Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-01 会場:102A 時間:5 月 24 日 10:00-10:15

走査型 SQUID 顕微鏡システムの開発と初期測定結果
Development of scanning SQUID microscope and initial results

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Scanning superconducting quantum interference device (SQUID) microscope (SSM) is a useful tool to image very weak magnetic fields with high spatial resolution. Fong et al. (2005) developed an SSM with a monolithic SQUID and applied to scan magnetic field produced by geological thin sections. Oda et al. (2011) succeeded in imaging of the magnetic stripes of hydrogenetic ferromanganese crusts using the SSM at Vanderbilt University developed by Fong et al. (2005) and could provide age model by correlating to the standard geomagnetic polarity timescale. In this project, we have developed an SSM to image vertical magnetic fields over thin sections of various rock samples for geological studies. We designed a hollow-structured cryostat to realize reliable SQUID assembly and repeatable adjustment of the vacuum separation from the sample. The SQUID based on niobium process is a single-washer magnetometer with the pickup area of 200 x 200 square micrometers and the size of the chip is 1 mm x 1mm. The SQUID chip is mounted on a conical sapphire rod and electrically connected to the non-magnetic electrodes with silver paste. The electrodes are patterned on the surface of the sapphire rod using metalization technique. The sapphire rod is connected to a copper block, which is thermally anchored to the liquid helium reservoir with copper bundle wires. The copper block is connected to a rigid shaft through a flexure spring, and the shaft extends through the hollow of the cryostat to the spindle placed on the top flange at room temperature. A 40-micrometer thick sapphire window separating the sample from the vacuum space can be adjusted toward the SQUID using a bellows structure. With this mechanism, we have achieved the separation of ~250 micrometers between the SQUID and the sample, so far. The field resolution of the SQUID was 1.1 pT/rtHz at 100 Hz in a flux locked loop (FLL) operation. In this talk, we will introduce the development of our SSM project and describe the performance of the system. Further, we will present some initial mapping results conducted on various geological samples, such as volcanic rocks, sediments, etc. The project is supported by JSPS KAKENHI Grant Number 25247073.

キーワード: 走査型 SQUID 顕微鏡, 残留磁化, 岩石薄片試料, 液体ヘリウム, 磁気シールド, XY ステージ
Keywords: scanning SQUID microscope, remanent magnetization, geological thin section, liquid He, magnetic shield, XY scanning stage

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-02 会場:102A 時間:5 月 24 日 10:15-10:30

磁性体薄膜ドットを用いたSQUID顕微鏡計測における位置決め手法の提案
Proposal of positioning method using a magnetized thin-film dot for scanning SQUID microscopy

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We have developed a scanning superconducting quantum interference device (SQUID) microscope (SSM) for imaging magnetic field distribution of geological rock samples. The rock sample, which is processed into a thin section and glued on a glass with non-magnetic resin, is placed on a XY table under the SQUID microscope, and is scanned. The distance between the SQUID and the sample can be calibrated with magnetic field generated with a dc-current applied to a thin and long wire. However, the position of the sample for the SQUID must be determined in another way. Positioning the magnetic field image for the structure of the sample is necessary for analysis of the magnetic field distribution. We propose a positioning method using a thin-film magnetized circular dot as a magnetic dipole marker.

Considering expected special resolution of about 200 μm or smaller, we designed four kinds of single circular dots with different diameter, which are 10 μm, 50 μm, 75 μm, 100 μm. We adopted FeCo as a material for the dot. A 500-nm-thick FeCo layer was deposited on a silicon substrate with DC-sputtering and was formed into circular dots with lift-off process. After forming the dots, the Si substrate was diced into square chips with the size of 3.5 mm $\times$ 3.5 mm, where each chip has a single dot. Scanning the 25-μm dot with the SQUID microscope, we obtained dipole-like field of ˜10 nT, which is large enough as a magnetic maker.

We plan to attach this chip with the dot adjacent to the sample on the sample holder. Finally, we can superimpose the magnetic field pattern on an optical image of the sample.

キーワード: スクイド顕微鏡, 岩石薄片試料, 位置決め, 磁性ドット, 薄膜
Keywords: SQUID microscope, geological thin section, positioning, magnetized dot, thin film

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-03 会場:102A 時間:5 月 24 日 10:30-10:45

Deconvolution of continuous paleomagnetic data: Implementation of convenient graphical software based on optimization

Deconvolution of continuous paleomagnetic data: Implementation of convenient graphical software based on optimization

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Deconvolution effectively overcomes the convolution effect of sensor response and improves the resolution of continuous paleomagnetic data acquired on pass-through superconducting rock magnetometers (SRM). However, the lack of an easy-to-use deconvolution tool has hindered the application of deconvolution for continuous paleomagnetic measurements. Here, we present MATLAB software UDECON with graphical user interface, as a convenient tool to perform realistically optimized deconvolution based on Akaike's Bayesian Information Criterion minimization method (Oda and Xuan, 2014). UDECON directly reads the original paleomagnetic measurement file, and allows the user to view, compare, and save paleomagnetic data before and after the deconvolution. We demonstrate that optimized deconvolution using UDECON can greatly help revealing detailed paleomagnetic information such as excursions that could be smoothed out during pass-through measurements. The application of UDECON to the vast amount of existing and future pass-through paleomagnetic and rock magnetic measurements on sediment archives recovered especially through the ocean drilling programs will contribute to our understanding of the geodynamo and paleo-environment by providing more detailed records of geomagnetic and environmental change through reliable deconvolution.

キーワード: superconducting rock magnetometer, deconvolution, sensor response, u-channel sample, ABIC minimization, MATLAB software
Keywords: superconducting rock magnetometer, deconvolution, sensor response, u-channel sample, ABIC minimization, MATLAB software

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-04 会場:102A 時間:5 月 24 日 11:00-11:15

動的磁化の時間/周波数領域測定と岩石磁気への応用
Measurement of dynamic magnetization in time domain and frequency domain

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交流磁化率の広帯域周波数スペクトルから、SP/SD 境界以下の微細磁性粒子のサイズ分布を推定する方法を、典型的な気候変動研究試料の中国黄土試料に適用したところ、古環境変化に対応した粒子サイズ変化を復元することができた (Kodama et al., 2014). 同様の方法で火山岩試料を測定した結果、SP から MD にわたる磁性鉱物のサイズ分布や磁区構造を反映した周波数スペクトルが得られた (Kodama, 2013)。これらのパターンは基本的にデバイ型周波数スペクトルで表され、そのパターンは磁性粒子集団の諸性質 (サイズ・保磁力・磁区構造など) を反映すると考えられる。一般に、このような周波数スペクトルを示す物理系は、時間領域でも測定することができる。例えば、試料に強いパルス磁場をかけて励起した磁化が自由減衰する過程を測定すればよい。岩石試料の場合、この減衰の時定数は磁化緩和時間に対応すると考えられる。線形応答理論によれば、時間領域のパルス応答と周波数領域のスペクトルは、フーリエ変換によって相互に変換可能である。したがって、磁化の自由減衰データから周波数スペクトルを計算し、逆に磁化率周波数スペクトルから磁場遮断後の自由減衰磁化を計算することもできる。本研究では、パルス後の自由減衰磁化を測定するために開発した装置 (Kodama, 2015) を用いて代表的な火山岩試料を測定し、その結果を離散フーリエ変換することによって間接的に周波数スペクトルを求めた。この”パルス法”ならば、一回の測定に約 10^{-3} sec、多数回繰り返してもスペクトル測定よりはるかに測定時間は短い。こうして得られたスペクトルのパターンや分散から、磁性粒子の磁区構造・サイズ分布・磁壁移動などを推定する方法を提案する。さらに、スペクトル法とパルス法それぞれの長所・短所、岩石磁気への応用などを議論する。

キーワード: 動的磁化, 岩石磁気, 磁気緩和, 周波数スペクトル, フーリエ変換
Keywords: dynamic magnetization, rock magnetism, magnetic relaxation, frequency spectrum, Fourier transfom

Japan Geoscience Union Meeting 2015
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SEM34-05 会場:102A 時間:5 月 24 日 11:15-11:30

御嶽山 2014 年噴出物の岩石磁気学的特徴
Rock magnetic properties of the September 2014 eruptive products from Ontake volcano, Japan

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2014 年 9 月 27 日に御嶽山が噴火し，多数の犠牲者を出す戦後最悪の火山災害となった。その後現在 (2015 年 2 月初頭) に至るまで，活動は低下しつつも噴気活動や地震活動が継続しており，入山規制が解除されるには至っていない (噴火警戒レベル 3 が継続中)。我々は 9 月 27 日の噴火プロセスと，その後現在まで継続している山麓への堆積物の移動プロセスを解明することを目的に，特に南麓の濁川に注目して研究を進めている。本発表では，今回の噴火で噴出した火山灰試料の磁性および磁性鉱物について報告する。

熱磁気分析の結果，今回の噴出物は特徴的な熱磁気曲線を描くことが分かった。磁化が弱く，400 ℃までにほぼ半減するが，400 ℃を超えてから急激に磁化が増加し，約 470 ℃で初期値の約 5 倍に達する。その後 600 ℃までの間に急減してほぼ最小値を取る。冷却曲線は (なお実験は空気中で行っている)，加熱曲線とは全く異なって約 580 ℃のキュリー点を示し，magnetite への変質を示唆するが，実験終了後の磁化は実験前の 2 倍以下とあまり増加していない。鏡下で観察すると試料中には pyrite が多く見られ，400 ℃で変質した鉱物は pyrite と考えられる。すでに報告されているように，今回の御嶽山の火山灰には多くの pyrite が確認されており (例えば池端ほか，2014，火山学会；井村ほか，2014，火山学会)，200 ℃以上の酸性熱水による変質で形成されたことが示唆されている (宮城ほか，2014，火山学会)。また磁化が急増している温度範囲内の約 420 ℃で加熱を停止して冷却した結果，磁化は 10 倍以上に増加した。約 400 ℃で pyrite が magnetite へ変化したと考えられるが，このことから，今回の噴出物は約 400 ℃以上には加熱されていないことが示唆される。先行研究の結果と合わせれば，今回の噴出物は 200 ℃以上かつ 400 ℃以下の温度条件下に存在していたものと考えられる。

また，濁川で観察された灰色の火山灰層の上下の堆積物も特徴的なシグナルを示した。噴火前の堆積物は，磁化強度が弱くなく，約 550 ℃のキュリー点を示した。曲線は reversible であり，主な磁性鉱物は御嶽火山噴出物中の titanomagnetite と考えられる。一方，今回の噴出物の直上から採取したサンプルはピークが弱いながらも 400 ℃のシグナルを示し，微量ながら今回の噴火で堆積した火山灰が，下流へ運搬され再堆積していると考えられる。この特徴に注目すれば，今回の火山灰がどの程度の時間をかけてどの程度下流まで運搬されていくか追跡できると考える。

磁気ヒステリシス測定の結果，今回の噴出物は Day-plot 上でそれほど分散せず，PSD 領域の右下にプロットされた。これまでに我々は，統合国際深海掘削計画 (IODP) の第 340 次航海で採取された火山砕屑性混濁流堆積物の研究から，流れによる分級と淘汰の効果の違いが岩石磁気学的に捉えられることを明らかにしてきた (例えば齋藤・片岡，2014，JPGU)。御嶽山麓に二次的に堆積した火山噴出物と海底に堆積した火山性砕屑性混濁流堆積物とは，運搬距離や堆積物の volume などが大きく異なるが，どちらも流れによる効果で淘汰され，その結果，ある程度集中した磁気ヒステリシスパラメーターを示したと考えられる。

キーワード: 御嶽山, 水蒸気噴火, 黄鉄鉱, 岩石磁気
Keywords: Ontake, phreatic eruption, pyrite, rock magnetism

Japan Geoscience Union Meeting 2015
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SEM34-06 会場:102A 時間:5 月 24 日 11:30-11:45

岩石磁気と化学分析から明らかになった仙台湾堆積物の季節変動と津波の記録
Tsunami and seasonal variation records in Senday Bay sediments revealed by rock magnetic and geochemical analyses

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Coastal marine sediments along island arcs have records of the past disaster events like tsunamis and seasonal floods. In order to reconstruct those events from the coastal marine sediments, we need to distinguish between tsunami effects and seasonal variations. Tsunami was occurred in 11 March, 2011, off the Pacific coast of Tohoku by the Earthquake (M 9.0). The earthquake source was located off Sendai city and near the axis of the Japan trench. This study is aimed to sort both past events based on rock magnetic properties and geochemical analysis from the sediments taken in Sendai bay. The sediment samples were collected at five stations in Sendai bay at every season during 2002-2011. The sediment particle size is larger at the offshore stations. It suggests that fine sediment particles are transported by the bottom current. For measurements of carbon, nitrogen and sulfur amounts in the sediments, CHNS analyses were conducted. Results indicated that the amounts of those elements decrease toward offshore stations, and the changes of the values depend on the season in the inner bay. Rock magnetic properties (natural, anhysteretic, and isothermal remanent magnetization, magnetic susceptibility, remanent corecivity, and corecivity) of the sediments were measured. The values also show seasonal variations at the stations in the inner bay. For discriminations between tsunami effects and seasonal variations, we focused on the samples taken in June 2007, 2008, and 2011. The amounts of carbon and sulfur are large in the 2011 samples after the tsunami. Thermo-magnetometric results indicate the presence of magnetite and iron sulfide in all samples. Especially, the 2011 samples at the offshore stations under the bottom current are found to contain iron sulfide as a dominant magnetic mineral. It may be implied that iron combines sulfur after deposition and that are prevented from the transportation of the bottom current.

キーワード: 津波堆積物, 岩石磁気, C/N
Keywords: Tsunami deposit, rock magnetism, C/N

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-07 会場:102A 時間:5 月 24 日 11:45-12:00

新生代の南太平洋赤色粘土の環境磁気学的研究
Environmental Rock-Magnetism of Cenozoic Red Clay in the South Pacific Gyre

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Red clay occupies about 40 % of the global ocean floor. Paleoceanographic and paleomagnetic studies of red clay were limited so far because red clay does not yield microfossils that can be used for precise age estimation and sedimentation rates were extremely low. However, red clay could be useful for elucidating long-range environmental changes. Recently, red clay has attracted interest because of the discovery that red clay rich in ∑REY (rare-earth elements and yttrium) distributes widely in the Pacific Ocean. We conducted an environmental rock-magnetic study using the Integrated Ocean Drilling Program (IODP) Site U1365 cores (75.5 m long above ~125 Ma basement) taken at the western edge of the South Pacific Gyre (SPG) in order to investigate long-range climatic and paleoceanographic changes during the Cenozoic. This is the first environmental rock-magnetic study in the SPG ever.

Magnetostratigraphy could be established above ~6 meters below the seafloor (mbsf) (~5 Ma). Below ~6 mbsf, the ages of the Site U1365 cores were transferred from published ages of nearby Deep Sea Drilling Project (DSDP) Site 596, which is based mainly on a constant Cobalt flux model, by inter-core correlation using magnetic susceptibility and ∑REY variation patterns. On first-order reversal curve diagrams, a non-interacting single-domain magnetic component, which is a characteristic of biogenic magnetite, was recognized throughout the sediment column. The ratio of anhysteretic remanent magnetization (ARM) susceptibility to saturation isothermal remanent magnetization (IRM) (k_{ARM} /SIRM), a proxy of the biogenic to terrigenous magnetic components, is high, in particular below ~8.0 mbsf (~35 Ma). In the results of IRM component analyses, the middle-coercivity (M) component likely carried by maghemite increased since ~35 Ma, whereas S ratios and k_{ARM}/SIRM values decreased. The increase of the M component accelerated after 5 Ma. These observations suggest increases of the input of terrigenous magnetic minerals, which is inferred to be transported as eolian dust. The Eocene/Oligocene boundary (~34 Ma) is known as the time of a major global cooling, and the increase of eolian dust supply in the South Pacific may have occurred since then. Northward shift of Australia to an arid region in middle latitudes should have also contributed to the increase of eolian dust supply. The second increase of eolian dust flux at ~5 Ma may have been caused by a further growth of the Antarctic glaciation at ~6 Ma.

キーワード: 赤色粘土, 環境磁気学, 南太平洋環流, 生物起源マグネタイト, 風成塵, 新生代
Keywords: red clay, environmental magnetism, South Pacific Gyre, biogenic magnetite, eolian dust, Cenozoic

Japan Geoscience Union Meeting 2015
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SEM34-08 会場:102A 時間:5 月 24 日 12:00-12:15

多様な蛇紋岩の磁性：中央インド洋海嶺ヨコニワ産の海底試料による制約
Variation in magnetic properties of serpentinized peridotites from Yokoniwa Rise, Central Indian Ridge

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Serpentinization of ultramafic rocks through hydrothermal alteration changes the physical, rheological, chemical, and magnetic properties of the oceanic lithosphere. Recent discovery of widespread exposures of serpentinized mantle materials on the seafloor in a slow-spreading environment renewed interest for this alteration process. However, we have limited understanding of the serpentinization mechanism because of the lack of data measured from seafloor rocks. Since magnetite is a direct product of serpentinization process, magnetic properties of serpentinized peridotites can be a good indicator to understand the process. We collected 30 peridotite samples of different degrees of serpentinization from the seafloor on the non-transform-offset massif called as the Yokoniwa Rise in the Central Indian Ridge. These 30 samples yielded a wide range (17-100%) of serpentinization degrees and provide us a good data set to evaluate the relationship between serpentinization and magnetic properties. The measured range of magnetic parameters are as follow; natural remanent magnetization (0.2-8.4 A/m), magnetic susceptibility (0.002-0.087 SI), and magnetite amount (0.1-5.5 wt%). The amount of magnetite varies nonlinearly, likely exponentially, as a function of serpentinization degree. Remarkable increase of magnetite amount occurs in samples with high degree of serpentinization (>70%), indicating larger production of magnetite during the late stage of serpentinization process. The results provide key constraints on the serpentinization mechanism, and insights on the potential of serpentinized mantle to contribute to marine magnetic anomalies.

キーワード: 蛇紋岩, 上部マントル, 岩石磁気, 低速拡大海嶺
Keywords: serpentinized peridotite, upper mantle, rock magnetics, slow spreading ridge

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-09 会場:102A 時間:5 月 24 日 12:15-12:30

Rock-magnetic properties of single zircon crystals sampled from the Tanzawa tonalitic pluton, central Japan
Rock-magnetic properties of single zircon crystals sampled from the Tanzawa tonalitic pluton, central Japan

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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 has been shown to be 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.

This study focuses 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. Although rock-magnetic properties of single zircon crystal are essential for establishing the paleointensity method, few rock-magnetic studies have been conducted for single zircon crystals, which is largely because of their small size and weak magnetic moment.

To establish paleointensity method, we conducted systematic rock-magnetic measurements for single zircon crystals. Zircon crystals were sampled from fluvial sands of the Nakagawa River, which crosses the Tanzawa tonalitic plutons in central Japan. Young crystallization ages and the clear thermal history of the Tanzawa zircon crystals made them suitable for evaluating the feasibility of conducting paleointensity experiment using single zircon crystals.

Based on the results of rock-magnetic measurements for 1037 grains of zircon crystals, the zircon crystals can be classified into three groups. The first group contains little or no ferromagnetic minerals. The second group is characterized by low natural remanent magnetization (NRM)/isothermal remanent magnetization (IRM) ratios (0.004-0.02), pseudo-single-domain-like hysteresis parameters, and moderate low-temperature demagnetization (LTD) memory of IRM (20-90%). The third group is characterized by high NRM/IRM ratios (0.02-2), single-domain-like hysteresis parameters, and high LTD memory of IRM (60-140%). Results from low-temperature magnetometry analyses indicate that the main remanence carriers of the second group are nearly pure magnetite. Thermoremanent magnetization (TRM) acquisition experiments were also carried out for the second group zircon crystals. Consequently, the TRM intensity was comparable with that of NRM, and rough estimation of the paleointensity using bulk NRM/TRM ratios show field intensities consistent with the geomagnetic field intensity at the Tanzawa tonalitic pluton for last 5 Myr. A future study using the second group zircon crystals could provide reliable paleointensity data.
Keywords: Zircon, Tanzawa tonalite, Rock-magnetism, Paleointensity

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-10 会場:102A 時間:5 月 24 日 12:30-12:45

非晶質シリケートの磁気異方性
Magnetic anisotropy of amorphous silicate

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星間の磁場方向を観測で推定する手段として，ダスト整列による偏光が広く用いられ，それらは惑星形成に関する理論的な考察にも寄与してきた．しかし星間ダストは主として非晶質シリカであるため，従来の物理的理解では整列が定量的に説明できない状況にある．従って，非晶質シリカの実効的な磁気異方性の有無を，実験的に検証する意義があると考えられる．近年, 天然の非晶質シリカ（テクタイト）の表面近傍で，不純物の Fe イオンに由来する局所的な磁気異方性が検出された [1]．本研究ではこの異方性の一般性を検証するため，生成条件が制御された合成試料について，表面から内部方向に，異方性の線分析を実施した．即ちはじめに非晶質シリカ試料を表面から内部方向に向かって薄片 (1.0x0.7x0.08mm) に分割した（薄片面は bulk 試料表面に平行)．その上で個々の薄片ごとに微小重力空間に開放し，静磁場（0.6T) に対する薄片の回転振動の周期から異方性を決定した [1]．その結果，合成試料でもテクタイトと同様に表面近傍で局部的に大きい異方性が確認された．先行研究と同様、試料表面に垂直な方向が，常に磁気的不安定軸であった．同時に上記の薄片に関して，電子スピン共鳴による g 値の異方性を検出し，シリカ内に孤立した鉄イオンの結晶場異方性が，回転振動で得た磁化率の異方性と矛盾しないことを確認した．

本研究でシリカ表面の法線方向が磁気的不安定軸になることが確認されたが，これにより非晶質粒子の磁気的主軸は（異方性が孤立イオン起源であるにもかかわらず)，一般に粒子の形状で制御できる事になる．例えばロッド状粒子の場合，法線が磁気的不安定である異方性を，微小表面に配置し全表面について積算すると，粒子全体ではロッド長軸が常に安定軸となる．その対極として球状の粒子の場合，全表面について積算した値はゼロとなる．このように非晶質表面で見出された異方性は，新しいタイプの粒子磁場配向の研究につながると期待される。

今後は，シリカ生成時の冷却条件，あるいは磁性イオンの差異による上記 profile の変動を測定し，異方性が発生する条件を原子レベルで明確にする．これにより星間ダストの整列機構についての考察も進展すると期待される．

[1] Yokoi et al :Planetary & Space Sci.(2014).

キーワード: 磁気異方性, ダスト整列, 微小重力, 回転振動, 磁場配向, 非晶質シリカ
Keywords: magnetic alignment, dust alignment, micro gravity, rotational oscillation, paramangetic anisotropy, amorphous silica

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-11 会場:102A 時間:5 月 24 日 14:15-14:30

Louisville ホットスポットの古緯度から推定される Hotspot Drift
Test of Hotspot Drift Using Recent Paleolatitude Data of Louisville Hotspot

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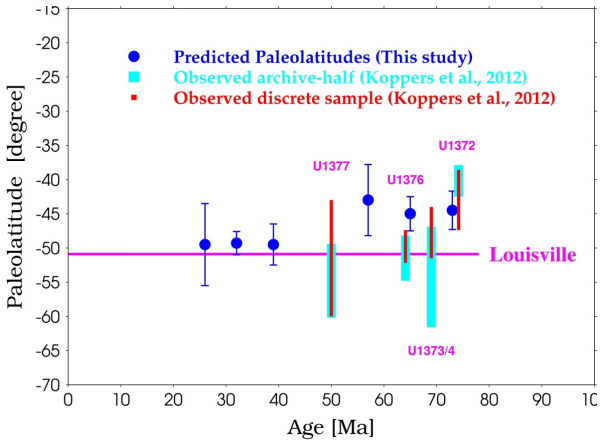
原田, 2007 JPGU では, Turduno et al.,2003 で得られた Hawaii ホットスポットトラックの古緯度のデータを解析し, このデータはホットスポットの相対運動の結果ではなく真の極移動だけで説明可能なことを示した. 本研究では同様な解析を Koppers et al., 2012 の Louisville ホットスポットトラックの古緯度のデータを用いて行った.

その結果は下図の様になり, 古緯度のデータの得られたサイト U1377 (50Ma), U1376 (64.1Ma), U1373 (69.5Ma), U1372 (74.2Ma) のデータは太平洋プレートの絶対運動と太平洋プレート上の古地磁気データから得られた (真の) 極移動曲線から推定された理論的な古緯度とよく一致することがわかった. このことより Hawaii, Louisville 両ホットスポットトラックの古緯度の変化は, ホットスポットのドリフトを仮定せずに良く説明できることが示された.

さらにこの太平洋プレートで得られた (真の) 極移動曲線は, 精密に求められたアフリカプレートの絶対運動モデルから独立に推定された (真の) 極移動曲線と整合的であることも明らかになった.

キーワード: Hotspot Drift, Louisville ホットスポット, 古緯度, 真の極移動
Keywords: Hotspot Drift, Louisville Hotspot, Paleolatitude, True Polar Wander Path



Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-12 会場:102A 時間:5 月 24 日 14:30-14:45

西南日本の時計回り回転運動のタイミング：中新世堆積岩から得られた証拠
Timing of the clockwise rotation of Southwest Japan: paleomagnetic evidence from Miocene sedimentary rocks

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HOSHI, Hiroyuki[1*] ; KATO, Daiki[1] ; ANDO, Yoshikazu[1] ; NAKASHIMA, Kazuo[2]

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The clockwise rotation of Southwest Japan is a textbook example of near-pivot arc rotation associated with back-arc opening. However, its timing is still a matter of debate; earlier studies suggested rapid rotation at about 15 Ma, but this does not seem to be supported by recent paleomagnetic data. To address this problem, we have carried out a paleomagnetic study of biostratigraphically well dated (15.8-15.7 Ma) Miocene sedimentary rocks in the eastern part of Southwest Japan. A total of 288 rock samples of siltstone and felsic fine tuff were collected from a ~90 m sedimentary sequence. Of these, 142 yielded reverse polarity characteristic remanence directions, resulting in a formation-mean direction that can be used for tectonic discussion. We conclude that about 80% of the entire ~45^o rotation occurred in a period between 17.5 Ma and 15.8 Ma at a rotation rate of ~21^o/Myr, and the remaining ~20% by 15 Ma. This clockwise rotation happened in the latest stage of the late Paleogene to early Neogene opening of the Japan Sea.

キーワード: 古地磁気, 岩石磁気, 西南日本, 回転運動, 瑞浪地域, 生俵層
Keywords: paleomagnetism, rock magnetism, Southwest Japan, tectonic rotation, Mizunami area, Oidawara Formation

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-13 会場:102A 時間:5 月 24 日 14:45-15:00

西南日本東部，濃飛流紋岩の岩石磁気と古地磁気
Rock magnetism and paleomagnetism of the Nohi Rhyolite in the eastern part of Southwest Japan

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SAKO, Kazuki[1] ; HOSHI, Hiroyuki[1*]

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The Nohi Rhyolite is a late Cretaceous large volcanic complex in the eastern part of Southwest Japan and has a paleomagnetic record that can be used to infer the tectonic development of the eastern Asian margin. Previous studies have documented two distinct groups of paleomagnetic directions. One has a set of dual polarity antiparallel directions marked by an eastward-deflected declination, which has been reported from the peripheral areas of the Nohi Rhyolite. The eastward deflection suggests a clockwise tectonic rotation. Another is a reverse polarity directional set marked by a southward declination, which has been found in the central part. The southward direction was interpreted in a previous study to be a result of either (1) remagnetization around a fault running in the central part or (2) block rotation occurring in relation to the strike-slip faulting along the fault. To address this problem, we carried out detailed paleomagnetic and rock magnetic experiments and microscopic observations of volcanic and sedimentary rocks collected at 51 sites. We obtained 40 site-mean directions, and our experimental results suggest that they are retained primarily by magnetite and partly by hematite. Positive results of the paleomagnetic baked contact test indicate that the eastward-deflected characteristic remanent magnetization (ChRM) directions were acquired before 68 Ma. Our microscopic observations confirmed the existence of Fe-Ti oxides suffered by high-temperature oxidation in pyroclastic rocks at some sites where the eastward-deflected ChRM directions were detected, implying that the directions are primary thermoremanent magnetization. We obtained 15 reliable site-mean directions that were considered to be a primary magnetization. Basically they are consistent with the directions reported previously, but suggest more complicated crustal deformation in the eastern part of Southwest Japan than has previously been suggested, possibly resulting from the Miocene collision of the Izu-Bonin arc with the Honshu arc. In the central part of the Nohi Rhyolite, we found an outcrop where originally reddish pyroclastic rocks have partly been altered to greenish ones, and detailed magnetic experiments and microscopic observations were carried out for both rocks. Our results indicate that the reddish and greenish rocks possess an eastward-deflected direction and a reverse southward direction, respectively. The greenish rocks contain small secondary magnetite grains within an altered biotite. Therefore, we conclude that the reverse southerly direction is a secondary magnetization.

キーワード: 濃飛流紋岩, 古地磁気, 岩石磁気, 回転運動, 後期白亜紀
Keywords: Nohi Rhyolite, paleomagnetism, rock magnetism, tectonic rotation, late Cretaceous

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-14 会場:102A 時間:5 月 24 日 15:00-15:15

地球電磁場ジャークとマントル深部電気伝導度
Further examination of the geoelectromagnetic jerk hypothesis

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Short time-scale geomagnetic main field variations such as a geomagnetic jerk may be influenced by electromagnetic induction and conduction in the lower mantle. Similar variations were seen in long baseline geoelectric field measurements that are in progress in the northwestern Pacific using thousand-kilometer-scale submarine cables. Geoelectric secular variation data from such measurements have potential to discuss the significance of the influence and to clarify the cause of the phenomenon if they are analyzed simultaneously with geomagnetic data. In our previous work, we found a sudden change of the geoelectric field trend at around 2006. By supposing simply that the geoelectric field variation has the same origin with the geomagnetic jerk in 2007 (geoelectromagnetic jerk hypothesis), which was evident in the south Atlantic and Africa, we made a numerical study to understand possible cause and conductivity structure in the mantle. As a result, it was found that the geoelectric and geomagnetic field variations were both explained if the variations were originated from a toroidal magnetic field at the core-mantle boundary. It was also suggested that significant electrical conduction currents existed in the D" layer beneath the area where the geomagnetic field variation was evident. In this presentation, the validity of the geoelectromagnetic jerk hypothesis is discussed by extending the analyses adding more recent geoelectric and geomagnetic field data. Also, we estimate the amplitude of motionally induced electric field variation in the ocean by using a large-scale ocean circulation model, ECCO (Estimating the Circulation and Climate of the Ocean), to confirm that motional induction is not the cause of the observed geoelectric signal.

キーワード: 地磁気ジャーク, 地球電場, マントル電気伝導度
Keywords: geomagnetic jerk, gelelectric field, electrical conductivity of mantle

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-15 会場:102A 時間:5 月 24 日 15:15-15:30

コア表面流の沸き出し・沈み込みによる地磁気永年変化
Geomagnetic secular variation due to upwelling and downwelling flows at the core surface

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Fluid flow near the core surface can be estimated from spatial distribution and secular variation of the geomagnetic field. We have developed a new approach into which the magnetic diffusion is incorporated inside the boundary layer at the core-mantle boundary (CMB), while it is neglected below the boundary layer as in the so-called frozen-flux approximation.

Locations of upwelling and downwelling flows can be derived from the core surface flow thus estimated, and the distribution inside and below the boundary layer provides information on existence of convective columns, which are classified into cyclonic and anti-cyclonic ones; an axial flow component from the CMB to the equator exists in a cyclonic column, whereas that from the equator to the CMB in an anti-cyclonic column. In reality, we have found typical distribution for convective columns in core surface flow below the Indian Ocean for the epoch of 1980.

In many numerical dynamo models, magnetic advection due to downwellings associated with cyclonic vortices is found to be in balance with magnetic diffusion, and cyclonic vortices at the core surface can be responsible for magnetic flux patches. Intense magnetic flux spots seen in equatorial regions might be generated by columnar flows near the equator. Hence we have examined secular variations due to upwelling and downwelling flows at the core surface. It turns out that intense flux spots in equatorial regions do not correspond to downwellings associated with axial flows in cyclonic columns near the equator. This result implies that pairs of intense magnetic flux spots in equatorial regions are produced by flux expulsion due to columnar flows there, and that magnetic diffusion is significant in equatorial regions.

キーワード: コア表面流, 永年変化, 地球磁場
Keywords: core surface flow, secular variation, geomagnetic field

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-16 会場:102A 時間:5 月 24 日 15:30-15:45

回転球殻中の磁気対流により引き起こされるアルフベン波の外側安定成層中の伝播
Propagation of Alfven waves in an outer stable layer excited by MHD thermal convection in a rotating spherical shell

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最近の地震波観測とその解析は地球の核マントル境界直下に厚さオーダー 100km の安定成層が存在することを示唆している. 深部対流運動の外側安定成層への貫入の程度はダイナモ過程通じての磁場生成ならびに磁気永年変導の成因を考える上で重要な問題のひとつである. Takehiro and Lister (2001) は磁場がない場合に柱状対流の安定成層への貫入厚さを理論的に導出し, 貫入厚さが惑星の自転角速度に比例し, 安定成層のブラントバイサラ振動数ならびに擾乱の水平波数に反比例することを示した. しかしながら磁場の影響下での貫入厚さのスケーリングはいまだ知られていない. ここでは, 安定成層下の対流運動によって引き起こされる安定成層中の流体運動と磁場擾乱を理論的に調べる.

Takehiro and Lister (2001) の理論モデルを磁気流体へと拡張する. 下面境界からの流体運動と磁気擾乱が鉛直方向半無限空間に存在する密度成層した磁気流体中へと貫入する. 系の回転軸は鉛直軸から傾いている. 粘性と拡散の効果を無視し, 安定成層が十分に強く基本場磁場が弱いことを仮定すると, 磁気流体運動が 2 つの磁気流体波動に分類されることが線形解析からわかる. ひとつは速いモードであり, コリオリ力・浮力およびローレンツ力が足しあわさって波の復元力がもたらされている. もう一つは遅いアルフベン波であり, 流体運動が水平方向に制限されている. 下面から与えられる擾乱の振動数が十分小さければ, 速いモードは安定成層を伝わることができず, その貫入距離は磁場のない場合のものに帰着する. これに対して遅いモードは, 与えられる擾乱の振動数がどんなに小さくても安定成層中を伝播することができる. その伝播 (貫入) 距離はアルフベン速度と拡散係数及び擾乱の全波数の比で表される.

伝播距離の理論的なスケーリングの正当性を評価するために, 一様磁場中に埋めこまれた上層に安定成層を伴う高速に回転する球殻中の磁気熱対流の線形解析を行った. 強い安定成層を与えると, 基本場磁場を強めていくにつれて, 安定成層下に閉じ込められていた中立モードの柱状流体運動と磁気擾乱が次第に安定成層へ貫入していく. 得られた中立モードの貫入距離は理論的スケーリングと良くあっている.

キーワード: 地球外核, 水星外核, アルフベン波, 核マントル境界, ダイナモ, 地磁気永年変動
Keywords: Earth’s outer core, Mercury’s outer core, Alfven waves, core mantle boundary, dynamo, secular variation of geomagnetic field

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-17 会場:102A 時間:5 月 24 日 15:45-16:00

回転球殻ダイナモにより引き起こされる磁気流体擾乱の強い安定成層への貫入
Penetration of MHD disturbances into a strongly stable outer layer caused by MHD dynamo in a rotating spherical shell

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外側に強い安定成層を伴う回転球殻中の磁気流体ダイナモの数値実験を行った. Takehiro and Lister (2001) により提唱された磁場のない場合の擾乱の安定成層への貫入距離の値が安定成層の厚さに比べて十分小さいにもかかわらず, 渦運動とトロイダル磁場擾乱は安定成層へ深く貫入する. この安定成層中の磁気流体擾乱は流体運動が水平面内に制限されたアルフベン波として解釈される. 新たに提案されたアルフベン波の伝播距離の理論的表現は数値的に得られた場が安定成層中をアルフベン波が減衰することなく完全に伝播することを示す.

キーワード: 地球外核, 水星外核, ダイナモ, アルフベン波
Keywords: Earth’s outer core, Mercury’s outer core, Dynamo, Alfven waves

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-18 会場:102A 時間:5 月 24 日 16:15-16:30

単一スポットの考古地磁気強度から得た過去 400 年間の地軸双極子モーメントの変化
Axial dipole moment over the past 400 years from single spot archeointensities

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過去 400 年間の地軸双極子モーメントの変化を、三宅島の火山岩から得られた考古地磁気データを基にして，gufm1 モデルと組み合わせて求めた．三宅島での噴出年代は古文書により明確に特定されており，フィールド調査との組み合わせで個々の溶岩流の年代は誤差なく与えられる．テリエ法による古地磁気強度は、上下のクリンカーとスコリアから得られた最近の火山岩について期待される地球磁場強度を与えた．三宅島の火山噴火は過去 400 年間に断続的に約 50 年おきに発生しており，時間と強度の両方で信頼性のある過去の地球磁場強度の記録を与える．熱消磁付き自動スピナー磁力計 TSpin を使用して、テリエ法による古地磁気強度測定を約 300 試料について行った．Gubbins et al., [2006] と同様の方法を適用して，三宅島の単一スポットの考古地磁気強度の変化から過去 400 年間に地軸双極子モーメントの単調な減衰を得た．1840 年以降の機器記録を外挿して 1590?1840 年まで地軸双極子モーメントの直線的減少を仮定する gufm1 に反して、 Gubbins et al., [2006] は既存の考古地磁気強度データベースからは地軸双極子モーメントに明確な時間的変化は認められないと主張した．データベースには様々な試料、場所や実験方法から得られた考古地磁気強度データが含まれており，年代と強度の両方に大きな誤差が含まれている．単一スポットの考古地磁気強度はこれらの問題を避けることができ，地軸双極子モーメントの変化を得るのに適している．

キーワード: 考古地磁気強度, テリエ法, 地磁気学
Keywords: archeointensity, Thellier method, geomagnetism

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-19 会場:102A 時間:5 月 24 日 16:30-16:45

陶邑窯跡群試料を用いた近畿地方における地磁気永年変化の再検討 (II)
Reexamination of geomagnetic secular variation in Kinki District using samples from Suemura kilns (II)

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1960-70 年代に、大阪府堺市周辺で大規模な宅地造成工事が行われ、それに伴い膨大な古窯跡が発掘された。それら古窯跡は詳細な考古学的研究が行われ、考古地磁気研究も、当時の大阪大学・川井研究室が行った。その結果、5 世紀から 10 世紀の地磁気永年変化曲線が決定されている。しかし、その測定は無定位磁力計によるもので、また、消磁も行われていないと言う問題点があった。幸いそれらの試料は現存しており、大阪大谷大学で保管されていた。岡山理科大学と熊本大学ではそれらの試料をもらい受け、2011 年から系統的な再測定を始め、2012 の JpGU で予察的な測定について発表した。今回は、残存試料のあるサイトの約 80% 215 サイト 1992 試料の測定を終えたので、古地磁気方位の概要について報告する。

測定は大半は熊本大学のスピナ磁力計（夏原技研製 SMM1985）に考古地磁気の大型試料用アタッチメントを付けて測定した。交流消磁は、各サイト 1 個のパイロットサンプルを選び、段階消磁して、その結果で選んだ消磁段階で一斉消磁を行なうという手順を基本とした。試料の磁化は一般に単純で、選んだ消磁強度の前後での磁化方位の変動は小さく、選択による結果の違いはほとんどない。古地磁気強度測定などの利用に備えて、各サイト 1 試料は非消磁で残した。

前回の JpGU での報告で問題となったのは、サイト内の古地磁気方位に孤立値やバラツキの多い部分があるものが多数見られたことであった。これらから孤立値を統計的に処理して平均を求め、地磁気永年変化曲線を暫定的に書いた。今回も、その手法での永年変化曲線の推定は試みるが、全試料の古地磁気方位の密度マップを作り、年代軸を必要としない永年変化曲線の推定を試みた。これは、今回測定したサイトの中に年代不明のものがかなり存在したからでもある。結果得られた永年変化曲線は、Hirooka (1971) や Shibuya (1980) によるものと、概要は類似しているが、伏角の振幅が大きいものとなった。また、密度マップにギャップがあるように見受けらた。永年変化速度に短期間の変動がないと仮定すると、陶邑工人集団の消長を表しているのかもしれない。

キーワード: 考古地磁気学, 地磁気永年変化
Keywords: Archeomagnetism, Geomagnetic secular variation

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-20 会場:102A 時間:5 月 24 日 16:45-17:00

2014 年水月湖採掘コアの予察的古地磁気分析
A preliminary paleomagnetic result from Lake Suigetsu 2014 cores

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Varved sediments were sampled in Lake Suigetsu by Fukui prefectural government in July to September, 2014. Core samples were collected from four bore holes named E, F, G and H near the center of the lake, c. 500 m. to the east of the deepest place. From hole E, 86 sections with a total length of 83.6 m were recovered, and from hole F we obtained 87 sections with a total length of 85.2 m, 28 of which were magnetically oriented. From hole G, we collected 38 sections, 13 of which were magnetically oriented, in order to fill the gaps in holes E and F cores. Sections from hole H are essentially back-ups. Sub-sampling from each core was made using double-L technique (Nakagawa et al. 2012). Sub-samples are 50 to 100 cm long with a cross section of 2 cm by 2 cm. They were all sealed up in Saran (polyvinylidene chloride) film, and vacuum-sealed with deoxidant agents in an aluminum-lined polyethylene bag, before transported to the laboratory. In addition, cubic specimens with a 2.2 cm side were collected from holes F and G cores in the lakeside workshop, and cubic specimens with a 2.0 cm side were re-sampled from LL-channel samples with a cross section of 2 cm by 2 cm in the laboratory of Kobe University.

Firstly, preliminary paleomagnetic analyses were conducted on two double-L channel samples, with progressive alternating field demagnetizations. All characteristic remanent magnetizations measured at 1-cm regular interval have almost constant directions close to the present geomagnetic field. This suggests the remanence of a core is intensively affected by secondary viscous remanent magnetizations (VRM). Next, we performed preliminary paleomagnetic analyses of discrete specimens with progressive thermal demagnetizations (THD). The result shows that secondary VRMs are removed below 350 ℃, and we confirmed that THD was more useful to isolate a primary remanent magnetization than AFD. From preliminary paleomagnetic analyses with progressive THDs for pilot discrete specimens collected from 100 to 10 cm intervals, we have obtained two excursional paleomagnetic directions. One is of an oriented specimen collected at a preliminary composite depth of about 32.50m, having negative inclination and northerly declination, and the other is of an unoriented specimen collected at a preliminary composite depth of 30.25m, having low positive inclination. Both are carried by a component with a temperature range from 400 to 590 ℃, which shows the carrier is magnetite. The Lake Suigetsu varve chronology suggests they are dated at 41 ka and 38 ka, respectively. The former or both may be correlated with the Laschamp excursion.

キーワード: 水月湖, 年縞堆積物
Keywords: Lake Suigetsu, Varved sediments

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SEM34-21 会場:102A 時間:5 月 24 日 17:00-17:15

美濃帯犬山地域に分布する上部三畳系層状チャートから得られた古地磁気・化石統合層序
Magneto-biostratigraphy of the Upper Triassic bedded chert succession from the Mino Belt, Inuyama area, central Japan

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Late Triassic magnetostratigraphy and biostratigraphy has recently been investigated in both continental and Tethyan marine sequences (Hounslow and Muttoni, 2010). However, there is no agreed on geomagnetic polarity timescale (GPTS) for the Late Triassic, because of poor age control of many Late Triassic magnetostratigraphic sections, missing or duplicated intervals, and within- section changes in sedimentation rates (Lucas, 2013).

In an attempt to circumvent this problem in the Carnian to Norian, we have established the magnetostratigraphy and biostratigraphy of two bedded chert successions from the Mino Belt, Inuyama area, central Japan.

Paleomagnetic samples from Inuyama area were drilled and oriented in the field at an average sampling interval of ˜20 cm. Chert samples were collected at two localities (Sakahogi and Momotaro sections) where Sugiyama (1997) investigated the radiolarian biostratigraphy. In this study, at Sakahogi section, 93 samples for the biostratigraphy study were collected from ˜30-m-thick early Carnian to late Norian red chert section (Section N; Sugiyama, 1997). We also sampled at Momotaro section where ˜15-m-thick early Carnian to late Norian red chert is well exposed (Section Q; Sugiyama, 1997). 45 samples for the biostratigraphy study and 156 oriented samples for the magnetostratigraphy from 176 beds were collected from this locality. In total, 294 samples were collected from Late Triassic (Carnian to Norian) red cherts of the Inuyama area. All samples were thermally demagnetized and analyzed at the paleomagnetic laboratory of Center for Advanced Marine Core Research, Kochi Univ.

We found many platform conodonts from 81 samples in the section N and Q, where the radiolarian biostratigraphy have previously been investigated (Sugiyama, 1997). These sections are relatively well exposed and continuous. Based on detailed study of the conodont biostratigraphy from the interval of the Carnian and the late Norian in the section N and Q, five conodont zones are recognized. These biozones are calibrated with the radiolarian zone studied in the Upper Triassic bedded chert successions in the Japanese accretionary complex. Thermal demagnetization showed four distinct remanent magnetization components from the cherts. Multiple components of secondary magnetization have been recognized from the red cherts of the Inuyama area (Shibuya and Sasajima 1986; Oda and Suzuki 2000; Ando et al. 2001). The lowest temperature component below 200 ℃ (component A) is a present-day viscous overprint. The second component has reversed polarity and unblocking temperatures between 200 ℃ to 420 ℃ (component B). The third-demagnetized component is removed up to 580 ℃ (component C). The first three components are interpreted to be secondary magnetizations. In contrast, the last-removed (highest blocking temperature) component (component D) shows positive reversal tests and is likely primary remanent magnetization. Paleomagnetic polarity reversals observed for the lower Carnian to late Norian are almost correlated with those of other marine sections.

キーワード: 後期三畳紀, 古地磁気層序, 化石層序, 層状チャート, 美濃帯, パンサラサ海
Keywords: Late Triassic, magnetostratigraphy, biostratigraphy, bedded chert, Mino belt, Panthalassa