Paleoenvironmental control on the magnetic mineral assemblage in the Izu rear arc over the last 1 Ma

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During April and May 2014, IODP Expedition 350 drilled a 1806.5 m deep hole at Site U4137 in the Izu-Bonin rear arc, in order to understand, among other objectives, the compositional evolution of the arc since the Miocene and track the missing half of the subduction factory. Mostly fine grained sediments were recovered and variations in magnetic properties and mineralogy are well documented. Routine rock magnetic measurements performed on about 360 samples in the first 120 meters of Hole U1437B showed that pseudo single domain to multidomain (titano-) magnetite is the main carrier of the remanence. The studied interval covers the last 1 Ma, i.e. marine oxygen isotope stages (MIS) 1 to 25. Rock magnetic properties and composition, concentration and grain size variations of the magnetic minerals are compared with the isotopic record in order to investigate the rock magnetic signature of climate changes in the Izu rear arc in the Late Pleistocene. The proxies for magnetic concentration (e.g. magnetic susceptibility, saturation isothermal remanent magnetization) show generally higher values during the interglacials; and lower values during the glacials. This might be partly explained by increasing volcanic activity at the glacial/interglacial transitions as is shown by an increase in the frequency of tephra layers near the time of the transitions. In addition, the composition of the magnetic assemblage also varies with the oxygen isotope record. After the mid Pleistocene transition (1250-700 ka), higher coercivity minerals (such as hematite) dominate the magnetic assemblage in the glacial stages, whereas lower coercivity minerals dominate the interglacial stages. The magnetic assemblage of the Izu rear arc sediments is thus complex with various origins. Ti-magnetite, of detrital and volcanic origins, dominates the interglacials whereas higher coercivity minerals dominate the glacials confirming an increasing supply of Asian dust in the sediments in glacial times. XRF measurements support our observations.

Keywords: Izu rear arc, IODP Exp 350

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電子顕微鏡を用いた中国レスにおける土壌化起源磁性ナノ粒子の観察

Microscopic observations of pedogenic nanoparticles causing magnetic enhancement in Chinese loess deposits

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Paleoclimatic signals have been recorded in various ways in Chinese loess-paleosol sequences. Magnetic susceptibility has been used as a reliable proxy for reconstructing Asian summer monsoon intensity because its enhancement is exactly related to paleorainfall through neoformation of magnetic nanoparticles during pedogenesis. However there are no observations which can interpret either formation process or form of such pedogenic nanoparticles exactly.
To investigare this problem, scanning electron microscope (SEM) observations were conducted after some rock magnetic experiments including magnetic susceptibility measurements, IRM composition analysis and thermomagnetic measurements, and we divided bulk samples into three subsamples with different grain size bands (D1: >10 μm, D2: 10~1 μm, D3: <1 μm) in advance so that we can obtain significant informations on grain sizes of pedogenic nanoparticles which may help the microscopic observations. Bulk samples used in this study include less-altered loess and mature paleosol showing extremely low (29 $\times 10^{-8} m^3 kg^{-1}$) and high (116 $\times 10^{-8} m^3 kg^{-1}$) magnetic susceptibility respectively and were selected as specimens from a sequence of loess L8 to paleosol S8 from Lingtai on central part of the Chinese Loess Plateau.
From results of IRM composition analysis and thermomagnetic measurements, pedogenic nanoparticles turned out to be magnetite or maghemite. Besides, results of magnetic susceptibility and its frequency dependence (FD) showed that D2 has the dominant contributions amounting to over 60 % to enhanced magnetic signals in paleosol. Considering FD indicates the total amount of super-paramagnetic (SP) particles whose grain sizes are tens of nm, we can suggest that the detritus grain size band in which pedogenic nanoparticles including some SP particles are concentrated is D2 and such ultra-fine particles exist in detrital particles in the form of inclusions. Based on these results and hypothesis, magnetic extractions were conducted on D2 of both loess and paleosol. A certain amount of particles was obtained from paleosol while particles were hardly obtained from loess, and these magnetically extracted particles from paleosol D2 were subjected to SEM observations. Energy dispersive X-ray spectroscopy (EDS) showed that such magnetically extracted particles include a lot of detritus silicates like chlorite, muscovite and quartz even they are non-magnetic minerals. Watching surface of these silicates with SEM carefully, nanoinclusions of iron oxide were observed. Further results including X-ray diffraction analysis and TEM observation will be shown on the poster.

キーワード：中国レス、土壌化、磁気増大、SEM観察
Keywords: Chinese loess, pedogenesis, magnetic enhancement, SEM observation

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日本海の海底表層堆積物中での磁性鉱物分布

Magnetic mineral distributions in surface sediments taken from the northeastern Japan Sea

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In order to understand how magnetic minerals assemblages are affected by the redox state of overlying bottom waters in the northeastern Japan Sea, rock magnetic and chemical analyses were conducted. Undisturbed surface sediments were taken at six sites with a multiple corer during the R/V Shinsei-maru KS-14-13 cruise in 2014. The sediments consist of silty clay, and water depths of the six sites range between 778 to 2709 m. Dissolved oxygen (DO) of bottom waters were measured directly with a DO meter on board immediately after recovering of the multiple cores. Water samples were taken from the cores using by a plastic syringe and were passed through a filter (pore diameter of 0.45 μm), and water samples 30 mL were stored in Teflon bottles. The water samples were treated with 1 mL of special grade nitric acid (1 mol/L concentration), and pH was adjusted below 1 at room temperature for dissolved iron (DI) analysis. DI was measured with a flameless graphite furnace atomic adsorption spectrometer. Dried and powdered sediment samples of approximately 20 mg were used for total organic carbon (TOC) and total nitrogen (TN) measurements with a CNHS analyzer. Thermal demagnetization of composite IRMs were conducted for determination of magnetic minerals in the samples. The dried powder samples (ca 50 mg) were packed in a small quartz cup (5 mm in diameter and 10 mm in height). A magnetic field of 2.5 T was applied along the vertical direction of the cup, and then fields of 0.3 T and 0.07 T were applied along the two remaining perpendicular axes using a pulse magnetizer. Results show that higher values of TN and TOC contents are recognized at sites which has lower DO in bottom water. Thermal demagnetization results for composite IRMs for samples from all site samples, soft (<0.07 T), and medium (0.07-0.3 T) components are demagnetized completely at around 580 degree which is the Curie point of magnetite. Slight thermal decay of the hard components (<2.5 T) is observed at 675 degree which is the Curie point of hematite in all samples. An inflection in demagnetization curves at around 320-400 degree is recognized in samples from all sites. Authigenic greigite which is not expected to be defined magnetic mineral to form under an oxic water column. The inflection suggests the presence of (titano)maghemite. The remanent magnetization intensities decrease at around 80-120 degree which is the Neel temperature of goethite at a most oxic site. DI concentration of the site show highest value, thus it suggest that suspended solids of iron hydroxides (<0.45 um in diameter) area bundantly present in the relatively oxic bottom waters, and goethite is stable under such condition. Magneto fossils were confirmed by TEM observations, and were classified three major morphologies which are elongate, tear drop, and equant. Morphology ratios varies by the redox state of overlying bottom waters.

キーワード：磁性鉱物種、底層水の酸化還元状態、走磁性バクテリア
Keywords: Magnetic mineralogy, Redox state of overlying bottom water, Magneto fossils

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石垣島産化石サンゴ骨格内に存在する磁性鉱物の磁気検出と強磁性共鳴の特徴

Magnetic Detection and Ferromagnetic Resonance Characterization of Magnetic Minerals in Fossil Coral Skeletons in Ishigaki Island, Japan

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The remanent magnetization of corals has been one of attractive archives because coral frameworks may provide us high-resolution paleomagnetic records from pre-observatory times, due to their high growth rates. The coral skeletons, mainly composed of aragonite, have following two advandages in the reconstruction of the geomagnetic field: 1) they can be dated by radiocarbon and uranium-thorium dating method, 2) a paleomagnetic standard 1-inch core sample gives an avaraged orientation for two-three years because they grow up at a rapid rate. Especially, the annual banded skeleton of *Porites* might have a great potential as a high-resolution paleomagnetic recorder due to their continuous growths through hundreds of years at a growth rate 11–20 mm-yr. Because of these characteristics, they may be able to record short-term geomagnetic paleosecular variation in a decadal or centennial scale, which are difficult to reconstruct with previus samples (e.g., lava flows, burnt archeological artifacts, lake or marine sediments, and speleothems). Unfortunately, in spite of the enormous possibility for paleomagnetic reconstruction, most coral skeletons have shown an extremely weak magnetization, and their magnetic origin has not been determined. However, a measureable magnetization has been reported in deceased coral tsunami boulders along the shorelines of Ishigaki Island where the coral reefs are grown on bedrock of Ryukyu limestone and Jurassic schist, even using a conventional spinner magnetometer. It is necessary to determine the characterization of magnetic assembladges in this coral skeleton to utilize them as a reliable paleomagnetic recorder, because paleomagnetic records are affected not only by past geomagnetic field variations but also by lithologic factors of samples, such as mineralogy, concentration, and grain size of the magnetic phases. Therefore, by using first-order reversal curve (FORC) measurements, ferromagnetic resonance (FMR) spectroscopy and petrological observations by FE-SEM of acid-treated residuals of our corals, we found that the magnetic mineral assemblage consists of a dominant biogenic-origin single-domain magnetite and a minor detrital component. From AF demagnetization of recently-ceased *Porites* coral skeletons, we also found that the characteristic remanence directions of almost all samples are relatively stable with some fluctuations. However, some samples exhibit obviously different remanence directions from its average, suggesting the rotation by a past tsunami event. Our findings suggest that *Porites* coral framework samples have a potential use as a high-resolution paleomagnetic recorder with careful examination of past rotations.

キーワード：岩石磁気、サンゴ骨格、強磁性共鳴
Keywords: rock magnetism, coral skeletons, ferromagnetic resonance

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伊能忠敬の山島方位記から19世紀初頭の日本の地磁気偏角を解析する。第10回報告

Analyzing the early 19th century's Geomagnetic declination in Japan from Tadataka Inoh's San-Tou-Houi-Ki,10th report.

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国宝「山島方位記」は伊能忠敬による1800年から1816年迄の北海道東岸から屋久島迄の推計約20万件の精度0°05′単位の陸上磁針測量方位角を記録した67巻でなる原簿である。1917年に詳細が既知であった江戸(東京)深川伊能隠宅位置での1802年と1803年の磁針測量方位角データからの地磁気偏角平均値の唯一解析以後頓挫した解析を続けている。我々は地磁気学、測量学、古地図学、郷土史を横断する学際同時解析により、分野別の伝統的な研究方法よりも真北方位、地磁気偏角及び山島方位記に記載の磁針測量実施基点や測量対象地点の位置を遥かに正確に解明する詳細根拠を増やすことができる。(1)解析手順 景観再現ソフトと国土地理院GSI電子国土地図により個々の測量対象地点の緯度経度と測量実施基点概略位置の緯度経度を知り、各測量実施基点から各測量対象地点への真方位角の概略を把握する。地磁気偏角=真北方位角-山島方位記に記載の磁針測量方位角。測量実施基点概略位置(緯度経度秒単位)から複数の測量対象地点位置(緯度経度0.1秒単位)への真方位角から磁針測量方位角を差し引いた総ての地磁気偏角(0.01秒単位)が互いにより近似になる測量実施基点詳細位置の緯度経度(0.01秒単位)を逆算計算し、測量当日の測量基点での個々の解析の地磁気偏角の平均値を分単位で発表している。計算速度向上と精度確保の為にエクセルの連続式を使う。 可能な限り測量実施基点の現地に行き実景を確認し、GPS送受信器で緯度経度を測り、地磁気偏角の数値を再計算する。 (2)「山島方位記」を解析し、日本を地磁気偏角データの過疎地から19世紀初頭の地磁気偏角データの集中地域に変え、北東アジアに新しいデータを提供することができる。合計解析地点数は197を超えた。(3)当時の日本列島の等偏角線の概要と西日本沿岸での0°15′毎の偏角の分布が現れ始めた。この分布を米国海洋大気庁NOAA作成Historical Magnetic Declination Mapの等偏角線と比較すると概ね同一ではあるが、NOAAの西偏は5年程度遅い傾向がある。(4)「山島方位記」の解析からは地域的な磁気異常も北海道東部南岸、能登半島の一部、伊勢の朝熊山,九州の延岡等で判明した。これらはNOAAのHistorical Magnetic Declination Mapには記載されていない。(5)郷土史上で重要な伊能忠敬の測量実施基点詳細位置、測量対象地点の緯度経度秒単位以下の正確な復元が可能になった。他の研究方法では不可能な程に正確である。解析は沿岸から本州内陸に向かっている。国宝「山島方位記」は伊能忠敬による1800年から1816年迄の北海道東岸から屋久島迄の推計約20万件の精度0°05′単位の陸上磁針測量方位角を記録した67巻でなる原簿である。1917年に詳細が既知であった江戸(東京)深川伊能隠宅位置での1802年と1803年の磁針測量方位角データからの地磁気偏角平均値の唯一解析以後頓挫した解析を続けている。我々は地磁気学、測量学、古地図学、郷土史を横断する学際同時解析により、分野別の伝統的な研究方法よりも真北方位、地磁気偏角及び山島方位記に記載の磁針測量実施基点や測量対象地点の位置を遥かに正確に解明する詳細根拠を増やすことができる。(1)解析手順 景観再現ソフトと国土地理院GSI電子国土地図により個々の測量対象地点の緯度経度と測量実施基点概略位置の緯度経度を知り、各測量実施基点から各測量対象地点への真方位角の概略を把握する。地磁気偏角=真北方位角-山島方位記に記載の磁針測量方位角。 測量実施基点概略位置(緯度経度秒単位)から複数の測量対象地点位置(緯度経度0.1秒単位)への真方位角から磁針測量方位角を差し引いた総ての地磁気偏角(0.01秒単位)が互いにより近似になる測量実施基点詳細位置の緯度経度(0.01秒単位)を逆算計算し、測量当日の測量基点での個々の解析の地磁気偏角の平均値を分単位で発表している。計算速度向上と精度確保の為にエクセルの連続式を使う。 可能な限り測量実施基点の現地に行き実景を確認し、GPS送受信器で緯度経度を測り、地磁気偏角の数値を再計算する。 (2)「山島方位記」を解析し、日本を地磁気偏角データの過疎地から19世紀初頭の地磁気偏角データの集中地域に変え、北東アジアに新しいデータを提供することができる。合計解析地点数は197を超えた。(3)当時の日本列島の等偏角線の概要と西日本沿岸での0°15′毎の偏角の分布が現れ始めた。この分布を米国海洋大気庁NOAA作成Historical Magnetic Declination Mapの等偏角線と比較すると概ね同一ではあるが、NOAAの西偏は5年程度遅い傾向がある。(4)「山島方位記」の解析から

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は地域的な磁気異常も北海道東部南岸、能登半島の一部、伊勢の朝熊山,九州の延岡等で判明した。これらはNOAAのHistorical Magnetic Declination Mapには記載されていない。(5)郷土史上で重要な伊能忠敬の測量実施基点詳細位置、測量対象地点の緯度経度秒単位以下の正確な復元が可能になった。他の研究方法では不可能な程に正確である。解析は沿岸から本州内陸に向かっている。

キーワード：地磁気偏角、伊能忠敬、山島方位記、測量基点、測量対象地点、学際
Keywords: geomagnetic declination , Tadataka Inoh, Santou-Houi-Ki, Survey reference point, Survey target point, interdiscplinary

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ジルコン単結晶を用いた古地磁気－包有物研究：丹沢トーナル岩の例
Mineral inclusions and magnetic properties of single zircon crystals from the Tanzawa tonalitic pluton

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Geomagnetic field paleointensity data provide critical information about the evolution of the core and mantle, and the state of the geomagnetic field are closely related to the condition of surface environment (Tarduno et al. 2014, 2015). Although it is essential to understand the variations in geomagnetic field intensity through the Earth history, data are still scarce to a resolve billion year-scale geomagnetic field variation. This is mainly due to the lack of well-preserved rocks for older eras, which often results in unsuccessful paleointensity experiments. To overcome this problem, recent investigates has focused on paleointensity experiments using single silicate crystals, which often accompany magnetic mineral inclusions, such as plagioclase (Tarduno et al. 2006), quartz phenocryst (Tarduno et al. 2010), pyroxene (Muxworthy and Evans 2012), olivine (Tarduno et al. 2012), and zircon (Tarduno et al., 2015, Sato et al., 2015).
Tarduno et al. (2015) demonstrated that paleointensity data of early Archean to Hedean zircons bearing magnetic inclusions from the Jack Hills conglomerate could be used to reconstruct the early geodynamo, and Sato et al. (2015) reported the rock-magnetic properties of the single zircon crystals sampled from the the Tanzawa tonalite (4-5 Ma). Sato et al. (2015) demonstrated that the various rock-magnetic properties such as natural remanent magnetization (NRM), isothermal remanent magnetization (IRM), hysteresis parameters, and transition temperature could be measured using the standard magnetometers (SQUID magnetometer, MPMS, and AGM). During their rock-magnetic measurements, many of single zircon crystals are below the limits of the sensitivity of the magnetometers employed, but for the 80 in 1037 zircons had values of M NRM $\geq 4 \times 10^{-12}$ Am^2 and M IRM $\geq 4 \times 10^{-12}$ Am^2, containing enough magnetic minerals to be measured in the DC SQUID magnetometer. According to the rock magnetic parameters, the main remanence carriers seem to be nearly pure magnetite and pyrrhotite, while direct identification of mineral inclusions in those zircons are not yet acquired.
In this study, we investigate mineral inclusions in Tanzawa zircons reported in Sato et al. (2015), with an optical microscope, Laser-Raman microspectroscopy and scanning electrom microscope equipped with EDS system. It is confirmed that zircon crystals with strong NRM intensity contain titano-magnetite and pyrrhotite. Significantly, titano-magnetite inclusions display fine exsolution lamellae indicating single- or pseudo-single-domain size. In this presentation, we will discuss the relationship between rock-magnetic properties and magnetic mineral inclusions in the Tanzawa zircons.

キーワード：岩石磁気、ジルコン、包有物
Keywords: Rock-magnetism, Zircon, inclusion

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Rock-magnetic properties of single zircon crystals sampled from the Yangtze River

Rock-magnetic properties of single zircon crystals sampled from the Yangtze River

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Geomagnetic field paleointensity data provide critical information about the thermal evolution of the Earth, and the state of the geomagnetic field is closely related to the surface environment. While it is pivotal to understand the variations in geomagnetic field intensity throughout the history of the Earth, data are still too scarce to resolve billion-year-scale geomagnetic field variation. This is primary because of the lack of geological samples for older eras, which often result in unsuccessful paleointensity experiments.
We focus on a paleointensity experiment using single zircon crystal. Zircon crystals play an important role in paleomagnetic studies because they have several mineralogical advantages: (1) they commonly occur in crustal rocks, (2) precise age determinations with U-Th-Pb and (U-Th)/He analyses are possible, and (3) they have highly resilient responses to alterations and metamorphism.
Recently Sato et al. (2015) reported the rock-magnetic properties of the single zircon crystals sampled from the Nakagawa River, which crosses the Tanzawa tonalitic pluton in central Japan. They demonstrated that the various rock-magnetic properties such as natural remanent magnetization (NRM), isothermal remanent magnetization (IRM), hysteresis parameters, and transition temperature could be measured using the standard magnetometers (SQUID magnetometer, MPMS, and AGM). Combining these rock-magnetic parameters, they proposed the sample selection criteria for paleointensity experiments using single zircon crystals.
In this study, we conducted rock-magnetic measurements for single zircon crystals sampled from the Yangtze River. NRM intensity (M_{NRM}) was first measured for the 1034 grains of zircon crystals. Then, low-temperature demagnetization (LTD) treatment was further conducted for 85 grains with M_{NRM} values larger than 5 $\times 10^{-12}$ Am^2, and the memory (NRM intensity after LTD treatment; $M_{NRM\text{-}LTD}$) was measured. For the 85 samples, we also carried out alternating field demagnetization (AFD) treatment at 10 mT, and the memory (NRM intensity after AFD treatment; $M_{NRM\text{-}AFD}$) was measured. After the NRM measurements, IRM was imparted with a field of 1 T using pulse magnetizer for the 1034 crystals, and the resultant IRM intensity was measured (M_{IRM}). Subsequently, IRM intensity after LTD treatment ($M_{IRM\text{-}LTD}$) and AFD treatment ($M_{IRM\text{-}AFD}$) were measured for the sample with M_{NRM} values larger than 5 $\times 10^{-12}$ Am^2.
M_{NRM} values of the single zircon crystals varied from 10^{-13} to 10^{-10} Am^2, and 101 crystals (9.8%) had M_{NRM} larger than 4 $\times 10^{-12}$ Am^2. M_{IRM} values of the single zircon crystals also varied by five orders of magnitude, and 402 crystals (38.9 %) showed M_{IRM} larger than 4 $\times 10^{-12}$ Am^2. The ratios of M_{NRM}/M_{IRM}, $M_{NRM\text{-}LTD}/M_{IRM\text{-}LTD}$, and $M_{NRM\text{-}AFD}/M_{IRM\text{-}AFD}$ varied 0.003-2.0, 0.005-2.4, and 0.005-2.4. There were several samples with the $M_{NRM\text{-}AFD}/M_{IRM\text{-}AFD}$ less than 0.1, which could be suitable for paleointensity experiment. Combining the rock-magnetic parameters, we will discuss the feasibility of the paleointensity experiment using single zircon crystals from the Yangtze River.

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キーワード：Rock-magnetism、Zircon、Paleointensity
Keywords: Rock-magnetism, Zircon, Paleointensity

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エチオピア洪水玄武岩から得られた30Ma頃の絶対古地磁気強度
Abusolute Paleointensities of about 30Ma from Ethiopian flood basalts

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エチオピアとイエメンに分布するエチオピアントラップはホットプルーム上昇に伴い30Ma頃に噴出した洪水玄武岩で、エチオピアでは約2000mの連続した溶岩層をなす。Rochette et al.(1998)はエチオピア・Lima-Limo地域とWegel Tena地域において42層準で試料を採取し、古地磁気測定と$^{40}Ar/^{39}Ar$年代測定を行い、下位よりを逆-正-逆の極性変化と28～30Maの年代値を得た。それに基づき、不確かさをあるものの極性変化はHuestis and Acton (1997)の地磁気極性逆転表（GPTS）のC11r-C11n.2n-C11n.1rに対応させ、エチオピアントラップが約100万年間かそれ以下の期間での活動であるとした。そこで我々は、Lima-Limo地域を対象に地磁気変動の詳細な解明と地磁気極性逆転史との対応を明らかにする目的で、94層準から試料を採取し研究を行っている。これまでの古地磁気測定による結果では、Rochette et al.(1998)の極性変化以外にエクスカーション的な変動や短期間の逆転と思われる変動が明らかとなった（Ann, 2015）。さらに、地磁気強度の変動を明らかにするために、低温消磁2回加熱ショー法(Yamamoto et al.,2003)による絶対古地磁気強度の推定を行い、現時点で10層準の11試料から、6.25～29.05 μTの強度データ（仮想地磁気双極子モーメントVADMで$1.21～7.28×10^{22}Am^{22}$）を得た。VGP緯度が45度より大きい試料の平均強度は17.63μT(VADM:$3.40×10^{22}Am^{2}$)で、VGP緯度が45度より小さい試料（１試料）の強度は6.25μTであった。現在のLima-Limoでの地球磁場強度はおよそ35μTで、高VGM緯度の試料の強度はその半分程度である。Plenier et al.(2003)による0～0.3Maの平均VADMは約$8×10^{22}Am^{2}$で、0.3Ma～300Maのそれは約$5×10^{22}Am^{2}$であり、高VGP緯度の試料の強度が現在の地磁気強度より小さいことは、約30Maの地磁気強度が現在より小さかったことを示唆する。低VGP緯度の試料の地磁気強度がさらに小さいことは、地磁気極性の変化時において地磁気強度が数分の一程度まで減少した可能性を示唆する。

キーワード：エチオピアントラップ、地磁気極性変化、絶対古地磁気強度
Keywords: Ethiopian trap, geomagnetic polarity change, absolute paleointensity

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GPSコンパスを用いた古地磁気試料の方位付け
Orienting paleomagnetic drill cores using a GPS compass

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古地磁気研究のためのドリルコアの方位は通常磁気コンパスを用いて測定し，時には太陽コンパスやバックサイティングで検証されます．気象条件や地理的な障害のため，しばしばこれらの補助的な測定を実行することはできません．また，強く磁化した火山岩は偏角を偏向させる局所磁場を発生させます．今回は直接方位付けデバイスに載せることができるコンパクトなGPSコンパスをテストし，いくつかの方位付けの方法によって火山岩のドリルコアの方位をクロスチェックしました．視界のよい場所にGPSコンパスを配置すると，方位測定はRMSが0.44度と優れた性能を示し，太陽コンパスとの角度の誤差は2.5度未満でした．このような高い精度を達成するために，RTK初期化のために約5分を待ち，35度以上の仰角には障害物がないことを確かめる必要がありました．実際のドリルコアの方位付けにおいては，露頭自体がしばしばGPSコンパスに対する障害物として作用しましたが，GPSコンパスの方位は太陽コンパスやバックサイティングの方位とほぼ一致しました．磁気コンパスは地域的な偏角補正により正確な方位を提供することが多いですが，ときには5度以上の比較的大きな偏差を示しました．この偏差量は単一サイト内でもサンプル間で異なることがあります．考古地磁気研究のための火山岩を採取するとき，磁気コンパス以外の方位付けの方法を用いて，それぞれのドリルコアの方位を確認する必要があります．

キーワード：古地磁気学、考古地磁気学、GPSコンパス
Keywords: paleomagnetism, archeomagnetism, GPS compass

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粘性残留磁化を用いた八丈島津波石の回転履歴の推定

Estimation for rotation history of tsunami boulders in Hachijo Island, by using viscous remanent magnetization

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In Hachijo Island, there are some huge volcanic-origin tsunamigenic boulders. These are about over 3000kg in weight without any sign of organic carbon, such as fossils. Because such huge boulders are mainly moved by extreme tsunami events, they are paid attentions as a key to understanding of past disaster events. If they are the coral boulders, we can estimate the date of past tsunami by using radiocarbon dating. However, we cannot estimate the date by using this theory for the volcanic boulders without any organic fossils. One of an alternative way to date volcanic boulders is the cosmogenic nuclide exposure dating because it simply accumulates on boulder surface. But, the cosmogenic dating can not apply to the boulders if the boulder had experienced multiple rotations. We applied paleomagnetic approach to these volcanic-origin boulders and tried to examine the age of tsunami event, and rotation history of these boulders. This method is useful for all boulders with a bit of magnetic grains regardless of its lithology, and we can determine multiple rotations. Boulders acquire the secondary magnetic component, called viscous remanent magnetization (VRM) after tsunami. This secondary viscous remanence is acquired to the original magnetic vector after the boulder has been removed from the original state. By using Neel’s thermal activation theory, the magnetization at low temperature for a long time can be demagnetized at high temperature in a short time. Thus, we can count backward to the age when VRM was acquired (i.e. the past tsunami event). And we can understand how they emplaced, by displacement of direction of magnetization.

As a result, some samples from these boulders have acquired VRM components. Especialy, andesitic boulder located on 20m above sea level, showed multiple VRM components, suggesting subsequent tsunamis. However, calculated age was older than geological age of Hachijo island. Thus, combination with other dating method such as cosmogenic nuclide dating, is required to verify a gap of tsunami age, and improve accuracy of paleomagnetic dating method.

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MIスピナー磁力計による残留磁化の不均一性の評価

Assessment of inhomogeneity of remanent magnetization by measurements with a magneto-impedance spinner magnetometer

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磁気インピーダンスセンサー（Magneto-Impedance sensor: MIセンサー）を用いたスピナー磁力計を改良して、試料-センサー間の距離を調節したり、ローパスフィルターの遮断周波数を二段階（6Hz/20Hz）変更できるようにした。その結果、双極子モーメントに加えて、八重極（octopole）までの多重極モーメントの影響を測定できるようになった。センサー配置はこれまでどおり、ペアのMIセンサーを180度ずらした差動出力なので、四重極（quadrupole）などの偶数次項は減衰するが、奇数次項（特に八重極）の効果は強調される。こうした特性を評価するため、offset-dipoleを模した試料を作成し、それらのoffset量や磁化方向が出力波形に及ぼす影響を検討した。あわせてoffset-dipoleのモデル計算を行い、MIスピナーの測定結果が理論値とよく一致することを確認した。さらに比較のため、これらのoffset-dipole試料を既存のフラックスゲートスピナー磁力計（SMD-88）で測定した。その結果、offset-dipoleの方向・強度やoffsetの程度によって、MIスピナーとフラックスゲートスピナーとで磁化方向や強度が有意に異なることがわかった。その原因を考察するとともに、残留磁化の不均一性が測定に及ぼす一般的な影響、MIスピナーによる不均一の定量的評価方法や補正方法などを提案する。

キーワード：スピナー磁力計、不均一残留磁化、多重極モーメント
Keywords: spinner magnetometer, inhomogeneity of remanent magnetization, multipole moment

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ガウス係数の数十年変動の経験的モード分解を用いた解析

The empirical mode analysis of the decadal variations in the geomagnetic Gauss coefficients

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地磁気の数十年変動は、外核内部の波が原因だと考えられている。その波としては、torsional oscillationsかMagnetic-Archimedes-Coriolis（MAC）波（Braginsky, 1993; Buffett, 2014）の軸対称モードがよく使われる。両者の波の流れはともに軸対称だが、原理的には、非軸対称な波でも数十年変動を説明できて良い。ガウス係数から、そのような非軸対称な波の成分を取り出すために、まず経験的モード分解を用いて数十年変動を取り出し、次に軸対称流による変動を取り除いた。
私たちが用いた時系列データは、次数4までの過去150年間（1865～2014年）のガウス係数である。今回、gufm1モデル（Jackson, 2000）、IGRF-12、CHAOS-5モデル（Finlay, 2015）のデータを組み合わせて、ガウス係数の時系列に対し経験的モード分解（Huang et al., 1998）を行った。
その分解によって、ガウス係数の赤道反対称成分は40か80年の周期を持つことが分かった。これらの成分のg-hプロットでは、直線的に偏光した振動が見られ、これは強制振動か振動する流れによる移流のいずれかによって起きていることを示している。
次に、軸対称流による移流が原因となる成分を取り除いた。この結果については会場で示す。

キーワード：地磁気の数十年変動、ガウス係数、外核、torsional oscillations、経験的モード分解
Keywords: geomagnetic decadal variations, Gauss coefficients, outer core, torsional oscillations, empirical mode decomposition

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Constraint of magnetic models using seismic tomography in Taiwan

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Uncertainty is often one of the sufferings when underlying structure models are constructed by using unitary geophysical data retrieved from field survey. Velocity-susceptibility models are constructed using velocity retrieved from seismic tomography transferring into susceptibility through characteristics of minerals and/or rocks determined by (Vp) together with (Vp/Vs ratio). Simulated values are computed from the models through 2D forward methods to compare with magnetic anomalies processed after field prospection. Two profiles with intense undulation of geomagnetic anomalies over sediment areas in central-west Taiwan and complex geological structures at the rim of the subduction zone in north Taiwan are used to examine consistency between the simulated values and magnetic anomalies. The consistent results suggest that rocks with high susceptibility can be identified in sediment areas and complex geological areas by using velocity tomography. Those models with two-parameter constraints shed light on understanding underlying magnetic structures through more confidence.

Keywords: Magnetic anomaly, Velocity tomography, Magnetic susceptibility

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