R004-01
C 会場 ：9/26　AM1 （9:00-10:30）
9:00〜9:15

#佐藤　雅彦[1,2], 潮田　雅司[3], 中田　亮一[4], 田村　裕二郎[5], 山本　伸次[5], 小澤　一仁[1], 高橋　太[6], 坂田　遼弥[7], 関　華奈子[1]
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Strong magnetic anomalies record the weak dynamo field of ancient Mars

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Magnetic field observations of the Mars Global Surveyor revealed that there are strong magnetic anomalies arising from the crustal remanences (Acuna et al. 1999, Science), which is estimated to be about 10 times as strong as the Earth's crustal magnetization (Voorhies et al., 2002, JGR). The strong crustal remanences require the particular origin such as the strong dynamo field of the ancient Mars, the high concentration of ferromagnetic mineral in the Martian crust, and so on. However, the origin of strong remanence has not been fully understood. Plagioclase crystals sometimes contain fine-grained magnetite inclusions as the results of exsolution at subsolidus condition (Feinberg et al., 2005, Geology), and the natural remanent magnetization carried by the exsolved magnetite crystals in plagioclase is most likely candidate of the source of Martian magnetic anomaly in terms of the remanence stability and crystallization process (Sato et al. 2018, GRL). In this study, to estimate the paleo-planetary field intensity of Mars based on the crustal remanence records, the magnetic hysteresis measurement combined with microscopic observation and synchrotron radiation study for the single-plagioclase crystals, the remanence acquisition/demagnetization measurements for the assemblages of plagioclase crystals, and the fractional crystallization trend calculations using a rhyolite-MELTS program were conducted. The experimental and calculation results indicate that the Martian crustal rock contains the high-concentration of exsolved magnetite and the exsolved magnetite efficiently acquires the thermoremanent magnetization, resulting in the high remanence acquisition efficiency of the Martian crust.

R004-02
C 会場 ：9/26　AM1 （9:00-10:30）
9:15〜9:30

惑星ダイナモ計算に基づく水星 Lowes 半径とダイナモ半径の比較

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Comparison between Mercury's Lowes radius and dynamo radius based on planetary dynamo simulation.

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MESSENGER (Mercury, Surface, Space Environment, Geochemistry, and Ranging) was the first spacecraft to enter Mercury's orbit. Based on these data, the Gauss coefficients of Mercury's intrinsic magnetic field was also estimated. The small intensity of Mercury's intrinsic magnetic field compared to its large metallic core has led to the proposal of an internal structure with a stably stratified layer (Christensen, 2006), and dynamo simulations based on this structure have recently reproduced the northward offset of Mercury's surface magnetic field (Takahashi et al., 2019).

The Mauersberger spectrum, which means the energy density spectrum of the potential magnetic field, is obtained from the Gauss coefficient, and the Lowes radius estimated from the slope corresponds to the radius of the equivalent current sphere, or the radius of the dynamo region. Earth's Lowes radius is close to the CMB (core-mantle boundary) radius, but the CMB radius for Mercury determined by magnetic field induced by Mercury's core in response to external magnetic field changes (Katsura et al., 2020) and geodetic studies (Genova et al., 2019) is approximately 2000 km, while the Lowes radius of Mercury estimated from the Gauss coefficient of Mercury's intrinsic magnetic field (Anderson et al., 2019) is just under 900 km (Yagi and Toh, 2023).

Jupiter's intrinsic magnetic field is calculated using dynamo simulation of the liquid metal-hydrogen layer, and energy spectrum from the calculated field is compared with the Mauersberger spectrum of the observed field. It is argued that the Lowes radius gives a lower limit for the dynamo radius.

In this study, we examine the effect of the stably stratified layer above the outer core on the intrinsic magnetic field generated in the dynamo region based on Mauersberger spectra obtained from numerical Mercury dynamo calculation (Takahashi and Shimizu, 2012). The dynamo calculations were performed using a double-diffusion convection model for a rotating spherical shell conductive incompressible Boussinesq fluid. In a previous study by Yagi and Toh (2023), the thickness of the outer core convective layer was varied in the Mercury dynamo calculations, and it was found that the Lowes radius remained relatively constant at approximately 1000 km. However, that calculation did not calculate a sufficient time for the magnetic diffusion time, and the calculation time was improved in this study.

The attenuation of the magnetic field due to skin effects by the stably stratified layer is discussed using dynamo calculations for different convection layer radii, and we discuss quantitatively the variation of the slope of the magnetic field energy spectrum in the region above the convection layer and that of the spectrum with convection layer radius, as done in Tsang and Jones (2019). We research the convective layer radius inside Mercury that is consistent with the observed Lowes radius of Mercury and report the results.

MESSENGER (Mercury, Surface, Space Environment, Geochemistry, and Ranging) は水星の周回軌道に初めて投入された探査機であり、惑星電磁気学的にはベクトル磁場観測データを用いて水星固有磁場のガウス係数も推定されている（Anderson et al., 2012）。水星固有磁場強度がその大きな金属核に比べて小さいことから、外核上部が成層している内部構造が提唱され（Christensen, 2006）、最近ではそれに基づくダイナモシミュレーションによって、北側にオフセットした水星表面磁場が再現されている（Takahashi et al., 2019）。

また、ガウス係数を用いて磁場の平均エネルギー密度スペクトルである Mauersberger スペクトルを求め、その傾きから惑星磁場の等価電流球半径、すなわちダイナモ半径に相当する Lowes 半径を推定することができる（Lowes, 1974）。地球の Lowes 半径は CMB（コア-マントル境界）半径に近い値となるが、外部の磁場変化に対して水星コアにより誘導される磁場（Katsura et al., 2020）や、測地学的研究（Genova et al., 2019）により求められた水星の CMB 半径がおよそ 2000km である一方で、水星固有磁場のガウス係数（Anderson et al., 2019）から求められる水星の Lowes 半径は 900km 弱（Yagi and Toh, 2023）である。

そして木星においては、液体金属水素層のダイナモシミュレーションを用いて固有磁場を求め、得られた磁場から計算されるエネルギースペクトルと観測磁場の Mauersberger スペクトルを比較して、Lowes 半径はダイナモ半径の下限を与えるという議論が行われている（Tsang and Jones, 2019）。

本研究では、外核上部の安定成層が外核下部のダイナモ領域で発生する固有磁場に与える影響について、水星ダイナモによる数値計算（Takahashi and Shimizu, 2012）から得られる Mauersberger スペクトルを用いて考察する。ダイナモ計算には、回転球殻導電性非圧縮ブジネスク流体の二重拡散対流モデルを使用した。Yagi and Toh (2023) で、上記の水星ダ

イナモ計算を用いて、外核対流層厚を変化させ計算したが、Lowes 半径は約 1000km の一定値であることを示した。しかしこの計算は磁気拡散時間に対して十分な時間の計算ができておらず、本研究では計算時間の改善を行った。

外核安定層による表皮効果による磁場の減衰について、異なる対流層半径のダイナモ計算結果を用いて考察し、Tsang and Jones (2019) で行われたように、対流層上部の領域における磁場エネルギースペクトルの傾きの変動と、対流層半径によるスペクトルの変化について定量的な議論を行う。そして観測された水星の Lowes 半径に整合する水星内部の対流層半径をサーチし、その結果を報告する。

R004-03
C 会場 ：9/26　AM1 （9:00-10:30）
9:30〜9:45

#松島　政貴 [1)], 南　拓人 [2)], 中野　慎也 [3)], 藤　浩明 [4)]
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Attempts to produce candidate models for the IGRF-14 (1)

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The International Geomagnetic Reference Field (IGRF) updated every five years is a standard mathematical description in terms of spherical harmonic coefficients, known as the Gauss coefficients, for the Earth's main magnetic field and its secular variation. In the last IGRF revision, the 13th generation of IGRF (IGRF-13), we submitted a candidate model of the Secular Variation (SV) from 2020 to 2025 (SV-2020-2025) only, in which geodynamo numerical simulations, data assimilation, and core surface flow modeling were adopted to produce the model (Minami et al., 2020). In the next IGRF revision, the 14th generation of IGRF (IGRF-14), we plan to submit all kinds of released models of the Definitive Geomagnetic Reference Field for 2020 (DGRF-2020), the IGRF for 2025 (IGRF-2025), and the Secular Variation (SV) from 2025 to 2030 (SV-2025-2030). At the present, we are focusing on determination of a model for DGRF 2020, simply because the definitive geomagnetic data are available for epoch 2020 both at the geomagnetic field observatories on the Earth and by Low-Earth-Orbit satellites, such as Swarm by the European Space Agency.

In this presentation, we show tentative results in relation to DGRF 2020. To do so, we have obtained the vector geomagnetic data every one minute at the Earth-based observatories and those measured by the Swarm satellites. For the purpose of this study, the satellite data were subsampled every 10 seconds, which corresponds to an along-track spacing of about 75 km. We have found that it is impossible to determine the Gauss coefficients up to the degree 13 of spherical harmonics only by the Earth-based observatories, due not to the number of observatories, but to the ill distribution of the observatories. This suggests that the geomagnetic data measured by satellites are absolutely necessary to produce a geomagnetic field model precisely. Furthermore, we have noticed that we need to select the geomagnetic field data with respect to the local time to avoid the effect of ionosphere as well as the geomagnetic latitudes to avoid field aligned currents. These procedures may also be effective to produce the IGRF 2025 field model in the future.

R004-04
C 会場 ：9/26　AM1 （9:00-10:30）
9:45〜10:00

房総半島南端地域に分布する海成層から得られたカエナ逆磁極亜帯上部境界の古地磁気記録

#谷元　瞭太 [1)], 岡田　誠 [1)]
(1 茨城大,(2 茨城大

A paleomagnetic record of the upper Kaena reversal from marine succession in the southernmost part of the Boso Peninsula

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Continuous paleomagnetic records of the Pliocene-Pleistocene have been obtained mainly from deep-sea bottom cores. However, deep-sea bottom cores covering before the Pliocene are limited, and there are few examples of revealing detailed magnetic field variations during geomagnetic reversals.

The Boso Peninsula is suitable for the reconstruction of detailed paleomagnetic variations because of the abundance of Pliocene-Pleistocene strata. However, it is known that it is difficult to remove secondary magnetization in the formations distributed in the Boso Peninsula by only progressive thermal demagnetization (pThD) or progressive alternating field demagnetization (pAFD) (e.g., Okada et al., 2012). Therefore, attempts have been made to remove secondary magnetization by a demagnetization method that combines ThD and pAFD (e.g., Okada et al., 2017, Konishi and Okada, 2020).

In this presentation, we investigate the optimal conditions for combined demagnetization around the upper Kaena reversal from the marine succession at the southernmost part of the Boso Peninsula, and report the results of preliminary paleomagnetic measurements.

The results of pThD and pAFD are consistent with Okada et al. (2012), indicating that the secondary magnetization of normal polarity acquired after the tilt of the formation may not have been removed. Since the secondary magnetization appears to be removed at 275 ℃-325 ℃ for pThD and at 5 mT-20 mT for pAFD, we concluded that ThD at 325 ℃ + pAFD is the appropriate condition for hybrid demagnetization.

The results of the hybrid demagnetization method showed that the direction of the normal polarity sample was indistinguishable from the geomagnetic axis dipole (GAD) field direction in the study area, while the reversed polarity sample was closer to the GAD field direction than the pThD and pAFD samples, but showed a slightly southwestward direction that did not pass the reversal test. However, the dispersion of the direction population of the hybrid demagnetization studied in this study is smaller than the dispersion of the paleomagnetic secular variation estimated from the site latitude, and it cannot be said that a sufficient number of horizons have been studied.

Reference

Konishi, T., Okada, M. (2020), PEPS, 7:35. Okada, M., Tokoro, Y., Uchida, Y., Arai, Y., Saito, K. (2012), Jour. Geol. Soc. Japan, 118:2, 97-108. Okada, M., Suganuma, Y., Haneda, Y., Kazaoka, O. (2017), EPS, 69:45.

これまで，鮮新-更新世における連続的な古地磁気記録は主に深海底コアから得られてきた．しかし，鮮新世以前をカバーする深海底コアは限られており，地磁気逆転時の詳細な磁場変動が明らかにされた例は少ない．房総半島には鮮新-更新統が数多く分布しており，詳細な古地磁気変動復元に適している．しかし，房総半島に分布する地層群では，段階熱消磁や段階交流消磁だけでは二次磁化を取り除くことが困難であることが知られている（たとえば，岡田ほか,2012）．そこで，熱消磁と段階交流消磁を組み合わせた消磁法によって二次磁化を取り除く試みが行われてきた（e. g., Okada et al., 2017，Konishi and Okada, 2020）．本発表では，房総南島南端地域に分布する海成鮮新統から得られたカエナ逆磁極亜帯上部境界付近において最適な組み合わせ消磁の条件を検討し，予察的に行った古地磁気測定の結果を報告する．

段階熱消磁および段階交流消磁の結果は岡田ほか（2012）と整合的であり，地層傾動後に獲得された正極性の二次磁化が取り除かれていないことを示した．段階熱消磁では 275 ℃-325 ℃，段階交流消磁では 5 mT-20 mT で二次磁化が取り除かれているように見えるため，組み合わせ消磁の条件は 325 ℃の熱消磁＋段階交流消磁が適切であると判断した．

組み合わせ消磁の結果は，正極性試料では本研究地域における地心軸双極子磁場方位と区別できない方位を示す一方，逆極性では段階熱消磁や段階交流消磁と比較してより地心軸双極子磁場方位に近づいたが，やや南西向きの方位を示し逆転テストに合格する結果は得られなかった．しかし今回検討した組み合わせ消磁の方位集団の分散は，サイト緯度から推定される古地磁気永年変化による分散と比べて小さく，十分な数の層準による検討が行われたとは言えない．今後試料採取層準を増やして逆転テストを再実施する必要がある．

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）の一部を使用して行われた．

引用文献

Konishi, T., Okada, M. (2020), PEPS, 7:35. 岡田 誠・所 佳実・内田 剛行・荒井 裕司・斉藤 敬二（2012），地質雑，118:2, 97-108. Okada, M., Suganuma, Y., Haneda, Y., Kazaoka, O. (2017), EPS, 69:45.

R004-05
C 会場 ：9/26　AM1 （9:00-10:30）
10:00〜10:15

綱川-ショー法・IZZI-テリエ法によるラシャンエクスカーションの絶対古地磁強度測定

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Absolute paleointensity determination of the Laschamp excursion by the Tsunakawa-Shaw and IZZI-Thellier methods

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Absolute paleointensities during geomagnetic excursions are important for understanding the variation of the Earth magnetic field and thus the characteristics of the Earth dynamo. The intermediate paleomagnetic directions, now widely known as the Laschamp geomagnetic excursion of about 40,000 years ago, were first reported from the lava and scoria of the Chaine des Puys in Massif Central, France. Roperch et al. (1988) reported 7.7 ± 1.6 μ T of the absolute paleointensity of the Laschamp excursion by using the Thellier-Thellier method with pTRM check. This weak value has been often cited as a typical value of absolute paleointensities in geomagnetic excursions. However, the quantity of the reported data appears to be not enough because it was an average of seven paleointensity estimates which consists of 2-3 measurements from three units: Laschamp lava and scoria, and Olby lava. In addition, no subsequent studies have reported the results of paleointensity measurements using the latest paleointensity methods such as the Tsunakawa-Shaw method, and the IZZI-Thellier method, leaving the room for reconsideration in terms of data quality. Therefore, we are conducting a study to reconsider the absolute paleointensities of the Laschamp excursion by measurements using these two methods. In this study, oriented rock samples were collected from six lava flow units: eight sites in total in Chaine des Puys, targeting the Laschamp excursion and pre- and post-date. Pilot IZZI-Thellier results on specimens from Laschamp and Royat flows were rejected by the selection criteria. On the other hand, the Tsunakawa-Shaw experiments yielded 1-4 paleointensity data from five sites where intermediate directions have been reported (Laschamp lava, Olby lava, Royat lava, 2 sites of Louchadiere lava). This presentation reports the results of rock-magnetic analyses and paleointensity measurements on these excursion records.

地磁気エクスカーションにおける絶対古地磁気強度を復元することは，地球磁場変動ひいては地球ダイナモの特性を理解する上で重要である．フランス中央高地に位置する Chaîne des Puys の溶岩およびスコリアからは中間方位が報告され，約 4 万年前のラシャンエクスカーションとして広く知られている．Roperch et al.（1988）はラシャンエクスカーションにおける絶対古地磁気強度を pTRM チェック付きテリエ法により測定し，7.7 ± 1.6 μ T と報告した．この報告値は地磁気エクスカーションにおける絶対古地磁気強度の典型的な値として引用されることが多い．しかし，報告されているデータは 3 サイト（Laschamp 溶岩，Laschamp スコリア，Olby 溶岩）からそれぞれ 2 – 3 個の測定値を得て平均したもので (N=7)，各ユニットごとのデータの量としては充分ではない．また，これらの火山岩記録に対して，綱川-ショー法や IZZI-テリエ法といった最新手法による古地磁気強度測定結果が報告されていない．最新の手法を用いてデータの質を再検討する余地がある．

そこで私たちは，綱川-ショー法と IZZI テリエ法を用いた古地磁気強度測定により，ラシャンエクスカーションにおける絶対古地磁気強度を再検討する研究を進めている．ラシャンエクスカーションおよびその前後の年代が報告されている溶岩を対象にして，Chaîne des Puys において 6 ユニットの溶岩（計 8 サイト）から定方位試料を採取した．古地磁気強度の初期分析では，Laschamp 溶岩と Royat 溶岩に IZZI-テリエ法と綱川-ショー法を適用した．IZZI-テリエ法を用いた結果はデータ選択基準を満たさず不合格となった．一方で， 綱川-ショー法を用いた場合には，それぞれの溶岩から基準を満たす測定結果が 3-4 個得られた．これらの結果に基いて，現在は綱川-ショー法を中心に Laschamp, Royat の測定数を増やしつつ，並行して未測定のサイトのパイロット測定を進めている．また，熱磁気分析の結果から岩石磁気的特徴も確認している．本発表では，中間方位が報告されている 5 サイト（Laschamp 溶岩，Olby 溶岩，Royat 溶岩，Louchadière 溶岩の 2 サイト）を中心に，岩石磁気学的測定および古地磁気強度測定の結果を報告する．

R004-06
C 会場 ：9/26　AM1 （9:00-10:30）
10:15〜10:30

IOPD Expedition 386 で日本海溝から得られた堆積物コアの古地磁気永年変化記録復元

#金松　敏也 [1)], 山本　裕二 [2)], ショーン　カンシー [1)], ワン　ヤンホン [3)], 奥津　なつみ [1)], 池原　研 [4)], ストラッサー　ミハエル [5)], エベレスト　ジェミー [6)], 前田　玲奈 [1)], 国際深海科学掘削計画第 386 航海　乗船研究者 [7)]
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Reconstruction of paleomagnetic secular variation record obtained from the Japan Trench, IODP Expedition 386

#Toshiya Kanamatsu[1)],Yuhji Yamamoto[2)],Kan-Hsi Hsiung[1)],Yanghong Wong[3)],Natsumi Okutsu[1)],Ken Ikehara[4)],Michael Strasser[5)],Jeremy Everest[6)],Leana Maeda[1)],IODP Expedition 386 Science Party[7)]
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IODP Expedition 386 was conducted to study the Japan Trench paleoseismology, which will be expected to provide spatial and temporal information related to plate boundary megathrust earthquakes such as the Tohoku-Oki earthquake in 2011. Core samples were collected from 15 sites using a Giant Piston corer (GPC) with long pipes (40 m in max). Because previous studies have revealed that the Japan Trench sediments contain excellent paleomagnetic secular variation records (PSV), we planned to reconstruct PSV records to contribute a precise stratigraphy on all cores taken by IODP Expedition 386.

In this study, u-channel samples collected from the working halves were investigated to measure natural remanent magnetization (NRM). NRM measurements were performed after alternating field demagnetizations from 0 mT to 80 mT peak field to evaluate the stableness of magnetizations. In general, stable single magnetic components were obtained for most intervals, but high maximum angular dispersions in the principal component analysis, suggesting unstable magnetizations, were often observed in silt to fine sand turbidite intervals. The declination data for each core showed a spiral trend with depth, which may have been caused by the rotation of the GPC barrels during penetration. This rotation needed to be corrected to restore the original paleomagnetic directional variation. In this initial study, the spiral trends were simply restored by assuming that it is a linear function of core depth. In some sections, abrupt shifts in declination were observed, which may have been caused by the fragmentation of the core. In fact, the fragmentations are observed in the core photographs and X-CT images. The data were shifted and restored to have continuity.

Because core samples were collected from multiple holes in most sites, a more appropriate evaluation on the reconstructed record is possible by comparing multi-PSV records. The PSV from sites M89 and M90 off Miyagi show similar trends to those of the Japan Trench PSV records obtained previously. These preliminary results suggest that Japan Trench PSV record can help establish a precise stratigraphy of the cores obtained.

日本海溝沿いのイベント堆積物の層序は 2011 年東北沖地震のようなプレート境界メガトラスト地震に関連する空間的・時間的情報を提供することが期待される。IODP Expedition 386 では日本海溝沿いの 15 地点でそのようなコア試料を収集するために実施された。水深 7,300m 以上の半閉鎖的な深海盆から、最大 40m の長尺パイプの巨大ピストン式コアラー（GPC）で試料が採取された。これまでの研究によると日本海溝のコア試料には古地磁永年変化記録（PSV）が良く記憶されおり、高解像度の層序を決定するのに有効であるため IODP Expedition 386 の試料においても古地磁気研究を進められている。本研究では、ワーキングハーフから採取した U チャンネル試料の PSV 記録を調査した。自然残留磁化測定は、0mT から 80mT のピークの交流消磁後に行われた。一般に、ほとんどの区間で安定した単一成分が得られたが、シルトから細砂のタービダイト区間では不安定な磁化を示唆する高い主成分分析における最大角分散が観察される事が多い。各コアの偏角データには深度に対して螺旋状に変化する傾向が見られ、これは GPC バレルが海底へ侵入する際に回転していることにより生じたと考えられる。本来の磁化方位変化に戻すためにこの回転を戻す必要があるが、現段階ではコアの深さの一次関数であると仮定して線形性を単純に復元した。また、一部の区間では、急激な偏角のシフトが観察された。このような急激な偏角の変化は、コアが分断されたために生じたと考えられる。実際、コア写真と X-CT 画像でコア試料の分断が確認されるため、GPC 貫入時それ以降にコア試料の分断が起こったと考えられる。これについても連続性を保つようにデータをシフトして復元した。

今回の航海では GPC ピストンコラーが大水深でパイプの曲がりや GPC の海底で束縛のリスクを回避するため、各サイトで短いコア（20〜30m）と長いコア（40m）を使って取得している。そのため 1 つのサイトから複数のコアの古地磁気記録が取得できるため、補正後の PSV をより適切に評価することができる。宮城沖のサイト M89 と M90 のデータはこれまで求めた日本海溝の PSV 記録と類似した傾向を示した。

R004-07
C 会場 ：9/26　AM2 （10:45-12:30）
10:45〜11:00

釧路市春採湖における津波堆積物・テフラの岩石磁気学的特徴: 予察

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Preliminary report on the rock magnetic properties of tsunami deposits and tephra in Lake Harutori-ko, Eastern Hokkaido

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Rock magnetic properties are useful for identifying extraordinary geological events such as tsunamis and volcanic eruptions (e.g., Lerner et al., 2022; Vigliotti et al., 2019). Nevertheless, these properties depend on sedimentary sources and their environmental and geomorphological settings. Hence, it is important to amass a repository of case studies from different regions. Lake Harutori, located in Kushiro City on the east coast of Hokkaido, Japan, is a coastal lake. The lake sediments were well preserved, with little impact from the artificial modifications. Nanayama (2021) identified twenty-two layers of tsunami deposits from sediment cores obtained from Lake Harutori over the past 9500 years. However, no prior instances utilizing rock magnetic techniques have been documented. Here, we present the preliminary results of rock magnetic analyses conducted on tsunami deposits and tephra recorded in the sediments of Lake Harutori, Kushiro, Japan.

Three sediment cores (R2H2, R4H3, and R4H4) were collected from Lake Harutori in August 2022. R2H2, R4H3, and R4H4 are 293, 200, and 225 cm in length, respectively. According to Nanayama (2021), tephra layers were identified as Komagatake c1 tephra (Ko-c1), Komagatake c2 tephra (Ko-c2), Tarumae a tephra(Ta-a), and Tarumae b tephra (Ta-b). Furthermore, two distinct tsunami deposits (GTS1 and 2) originated from two earthquakes in the 13th and 17th centuries, respectively. We measured magnetic susceptibility (K), anhysteretic remanent magnetization (ARM), and isothermal remanent magnetization (IRM) for the R2H2 core. The saturation IRM (SIRM) was determined by applying a maximum field of 2.4 T in the forward direction, followed by measurements at 100 and 300 mT in the opposite direction. These latter measurements were employed to calculate the S-ratio (S-0.1, S-0.3) and high field isothermal remanent magnetization (HIRM).

In the R4H2 core, there was an evident increase in both the K and ARM peaks for stratigraphic levels correlated with Ta-a. This result was likely attributable to the presence of volcanic ash. A similar pattern was identified in the tephra layers of undetermined ages. However, no such trend was identified for Ko-c1. Moreover, the SIRM and HIRM values significantly increased in the layers correlated with the tsunami deposits during the Tempo era. Furthermore, even in layers where sedimentological observations indicated no apparent changes, fluctuations in ARM and S-ratio were observed.

Further measurements and analyses of the R4H2 and R4H3 cores will be conducted, as well as magnetic hysteresis and FORC measurements of the characteristic samples, as mentioned above.

磁性鉱物の特性は，津波や火山噴火といった地質学的イベントを特定する有用なツールの一つである（例えば Lerner et al., 2022; Vigliotti et al., 2019）．しかしこうしたパラメータは堆積物の供給源や堆積場の環境や地形に大きく影響を受けるため，各地域での研究例の蓄積が重要である．春採湖は，北海道東岸の釧路市に位置する海跡湖であり，人口改変の影響が少なく湖底堆積物の保存状態も良好である．これまでに，春採湖で得られたコアから過去 9500 年間に 22 層の津波堆積物が認定されているが（Nanayama, 2021），岩石磁気学的手法を用いた研究例はない．現在，釧路市春採湖の湖底堆積物に記録された，津波堆積物やテフラの岩石磁気学的分析を行っており，その予察的な結果を報告する．

試料は，春採湖において 2022 年 8 月に新たに採取された 3 本の堆積物コア (R2H2, R4H3, R4H4) を用いている．コア長はそれぞれ 293 cm（R4H2），200 cm（R4H3），225 cm（R4H4）で，Nanayama (2021) との対比から，北海道駒ヶ岳火山起源（Ko-c1, Ko-c2）や樽前火山起源（Ta-a, Ta-b）といったテフラ層や 17 世紀と 13 世紀にそれぞれ発生した巨大地震による津波堆積物（GTS1, 2）が認められる．

これまでに R4H2 コアから，初期帯磁率（K），ARM（非履歴性残留磁化），IRM（等温残留磁化）の測定を行った．IRM は 2.4 T で SIRM（飽和残留磁化）を測定した後，逆方向に 0.1, 0.3 T で着磁して測定を行った．これらの値は，S 比（S-0.1，S-0.3）や HIRM（強磁場等温残留磁化）を計算するために利用した．

R4H4 コアについて，Ta-a に対比される層準において，K，ARM がピーク的に増加した．これは，火山灰が原因と考えられ，起源が不明なテフラ層においても同様の傾向が見られる．一方で，Ko-c1 に関してはそのような傾向が見られない．また，天保年間に発生した津波堆積物に対比される層準では，SIRM と HIRM にピーク的な増加が見られる．さらに，堆積学的な観察からは変化が見られない層準においても，ARM や Sratio の変動が見られる．

今後，R4H2，R4H3 コアの測定や解析を進める他，上記で示したような特徴的なサンプルについては，磁気ヒステリシスや FORC 測定を進めていく．

謝辞：本研究は科研費 21H04523 の支援を受けた。釧路市立博物館の石川孝織様には堆積物試料採取にあたって大変お世話になった。

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R004-08
C 会場 ：9/26　AM2 （10:45-12:30）
11:00〜11:15

土壌性磁性鉱物生成の水熱実験（予報）

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A preliminary report of hydrothermal experiments for pedogenic magnetic mineral formation

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Soils are formed on the earth's surface by aqueous alterations of clastics produced by physical and chemical weathering of rocks. Pedogenesis is associated with formation of magnetic minerals that cause magnetic enhancement. Therefore, the degree of pedogenesis is often represented by magnetic susceptibility, which is also often used as a proxy of paleoprecipitation. In spite of these practical usages of magnetic proxies, we do not fully understand how magnetic minerals are formed in soils. To elucidate the formation process of pedogenic magnetic minerals, we carried out hydrothermal experiments at temperatures of 150 – 200 degrees C with closed-type pressurized reactor cases, using loess/paleosol samples from the Chinese Loess Plateau. All the samples increased in magnetic susceptibility, the increase rate of which depends on the degrees of pedogenesis of samples. Hysteresis measurements and IRM acquisition experiments reveal that SP and SD (/vortex) size magnetite particles are newly formed, with magnetization decreases caused by thermal oxidation of fine-grained detrital magnetite particles. We discuss temporal changes of neoformation of magnetic particles during the hydrothermal experiments, based on the data of hysteresis parameters, saturation isothermal remanent magnetization intensity, and magnetic susceptibility.

R004-09
C 会場 ：9/26　AM2 （10:45-12:30）
11:15〜11:30

#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,[3] 東大・地惑

Different contributions to paleomagnetic signals subjected to diagenesis: Overlooked hematite vs. overstated magnetic inclusions

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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. Hematite is known as high coercivity mineral and is more resistive to reductive diagenesis compared to other common magnetic minerals (e.g., magnetite). Thus, those minerals 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. Rock magnetic measurements indicate that severe diagenetic iron-mineral dissolution occurred below about 6 m in depth in the studied sediments, where natural remanent magnetization (NRM) intensity is about 10% of that above 6 m. However, information on paleomagnetic declination and paleointensity could still be recovered. To characterize the mineral composition of the remanence carrier in the reduced sediments, a series of well-designed techniques were applied on selected samples from different phases of diagenesis. Silicate-hosted magnetic inclusions were separated from bulk sediments by chemical procedures. They contribute about 50% or more of saturation isothermal remanent magnetization (SIRM) in the reduced sediments but they possess a relatively low NRM acquisition efficiency as indicated by grain size analysis. High coercivity hematite was identified as another major remanence carrier in the reduced sediments from rock magnetic measurements including IRM decomposition. The presence of hematite is further confirmed by conducting stepwise thermal demagnetization of three-component IRM on bulk samples from the reduced sediments.

R004-10
C 会場 ：9/26　AM2 （10:45-12:30）
11:30〜12:00

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Problems of relative paleointensity estimations from marine sediments and their relation with biogenic magnetite

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Studies on relative paleointensity (RPI) estimations using sediments started 1970's and progressed rapidly in 1990's and 2000's. Until now, global and regional RPI stacks were constructed for periods after ca. 3 m.y., and the basic features of geomagnetic intensity variations such as large variations within a stable polarity with the timescales of 10^3 to 10^5 were revealed. However, it becomes recognized that lithological changes of sediments associated with environmental changes influence RPI estimations, known as lithological contamination. This problem hinders us to understand fundamental problems of the geomagnetism including possible relations between paleointensity and reversal frequency and possible connections between the magnetic field and climate and/or earth's orbit. Recent studies revealed that the RPI recording efficiency of magnetofossils is lower than that of detrital magnetites. This was contrary to the expectation from the single-domain (SD) sizes of magnetofossils, and we still do not understand the reason. This causes the inverse correlation between the proportion of magnetofossils and detrital magnetic minerals, which is frequently observed in marine sediments. In fortunate cases that coercivity distributions of the two components are separated enough, uncontaminated RPI estimations would be possible using a slope segment representing the magnetofossil or detrital component in NRM-ARM and/or NRM-IRM demagnetization diagrams. The identification of the magnetofossil component is often relied on the recognition of the central ridge in FORC diagrams, which represents the non-interacting SD feature of magnetofossils. However, complication arises from the configurations of magnetofossils such as bacterial magnetosomes being single or multi-stranded and the degree of chain collapse after death of magnetotactic bacteria (MTB). Chain collapse and multi-stranded chains contribute to a component with a vertical spread in FORC diagrams.

I think that problems of RPI estimations ultimately arise from our lack of the understanding of DRM acquisition processes, an old problem. It was revealed that magnetofossils are ubiquitous in marine sediments, and an important carrier of DRM. However, we have not yet understood where in a sediment column and how DRM carried by magnetofossils are acquired. Some species of MTB are known to prefer to live within the oxic-anoxic transition zone (OATZ) in a sedimentary column, whose depth depends on sedimentary environments. However, magnetofossils are abundant even in oxic red clay without OATZ. Do MTB live at the sediment-water interface in such environments? In this way, ecology of MTB may control DRM fixing depths. Then, how well MTB are aligned to the geomagnetic field when they are alive, and after their death how well original magnetofossil chains are preserved?

R004-11
C 会場 ：9/26　AM2 （10:45-12:30）
12:00〜12:30

宍道湖西岸の汽水域堆積物に記録された完新世の古地磁気永年変化と環境変遷

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Paleomagnetic secular variation and enviro-magnetic records from the Holocene estuary deposits, the west shore of Lake Shinji

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Fine-grained marine and lacustrine sediments are valuable for paleomagnetic secular variation (PSV) studies, especially in lakes and bays with high sedimentation rates, which may provide a high-resolution record. However, brackish-water environments are susceptible to sea-level variations and paleogeographic changes, often making the magnetic properties of sediments non-uniform. Therefore, to certify the reliability of paleomagnetic records, it is inevitable to investigate the origin and modification of magnetic minerals due to changes in sediment supply patterns and early diagenetic processes. In this presentation, we report the results of the study of remanent magnetization and other magnetic properties of Holocene sediments collected near the mouth of Hii River on the western shore of Lake Shinji in 2019 (HK19 core) and core samples collected at the same site in 2022 (HK22 core).

The sediments of the HK19 and HK22 cores were deposited in an inner bay or a brackish lake after the post-glacial sea-level rise around 10,000 years BP. Magnetic measurements of U-channel samples collected from the HK19 core (Hayashida et al., 2022) revealed the existence of stable remanent magnetization components in the sediments deposited in the inner bay environment (24.0-33.0 m depth). The inclination variation at this interval is correlative to the PSV record of 7.5-9.5 ka reported from Lake Biwa. However, the upper sediments (11.4-23.9 m depth) deposited in the enclosed brackish-water environment have relatively low remanent magnetization intensities, and a clear record of the PSV was not obtained. At this interval, not only the remanent magnetization intensity but also the initial magnetic susceptibility and the anhysteretic susceptibility (ARM susceptibility) decreased, suggesting that due to early diagenesis, the magnetic minerals have dissolved or altered, affecting the remanent magnetization record. Magnetic hysteresis data such as saturation magnetization, saturation remanent magnetization, coercive force, and remanence coercive force measured by a vibrating sample magnetometer show variations consistent with the initial and ARM susceptibilities, suggesting that the diagenesis has strongly affected the content and particle size of ferromagnetic minerals, especially in brackish-water deposits.

Above 11.4 m depth, the lacustrine or fluvial sediments are suggested to have been deposited near the mouth of the Hii River after the ”Hii River East Rerouting Event” (Seto et al., 2006). Stable remanent magnetization was observed particularly in the fine-grained part (7.2-11.4 m depth). It is suggested that at this interval, the influence of reductive diagenesis disappears with the change from a brackish to a freshwater environment, and the amount of magnetic mineral inflow from the river increases. The ARM susceptibility increases rapidly at a depth of 11.4 m, whereas the value of the initial magnetic susceptibility increases progressively to a depth of about 9 m. Compared to the initial magnetic susceptibility, which indicates the total amount of magnetic minerals, the ARM susceptibility is considered to reflect the content of very fine-grained ferrimagnetic particles. This suggests that the input of suspended sediments including fine-grained magnetite first increased, followed by a gradual increase in the inflow of coarse-grained clastic material originating from granitic rocks of the Sanin Belt. Since the environmental changes associated with the ”Hii River East Rerouting Event” are considered to have occurred in the 1200s A.D. based on radiocarbon calendar year calibration ages around 11.4 m depth, the remanent magnetization record from the freshwater fine-grained sediments is possibly correlated with the PSV record indicated by archaeomagnetic methods.

海洋底や湖底の細粒堆積物は古地磁気永年変化の研究のための重要な試料であり，特に堆積速度の大きい湖沼や内湾の堆積物からは時間解像度の高い記録を取得できる可能性がある。ただし汽水域の環境は海水準変動や古地理変遷の影響を受けやすく，堆積物の磁気特性が一様ではないことが多い。したがって古地磁気方位の信頼性を高めるために，堆積物の供給様式の変化や初期続成作用による磁性鉱物の変化についての検討が欠かせない。本講演では，宍道湖西岸の斐伊川河口付近で 2019 年に採取された完新世堆積物（HK19 コア）と 2022 年に同一地点で採取されたコア試料（HK22 コア）を対象に行った残留磁化および他の磁気特性の検討結果について報告する。

HK19 および HK22 コアの堆積物は約 1 万年前に起こった後氷期の海進以降に内湾あるいは汽水湖で形成されたものである。U チャネル試料を用いた HK19 コアの残留磁化測定（林田ほか，LAGUNA(汽水域研究), 29, 75 – 86, 2022）では，内湾環境で堆積したと推定される層準（深度 24.0 – 33.0m）に安定な磁化成分が認められ，琵琶湖の古地磁気永年

変化曲線の記録（約 7.5 – 9.5ka）と対比可能な伏角の変動が確認された。しかし，その上位の閉鎖的汽水域の堆積物（深度 11.4 – 23.9m）では残留磁化強度が比較的小さく，明瞭な永年変化の記録を得ることができなかった。この層準（深度 11.4 – 23.9m）では，残留磁化強度だけでなく初磁化率と非履歴性残留磁化率（ARM 磁化率）が減少しており，初期続成作用によって磁性鉱物が溶解あるいは変質して残留磁化の記録に影響が及んだことが示唆された。振動試料型磁力計によるヒステリシス測定で得た飽和磁化，飽和残留磁化，保磁力，残留保磁力のデータも初磁化率や ARM 磁化率と対応する変化を示し，特に閉鎖的汽水域の堆積物において強磁性鉱物の含有量および粒子サイズに初期続成作用の影響が強く及んでいることが確認された。

深度 11.4m より上位の堆積物は近世の「斐伊川東流イベント」（瀬戸ほか, 第四紀研究, 45, 375 – 390, 2006）以降に河口付近で堆積したと考えられ，その細粒部（深度 7.2 – 11.4m）には安定な残留磁化成分が見出された。この層準では汽水環境から淡水域への変化に伴って還元的続成作用の影響がなくなるとともに河川からの磁性鉱物の流入量が増加したことにより，安定な残留磁化が保存されたと考えることができる。ここでは，ARM 磁化率が深度 11.4m で急増するのに対し，初磁化率の値は深度約 9m まで漸移的に増加するという違いが見られた。磁性鉱物の総量を示す初磁化率に比べ ARM 磁化率は極細粒のフェリ磁性粒子の含有量を反映すると考えられることから，まず細粒マグネタイトを含む浮遊性粒子の流入量が増加し，その後，山陰帯の花崗岩類を供給源とする粗粒砕屑物の流入が次第に増加していったことが示唆される。深度 11.4m 付近の放射性炭素暦年較正年代に基づいて「斐伊川東流イベント」に伴う環境変化は西暦 1200 年代に起こったと考えられるため，淡水性細粒堆積物の磁化方位は考古地磁気の手法で示された永年変化の記録と対比できる可能性がある．

R004-P01
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

#高橋　太 [1)]
(1 九大・理・地惑

Numerical study of dynamo action generating equatorially asymmetric magnetic fields

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The geomagnetic field is apparently asymmetcic with respect to the equator. It is because that the geomagnetic field consists of the equatorially anti-symmetic and symmetric components. The anti-symmetic component is referred to as the dipole family, while the other is to the quadrupole family. Theoretically, the magnetic field of diffrent family is linealy independent if the velocity field consists solely of the equatorially symmetric conponent, which is supposed to be dominant in the Earth's core. On the other hand, a slight devition in the velocity field from the equatorial symmetry by superimposng the anti-symmetic component often results in a substantially asymmetic magnetic field due to non-linear coupling between the velocity and magnetic fields. It is still unclear how the asymmetic magnetic field is established by a dominantly symmetic velocity field with a slightly anti-symmetic component, and how it evolves with time.

Here, we use numerical dynamo modeling to examine effects of the non-linear coupling between the dipole and quadrupole families on the resultant magnetic field. For this purpose, we perform two dynamo runs at the same parameters, where the initial conditions are designed to yield a dynamo solution of the purely dipole family magnetic field, and that of the mixed-family magnetic field. Consequently it is found that the critical Rayleigh number for self-sustaining dynamo action is different for these solutions. Strength and morphology of the mangetic field are also different in some cases. Results of preliminary analysis will be discussed in this presentation.

This work was supported by JSPS KAKENHI Grant Number JP21K03725.

R004-P02
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

モンゴル西部 Zavkhan テレーンに分布する 3-8 億年前の火成岩および深成岩の残留磁化の評価（予察）

#穴井　千里 [1)], 小田　啓邦 [2)], 長谷部　徳子 [3)], 長谷川　精 [1,4)]
([1] 高知大・海洋コア国際研究所,[2] 産総研・地質情報,[3] 金沢大・環日本海域環境研究センター,[4] 高知大学　理工学部

Evaluation of Remanent Magnetization of 300-800 Ma igneous and plutonic rocks in the Zavkhan Terrane, Mongolia (preliminary study)

#Chisato Anai[1)],Hirokuni Oda[2)],Noriko Hasebe[3)],Hitoshi Hasegawa[1,4)]
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The purpose of this study is to conduct fundamental research to evaluate the remanent magnetization of igneous and plutonic rock samples from 500-800 Ma in multiple data and to estimate the timing of the inner core growth of the Earth. According to the recent paleomagnetic studies, the inner core began to form 400-570 Ma. The timing of the growth of the inner core estimated in the previous studies coincides with major events in Earth history, such as the third “Snowball Earth” (approximately 600 Ma) and the transition from the extinction of the Ediacara fauna (multicellular mollusks: 530-570 Ma) to the Cambrian explosion. Although it is still unclear whether these events are closely related to the inner core growth, an accurate estimation of the timing of the inner core growth is extremely important for the history of the Earth, especially for the global environment history. To estimate the timing of the growth of the inner core from paleomagnetic studies, it is important to evaluate the reliability of the record. In this study, we try to extract remanent magnetization from igneous and plutonic rocks in the Zavkhan Terrane, Mongolia with age of 300-800 Ma, and evaluate the acquisition mechanism and its timing.

All samples were collected with orientation marking as follows: 6 blocks of 770 Ma Granite from 2 sites, 8 blocks of 508 Ma Granite from 4 site, 3 blocks of 446 Ma Rhyolite from 1 site, 6 blocks of Basalt from 2 sites. Although the exact age of Basalt is unknown, it is confirmed to occur in contact with the lower part of the 446 Ma Rhyolite. We performed rock magnetic analysis and paleomagnetic measurements at KCC, additionally, magnetic mapping of natural remanent magnetization (NRM) with the SQUID microscope at AIST on these pilot samples to evaluate the magnetic properties for the extraction of paleomagnetic data.

Based on these results, we evaluate methods for extracting magnetization information at the time of formation and proceed with the measurements including paleointensity. Especially the paleomagnetic results from the granite with an age of 508 Ma is important, since it is close to the age reported for the growth of the inner core. Thus, the mechanism of magnetization acquisition and its age should be carefully examined.

Acknowledgements

This study was supported by JSPS KAKENHI Grant No. 21H04523. We also thank Dr. Davaadorj Davaasuren, Dr. Niiden Ichinnorov, Mr. Shuukhaaz Ganbat and local drivers for their assistance in collecting samples in Mongolia.

本研究は、3-8 億年前の火成岩・深成岩試料の残留磁化を多角的に評価し、地球内核形成時期の推定に役立てる基礎研究を行うことを目的とする。最近の古地球磁場研究では 4-5.7 億年前に地磁気強度の極小値とその後の磁場強度急増が報告されており、これは地球内核が形成されたことが原因とされている。これら研究で推定される地球内核形成時期は 3 回目の全球凍結（スノーボールアース; 約 6 億年前）やエディアカラ動物群（5.3-5.7 億年前の多細胞軟体性動物）の絶滅からカンブリア爆発（生物の爆発的な多様化）への移行など地球史の重要イベントが発生した時期と一致している。これらのイベントが地球内核形成と密接に関わるのかどうかは未だ不明であるが、地球磁場強度の極小値とその前後の磁場強度の時間変化を正確に知ることは、地球史、特に地球環境史にとって極めて重要である。地球内核形成時期を地球磁場研究から推定するためには、その地球磁場記録の信頼性を評価することが重要である。本研究では、モンゴル Zavkhan テレーンに分布する 3-8 億年前の火成岩および深成岩から、残留磁化を抽出し、磁化獲得機構とその時期を評価する．

試料は 770Ma の Granite を 2 地点から 6 ブロック，508Ma の Granite を 4 地点 8 ブロック，446Ma の Rhyolite を 1 地点 3 ブロック，Basalt を 2 地点 6 ブロック，全て定方位で採取した．Basalt の年代は不明であるが，446Ma の Rhyolite の下位に接していることを確認している．これらのパイロット試料に対して岩石磁気・古地磁気方位測定および産業技術総合研究所の SQUID 顕微鏡での磁気マッピングを行い，古地磁気強度データ抽出のための磁気特性の確認を行なった．古地磁気方位測定はその後古地磁気強度測定を行うために低温消磁を併用している．

Granite (770Ma) は交流消磁の結果少なくとも 4 つの成分が確認できた．Day-Plot 上では疑似単磁区（PSD）領域に分布するが，SQUID 顕微鏡の NRM 磁気画像を確認すると多磁区（MD）から単磁区（SD）まで様々な磁性粒子を保有していることが示された．Basalt(446Ma ＋ α) は 2 成分が確認でき，Day-Plot でも NRM 磁気画像でも SD 粒子が卓越している．ただし，Zijderveld 図で確認すると，特徴的残留磁化成分 (ChRM) は原点方向に対して僅かにずれている．

Rhyolite(446Ma) は 3 成分が確認できるがこれも Basalt と同様に ChRM は原点に向かわない．Day-Plot 上では SD と超常磁性（SP）粒子の混合曲線に近い値を示し，NRM 磁気画像でも比較的粒度が揃っていることが確認できる．

今後は，これらの結果をもとに，年代値に対応した磁化の情報を取り出すための手法を検討し測定を進めていく．特に 508Ma の年代値を示す Granite は地球内核形成時期と報告されている年代に近く，古地磁気強度測定結果が重要になると予想されるため，磁化強度と年代値の信頼性確保が必要である．

謝辞：本研究は科研費 21H04523 の支援を受けた。また、モンゴルでの試料採取では，Davaadorj Davaasuren 博士，Niiden Ichinnorov 博士，Shuukhaaz Ganbat 氏，および現地ドライバーの方にお世話になった。心より感謝いたします．

R004-P03
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

伊能忠敬の「山島方位記」から 19 世紀初頭の日本各地の地磁気偏角と地域環境を解析する。

#辻本　元博 [1)]
([1] 無し

Analyzing the early 19th century's geomagnetic declination and the local environment in Japan from Tadataka Inoh's Santou-Houi-Ki.

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

The Santou-Houi-Ki is national treasure of Japan,, consist of 67 volumes ledger of approximately 200,000 magnetic compass survey azimuth data by 5 min unit in 1800 to 1816, cover from eastern Hokkaido to Yakushima recorded by Tadataka Inoh.. We execute

interdisciplinary and simultaneous real analysis, magnetic declination, precise position of the survey reference point and target points where the value of declination to any targets are similar or proximate. We analyzed the declination at 227 points in Japan .

There are lack of declination data in Japan the term of national isolation of Japan. It is necessary to introduce the declination data analyzed from Santou-Houi-Ki to GUFM1 or NOAA. It is possible to restore the Social environment of the detailed location of the survey site.

国宝「山島方位記」は伊能忠敬により 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 巻磁針測量方位角原簿で測量対象地点及び測量実施地点の地名と 0 度 05 分単位の推計約 20 万件の磁針測量方位角を収録。　複数の測量対象地点への磁針測量方位角に含まれる地磁気偏角が一定或いは近似になる地点が磁針測量実施地点である。227 地点で地磁気偏角を解析した。世界では鎖国期の日本の地誌磁気偏角データが不足しておりそれを補足する。

同時に測量時の測量実施地点付近の道路等の社会環境の復元も可能になる。磁気異状地点ではその原因地質も判明する。

R004-P04
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

東南極大陸，リュツォホルム岩体の古地磁気情報：ルンドボークスヘッタ地域，明るい岬地域，天文台岩地域

#石川　尚人 [1)]
(1 地球システム・富山大

Paleomagnetic information from the Lutzow-Holm Complex, East Antarctica: Rundvagshetta, Akarui Point and Tenmondai Rock areas

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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 around 500Ma. The Lutzow-Holm Complex (LHC), extending in the coastal region of Enderby Land between longitudes 39 and 45E 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. In order to re-examine tectonic movements in East Antarctica during the amalgamation process, paleomagnetic analyses has been performed on the LHC, paleomagnetic results from Rundvagshetta (RH), Akarui Point (AP) and Tenmondai Rock (TR) areas will be presented.

The LHC is composed of metamorphic rocks from granulite to amphibolite facies, and its metamorphic grade decreases progressively eastward. Metamorphic rocks in RH area show the highest grade in granulite facies. AP and TR areas belong to the transitional zone between granulite and amphibolite facies and to the amphibolite faces zone, respectively. Based on protolith ages by U-Pb dating analyses, geological subdivisions are proposed in the LHC, and RH area and AP-TR region belong to different units. Gneisses and granitic rocks were corrected at 28 sites in RH, 10 sites at AP and 11 sites at TR.

Progressive thermal demagnetization analyses provided characteristic remanent magnetic components (ChRMs) carried by magnetite, which were isolated in high temperature above 500C, from samples of 22 sites at RH, 8 sites at AP and 5sites at TR. Tentatively-estimated virtual geomagnetic poles of ChRMs seem to be located close to mean paleomagnetic poles of about 500 Ma in the synthetic apparent polar wonder path for East Antarctica (East Gondwana) proposed by Torsvik et al. (2008).

R004-P05
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

宮古島礁性石灰岩の古地磁気層序および岩石磁気の特徴

#小田　啓邦 [1)], 穴井　千里 [2)], 兼子　尚知 [1)]
([1] 産総研・地質情報,[2] 高知大・海洋コア国際研究所

Magnetostratigraphy and Rock magnetic signatures of reefal limestones from Miyakojima Island

#Hirokuni Oda[1)],Chisato Anai[2)],Naotomo Kaneko[1)]
([1]Research Institute of Geology and Geoinformation, Geological Survey of Japan, AIST,[2]Marine Core Research Institute, Kochi University

Reefal limestones are composed of corals and other organisms fossils with significant heterogeneity in the samples and their magnetizations are weak in general. Previous studies on the reefal limestones in Miyakojima Island (e.g. Anai et al., 2018) suggest that magnetite seems to be the main carrier of their weak magnetism, and the origin of magnetite is considered to be biogenic (fossil magnetotactic bacteria) and/or detrital. In the reefal limestones, other magnetic minerals (e.g. hematite and/or goethite) are also present, which prevents to extract primary magnetizations carried by magnetite. Thus, standard magnetization measurement using superconducting magnetometer, and AF or thermal demagnetization or thermal is not easy for paleomagnetic studies including magnetostratigraphy. Anai et al. (2018) was successful in minimizing the influence of secondary magnetizations carried by hematite and/or goethite using reductive chemical demagnetization (RCD). With this new technique, magnetostratigaphy of reefal limestone provides reliable age constraints. In addition, reefal limestone is known to be an excellent recorder of paleoenvironment, such as sea-level change and/or climate change. Here, we present preliminary results of magnetostratigraphic and rock magnetic studies using specimens of nineteen sites collected in 2021 from the outcrops including two consecutive sections from the southern coastal area of Miyakojima Island.

We have taken samples from seven (MK3~MK9) and eight (MK11~MK18) sites along the western and eastern road sections, respectively. We conducted NRM measurements on all paleomagnetic specimens and stepwise AF demagnetization experiments on pilot specimens for all sites. The results suggest that the paleomagnetic polarity boundaries corresponding to Matuyama-Brunhes transition are between MK4 (normal) and MK5 (reversed), and MK12 (normal) and MK13 (reversed), which has the approximate altitude of 35 m. Rock magnetic measurements were conducted on a selected specimen for each site using Lake Shore VSM 8604; i.e. hysteresis, back field DC demagnetization, IRM acquisition and first order reversal curve (FORC). FORC analysis suggest that there are varying proportions of single domain (SD), multidomain (MD) and vortex state grains, which is considered as mainly magnetite. Specimens with corals and coral fragments are generally unstable, whereas specimens with rhodolith are stable with prominent central ridge suggesting biogenic magnetite. Although IRM acquisition curves are noisy with low SN-ratio, IRM unmixing suggests the presence of higher coercivity minerals, which is considered as hematite or goethite. Day-plot of hysteresis parameters show distribution around PSD range, which is consistent with FORC results. SIRM, $S_{-0.1T}$, $S_{-0.3T}$ and hysteresis parameters plots versus stratigraphic level suggest that

B_{cr}/B_c is around 2.5 for the horizon around Matuyama-Brunhes polarity boundary and above, which increases gradually downward and increase further 5m below the boundary suggesting more contribution of MD grains. Although M_{rs}/M_s between the two sections are not completely overlapping, the general trend shows that the values are higher for the horizon above Matuyama-Brunhes polarity boundary with a peak just below the boundary suggesting more contribution of SD grains. The other parameters are not consistent between the two road sections. Four sub-specimens are selected from a specimen of MK1 to understand heterogeneity. Some specimens show significant scatter from the mean values. However, after RCD, the scatter of the parameters is suppressed. This indicates that secondary magnetic minerals such as hematites and goethites are removed by RCD, which contribute to improve the reliability of rock magnetic parameters.

Acknowledgements
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Anai et al. (2018) Reductive chemical demagnetization: a new approach to magnetic cleaning and a case study of reef limestones, Earth, Planets and Space, 70, 184.

R004-P06
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

#臼井　洋一 [1)]
([1] 金沢大学

Limited variations in North Pacific magnetofossils around the Cretaceous-Paleogene (K-Pg) transition

#Yoichi Usui[1)]
([1]Kanazawa University

Pelagic clays, particularly old ones, often contain a large proportion of biogenic magnetite produced by magnetosomes (magnetofossils). Many studies have reported octahedral grains as the dominant magnetofossil morphology in pelagic clay. A notable exception of bullet-shaped magnetofossils has been observed from sediments around Minamitorishima Island. The bullet-shaped magnetofossils are interpreted to reflect increased organic carbon flux. Such a condition may be found under the paleo-equatorial zone, corresponding to the latest Cretaceous for Minamitorishima. Alternatively, a large biological perturbation, such as the K-Pg transition, might have also affected the magnetofossil abundance. To test this latter hypothesis, we investigate sediments from DSDP Site 576, which lies around 10º North of Minamitorishima Island.

Previous studies identified the K-Pg transition as a peak in Ir content at 54.5 mbsf with a resolution of around 5 cm. Continuous magnetic susceptibility measurements using a touch sensor on the split surface detect a peak at 54.51 mbsf with a width of around 15 cm, which we interpret as the K-Pg boundary. We took discrete samples from 54.22 to 55.44 mbsf with approximately 1 cm resolution. First-order reversal curve diagrams show that the susceptibility peak corresponds to reduced relative contribution from the central ridge, indicating that the susceptibility peak reflects an influx of relatively coarse (“PSD”) magnetic grains, possibly as a spinel associated with impact spherules. Ferromagnetic resonance spectroscopy also reveals a more symmetric shape just at the K-Pg boundary. Otherwise, there is no clear indication of changing morphology of magnetofossils such as those observed around Minamitorishima Island. This result suggests that the distribution of bullet-shaped magnetofossils may be limited to the paleo-equatorial zone, suggesting a potential for a paleogeographic marker.

西太平洋赤道域 IODP Expedition 363 の深海底堆積物の約 900〜1800 万年前の古地磁気層序と相対古地磁気強度

熊谷　祐穂 [1)],#中村　教博 [2)], 山崎　俊嗣 [3)]
[(1] 国土地理院,[(2] 東北学院大学,[(3] 東大大気海洋研

Miocene magnetostratigraphy and relative paleointensity of deep-sea sediment in western equatorial Pacific: IODP Expedition 363

Yuho Kumagai[1)],#Norihiro Nakamura[2)],Toshitsugu Yamazaki[3)]
[(1]Geospatial Information Authority of Japan,[(2]Tohoku Gakuin University,[(3]Atmosphere and Ocean Research Institute, University of Tokyo

We present palaeomagnetic results from the Miocene part of the International Ocean Discovery Program Site U1490, which is located in 2341 m-deep water. High-resolution multichannel seismic profiles across the site showed that an uninterrupted accumulation of mud waves occurred (Baldwin et al. 2017). This deposition of the drift sediments under an intensified bottom water current with abundant oxygen may have caused oxidized conditions in the sedimentary column, being suitable for preserving paleomagnetic records. Detailed magnetostratigraphic investigations are essential to provide a long-term record of Miocene relative paleointensity (RPI) variations, and also the palaeoclimatic and palaeo-oceanographic history of the Cenozoic of the Equatorial Pacific and to improve the database of Pacific magnetostratigraphy. Rock magnetic measurements were carried out at 1 cm resolution on U-channel samples from the spliced section with the goal of extracting a high-resolution record of the magnetostratigraphy. Stepwise demagnetization of the natural remanent magnetization yielded well-defined magnetostratigraphy over a time interval of approximately 9 Ma between the upper boundaries of Chron C5En (18.056 Ma) and the Chron C4An (8.771 Ma) with the geomagnetic polarity timescale (GPTS: Gradstein et al., 2012) and with the biostratigraphy of the cores (Expedition 363). Our results confirm published results from the hole's middle to late Miocene section. The main magnetic carriers are both a single-domain biogenic magnetite which shows an equant octahedron in shape and a small pseudo-single-domain detrital magnetite. Our paleomagnetic data is of the highest quality as being comparable with Ohneiser et al. (2013)'s long-term RPI record from IODP Expedition 320/321 Pacific Equatorial Age Transect (PEAT) during the early to middle Miocene. We compare our RPI records with the Ohneiser et al. (2013) results to confirm the evolution of the middle Miocene geomagnetic field in this presentation.

R004-P08
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

#佐藤　哲郎 [1)], 山田　昌樹 [2)], 佐藤　雅彦 [3)], 浅香　成哉 [2)]
[(1] 早稲田大学,[(2] 信州大学,[(3] 東大・地惑

Viscous remanent magnetization dating of reworked boulders from Beppu Bay

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Fields of coastal boulders are amongst the most impressive sedimentary evidence of past catastrophic tsunami and extreme storm events. Dating the deposition age of these boulders enables prediction of frequency-magnitude patterns of high-energy wave events. Although the radioisotope ages from marine organisms can reveal the reworking history at the site, those rely on the availability of datable organisms. As an attempt to overcome challenges for dating the dislocation of singular boulders, we used a viscous remanent magnetization (VRM) dating method. Reworked boulders are expected to acquire a VRM approximately parallel to the geomagnetic field. The magnitude of such a VRM depends on several factors, including the time since reworking and ambient temperature for which there are well-known theoretical relationships of single-domain (SD) magnetic particles. VRM unblocking temperature can, therefore, be a tool for determining the reworking age of boulders. Most boulders on Itogahama beach in Beppu Bay are composed of andesite, and their features are consistent with the Akisada pyroclastic flow deposits (0.43 Ma) that are distributed behind the boulder site. It is thus possible that the boulders originate from the cliffs of the pyroclastic flow deposit. However, it is also possible that the boulders on the beach were reworked by tsunamis and, thus, may provide an insight into the local history of earthquakes and tsunamis. Although one-inch core samples have shown the two-magnetic vector components, the unblocking temperature of younger components were higher than 200 degree Celsius, which indicates the chemical alteration of pre-existing magnetic minerals. To avoid such difficulties, we conduct the paleomagnetic analysis of single silicate crystal. The thermal demagnetization result has shown the three magnetic vector components, and those unblocking temperatures are lower than 200 degree Celsius. The youngest VRM component suggests the reorientation of the boulder by paleotsunami, and the VRM ages correspond to the previously reported four sandy tsunami sediments. On the other hand, older VRM component ages are much older than the 0.43 Ma. Here, we discuss about those ages using a modified VRM dating method (e.g., Sato et al. 2016), which considers the effects of distribution of grain size and magnetic domain state other than SD.

R004-P09
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

被熱による粘土〜土器中の磁性鉱物の生成と変化について (1)
－ 復元窯焼成実験と段階熱磁気分析による逐次観察から －

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Transformation of magnetic minerals in potteries upon heating I: Firing in a restored medieval kiln and stepwise Js-T analysis

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It has been recognized empirically that heated archaeological artifacts such as potteries, kiln bodies, and burned clay from fire sites have higher remanent magnetization and susceptibility than the unheated surroundings. This is because the iron-bearing minerals in the clay or soil transform into magnetic minerals upon heating, but the details of what magnetic minerals are formed under what temperature and chemical conditions are not known. In this study, we conducted firing experiments in a restored medieval Bizen kiln and stepwise thermomagnetic (Js-T) analysis to compare the magnetic mineral assemblage before and after heating, and monitor the changes occur at different temperatures. The samples were three types of clay collected in Okayama and Fukuoka, which are considered to be the paste of ancient Bizen and Sueki wares. Verwey transition of (titano)magnetite was clearly observed in the low-temperature magnetic measurements of all three samples before heating. Contribution of iron hydroxides such as goethite and lepidocrocite was also indicated. Firing experiments was conducted in the restored medieval Bizen kiln factory built by Tadashi Hirakawa, a master Bizen potter, under his cooperation. In order to examine the effect of different firing environment on magnetic minerals production, samples were placed in five different locations in the kiln and fired. Gray to reddish brown variations in the color of the fired products were observed. Upon thermomagnetic experiments of the fired products, two components with Curie point of ~120 ℃ and ~550 ℃ were recognized, and their ratio varied between samples. We interpret that these two components represent luogufengite and magnetite, respectively, and the variations in the ratio of magnetic components and color of the products are possibly linked to the difference of firing environment. The intensity of isothermal magnetization at low temperature increased by an order of magnitude after heating, and the Verwey transition became unclear. In addition, a series of Js-T analyses with maximum temperature of 150 ℃ to 700 ℃ with 50 ℃ intervals was performed on a clay sample to observe the changes in magnetism occur at each temperature. Experiments were performed in air and in vacuum (<1 Pa). in both conditions, increase of magnetization, possibly due to the decomposition of iron hydroxides and the formation of magnetite or maghemite, was observed at relatively low temperature. The maximum magnetization was reached at 550 ℃ in air and 600 ℃ in vacuum, and the maximum for the sample heated in vacuum was about three times larger than that for the sample heated in air. At around 700 ℃, the magnetization decreased that suggests that magnetite was oxidized to hematite. Such decrease in magnetization contradicts from the tendency in archeological samples that the higher the exposed temperature, the larger the magnetization and susceptibility, and investigations at higher temperatures are required. In the presentation, the comparison of three samples will also be discussed.

経験的に、土器や窯跡、火事跡の焼土などの被熱考古遺物は周囲と比較して残留磁化や帯磁率が大きいことが知られている。これは、原料となる粘土や土壌に含まれる鉄鉱物や非晶質中の鉄が加熱により磁性鉱物に変化するためであるが、どのような温度・化学条件でどのような磁性鉱物が生成されるかは詳しく分かっていない。本研究では、土器の焼成過程に着目し、中世古備前復元窯による焼成実験と段階熱磁気分析により、加熱前後の磁性鉱物の変化や温度ごとに生成・変化する磁性鉱物の推定を行った。試料として、古備前や須恵器の胎土と目される 3 種類の粘土を用いた。加熱前の粘土の低温磁気分析および等温残留磁化獲得実験の結果、使用した 3 種類の粘土すべてに（チタノ）マグネタイトが含まれることが分かった。また、ゲータイトやレピドクロサイトといった鉄水酸化物の寄与も示唆される。粘土焼成実験は備前焼平川忠陶房復元窯にて行った。焼成環境の違いによって生成される磁性鉱物にどのような影響があるのかを検討するため、窯内の 5 か所に粘土試料を配置し、焼成を行ったところ、焼成物の色には灰色〜赤褐色のバリエーションが見られた。熱磁気分析の結果、キュリー点が約 120 ℃と約 550 ℃の成分がみられ、その量比は試料ごとに異なっていた。これらはルオグフェンジャイトとマグネタイトに対応すると考えられ、焼成環境の違いや色の違いとの関連性が示唆される。また、低温磁気分析の結果、焼成前と比較して磁化強度は一桁上昇し、フェルベー点は不明瞭化していた。段階熱磁気分析では、最高到達温度 150 ℃から 700 ℃の熱磁気分析を同一の試料に対して 50 ℃ごとに連続的に行うことで、各温度で起こる磁性・化学変化を観察した。実験は空気中と真空中（<1 Pa）で行い、そのどちらにおいても比較的低温で鉄水酸化物の分解とマグネタイトもしくはマグヘマイトの生成によると考えられる磁化強度の増加がみられた。空気中加熱では 550 ℃、真空中では 600 ℃で磁化強度の極大に達し、その大きさは真空中加熱された試料が空気中加熱試料の 3 倍程度であった。700 ℃付近では加熱前後で磁化強度が低下していることから、マグネタイトが酸化してヘマタイトに変化したことが示唆される。これは被熱温度が高いほど磁化や帯磁率が大きいという実際の考古遺物でみられる傾向に反して

おり、さらに高温での実験が必要である。発表では、3 種類の粘土鉱物の比較についても論じる。

R004-P10
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

被熱による粘土〜土器中の磁性鉱物の生成と変化について (2) − 最高到達温度と生成磁性鉱物の関係性 −

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Transformation of magnetic minerals in potteries upon heating II: Relationship between maximum temperature and magnetic minerals

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Burned soil such as earthenware, kilns, and furnace sites contain more magnetic minerals than the background soil, rocks and clay, resulting in the retention of strong thermoremanent magnetization. This is the reason why paleomagnetic and rock magnetic techniques are used in archaeomagnetism, magnetic exploration of buried heated remains, and determination of fired soil by surface magnetic susceptibility. However, the details of the formation and changes of magnetic minerals during the heated process are not well understood. In this talk, following the presentation by Kato et al. in this session on the formation of magnetic minerals using a reconstructed kiln, we will present the results of rock magnetic studies on the changes in mineral species, especially magnetic minerals, obtained from heating of clays in a laboratory environment. The samples for analysis were prepared by firing cylindrical samples (5 mm dia.) of ceramic clay and other materials in a small electric furnace at several maximum temperatures. These were analyzed magnetically and mineralogically. For example, isothermal remanent magnetization (IRM) acquisition measurements of Bizen pottery clay (red clay) after 96 hours of heating at various temperatures from 400 to 1200 ^{o}C in air revealed two peaks of low coercivity (50 mT) and high coercivity (near 1 T) in the unheated clay, and the former peak decreased with heating, and instead a weaker 10-20 mT peak. As the temperature is further increased, this peak weakens again and the 1 T peak increases in abundance. Thus, the type and amount of magnetic minerals in a fired sample, as well as the surface and cross-sectional color, are strongly influenced by the maximum achievable temperature. In this presentation, the relationship between temperature, oxygen atmosphere, and the minerals produced will be discussed.

人間が熱を加えた土器やそれを焼成した窯、炉跡などの焼土には、周囲の土壌や粘土と比較して多くの磁性鉱物が含まれ、結果的に強い熱残留磁化を保持している。このことが考古地磁気学や埋没被熱遺構の磁気探査、表面帯磁率による焼土判定等、考古理学として古地磁気・岩石磁気的手法が利用される背景となっている。しかし、被熱過程における磁性鉱物の生成や変化について詳細がわかっていない。本講演では、本セッションの加藤らによる復元窯を用いた磁性鉱物生成の研究講演に引き続き、実験室内環境での粘土の加熱を行いそれに伴う鉱物種、とくに磁性鉱物の変化について岩石磁気研究の結果を紹介する。分析に供した試料は、小型電気炉を用いて数種類の最高温度を設定し、陶芸用粘土等の円筒形試料（φ 5mm）を焼成して作成した。これを磁気的・鉱物学的に分析した。例えば、備前焼用粘土（赤土）を空気中での 400〜1200 ℃の各温度で 96 時間加熱後に等温残留磁化（IRM）着磁を行った測定では、非加熱の粘土では低保磁力（50mT）および高保磁力（1T 近辺）に 2 つのピークがあるが、前者は加熱と共に減り、代わってさらに弱い 10〜20mT のピークが強くなる。さらに温度を上げるとこのピークは再び弱くなり、1T のピークが増量する。このように、焼成試料に含まれる磁性鉱物の種類や量、さらに表面や断面の色は、最高到達温度に強く影響を受ける。本講演では、温度・酸素雰囲気と生成鉱物の関連性について論じる。

R004-P11
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

奈良県の布留遺跡から出土した土器の予察的な胎土・磁気分析

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Preliminary X-ray fluorescence and magnetic analyses on pottery excavated at the Furu site in Nara Prefecture

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Natural scientific methods such as radiocarbon dating and X-ray fluorescence (XRF) analysis have long since been introduced to improve the reliability of dating and identification of a place of origin of artefacts, but the introduction and development of further methods is long overdue. It is possible that the magnetic property of pottery material may be similar between material from the same period and same locality and different between material from different periods and different localities, but no systematic examination of the relationship has been carried out to date. As a case study, we have started work on XRF and magnetic analyses of excavated potteries at the Furu site, where is a Palaeolithic to Medieval complex site. So far, we have carried out preliminary analyses of four medieval excavated pottery types that are close in time but of different provenance and firing techniques and we report these results.

土器型式の年代や産地の比定の信頼性を向上させるため、放射性炭素年代測定法や胎土分析法などの自然科学的手法が導入されて久しいが、さらなる手法の導入と開発が待望されてきた。土器資料の磁性は、同時代・同産地の資料間では類似し、異時代・異産地の資料間では異なる可能性が考えられるが、これまでに関連の系統的な検討は全く行われていない。事例研究として、「布留式」の標識遺跡であり、旧石器時代～中世の複合遺跡である布留遺跡の出土土器を対象とした胎土分析と磁気分析の取り組みを開始した。今回は、時期的には近いものの、産地や焼成技術は異なる中世の出土土器の 4 つの器種（瓦器、東播系須恵器、常滑焼甕、土師器皿）を対象とした予察的な分析を行った。

胎土分析は、蛍光 X 線分析装置（Rigaku ZSX Primus Ⅱ）を用いて、各器種 5 点ずつを対象に主要元素 10 元素と微量元素 15 元素について実施した。磁気分析は、磁気特性測定システム（MPMS-XL5）と振動型磁力計（MicroMag 3900 VSM）を用いて、各器種 3-5 点ずつを対象に等温残留磁化の段階獲得実験（低温・常温）と温度変化実験、ヒステリシスパラメーターの測定を行った。詳細な結果は追って報告するが、胎土分析の結果に基づくと「土師器皿」「瓦器」「常滑焼甕と東播系須恵器鉢」の 3 つのグループが識別でき、磁気分析の結果に基づくと「土師器皿」「常滑焼甕」「瓦器と東播系須恵器鉢」の 3 つのグループが識別できることが示唆された。つまり、いずれかの分析のみで「土師器皿」のグループが識別でき、さらに両者の分析を組み合わせることで「瓦器」「常滑焼甕」「東播系須恵器鉢」を独立のグループとして、自然科学的視点で識別できることが示唆される。

R004-P12
ポスター 2 ：9/25　AM1/AM2 （9:00-12:30）

考古岩石磁気学的手法によるベトナム・ランヴァイン岩陰遺跡土壌の被熱判定

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Estimating the thermal history of soils at the Lang Vanh rock-shelter in Vietnam using archaeo-rock magnetic analysis methods

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Archaeo-rock magnetism is a new field of research that aims to contribute to solving various problems in archaeology by applying rock magnetic methods, traditionally studied in the earth sciences, to the analysis of archaeological artifacts (Yamamoto et al., 2023; Hatakeyama et al., 2021; Hatakeyama et al., 2017).

This study used various analytical techniques based on archaeo-rock magnetism to identify stratigraphy, determine the presence or absence of thermal history, and estimate heating temperatures within the excavation trench at the Lang Vanh rock-shelter in Hoa Binh Province, North Vietnam. The Lang Vanh rock-shelter is one of the archaeological sites associated with the Hoabinhian culture, an archaeological culture characterized by a settlement style using cave or rock-shelters in limestone mountains (e.g. Han.V.K., 2008), and the age of the cultural layer at the site has been estimated by radiocarbon dating to be 16470 +/- 80BP (Nguyen.V., 2008). Excavations at the site are currently underway, led by the Center for Southeast Asian Prehistory, and the soil samples used in this study were collected in 2022 from 20 cm, 40 cm, 60 cm, and 80 cm above the bottom of the excavation trench.

In this study, six magnetic analyses were carried out on the four soil samples, including (1) magnetic susceptibility measurements, (2) stepwise IRM acquisition experiments, (3) low-temperature magnetic analysis, (4) stepwise thermomagnetic analysis, (5) magnetic hysteresis analysis and (6) FORC analysis. As a result, three conclusions can be obtained from the archaeo-rock magnetic perspective: (A) the stratigraphy in this study sampling area of the trench can be roughly divided into three layers; (B) the soil collected from 20 cm above the bottom of the trench is likely to have been fired; and (C) the maximum temperature in the fired area is estimated to be 500-550 oC. These conclusions can be seen as corroborative, as they are consistent with what the archaeologists had previously estimated on the basis of archaeological evidence.

考古岩石磁気学は、従来、地球科学分野において研究が進められてきた岩石磁気学的分析手法を考古遺物の分析に適用し、考古学分野における各種問題解決に資することを目的とした新たな研究領域である（山本ほか, 2023；畠山ほか, 2021；畠山ほか, 2017）。

本研究では、考古岩石磁気学に基づく各種分析手法を使用し、ベトナム北部ホアビン省に位置するランヴァイン岩陰遺跡の最新トレンチの層序判別・被熱判定・被熱温度推定を実施した。ランヴァイン岩陰遺跡は、石灰岩山地帯の洞穴・岩陰での居住スタイルを特徴とする考古文化「ホアビン文化」に関連する遺跡の一つであり（e.g. Han.V.K., 2008）、同遺跡の文化層の年代は、放射性炭素年代測定法により 16470 +/- 80BP と推定されている（Nguyen.V., 2008）。同遺跡では現在、東南アジア先史研究所の主導による発掘調査が継続的に実施されており、本研究で使用した土壌試料は、2022 年に発掘トレンチ底部より 20cm・40cm・60cm・80cm の高さの各位置より採取したものである。

本研究では、これら 4 種の土壌試料に対して (1) 帯磁率測定、(2) 段階 IRM 獲得実験、(3) 低温磁気分析、(4) 段階熱磁気分析、(5) 磁気ヒステリシス分析、(6)FORC 分析の 6 項目の磁気分析を行った。結果として、考古岩石磁気学的観点より、(A) トレンチの本研究試料採取範囲における層序は大まかに 3 層に区分可能である、(B) トレンチ底部より 20cm の土壌は被熱している可能性が高い、(C) 被熱部の最高到達温度は 500〜550 ℃と推定されるという 3 つの結論を得ることができた。これらの結論は、事前に発掘調査担当者が考古学的所見に基づいて推定していた内容と矛盾しないことから、その一つの裏付けになり得ると考えられる。