surface acquired remanent magnetization due to cooling before emplacement. During emplacement, the volcanic mass underwent rotation or deformation, and the remanent magnetization at the surface deviated significantly from the direction of the earth's magnetic field in 1989. Magnetite was formed only around the void in the interior of the volcanic mass during cooling, and remanent magnetization parallel to the direction of the earth's magnetic field was acquired after emplacement. Magnetite formed by oxidation around the voidsis far less in quantity than the original titanomagnetite, but its fine-grained nature contributes greatly to stable remanent magnetization. In basalt/andesite lava in which titanomagnetite and magnetite coexist, the low unblocking temperature component is the thermoremanent magnetization caused by the originally contained titanomagnetite, and the high unblocking component is the thermal/chemical remanent magnetization caused by magnetite formed by oxidation during cooling.

陸上の火山岩は過去の地球磁場の代替の効かない記録媒体であり，冷却にともないどのように磁化を獲得するのかは古地磁気記録を読み解くのに重要である．玄武岩／安山岩溶岩には通常キュリー点が異なるチタノマグネタイト／マグネタイトが共存する．しかし，溶岩は冷却中に大きく回転することはないため，残留磁化の方向から冷却と磁化獲得の過程を再現することはできない．今回，1989 年に十勝岳から空中に放出された火山岩塊から比較的大きな（約 10 × 10 × 15cm）定方位ブロックを複数個採取して板状の試料を切り取り、表面からの距離の関数として自然残留磁化方向の変化を求めた．キュリー点および磁気ヒステリシス特性の表面から内部への変化も得た．さらに，ラマン顕微鏡を用いて表面から内部へ向けてチタノマグネタイトの組成がどのように変化するかを求めた．

消磁前の自然残留磁化の方向は，表面は 1989 年の地球磁場の方向から大きく逸れているが，内部に向かって 1989 年の方向に近づく．一方，自然残留磁化強度は表面から 5〜10 cm の距離で急激に数倍に増加する．熱消磁をおこなうと，表面の数 cm を除いて約 300 ℃以上のアンブロッキング温度をもつ 1989 年の地球磁場に平行な特有残留磁化を得ることができる．熱磁気分析では表面からの距離によらずキュリー点が約 200 ℃と 300 ℃のチタノマグネタイトが見られ，表面から数 cm より内部ではキュリー点 580 ℃のマグネタイトも少しだが加わる．ヒステリシスパラメータはいずれも深さ方向に大きな変化はせず，飽和残留磁化/飽和磁化比 (Mr/Ms) は 0.1 以下と低いがマグネタイトも出現する深さでは Day plot 上のトレンドが右にシフトする．ラマン顕微鏡では数百ミクロンの斑晶と 10 ミクロン前後の石基中のチタノマグネタイトが表面からの距離によらず観察できる．マグネタイトが見られるのは数 cm より内部の空隙のまわりのみである．

火山岩塊には噴出前はチタノマグネタイトのみが含まれており，表面数 cm の部分は定置される前に冷却により残留磁化を獲得した．定置時に火山岩塊は回転もしくは変形をうけ，表面部の残留磁化は 1989 年の地球磁場の方向から大きく逸れる．その後火山岩塊の内部では冷却にともない空隙のまわりのみでマグネタイトが生成し，定置後に地球磁場の方向に平行な残留磁化を獲得した．定置後に空隙の周囲に酸化により生成したマグネタイトはもとから含まれるチタノマグネタイトより量的には圧倒的に少ないが，細粒であるため安定な残留磁化に大きく寄与する．チタノマグネタイトとマグネタイトが共存する玄武岩／安山岩溶岩では，低アンブロッキング温度成分が元来含まれていたチタノマグネタイトが担う熱残留磁化であり，高アンブロッキング成分は冷却中に酸化されて生成したマグネタイトによる熱／化学残留磁化である．

R004-08
D 会場 ：11/25　PM2 （15:00-18:00）
17:00〜17:15

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The detection of tsunami sediments caused by the 2024 Noto Peninsula Earthquake using by magnetic analysis.

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On 1 January 2024, an earthquake of magnitude 7.6 struck the Noto Peninsula, north-central Japan. The tsunami was observed after the earthquake at Nagahashi station where is in the peninsula. The station had been monitored the tidal and tsunami, the gauges were broken by the earthquake, therefore the detail was unknown. In order to estimate tsunami current speed and particle transfer on the seafloor, we took sediment samples from three stations where sediments were collected in 2008 by the Geological Survey of Japan, off Nagahashi. Results of grain size analysis, the distributions of sedimentary grains were changed at two sites after the tsunami. Especially, the grain size was increased from fine sand to granule at a site. There is no main river which can drive pebble size grains, therefore the drastic train size changes are seemed to be caused by the tsunami. Previous studies reported that magnetic susceptibility (MS) is used for the detection of tsunami sediments (e.g., Abe et al., 2022), therefore we also measured MS of the marine sediments. A sample of MS indicates maximum value, suggesting the tsunami sediments. Results of thermomagnetometry indicates that magnetite accounted for the principal magnetic carrier of the sediment samples. Results of the isothermal remanent magnetization (IRM) curves of the sediment samples have some magnetic components, and the components are characterized per the sampling sites. We also collected a new bathymetric data using multibeam echo sounder in January and February 2024, and compared it with previous bathymetric data collected in 2010. Based on the geographic results, tsunami sediments are found at the site in a basin caused by fault. We think that when the tsunami occurred and drive the pebble size grains, and that the grains have been deposited at the site.

R004-09
D 会場 ：11/25　PM2 （15:00-18:00）
17:15〜17:30

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Effects of religious activities on magnetic properties of surface sediments in caldera lakes (Lakes Buyan and Tamblingan, Bali)

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For people who live on the island of Bali, Indonesia, lakes are sacred. Therefore, some religious places or temples (known locally as puras) where religious activities take place are on the lakes' shores. We studied the surface sediments of two caldera lakes in Bali, namely Lake Buyan and Lake Tamblingan, to identify the effects of religious activities. Both lakes are adjacent but not connected to each other. These are parts of the dormant Bratan Caldera. Lake Buyan is more exposed to human activities (settlements, agriculture, and tourism) compared to the more secluded Lake Tamblingan. Lake Tamblingan historically has more puras compared to Lake Buyan. Sediment samples were collected from various locations within the lakes and were analyzed using magnetic and geochemical methods. The results showed that the values of magnetic susceptibility are higher in places near Puras, especially in Lake Tamblingan. Concentrations of trace metals and REEs are also higher in the sediments of Lake Tamblingan compared to those of Lake Buyan, except for concentrations of SiO2 and Gd. These findings, along with the presence of CuO and ZnO, which were not detected in the surrounding rocks, imply that the surface sediments of Lakes Buyan and Tamblingan recorded remnants associated with religious activities. The fact that the sediments of the secluded Lake Tamblingan are more magnetic and have higher concentrations of trace metals infers that religious activities might affect the quality of lake sediments.

R004-10
D 会場 ：11/25　PM2 （15:00-18:00）
17:30〜17:45

常温保管中に起こった水熱加熱後の古土壌乾燥試料の残留磁化増加

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Remanence increases during storage for paleosol samples dried after hydrothermal heating

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地球表面岩石の風化により生成された砕屑物は水に接する環境下で生物の営みの影響を受けて変質し土壌が形成される。それに伴ない、造岩鉱物が水質変成し、二次鉱物として多種類の粘土鉱物が生成される。一方、風送塵が堆積したレス層では土壌化にともなう帯磁率の増加が起こることが分かっている。その帯磁率の増加は、石英・長石などケイ酸塩鉱物粒子の間隙水中で化学起源、生物起源の細粒酸化鉄粒子が生成されることが原因であると考えられているが、まだ実証されていない。最近、レス・古土壌層に含まれる粘土鉱物の層状珪酸塩鉱物の層間に多量のナノサイズの磁鉄鉱・赤鉄鉱粒子が発見され、それらが帯磁率増加に寄与している可能性が出てきた（Hyodo et al., 2020, JGR）。本研究では、その土壌性磁性粒子の生成過程の解明をめざし、レス・古土壌試料を使って水熱実験を行った。まず、第 1 段階として、1) 水熱加熱（200 ℃、170 ℃、150 ℃）により帯磁率が増加すること、2) 温度が高いほど増加量が大きくなること、3) 加熱時間が増すほど帯磁率も増加するが、4) 時間経過とともに一時的な減少も起こることを確認した。残留磁化強度は、長時間水熱加熱した場合を除き、ほとんど増加していない。しかし、水熱加熱後の試料を自然乾燥させて常温保管中に残留磁化が増加することを発見した。そこで、加熱時間 1〜20 時間の水熱実験を行った試料を自然乾燥し常温で保管して、7 日後、約 150 日後、約 300 日後に磁気ヒステリシス測定と等温残留磁化（IRM）成分解析を行った。その結果、飽和 IRM、magnetite 成分、hematite 成分は増加し、maghemite 成分は変化しないことが分かった。これらの結果は以下のことを示唆する。1) 水熱加熱実験直後は主に超常磁性粒子サイズ（<~25 nm）の Magnetite、Hematite が生成されて帯磁率増加をもたらす、2) その超細粒の磁性粒子が凝集して粒径が単磁区粒子サイズ以上（>~80nm）に増加して残留磁化増加に寄与する、3) これまで土壌性強磁性鉱物とみなされてきた Maghemite は非土壌性の可能性が高い。

R004-11
D 会場 ：11/25　PM2 （15:00-18:00）
17:45〜18:00

地質試料のための走査型 SQUID 顕微鏡システム：磁気画像データ処理ソフトウェアの開発

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Scanning SQUID microscope system for geological samples: Development of post-processing software on magnetic image data

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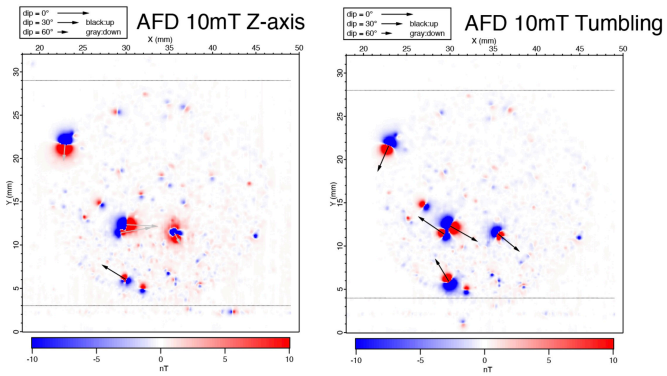
We developed a scanning superconducting quantum interference device (SQUID) microscope for imaging the magnetic field of geological samples in 2015 and have been improving. Since the development of the scanning SQUID microscope (SSM) system, various geological samples were measured including marine ferromanganese crusts, ferromanganese nodules, single grain zircon crystals, fault gauge samples, stalagmites with ultra-low magnetizations, ultramafic rocks with strong magnetization. Here, we provide details on the post-processing software ProcSQMicro that has been developed using Igor Pro since the introduction of the system. The main features are offset correction, a suite of drift corrections, flux-jumps correction, median filter, dipole fitting, dipole subtraction, upward continuation, and reduced-to-the-pole transformation. With “Advanced analyses” panel, a GUI with buttons and variable settings in ProcSQMicro used to fit dipole to a magnetic image, and subsequent subtraction. The panel also allows upward continuation, reduction-to-the-pole transformation as well as median filter. In the presentation, we demonstrate the features obtained for various geological thin sections. The figures below show examples of dipole fitting feature using SSM data obtained for a limestone sample from Miyako-jima Island. Left figure is a magnetic image for a thin section after AF demagnetization at 10 mT in Z-axis. Arrows are directions of the five largest dipoles fitted using ProcSQMicro. Black arrows are upward and gray ones are downward directions. Right figure is a magnetic image after AF demagnetization at 10 mT with tumbling. The difference in the directions of dipoles is considered as sporadic move of magnetization directions carried by multidomain magnetic minerals.



R004-P01
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

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Effects of symmetric-antisymmetric interaction on the planetary magnetic fields

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Planetary magnetic fields as well as the geomagnetic field have diversity in their morphology. Apparently asymmetric structure with respect to the equator is obvious in the fields of the Earth, Mercury, Jupiter, and so on. Such an asymmetric morphology is a result of composites of the symmetric and anti-symmetric components. The anti-symmetric field is referred to as the dipole family component, while the symmetric field is to the quadrupole family component. The axial dipole field is a typical anti-symmetric component, while the axial quadrupole is a symmetric component. Theoretically, the magnetic field of different family is decoupled, if and only if the velocity field consists solely of the equatorially symmetric component, which is supposed to be the dominant component in the Earth's core. Thus, generation processes of the dipole/quadrupole family field and its reaction to the velocity can independently be examined by suitably choosing a velocity field even in non-linear MHD (Magneto-Hydro Dynamic) models. It is well known that slight deviation in the velocity field from the equatorial symmetry by superimposing the anti-symmetric flow often results in a substantially asymmetric magnetic field like Mercury's dynamo due to non-linear coupling between the velocity and magnetic fields (Takahashi et al. 2019).

Here, we use numerical dynamo modeling to examine non-linear coupling processes between the dipole and quadrupole families. Dynamo simulations are run at the fixed parameters, where different initial conditions are used. Initial perturbations for the buoyancy are designed to drive either purely symmetric convection or asymmetric convection. We investigate behavior of the dynamo solution by varying the Rayleigh number. As a result, in some cases, substantially different dynamo solutions are obtained even at the same parameter values due to advent of non-linear coupling. In this presentation, results of our preliminary analysis for dynamos on kinetic and magnetic energy, spectra, and their dependence on the Rayleigh number will be shown and discussed.

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R004-P02
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

表皮効果が水星固有磁場に与える影響：ダイナモシミュレーションによる解析

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Influence of Skin Effect on Mercury's Magnetic Field: A Dynamo Simulation Approach

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It is thought that a stably stratified layer exists in the upper part of Mercury's outer core from its intrinsic magnetic field (e.g. Takahashi et al., 2019; Nat. Commun.). This is because higher-degree magnetic field components generated within a lower convective layer decrease selectively by skin effect within a stably stratified layer, and the magnetic field at the upper part of the core is dominated by lower-degree components. However, when estimating the depth of the intrinsic magnetic field generation using the Lowes radius —an indicator proposed by Lowes (1974; Geophys. J. Int.)—, the estimated value for Mercury is approximately half of the core radius. Importantly, the Lowes radius requires the assumption that the electric conductivity is zero above the magnetic field generating region. Still, if there is a region where the conductivity is sufficiently large such that a stably stratified layer exists over the convective layer, this assumption may not hold if a stably stratified layer with sufficiently high electrical conductivity exists above the convective layer. Therefore, when estimating the depth at which intrinsic magnetic field are generated, the magnetic field reduction by skin effect needs to be considered.

In this study, using the planetary dynamo simulation (Takahashi, 2012; J. Fluid Mech., Takahashi, 2014; Phys. Earth Planet Inter.), we try to estimate quantitatively decrease of the magnetic field by skin effect above the convective region. While it is known that the rate of magnetic field attenuation depends on its temporal frequency, but the relation between the degree of the magnetic field and its time-frequency is not obvious. Previous studies have shown a negative correlation between the degree of the magnetic field and its temporal variations by geomagnetic field analysis (Olsen et al., 2006; Geophys. J. Int.) and geodynamo simulation (Christensen and Tigner, 2004; Nature). However, a stably stratified layer is not thought to exist and the dynamo is driven only by thermal convection in those studies, so to examine a skin effect within a thermal stably stratified layer, a dynamo model driven by thermal convection with a thick thermal stably stratified layer is necessary. Therefore, using this dynamo model, we focused on estimating the relationship between the degree of the magnetic field and its attenuation within such a model.

Derived from Mercury's Lowes radius from MESSENGER's data, we considered a core structure where a stably stratified layer occupies 40%, 50%, or 60% of the outer core, and calculated the simulations with other parameters fixed. According to the results, we confirmed that a higher-degree component of the magnetic field has higher frequency, and this attenuates more in a stably stratified layer. In this presentation, we discuss the rate of skin effect to distance attenuation, a characteristic frequency of each degree, and the correlation between these and the thickness of a stably stratified layer. Moreover, we consider Mercury's Lowes radius taking skin effect into consideration.

固有磁場の特徴から，水星外核上部に安定成層が存在すると考えられており，そのコア構造モデルを用いたダイナモ計算が行われている（例えば，Takashi et al, 2019; Nat. Commun.）．これは安定成層内で起こる表皮効果によって，下部対流層で生成される磁場の高次成分が選択的に減少することで，外核上部では低次成分が支配する磁場構造が観測されることに由来する．他方で，ガウス係数を用いて固有磁場発生深度を意味する Lowes 半径（Lowes, 1974; Geophys. J. Int.）を推定すると，水星での値はコア半径の半分以下の値を示す．重要な点は，Lowes 半径が固有磁場発生領域以上は絶縁体であるという仮定のもとの値であるため，外核上部に安定成層が存在するような，対流層上部に電気伝導度が十分高い領域がある場合はこの限りではないということである．これらのことから，外核内部の固有磁場発生領域推定には，現状の Lowes 半径に加えて，水星で想定されている外核上部安定成層で起こる表皮効果による磁場減衰を考慮する必要がある．

そこで，惑星ダイナモシミュレーション（Takahashi, 2012; J. Fluid Mech., Takahashi, 2014; Phys. Earth Planet Inter.）を用いて，対流層以上における表皮効果による磁場減衰の定量化を試みた．表皮効果による磁場減衰率は磁場の時間周波数に依存していることは既知だが，磁場の次数と時間周波数の関係性は自明ではない．また，表皮効果の磁場減衰は地磁気データの解析 (Olsen et al., 2006; Geophys. J. Int.) や地球ダイナモ計算 (Christensen and Tigner, 2004; Nature) による先行研究で，次数と磁場変動のタイムスケールに逆相関を示すことがわかっているが，これらの研究では安定成層の存在を想定しておらず，かつ熱対流のみのダイナモを考えている．本研究では熱的安定成層による表皮効果について調査するために，厚い安定成層を持つ熱対流によって駆動されるダイナモモデルを用いて，磁場の次数と時間周波数の関係を新たに推定することに取り組んだ．

観測値より推定される水星 Lowes 半径をもとに，本研究でのコア構造は安定成層が外核上部の 4 割から 6 割を占めるモデルを考え，無次元パラメータなどの他の入力値は固定して計算を行った．結果より，高次ほど磁場の時間周波数が高く，安定成層内でより大きく減衰することが確認された．本講演ではさらに，コア安定成層内の磁場減衰全体に対する表皮効果による磁場減衰の割合や，磁場各次数の特徴的な変動を表す周波数と安定成層の厚さとの関連性も併せて議論する．加えて，水星における表皮効果を考慮した Lowes 半径についても議論する．

R004-P03
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

逆転頻度と地磁気双極子モーメントの関係から示唆される地磁気ダイナモの長期的サイクル

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Long-term cycle of the geodynamo revealed from relationship between reversal frequency and dipole strength

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The relationship between paleomagnetic dipole moment and geomagnetic reversal frequency on the time scale of tens of millions of years is important for understanding the behavior of the geodynamo and past core-mantle interactions. To reveal a true relationship between reversal frequency and dipole moment, it is necessary to investigate the number of data required to calculate the mean paleomagnetic field intensity because paleomagnetic field intensity (paleointensity) is highly variable. In this study, we used a Monte Carlo method to obtain a criterion for the minimum number of paleointensity data to estimate correct means. Then, we analyzed paleointensity data extracted from the PINT database (Bono et al., 2022) for each time bin, which includes 29 or more data meeting the criterion. The obtained biplots of mean or median values of virtual (axial) dipole moment (V(A)DM) versus reversal frequency revealed a cyclic relationship; (1) V(A)DM is strong when reversal frequency is low, (2) V(A)DM decreases rapidly at the beginning of a reversal frequency increase, (3) V(A)DM is weak in periods of increasing reversal frequency and high reversal frequency, and (4) V(A)DM increases rapidly at the beginning of a reversal frequency decrease. The long-term cycle is different from predictions of geodynamo models. The cycle suggests that the present geodynamo is in a period of decreasing reversal frequency towards a future superchron. The relationship between reversal frequency and dipole moment found in this study is consistent with the hypothesis that the time variation of the subduction flux controls the reversal frequency suggested by Hounslow et al. (2018). This new insight into the dynamics of the Earth's core provides us clues to understand mantle convection in the past and future.

数千万年スケールでの地磁気双極子モーメントと地磁気逆転頻度の関係は、地磁気ダイナモの挙動や過去の核-マントル相互作用を理解する上で重要である。逆転頻度と地磁気双極子モーメントの真の関係を明らかにするためには平均古地磁気強度を計算する必要がある。一方、古地磁気強度の変動は大きいため平均古地磁気強度を求めるのに必要なデータ数を調べる必要がある。本研究では、モンテカルロ法を用いて正しい平均値を推定するための古地磁気強度の最小データ数の基準を調べた。そして PINT データベース（Bono et al., 2022）から抽出した古強度データを 29 個という基準以上のデータを含む各時間ビンについて解析した。得られた仮想（地心軸）双極子モーメント（V(A)DM）の平均値または中央値の逆転頻度に対するバイプロットから、(1) 逆転頻度が低いときに V(A)DM は強く、(2) 逆転頻度が増加し始めると V(A)DM は急激に減少し、(3) 逆転頻度が増加する時期や逆転頻度が高い時期には V(A)DM は弱く、(4) 逆転頻度が減少し始めると V(A)DM は急激に増加する、という周期的な関係が明らかになった。この長期的なサイクルは地磁気ダイナモモデルによる予想とは異なる。また、このサイクルは現在の地磁気ダイナモが将来のスーパークロンに向かって逆転頻度が減少する時期にあることを示唆している。今回示唆された逆転頻度の順序は、Hounslow et al. (2018) によって示唆された沈み込みフラックスの時間変化が逆転頻度をコントロールするという仮説と一致する。今回の外核のダイナミクスに関する結果は、過去と未来のマントル対流の理解につながると思われる。

R004-P04
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

西太平洋赤道域 IODP U1490 の深海底堆積物の約 900〜1800 万年前の相対古地磁気強度

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Relative paleointensity from the Miocene section of IODP Site U1490 deep-sea sediment in the western equatorial Pacific

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We present relative paleointensity (RPI) results from the Miocene section of International Ocean Discovery Program Site U1490, and compare them with existing published RPI data from the early to middle Cenozoic. Detailed magnetostratigraphic studies are critical for providing a long-term record of Miocene RPI variations in the Equatorial Pacific. Our sample are taken from the northern part of Eauripik Rise in the western equatorial Pacific, characterized by current-controlled bedforms. Paleomagnetic measurements were conducted at a resolution of 1 cm on U-channel samples from the spliced section to obtain a high-resolution magnetostratigraphic record. Stepwise demagnetization of the natural remanent magnetization produced a well-defined magnetostratigraphy spanning approximately 9 million years, between the upper boundaries of Chron C5En (18.056 Ma) and Chron C4An (8.771 Ma), in accordance with the geomagnetic polarity timescales (GPTS: Gradstein et al., 2012) and the biostratigraphy of the cores (U1490). Rock magnetic analyses revealed that the sediments in the interval of current-controlled bedforms are suitable for reliable RPI estimates since the magnetic minerals in the sediments are mainly of biogenic origin. We found rod-shaped magnetofossils up to 1 mm in length in the sediments. Outside of this interval, reductive dissolution of magnetic minerals has occurred. Our RPI data is of exceptionally high quality, comparable to the long-term RPI record from IODP Expedition 320/321's Pacific Equatorial Age Transect (PEAT) during the early to middle Miocene, as reported by Ohneiser et al. (2013). In the presentation, we will show the comparison of our RPI records with the RPI results from Ohneiser et al. (2013) in Miocene, Channell and Lanci (2014) in late Oligocene to early Miocene, Tauxe and Hartl (1997) in Oligocene, and Yamamoto et al., (2014; 2022) in Eocene to extent global RPI stacks before 2Ma.

R004-P05
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

エチオピアアファール凹地の溶岩連続層による地磁気遷移期の古地球磁場変動の研究

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Paleomagnetic field variation during the transitional geomagnetic field from lava sequence in the Afar Depression, Ethiopia

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Reconstructing temporal changes in paleomagnetic intensity as well as paleomagnetic direction are important to better understand the variation of the Earth's magnetic field during geomagnetic reversals and geomagnetic excursions. Lava sequences, which provide a continuous record of the earth's magnetic field, are useful in reconstructing temporal changes in absolute paleomagnetic intensity. The Afar depression in Ethiopia is located at the triple junction of three expanding plates and is an area where aspects of ocean floor expansion can be seen above ground. Tendaho Graben is a 50 km wide rift formed by the extension of the Red Sea Rift propagator to the center of the Afar depression, and is dominated by normal faults with northwest-southeast strike. The cliffs created by the Tendaho Graben normal faults expose lava sequences, making this paleomagnetic records useful for studying temporal variations in paleomagnetic field variations, including those during the geomagnetic transition. Previous studies have reported the ages and paleomagnetic directions from the lavas in the Tendaho Graben. We collected samples from two sections of lava sequences (Section 1: 18 lavas; Section 2: 10 lavas) that may have recorded the Matuyama-Brunhes reversal. In addition, one section (Section 3: 5 lavas) was sampled for the 600 ka excursion reported in Kidane et al. (2003). In this study, we measured absolute paleomagnetic intensity using the Tsunakawa-Shaw method for three sections of the Tendaho Graben lava sequence. For the 18 lavas of Section 1, about 2~5 sample of each lava was measured; the results show paleomagnetic polarity changed from reverse to normal between Units 5 and 6 and it also changed normal to reverse between Units 10 and 11. Absolute paleomagnetic intensity showed a large increase between Units 6 and 7 and a decrease between Units 8 and 9.

For the 5 lavas of Section 3, measurements of 1~4 samples of each lava showed intermediate directions in five units. Of these, multiple lavas showed the similar directions as that of the 600 ka excursion reported by Kidane (2003). Absolute paleomagnetic intensity showed values below 10 μ T.

地磁気遷移期の地球磁場変動の理解を深めるためには、古地磁気強度および古地磁気方位の時間変化を復元することが重要である。溶岩連続層は、絶対古地磁気強度および古地磁気方位の時間変化を復元する上で、有用である。

エチオピアにあるアファール凹地は、3 つの拡大プレートの三重会合点にあり、海洋底拡大の様相を地上で観測することができる地域である。とくに、Tendaho Graben は、紅海リフトがアファール凹地の中央地まで延びて形成された幅 50 ㎞の地溝であり、正断層が卓越している。Tendaho Graben の正断層がつくる崖には溶岩連続層が露出しているため、地磁気遷移期を含めた古地球磁場変動の時間変動の研究に対して有益な古地磁気記録である。

これまでの研究により、Tendaho Graben の溶岩の年代や古地磁気極性の大まかな分布が分かっている。そこで、2022 年の調査では、77 万年前の松山-ブルン地磁気逆転を記録した可能性がある溶岩連続層 2 セクション（Section 1: 18 溶岩; Section 2: 10 溶岩）、Kidane et al. (2003) で報告されている 60 万年前のエクスカーションを記録した溶岩を目的に溶岩連続層 1 セクション（Section3: 5 溶岩）を対象に試料採取を行った。

本研究では、Tendaho Graben の 3 地点の溶岩連続層に対して Tsunakawa-Shaw 法による絶対古地磁気強度測定を行っている。今回の発表では、Section 1 と Section 3 の古地磁気測定の結果について報告を行う。Section 1 の 18 溶岩については各溶岩 2～5 試料の測定を行った結果、Unit 5-6 間と Unit 10-11 間でそれぞれ逆磁極－正磁極、正磁極－逆磁極の古地磁気方位の反転を示した。絶対古地磁気強度では Unit 6-7 と Unit 8-9 で大きな増減を示した。Section3 の 5 溶岩については各溶岩 1～4 試料の測定を行った結果、全 5 溶岩が中間方位を示した。複数の溶岩が Kidane(2003) が報告した 60 万年前のエクスカーションの方位と同じ方位を示した。絶対古地磁気強度は 10 μ T 以下の値を示した。

R004-P06
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

アイスランド東部に分布する溶岩群の岩石磁気学的特徴―高逆転頻度期の地球磁場変動の解明を目指して

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Rock magnetism of lava flows in eastern Iceland―Toward elucidating geomagnetic field variations during high reversal rate period

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The polarity of the Earth's magnetic field has been frequently reversing between normal polarity and reversed polarity at various time intervals. The history of these reversals has been known back to 160 million years ago (e.g. Ogg, 2020), and reversal frequency has changed with time. On the other hand, the history of variation in geomagnetic intensity and the range of variation in geomagnetic direction which change significantly even during the same polarity period, are still largely unknown.

Elucidating the variation of geomagnetic intensity and direction by focusing on the temporal evolution of reversal frequency is important for a deeper understanding of the essential property of the earth dynamo that produces the large-scale earth magnetic field.

The reversal frequency is the highest since the Cretaceous, especially around 11 Ma, with a frequency of 4.7 reversals per million years (the high reversal rate period). Paleomagnetic direction variations including this period have been reported from lava sequences in eastern Iceland (Kristjansson et al., 1995), where lava with intermediate polarity is relatively common. We have total of 66 lava samples with clear stratigraphic relationships were systematically collected from two new adjacent sections (lava sequences) and are working to elucidate the geomagnetic variation during the high reversal rate period. To date,we have completed stepwise AF demagnetization analysis and stepwise thermal demagnetization analysis for each of the four lava samples. As a result, it is becoming apparent that the virtual geomagnetic poles (VGP) tended to vary over a much lower latitudinal range than at present, and the possibility that the earth dynamo at that time may have been of a relatively low polar stability property was reported in Koremura et al. (2024JpGU).

In this study, magnetic hysteresis measurements and thermomagnetic analysis of samples from two sections of 66 lava masses are carried out to verify the reliability of these palaeomagnetic direction records and to obtain basic information for sample selection for future palaeomagnetic intensity analysis. So far, we have been completed for a group of samples from one section. On the Day-Plot (Day et al., 1977), which prepared on the basis of the measurement results, The data points were distributed in that the ratio of coercive force to remanent magnetisation coercivity (Hcr/Hc), ranges from 1.66 to 3.64, and the ratio of saturation remanent magnetization to saturation magnetization (Mrs/Ms), range from 0.05 to 0.31, in addition, the distribution tended to be concentrated on and near the SD-MD mixing curve. We will further analysis and report a series of rock magnetic features.

地球磁場の極性は，正極性と逆極性との反転を様々な時間間隔で頻繁に繰り返してきた．その逆転史は過去 1 億 6000 万年前頃までについて明らかになっており (e.g. Ogg, 2020)，逆転頻度は時間とともに変化してきたことが分かっている．一方で，地磁気強度の変動史や，同一極性期間中にも大きく変化する地磁気方位の変動幅などについては未解明な部分が多い．逆転頻度の時間変遷に着目して，地磁気強度変化，地磁気方位の変動幅を解明することは，大規模な地球磁場を作り出す地球ダイナモの本質的な性質を深く理解するために重要である．

逆転頻度は，白亜紀以降では特に 11 Ma 頃が最も高く，4.7 回/百万年である (以下，高逆転頻度期)．この期間を含む古地磁気方位変動については，アイスランド島東部の溶岩層序群からの報告 (Kristjansson et al., 1995) があり，中間極性を記録した溶岩が頻出するセクションが存在する．我々は，そのセクションに近接する 2 つのセクションを新たに選定し，時間的前後関係が明確な計 66 枚の溶岩群から試料を系統的に定方位採取して各種分析を行うことで，高逆転頻度期の地球磁場変動の解明に取り組んでいる．これまでに，各溶岩 4 試料の段階交流消磁分析と段階熱消磁分析を完了させ，予察的な古地磁気方位変動の様子を明らかにした．その結果，仮想地磁気極 (VGP) は現在と比べてかなり低い緯度帯の範囲で変化していた傾向が見えつつあり，当時の地球ダイナモは比較的極性安定度が低い性質を帯びていた可能性があることを，惟村ほか (2024JpGU) で報告した．

現在我々は，これらの古地磁気方位記録の信頼性を検証することと，将来の古地磁気強度分析のための試料選定の基礎情報を得ること等を目的に，2 つのセクションの計 66 枚の溶岩群からの試料の磁気ヒステリシス測定と熱磁気分析を行っている．これまでに，1 つのセクションからの試料群については磁気ヒステリシス測定を完了させた．測定結果に基づいて作成した Day-Plot(Day et al.,1977) 上では，残留磁化保磁力と保磁力の比である Hcr/Hc は 1.66～3.64 の範囲，飽和残留磁化と飽和磁化の比である Mrs/Ms は 0.05～0.31 の範囲で分布し，SD-MD 混合曲線上およびその付近に集中して分布する傾向があることが分かった．今後さらに分析を進め，一連の岩石磁気的特徴について報告する．

R004-P07
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

小笠原諸島・西之島における 2017 年および 2019〜2020 年の噴火で形成された溶岩の古地磁気強度分析・岩石磁気分析

#与謝野 勲 [1)], 山本 裕二 [1)], 多田 訓子 [2)], 前野 深 [3)], 武尾 実 [3)]
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Paleointensity and rock magnetic analyses of lavas formed by the 2017 and 2019-2020 eruptions on Nishinoshima, Ogasawara Islands

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Nishinoshima, a volcanic island located in the Ogasawara Islands of Japan, has been experiencing active eruptions accompanied by lava flows since 2013. During the first eruptive phase (Episode 1, 20132015), a volcanic cinder cone approximately 2 km in diameter and 140 m in height was newly formed, expanding the island's area to about 12 times that of the 1973-1974 eruption (Maeno et al., 2016). This was followed by the second phase (Episode 2, 2017) and the third phase (2018), and the subsequent fourth phase(Episode 4, 2019-2020) was more intense Strombolian eruptions and continuous phreatic explosions compared to previous eruptions. This is presumed to be due to the supply of deep magma, rich in volatile components, to a shallow magma chamber (Kaneko et al., 2021).

Lava acquires thermoremanent magnetization (TRM) during its formation (cooling), and the remanent magnetization intensity is proportional to the strength of the external magnetic field at the time of cooling. This external magnetic field is fundamentally considered to be the large-scale intrinsic geomagnetic field originating from the outer core, and the distribution of the geomagnetic field on Earth since 1900 can be calculated using the International Geomagnetic Reference Field
(IGRF) model. The latest model is IGRF-13 (Alken et al., 2021), and the "model total magnetic force values" for Nishinoshima from 2013 to 2020 can also be calculated. Therefore, by applying the absolute paleo intensity (API) estimation method to the Nishinoshima lava and comparing the results with the "model total magnetic force values," it is possible to assess the reliability of the API estimation method.

To date, the reliability of API estimation using the Tsunakawa-Shaw method has been assessed for several "historical lavas" associated with volcanic eruptions since 1900. For "historical lavas" in the Japanese archipelago, examples of research include the study on the 1914 and 1946 andesitic lavas from Sakurajima volcano (Yamamoto and Hoshi 2007). For Nishinoshima lava, the Episode 1 lava has been studied, with an API estimated value of 41.3 $\pm$ 4.4 μ T, which was accurately estimated to match the "model total magnetic force value" of 41.7 μ T for the Nishinoshima area during
2014-2015 (Yamamoto et al., 2021, SGEPSS).

In this study, we further examine Episode 2 and 4 lavas. Specifically, API estimation using the "Tsunakawa-Shaw method" and rock magnetic analyses such as room-temperature hysteresis measurements and thermomagnetic analyses are conducted. For the Episode 2 lava, six block samples collected from the southwestern coast of Nishinoshima are used. For the Episode 4 lava, five block samples collected from the northeastern coast are used. From these blocks, mini-core samples (1 inch in diameter) were cut into columns and further shaped into specimens. API estimation was then performed using the TsunakawaShaw method. Additionally, chip fragments were cut from each specimen for magnetic hysteresis and thermomagnetic analyses. So far, API values have been estimated from five block samples of the Episode 2 lava. The average values and standard deviations are 44.3 $\pm$ 2.4 μ T, 39.0 $\pm$ 4.1 μ T, 35.4 $\pm$ 1.3 μ T, 41.2 μ T, and 42.6 $\pm$ 1.8 μ T, with the overall mean and corresponding standard deviation being 40.5 $\pm$ 3.4 μ T. Magnetic hysteresis analyses show that both the Episode 2 and Episode 4 lavas exhibit a certain spread on the Day-Plot, but no significant differences were observed. Thermomagnetic analyses indicated the presence of titanomagnetite in both the Episode 2 and Episode 4 lavas, as evidenced by the thermomagnetic (Js-T) curves. Further analysis will be conducted to assess the reliability of the API estimation, considering the rock magnetic properties.

西之島は日本の小笠原諸島に位置する火山島であり，2013 年以降，溶岩流を伴う活発な噴火活動が続いている．第 1 期噴火（2013〜2015 年）では，直径約 2 km，高さ約 140 m の火山砕屑丘が新たに形成され，島全体の面積が 1973〜1974 年の噴火以前の旧島と比べて約 12 倍となった（Maeno et al., 2016）．第 2 期噴火（2017 年），第 3 期噴火（2018 年）と引き続き, 最新の第 4 期噴火（2019 年〜2020 年）では，従来の噴火と比べて激しいストロンボリ式噴火，並びに継続的な水蒸気爆発が観測され，これは揮発性物質を多く含む深部マグマが浅部のマグマ溜まりに供給されたことによるものと推定されている（Kaneko et al., 2021）．

溶岩は形成時（冷却時）に熱残留磁化を獲得し，残留磁化強度は冷却時の外部磁場の強度に比例する．その外部磁場は，基本的には外核起源の大規模固有磁場であると考えられ，地球における 1900 年以降の固有磁場の分布は国際標

準地球磁場モデル (International Geomagnetic Reference Field, IGRF) で算出できる．最新モデルは IGRF-13(Alken et al., 2021) であり，西之島の位置における 2013〜2020 年の「モデル全磁力値」も算出することができる. 従って，西之島溶岩に古地磁気強度絶対値 (Absolute Paleo Intensity, API) 推定法を適用し，その結果を「モデル全磁力値」と比較・検討することで，API 推定法の信頼性を検証することができる.

これまでに，1900 年以降に起こった数々の火山噴火に伴う「歴史溶岩」を対象に，綱川-ショー法による API 推定の信頼性の検証が行われてきた．日本列島の「歴史溶岩」では，桜島火山 1914 年と 1946 年の安山岩溶岩を対象とした研究例 (Yamamoto and Hoshi 2007) などがある．西之島溶岩については第 1 期噴火溶岩を対象に行われ，API 推定値として 41.3 ± 4.4 μ T が得られ, 西之島の位置における 2014-2015 年の「モデル全磁力値」である 41.7 μ T を精度良く推定できていると報告されている（山本ほか,2021SGEPSS）.

本研究では，さらに第 2 期および第 4 期噴火溶岩を対象として検証を行う．具体的には「綱川・ショー法」による API 推定と，常温ヒステリシス測定や熱磁気分析などの岩石磁気分析を行う．まず，西之島の南西岸より採取された第 2 期溶岩のブロック試料 6 個と，北東岸から採取された第 4 期溶岩ブロック試料 5 個から直径 1 インチのミニコア試料群を柱状に切り出し，さらにそれぞれ試片に整形した．これらに対して，綱川-ショー法を適用して API 推定を行った．また，各試片からチップ片も切り出し，磁気ヒステリシス分析と熱磁気分析を行った．これまでに，第 2 期溶岩については 5 個のブロック試料から API 推定値が得られている．平均値と標準偏差はそれぞれ 44.3 ± 2.4 μ T，39.0 ± 4.1 μ T，35.4 ± 1.3 μ T，41.2 μ T，42.6 ± 1.8 μ T であり，全平均と対応する標準偏差は 40.5 ± 3.4 μ T である．磁気ヒステリシス分析からは，第 2 期溶岩と第 4 期溶岩はともに Day-Plot 上で一定の広がりをもった分布を示すが，大きな違いは見られなかった．熱磁気分析からは，第 2 期溶岩と第 4 期溶岩に共通してチタノマグネタイトの存在を示唆する熱磁化（Js-T）曲線が確認された．今後，さらに分析を進め，岩石磁気特性も踏まえた，API 推定の信頼性の検証を行う．

R004-P08
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

最新データセットを用いた北西太平洋の中生代における磁気異常縞模様の再検討

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Revising Mesozoic magnetic anomaly lineations in the northwestern Pacific Ocean using updated data

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We revised Mesozoic magnetic anomaly lineations in the northwestern Pacific Ocean using the latest geomagnetic data. There are five magnetic anomaly lineation sets exist in the northwestern Pacific Ocean (Nakanishi et al., 1992). Several studies revised the magnetic anomaly lineations in the special areas (e.g., Nakanishi and Winterer, 1998; Nakanishi et al. 1999, 2015; Nakanishi, 2011).

The data used in this study are composed of total geomagnetic field data by surface-towed magnetometers and vector geomagnetic data by shipboard vector magnetometers. The geomagnetic data are obtained from the databases of Japan Agency for Marine-Earth Science and Technology and National Centers for Environmental Information/National Oceanic and Atmospheric Administration (NCEI/NOAA). We calculated magnetic anomalies using Comprehensive Model 4 (CM4, Sabaka et al. 2004) and International Geomagnetic Reference Field (IGRF, Alken et al., 2021).

We revised magnetic anomaly lineations in several regions (e.g., around the Shatsky Rise, Japan and Kuril trenches). Our examination of multibeam data southeast of the Shatsky Rise found elongated topographic structures like abyssal hill fabric, which strike is different from that of magnetic anomaly lineations. The discrepancy in strike is due to propagating rifts or overlapping spreading centers. We found that the strike of Hawaiian lineation set changed before M12 (135 Ma), although Nakanishi et al. (1989) proposed that the change M12 and M10 (130 Ma).

最新のデータセットを使用して北西太平洋に存在する中生代の磁気異常縞模様を再検討した。北西太平洋には日本縞模様群、ハワイ縞模様群、中部太平洋海山群縞模様群、マゼラン縞模様群、フェニックス縞模様群の 5 つの磁気異常縞模様群が存在する（例えば、Nakanishi et al., 1992）。Nakanishi et al. (1992) 以降、日本海溝付近（Nakanishi, 2011）、シャツキーライズ付近（Nakanishi et al., 1999; 2015）、オントンジャワ海台近傍（Nakanishi et al., 2019）など局所的には縞模様は再検討されたが、再検討されていない場所も広く存在する。本研究では、最新のデータセットを使って、まだ再検討されていない海域の磁気異常縞模様を同定した。本研究で用いたデータは曳航式磁力計で取得された全磁力データと船上三成分磁力計で取得された地磁気データである。

全磁力データから磁気異常を算出するために用いた標準磁場は Comprehensive Model 4 (CM4, Sabaka et al, 2004) と国際標準磁場 (International Geomagnetic Reference Field: IGRF) の最新版 (Alken et al., 2021) である。

これまでの解析によって、いくつかの海域において、磁気異常縞模様を再同定した。本報告では、シャツキーライズの南東に存在するハワイ縞模様群の磁気異常縞模様の再同定結果を主に報告する。この海域では、先行研究で同定された磁気異常縞模様の走向がアビサルヒルのような線状の海底地形の走向と一致していないことを発見した。この走向の違いは、伝播性中央海嶺あるいは重複拡大軸によるものであると考えられる。また、先行研究ではハワイ縞模様群において磁気異常番号 M12 (135 Ma) から M10 (130 Ma) の間で磁気異常縞模様の走向が変化したとされていたが、本研究結果からは、M12 以前から磁気異常縞模様の走向の変化が起こっていたことが判明した。

R004-P09
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

東南極，リュツォ・ホルムス湾沿岸域のスカレビークハルセン地域に分布するリュツォ・ホルム岩体に対する古地磁気解析

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Paleomagnetic analyses on the Lutzow-Holm Complex at Skalevikshalsen in the coastal area of Lutzow-Holm Bay, East Antarctica

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East Antarctica is one of key cratons in the formation history of supercontinents during the Earth history. Although East Antarctica had been considered to behave as a single craton in the period from the break-up of Rodinia to the formation of Gondwana continent, tectonic blocks belonging to other cratons of Gondwana members have been suggested in East Antarctica, and East Antarctica craton has been considered to have formed during the formation process of the Gondwana continent at about 550-500 Ma (e.g., Boger, 2011). The Lutzow-Holm Complex (LHC), exposing sporadically along the coast of Enderby Land between longitudes 39ºE and 45ºE in East Antarctica, is a metamorphic belt of amphibolite to granulite facies. The LHC provides geochronological data of about 500 Ma, indicating that the LHC had suffered the Pan-African orogenic event related to the amalgamation of Gondwana members. The number of paleomagnetic data has been still rare from the LHC as well as East Antarctica, and previous paleomagnetic data from East Antarctica has supported the amalgamation event. Paleomagnetic analyses has been performed on the LHC re-examine tectonic movements in East Antarctica during the amalgamation process, and paleomagnetic results from Skalevikshalsen (SVH) in the southern coastal area of Luzow-Holm Bay will be presented.

The metamorphic grade of the LHC decreases progressively eastward from granulite to amphibolite facies. Based on protolith ages by U-Pb dating analyses, geological subdivisions are proposed in the LHC (Dunkley at al., 2020). SVH is included in SKV unit, located north of RVG unit including Rundvagshetta (RH) in the southernmost area of Luzow-Holm Bay, which shows the highest metamorphic grade. Samples for paleomagnetic analyses were collected at 27 sites of granitic gneisses (Grgg: 11 sites), granodioritic gneisses (Gdg: 13 sites) and granodioritic dikes (3 sites).

Progressive thermal demagnetization analyses provided characteristic remanent magnetic components (ChRMs) carried by magnetite, which were isolated in high temperature levels between 500 and 590ºC, from samples at 4 sites of Grgg and 7 sites of Gdg. Mean directions of Grgg and Gdg were consistent, and an over-all mean of the 11 sites (D=334.8º, I=63.7º, alpha-95=2.6º) was regarded as a characteristic paleomagnetic direction from SVH.

A virtual geomagnetic pole (VGP) of the ChRM from SVH is close to VGPs of the ChRM s from RH in RVG unit, Langhovde (LH in LHV unit) and Ongle Islands (OG in LHV and EOG units) in the LHC, and is located close to mean paleomagnetic poles of 510 and 500 Ma in the synthetic apparent polar wonder path for East Antarctica (East Gondwana) proposed by Torsvik et al. (2008). According to geochronologic data of RH (518 Ma of zircon U-Pb age and 500 Ma of hornblende K-Ar age), it is implied that the ChRM of SVH, as well as the ChRMs of RH, LH and OG, was acquired at 510-500 Ma in the cooling process from the peak metamorphic stage in the LHC associated with the formation of East Antarctica. It may be suggested that no significant differential tectonic movements have undergone among the subdivided units of the LHC in the coastal region of Luzow-Holm Bay since the formation of East Antarctica.

R004-P10
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

西フィリピン海盆における磁気異常縞模様の再検討

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Reidentification of the magnetic anomaly lineations in the West Philippine Basin

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The West Philippine Basin is believed to have formed by back-arc spreading originated by the subduction of the Pacific Plate ˜52 Ma (Ishizuka et at., 2015). Though Hilde and Lee (1984) identified the magnetic anomaly lineations throughout the basin, some of which identified predate the age of the Pacific Plate subduction. This is inconsistent with the process of back-arc spreading caused by plate subduction, and is not sufficient to explain the formation process of the basin. For this reason, it is necessary to newly identify magnetic anomaly lineation in the West Philippine Basin. Although partial reidentification has been so far, reidentification through the basin has not been sufficient.

We created a magnetic anomaly contour map of the entire basin using geomagnetic total force to identify magnetic anomaly lineations. Crossover errors was reduced by the method of Ishihara (2015). In addition, we used the geomagnetic reversal chronology of Ogg (2020) to identify the magnetic anomaly lineations.

The identification results showed that the oldest magnetic anomaly lineations is magnetic anomaly number 20r (˜50 Ma). This age supports the theory that the West Philippine Basin began to open due to the Pacific Plate starting to subduct under the Philippine Sea Plate ˜52 Ma.

西フィリピン海盆は，52 Ma 頃に太平洋プレートがフィリピン海プレートの下に沈み込み始めたことに起因する背弧拡大によって形成されたとされている (Ishizuka et al., 2015)．海盆内にある中央海盆断層 (CBF) の走向や観測される磁気異常縞模様の分布から，CBF を中心に対称的に拡大した形跡が見られる．Hilde and Lee (1984) は海盆内全体の磁気異常縞模様を特定したが，同定した磁気異常縞模様の中に太平洋プレート沈み込み開始の年代よりも前のものがある．これはプレートの沈み込みによって引き起こされる背弧拡大のプロセスに矛盾し，海盆の形成過程を説明するのに十分な結果とは言えない．このようなことから新たに西フィリピン海盆における磁気異常縞模様を同定する必要がある．これまで部分的な再検討は行われてきているが，海盆全体では再検討が十分ではない．

本研究では曳航式磁力計で取得された全磁力データを使用して海盆全体の磁気異常コンタ図を作成し、磁気異常縞模様の再検討をおこなった。クロスオーバーエラーの軽減には Ishihara (2015) の手法を用いた。また、磁気異常縞模様の同定には Ogg (2020) の地磁気逆転年表を使用した。

同定結果から、一番古い磁気異常縞模様は、磁気異常番号 20r (約 50 Ma) である．この年代は、52 Ma 頃に太平洋プレートがフィリピン海プレートの下に沈み込みを開始したことにより、西フィリピン海盆が形成開始したという説 (Ishizuka et al., 2015) を支持する。

R004-P11
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

古地磁気強度変動を用いたシャツキーライズ南方海域堆積物コアの年代推定

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Dating the Southern Shatsky Rise Marine Sediment Cores Using Paleomagnetic Intensity Variability

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Nutrient supply mechanisms associated with turbulent and upwelling flows in the southern oligotrophic zone of the Shatsky Rise, the oldest extant marine plateau, have been the focus of much attention. Four piston cores (PC01-04) were obtained from the vicinity of Shatsky Rise on research cruise KH-24-1 to clarify the time variations of behavior of upwelling and bottom current and the distribution of nutrients. Now, their ages need to be determined.

We therefore performed paleomagnetic measurements on PC02, a 1144.6 cm long core collected from 4352 m depth. The main lithology of the sediments is nannofossil ooze and clay alternating on the meter scale, with varying amounts of diatoms and volcanic ash. The sediment is moderately to heavily bioturbated throughout the core. The color of the sediment corresponds to lithological variation, with yellowish brown in clay-rich parts, whereas yellowish gray or grayish yellow in nannofossil-rich parts. For paleomagnetic measurements, samples from Section 1 were collected using cubes, while those from Sections 2-12 were collected using u-channels. Variations of intensity, declination, and sagittal inclination are recovered by stepwise AF demagnetization of natural remanent magnetization, and variations of magnetite content are also recovered from anhysteretic remanent magnetization. Cube samples were measured using a spinner magnetometer, while u-channel samples were measured continuously using a pass-through magnetometer. The results of the natural remanent magnetization measurements show that the declination does not change abruptly through the core and the inclination takes a roughly constant value. Therefore, the entire core sample is considered to have been deposited during the Brunhes chron, i.e., younger than 0.77 Ma.

In the presentation, we will present results of age estimation of this core by comparing the paleomagnetic intensity variations with a known variation curve (SINT-800) based on normalized natural remanent magnetization. In addition, nannofossil oxygen isotope ages will also be presented.

巨大な海洋高原であるシャツキーライズの南方貧栄養域における乱流・湧昇流に伴う栄養塩供給機構が注目されている。湧昇流、底層流の挙動や栄養塩の分布の時間変動を明らかにするために研究航海 KH-24-1 ではシャツキーライズ周辺から 4 本のピストンコア（PC01-04）が得られた。現在このコアの年代決定が必要とされている。

そこで私はこのうち PC02 についての古地磁気測定を行った。PC02 は水深 4352 m から採取した全長 1144.6 cm のコアである。堆積物の主要な岩相はナノ化石軟泥と粘土がメートルスケールで互層したもので、珪藻や火山灰が様々な量で含まれている。堆積物はコアを通じて中程度〜激しく生物擾乱されている。堆積物の色は岩相変化に対応しており、粘土に富む部分では黄褐色であるのに対し、ナノ化石に富む部分では黄灰色または灰黄色である。古地磁気測定のために、セクション 1 の試料はキューブを用い、セクション 2〜12 は u チャネルを用いて採取した。自然残留磁化の段階交流消磁により強度、偏角、伏角の変動を復元し、非履歴性残留磁化から磁鉄鉱含有量の変動も復元した。キューブ試料はスピナー磁力計を用いて測定を行い、u チャネル試料はパススルー型磁力計で連続的に測定を行った。自然残留磁化の測定結果から、コアを通じて偏角が急激に変化しておらず伏角がおおよそ一定の値を取ることがわかる。そのため、このコア試料は全体がブリュンヌ正磁極期に堆積したと考えられ、すなわち 77 万年前よりも若いといえる。

発表では規格化した自然残留磁化から古地磁気強度変動を既知の変動曲線（SINT-800）と比べて本コアの年代推定を行った結果、また有孔虫酸素同位体年代についても報告を行う。

R004-P12
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

古地磁気・岩石磁気学的手段による被熱遺物の熱履歴の復元

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Reconstruction of thermal history of heated artifacts by paleomagnetic and rock magnetic methods

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Among archaeological artifacts and remains, if the maximum temperature of a heated artifact is below the Curie point of the magnetic minerals contained, it is possible to use paleomagnetic techniques (stepwise thermal demagnetization) to determine the blocking/unblocking temperature and investigate the temperature at which it was secondarily heated and its thermal history. It is also possible to obtain information about heat exposure in the past using rock magnetic techniques.

In this study, we used paleomagnetic measurement with the stepwise thermal demagnetization method and measurement of the magnetic susceptibility at each thermal stage to examine whether the tiles of Omi Sakamoto Castle (1571-1586) in Otsu City, Shiga Prefecture, may have been heated during the fall of the castle after the Honno-ji Incident in 1582.

As a result, some of the tiles known as “damaged tiles” showed signs of secondary heating at around 400 ℃ (the primary heating was when the tiles were made). In addition, one of the undamaged tiles showed evidence of insufficient firing (either the temperature did not reach a high enough level or the time it reached that level was short). The results are compared with estimates of the temperature reached using the separate infrared stimulated luminescence method (IRSL), and the question of whether there was secondary heating is discussed.

考古遺物や遺構のうち、熱を受けているもの（被熱遺物）はその最高温度が含有磁性鉱物のキュリー点以下であった場合、古地磁気学的手法（段階熱消磁法）を用いてブロッキング温度を選り分け、そこから加熱された温度やその履歴を調べることができる。また、岩石磁気学的手法を用いても過去に被った熱に関する情報を得ることができる。

今回我々は、滋賀県大津市の近江坂本城（1571～1586）の瓦について段階熱消磁法による古地磁気測定と各熱段階での初磁化率の測定を用いて、1582 年の本能寺の変後の落城時に熱を受けた可能性があるかを検証した。

その結果、「被災瓦」と呼ばれる瓦の一部については、400 ℃前後での 2 次加熱 (1 次加熱は瓦の作成時) の痕跡が確認された。また、非被災瓦のうち 1 つは、不十分な焼成（高温まで温度が達していないか、達した時間が短い）の証拠が見つかった。結果を別途行った赤外線ルミネッセンス法による到達温度推定とも比較し、2 次的な加熱があったかについて議論する。

R004-P13
ポスター 4 ：11/26　AM1/AM2 （9:00-12:00）

ベトナム中部トゥーボン川下流平野堆積物の磁気特性に関する基礎研究

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Fundamental research on the magnetic properties of sediments from the lower reaches of the Thu Bon River in central Vietnam

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Duy Xuyen District, Quang Nam Province, an administrative region in central Vietnam, is located in the lower reaches of the Thu Bon River. The district is home to the political center of Tra Kieu, the religious center of My Son, and the economic center of Hoi An, the capital of the Champa Kingdom that flourished from the 2nd to the 15th century. In March 2024, a drilling survey was conducted in Duy Xuyen Province to clarify the stratigraphy of the sediments around the Tra Khu city walls and their formation environment, with the aim of understanding the environmental characteristics of the site of Tra Khu, the early royal capital of the Champa Kingdom. In this study, we performed measurements of (1) natural remanent magnetization (NRM), (2) anhysteretic remanent magnetization (ARM), and (3) anisotropy of magnetic susceptibility (AMS) on a total of 83 cubic samples collected from a drill core at approximately 15 m depth, and provided fundamental considerations on the formation age and environment of the sediments at each depth. The following characteristic behavior was observed in some of the magnetic parameters obtained as a result of this study. First, it was observed that the inclination obtained from the NRM measurements generally varied around 40^o. The inclination around Duy Xuyen calculated from the global field model also varies around 40^o, thus it is very likely that the inclination recorded in the core accurately reflects the paleomagnetic direction change. Next, it was observed that the ARM intensity, which reflects the difference in the types of minerals contained in the sediments, decreased from 15 m to 3 m and increased from 3 m to the surface. These patterns of variation may reflect some kind of environmental change or the change in the source of sediments. Next, it was observed that the trend of increasing or decreasing value of median demagnetization field of the ARM (MDF_{ARM}), which reflects differences in sediment grain size, changed at depths of 5 m, 3 m, and 1 m. These changing trends may also reflect the change in the source of sediments.

ベトナム中部の行政区であるクアンナム省ズイスエン県は、トゥーボン川の下流平野に位置し、2 世紀から 15 世紀頃にかけて栄えたオーストロネシア語族系民族による王国、チャンパ王国の政治的センターであるチャーキュウ、宗教的センターであるミーソン、経済的センターであるホイアンを擁する地域である。2024 年 3 月、ズイスエン県において、チャンパ王国の初期王都・チャーキュウ城市の立地の環境的特性の理解を念頭に、チャーキュウ城壁周辺の堆積物の層序とその形成環境を明らかにすることを目的とするボーリング調査が実施された。本研究では、約 15 m のボーリングコアから採取された計 83 個のキューブ状試料に対して（1）自然残留磁化（NRM）測定、（2）非履歴性残留磁化（ARM）測定、（3）帯磁率異方性（AMS）測定を実施し、各深度の堆積物の形成年代と形成環境に関する初歩的考察を行った。本研究の結果として得られたいくつかの磁気パラメータにおいては、次のような特徴的な挙動が観察された。まず、NRM 測定によって得られた伏角が、全体的に 40° 周辺で変動していることが観察された。全球的磁場モデルに基づいて計算されたズイスエン県周辺における伏角も同様に 40° 周辺で変動していることから、ボーリングコアが記録する伏角は、古地磁気方位変動を正しく反映している可能性が高いと考えられる。次に、堆積物中に含まれる鉱物の種類の違いを反映する ARM 強度の値が、深度 15m から 3m にかけて減少し、3m から表層にかけて増加していることが観察された。これらの変動パターンは、何らかの環境変動や堆積物の供給源の変化を反映している可能性がある。続いて、堆積物の粒子サイズの差を反映する ARM の磁化半減磁場（MDF_{ARM}）の値の増加または減少の傾向が、5m・3m・1m の各深度を境に変化していることが観察された。これらの傾向の変化もまた、堆積物の供給源の変化を反映している可能性がある。