

## 出雲市杉沢遺跡炉跡の古地磁気学

## Paleomagnetic study on baked earth from Izumo-Sugisawa ruins

\*島山 唯達<sup>1</sup>\*Tadahiro Hatakeyama<sup>1</sup>

1.岡山理科大学情報処理センター

1.Information Processing Center, Okayama University of Science

考古遺跡を対象として過去の地磁気方位の復元を試みる考古地磁気方位測定では、遺跡の被熱面を定方位採取し古地磁気測定を行う。通常、被熱面は見た目によく焼かれているものが多く、明らかに磁鉄鉱のキュリー温度を上回っている。特に須恵器等を焼成した閉鎖窯跡では良く火が当たる天井のみならず床面もかなり高温に焼き固められている場合が多く、熱残留磁化を保持しているという意味では極めて良質なものが多い。しかし、古墳時代前期・5世紀前半に日本において須恵器窯が登場する以前は上が開いた状態の窯や炉の跡が測定の対象となるため、これらの被熱度合いが大きな問題となる。さらに被熱遺構の量および年代値の不確定性もあって、弥生時代以前の考古地磁気測定の量は極めて少なく、その値のばらつきもかなり大きい。

そのような中で、今回は弥生時代中期後葉(紀元前後)の大規模集落における住居・建物跡から見つかった炉跡と考えられる被熱床面に対する古地磁気・岩石磁気を行った結果を報告する。対象は島根県出雲市(旧斐川町)にある杉沢遺跡で、工業団地の造成に伴って発見・発掘されている比較的大きな集落跡である。集落のごく近傍には当時の山陰道が推定され、活発な人の行き来があった場所に位置すると考えられている。発掘は出雲市教育委員会によって行われ、自然科学測定の一環として古地磁気測定を行った。試料は遺跡内C丘陵に位置する「竪穴建物3(SI02)」および「加工段10(SI03)」内の被熱床面より表面付近が赤色化した10-15cmのブロック試料を各6個採取した。また、対象測定を行うためにそれぞれの建物跡より2ブロックずつ被熱していないと思われる床面(被熱部位より1~2m離れた位置より)を採取した。

スピナー磁力計を用いた予備測定により、この試料の残留磁化はいずれもかなり弱いことが分かったので、高知大学海洋コア総合研究センターの超伝導磁力計を用いて、測定を行った。その結果、多くの被熱床面試料の残留磁化は極めて不安定でばらつきが大きいことが分かり、どれが初生であるかの判断をすることが困難であった。

一方で、いくつかの試料に対して磁気天秤を用いた熱磁気分析(真空中)を行ったところ、降温時には約400℃より低温部で昇温時より低い磁化強度を示した。このことから昇温時400℃付近で還元的環境下における化学的変質が起きて別の磁性鉱物に置き換わったことが想定される。温度条件等から、この磁性鉱物の変化はマグヘマイト→マグネタイトと想定される。前者・後者ともに元から床面(土壌)に含まれると考えられるが、残されたマグヘマイトは、炉使用時に元からあったものが変質されずに残ったものと考えるのが妥当であろう。つまり、この炉の床面は操業時に400℃以上まで加熱されなかった、あるいはごく表層のみが加熱され、試料厚さ(1.5cm)内ではすでに400℃以下の温度にしかならない深さであった、と考えられる。古地磁気方位測定を行った中で、最も安定な磁化方位を示したサンプルでは、熱磁気分析の昇温時と降温時の磁化の差が最も小さかった。この試料は他と比べて良く加熱された部位から採取したものと推定される。

キーワード：考古地磁気学、古地磁気学、弥生時代

Keywords: Archaeomagnetism, Paleomagnetism, Yayoi Era

## 秋田県一ノ目潟のコア堆積物から得られた古地磁気方位の変動の信頼性

Reliability of paleomagnetic directions of the Ichi-no-megata Marr sediments as a secular variation record

\*安樂 和央<sup>1</sup>、林田 明<sup>2</sup>、北場 育子<sup>3</sup>、スタッフ リチャード<sup>4</sup>、原口 強<sup>5</sup>、篠塚 良嗣<sup>6</sup>、山田 和芳<sup>7</sup>、五反田 克也<sup>8</sup>、米延 仁志<sup>9</sup>

\*Kazuhiro Anraku<sup>1</sup>, Akira Hayashida<sup>2</sup>, Ikuko Kitaba<sup>3</sup>, Richard A. Staff<sup>4</sup>, Tsuyoshi Haraguchi<sup>5</sup>, Yoshitsugu Shinozuka<sup>6</sup>, Kazuyoshi Yamada<sup>7</sup>, Katsuya Gotanda<sup>8</sup>, Hitoshi Yonenobu<sup>9</sup>

1.同志社大学大学院理工学研究科、2.同志社大学工学部環境システム学科、3.立命館大学古気候学研究センター、4.オックスフォード大学考古学美術史学研究所、5.大阪市立大学大学院理学研究科、6.立命館大学立命館グローバル・イノベーション研究機構、7.静岡県 文化・観光部 文化学術局 ふじのくに地球環境史ミュージアム整備課、8.千葉商科大学政策情報学部、9.鳴門教育大学大学院学校教育研究科

1.Graduate School of Science and Engineering, Doshisha University, 2.Department of Environmental Systems Science, Doshisha University, 3.Research Centre for Palaeoclimatology, Ritsumeikan University, 4.Research Laboratory for Archaeology and the History of Art, University of Oxford, 5.Department of Geosciences, Graduate School of Science, Osaka City University, 6.Ritsumeikan Global Innovation Research Organization, Ritsumeikan University, 7.Museum of Natural and Environmental history, Shizuoka, 8.Faculty of Polcy Informatics, Chiba University of Commerce, 9.Graduate School of Education, Naruto University of Education

近年、完新世の古地磁気永年変化 (PSV) の全球的モデルが提案されているが、その基礎となる堆積物の古地磁気データの中には近接地点にもかかわらず調和的な変化を示さないものも存在する。モデルの構築に用いられるデータの分布と質を改善するためには、得られている古地磁気データの数が少ない地域で高精度編年に基づいた複数のコア間や特定の地域内で調和的な古地磁気データを得る必要である。本研究では秋田県男鹿半島に位置する一ノ目潟の湖底堆積物について、複数のコアの残留磁化を測定し、PSVの記録としての信頼性を検討した。

一ノ目潟では、2006年と2013年にシンウォール・サンプラーを用いたコアリングが行われ、年縞を伴う泥質堆積物と砂質タービダイトを含むコア試料IMG06 (全長37m) およびIMG13 (全長118m) が採取された。これらのコアの完新世堆積物から得たUチャンネル試料のパススルー測定と合わせ、2013年に採取したピストン・コア IMG13P-1およびIMG13P-2 (全長5.9m、6.2m) について7cm<sup>3</sup>キューブ試料の磁化測定を行った。IMG06コアについてはEvent free depth (EFD) で制約を加えたベイズ統計モデルによるウイグルマッチ法により (Bronk Ramsey et al., 2012)、高精度の年代決定を行った。IMG13コアおよびIMG13P-1とIMG13P-2については特徴的な岩相および初磁化率の変動をIMG06と対比することによって年代推定を行った。得られる残留磁化の偏角については、コアのセクション境界にて不連続となることの補正が困難であるため、相対値を用いて議論を行う。

Uチャンネル試料とキューブ試料の段階交流消磁の結果、ラミナ層と砂質タービダイト層のいずれにおいてもNRMが原点に向かって直線的に減衰することが確認できた。このうち、約120年前の厚さ20-30cmのタービダイト層について主成分解析によって求めた磁化方位を4つのコア間で比較したところ、伏角の値に有意な差が見られた。その原因として、コア採取時あるいはサブサンプリング時に砂質粒子の擾乱が起こった可能性が考えられる。ラミナ層の磁化の伏角と相対的な偏角の変動はコア間でよく一致しており、PSVを反映している可能性が高い。さらに、琵琶湖から報告されたPSVの記録 (Ali et al., 1999) と類似していることから、地域的な再現性も高く、日本列島および周辺地域におけるPSVの標準的な記録として堆積物の編年やモデルの基礎として利用できることが明らかになった。

キーワード：残留磁化、古地磁気永年変化、一ノ目潟、完新世

Keywords: remanent magnetization, paleomagnetic secular variation, Ichi-no-megata Maar, Holocene

アイスランドの鮮新世溶岩からの古地磁気強度測定－2つの直線部を伴う Arai プロットの問題に重きを置いて

Palaeointensities from Pliocene lava sequences in Iceland: Emphasis on the problem of Arai plot with two linear segments

田中 秀文<sup>1,2</sup>、\*山本 裕二<sup>2</sup>

Hidefumi Tanaka<sup>1,2</sup>, \*Yuhji Yamamoto<sup>2</sup>

1.高知大学 教育学部、2.高知大学 海洋コア総合研究センター

1.Faculty of Education, Kochi University, 2.Center for Advanced Marine Core Research, Kochi University

Palaeointensity experiments were carried out to a sample collection from two sections of basalt lava flow sequences of Pliocene age in north central Iceland (Chron C2An) to further refine the knowledge of the behaviour of the palaeomagnetic field. Selection of samples was mainly based on their stability of remanence to thermal demagnetization as well as good reversibility in variations of magnetic susceptibility and saturation magnetization with temperature, which would indicate the presence of magnetite as a product of deuteric oxidation of titanomagnetite. Among 167 lava flows from two sections, 44 flows were selected for the Königsberger-Thellier-Thellier experiment in vacuum.

In spite of careful pre-selection of samples, an Arai plot with two linear segments, or a concave-up appearance, was often encountered during the experiments. This non-ideal behaviour was probably caused by an irreversible change in the domain state of the magnetic grains of the pseudo-single-domain range. This is assumed because an ideal linear plot was obtained in the second run of the palaeointensity experiment in which a laboratory thermoremanence acquired after the final step of the first run was used as a natural remanence. This experiment was conducted on six selected samples, and no clear difference between the magnetic grains of the experimented and pristine sister samples was found by scanning electron microscope and hysteresis measurements, i.e. no occurrence of noticeable chemical/mineralogical alteration, suggesting that no change in the grain size distribution had occurred.

Hence, the two-segment Arai plot was not caused by the reversible multidomain/pseudo-single-domain effect in which the curvature of the Arai plot is dependent on the grain size. Considering that the irreversible change in domain state must have affected data points at not only high temperatures but also low temperatures,  $f_v \geq 0.5$  was adopted as one of the acceptance criteria where  $f_v$  is a vectorially defined fraction of the linear segment. A measure of curvature  $k'$  was also used to check the linearity of the selected linear segment. It was avoided, however, to reject the result out of hand by the large curvature  $k'$  of the entire data points because it might still include a linear segment with a large fraction.

Combining with the results of Shaw's experiments, 52 palaeointensities were obtained out of 192 specimens, or 11 flow means were obtained out of the 44 lava flows. Most of the palaeointensities were from the upper part of the lava section (Chron C2An.1n) and ranged between 30 microT and 66 microT. Including two results from the bottom part of the lava section, the mean virtual dipole moment for 2.5–3.5 Ma is  $6.3 \pm 1.4 \cdot 10^{22} \text{ Am}^2$  (N=11), which is about 19% smaller than the present-day dipole moment.

キーワード：古地磁気強度、岩石磁気学、玄武岩溶岩、アイスランド

Keywords: Palaeointensity, Rock and mineral magnetism, basalt lava, Iceland

IODP Site U1403の海洋コアから推定する中期始新世における古地磁気強度相対値連続変動  
Relative paleointensity variation in the Middle Eocene estimate to the marine sediment  
cores recovered from IODP Site U1403

\*深見 洋仁<sup>1</sup>、山本 裕二<sup>2</sup>、山崎 俊嗣<sup>3</sup>

\*Hiroto Fukami<sup>1</sup>, Yuhji Yamamoto<sup>2</sup>, Toshitsugu Yamazaki<sup>3</sup>

1.三洋テクノマリン株式会社、2.高知大学 海洋コア総合研究センター、3.東京大学大気海洋研究所

1.Sanyo Techno Marine Co., Ltd., 2.Center for Advanced Marine Core Research, Kochi University,

3.Atmosphere and Ocean Research Institute, The University of Tokyo

1億年スケールで見る地球磁場変動の特徴として、白亜紀から現在にかけて、地磁気逆転頻度が100万年あたり0回から5回へと増加してきていることが知られている (e.g. Merrill et al., 1996). このような長期に渡る地磁気極性変化の特徴が分かっているのに対して、古地磁気強度連続変動は過去約200-300万年間しか詳細に解明されておらず (e.g. Valet et al., 2005; Channel et al., 2009; Yamazaki & Oda, 2005), 逆転頻度と強度連続変動の関係性は明らかになっていない. 統合国際深海掘削計画 (IODP) 第342次研究航海では、暁新世から始新世の気候変動解明を目的に、北西大西洋ニューファンドランド沖から海底堆積物が掘削された (Expedition 342 Scientists, 2012). 本研究では、この航海によって Site U1403より掘削された海洋コアを対象に古地磁気・岩石磁気学的測定を行い、当該期間における古地磁気強度相対値連続変動の解明に取り組んだ.

測定は25-160 mcd (meter composite depth)の区間を対象に行った. 自然残留磁化 (NRM)測定の結果に基づく古地磁気極性層序から、この区間は、40.145 Ma (クロン境界 C18n.2n/C18r)から49.344 Ma (C22n/C22r)の期間をカバーすると推定された. さらに、非履歴性残留磁化 (ARM), 等温残留磁化 (IRM), 粒子サイズの指標となるARM/SIRM比, 磁性鉱物種の指標となるS-ratio (-0.1 T, -0.3 T)の測定・分析の結果に基づくと、とくに50-101 mcd (40.145 Ma (C18n.2n/C18r)から約44 Ma (C20r))の区間は岩石磁気的に比較的均質な層準であり、古地磁気強度相対値変動の推定に適していると判断できた. この区間についてNRMをARMおよびIRMによって規格化することで、新たに古地磁気強度相対値連続変動を推定した.

新たに推定した連続変動の様子によると、古地磁気強度相対値はクロン境界で極小を示し、クロン内においても大きな振幅を伴う変動を示す. また、3つのクロン境界 (C18r/C19n, C19n/C19r, C19r/C20n)の前後においては、地磁気逆転にともない古地磁気強度相対値は約5 万年かけて緩やかに減少し、クロン境界における極小へと達した後、約1万年かけて急激に強度が増加し回復する傾向を示した. このような特徴は、過去約200万年間の古地磁気強度相対値連続変動および、この期間に起こった5回の地磁気逆転の前後において見られる特徴 (Valet et al., 2005)と同様である. 中期始新世は地磁気逆転頻度が現在の約半分であったことが知られているが (e.g. Merrill et al., 1996), 逆転頻度の変化に関わらず、このような特徴は少なくとも当時から現在まで継続している地磁気変動に共通の特徴であるということが示唆される.

キーワード：古地磁気、海底堆積物、古地磁気強度相対値

Keywords: paleomagnetism, marine sediment core, relative paleointensity

中部日本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  
Integrated magnetostratigraphy and biostratigraphy of the Upper Triassic bedded chert  
sequences from Inuyama area, central Japan

\*山下 大輔<sup>1</sup>、宇野 康司<sup>2</sup>、尾上 哲治<sup>1</sup>

\*Daisuke Yamashita<sup>1</sup>, Koji Uno<sup>2</sup>, Tetsuji Onoue<sup>1</sup>

1.熊本大学大学院自然科学研究科理学専攻地球環境科学講座、2.岡山大学大学院教育学研究科理科教育講座  
1.Graduate School of Science and Technology, Department of Earth and Environmental Sciences,  
Kumamoto University, 2.Graduate School of Education, Okayama University

The Late Triassic was characterized by several catastrophic events, such as widespread eruption of the Central Atlantic Magmatic Province flood basalts, and large extraterrestrial impacts. The stratigraphic record of these events has been recently reported from the Triassic bedded chert successions in Japan, deposited within a Paleo-Pacific (Panthalassa) deep basin. However, the ages and durations of these events are uncertain because the magnetostratigraphic studies and the conodont biostratigraphic studies of chert sequence in Japan are not well known, and the radiolarian biostratigraphy of Sugiyama (1991) established in the chert sequence is not correlated with the Tethyan biostratigraphy.

Here we present Carnian to Rhaetian magnetostratigraphy and biostratigraphy (conodont and radiolaria) of the Upper Triassic bedded chert successions from the Mino belt, Inuyama area, central Japan. 416 oriented samples were collected at four sections (Section H, N, Q, R) where Sugiyama (1997) investigated the radiolarian biostratigraphy. All samples were thermally demagnetized and analyzed at the paleomagnetic laboratory of Center for Advanced Marine Core Research, Kochi Univ.

Based on detailed study of the conodont biostratigraphy from the study sections, seven conodont zones are recognized and calibrated with the Sugiyama's radiolarian zone. Thermal demagnetization showed four distinct remanent magnetization components from the cherts. The highest blocking temperature component shows positive reversal test and is regarded as the primary remanent magnetization, which produced a magnetostratigraphy of the Carnian to Rhaetian. Paleomagnetic polarity reversals observed at the vicinity of Carnian/Norian boundary and middle Norian/upper Norian boundary are correlated with those of Tethyan marine sections (Pizzo Mondello and Silická Brezová). Assuming that the rocks in the two Tethyan marine sections were deposited in the Northern Hemisphere, the magnetostratigraphic correlation indicates that the bedded chert of Inuyama area was deposited in the Northern Hemisphere. The mean inclination of the last demagnetized component suggests the bedded chert originated in an equatorial area.

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

## 西部赤道太平洋の海底堆積物における堆積残留磁化獲得深度の検討

## Lock-in depth of pDRM Acquisition on Marine Sediments of the Western Equatorial Pacific Ocean

櫻本 晋洋<sup>1</sup>、\*山崎 俊嗣<sup>1</sup>、木元 克典<sup>2</sup>、宮入 陽介<sup>1</sup>、横山 祐典<sup>1</sup>Yukihiro SAKURAMOTO<sup>1</sup>, \*Toshitsugu Yamazaki<sup>1</sup>, Katsunori Kimoto<sup>2</sup>, Yosuke Miyairi<sup>1</sup>, Yusuke Yokoyama<sup>1</sup>

1.東京大学大気海洋研究所、2.海洋研究開発機構

1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Japan Agency for Marine-Earth Science and Technology

On reconstructing past geomagnetic-field variations from marine sediments, lock-in depth of post-depositional remanent magnetization (pDRM) acquisition has been controversial for a long time. By direct comparison of relative paleointensity (RPI) and <sup>10</sup>Be flux, Suganuma et al. (2010, 2011) proposed a lock-in depth of ~15 cm, whereas Valet et al. (2014) reported ~0 cm. We studied lock-in depth of pDRM using a marine sediment core obtained from the West Caroline Basin in the equatorial Pacific Ocean (R/V "MIRAI" MR14-02 cruise, core PC01). RPI and <sup>10</sup>Be flux did not show obvious constant shift around the onset of the Olduvai subchron and the Gauss-Matuyama transition. This implies a negligibly small lock-in depth for the studied core. We also examined the lock-in depth of the PC01 core by comparing  $\delta^{18}O$  based ages of recorded polarity boundaries and GPTS ages, and by comparisons of RPI records among PC01, MD982187 (Yamazaki and Oda, 2005) and IODP Site U1314 (Ohno et al., 2012), which have different sedimentation rates. The results were consistent with the negligibly small lock-in depth of the PC01 core. This contrasts to the ~15 cm lock-in depth of the MD982187 core (Suganuma et al, 2010, 2011), which was obtained from the same area. Furthermore, Horiuchi et al. (in press) obtained lock-in depths of ~6 cm and ~10 cm from two cores in the same area. Lock-in depth may depend on lithology and depositional processes of each core.

キーワード：古地磁気強度、堆積残留磁化獲得深度、ベリリウム同位体

Keywords: paleointensity, lock-in depth, <sup>10</sup>Be

## ピルバラクラトンの34.6億年前のデイサイトにおける古地磁気フィールドテストの再検討

Paleomagnetic re-examination of ca. 3.46 Ga dacite in the Pilbara Craton: a positive field test?

\*臼井 洋一<sup>1</sup>、西澤 学<sup>1</sup>、斎藤 誠史<sup>1</sup>、谷 健一郎<sup>2</sup>、渋谷 岳造<sup>1</sup>、奥村 知世<sup>1</sup>

\*Yoichi Usui<sup>1</sup>, Manabu Nishizawa<sup>1</sup>, Masafumi Saitoh<sup>1</sup>, Kenichiro Tani<sup>2</sup>, Takazo Shibuya<sup>1</sup>, Tomoyo Okumura<sup>1</sup>

1.国立研究開発法人海洋研究開発機構、2.国立科学博物館

1.Japan Agency for Marine-Earth Science and Technology, 2.National Museum of Nature and Science

西オーストラリア、ピルバラクラトンの34.6億年前のデイサイトおよびバサルトから、古地磁気褶曲テストの合格例が報告されている (McElhinny and Sananayake, 1980)。これは、南アフリカから近年報告された礫岩テスト (Usui et al., 2009; Biggin et al., 2011) と並び、世界最古の古地磁気フィールドテストとされてきた。しかし、ピルバラクラトンの古地磁気テストは単純な地質構造を仮定して行われているため、信頼度について意見が分かれている。本発表では、先行研究と同じ層準のデイサイト溶岩、およびその見かけ直上のデイサイト質火山角礫岩を対象に新たに古地磁気測定を行った結果を報告する。溶岩は高度な高温酸化を被っており赤色を呈する。火山角礫岩も同様の岩相である。先行研究と同様に、段階消磁により典型的には三つの磁化成分が分離される。しかし、褶曲テストにパスするとされた磁鉄鉱の成分および地域的な二次磁化とされた赤鉄鉱の成分は、火山角礫岩においては溶岩と異なった方位を示す。さらに、磁鉄鉱の成分と赤鉄鉱の成分は共に同一露頭内の礫間で方位が一致しない。従って、初生磁化でありかつ火山角礫岩は低温堆積しており、実際上の礫岩テストを見ているか、または様々な程度の再磁化を被っており初生磁化とは言えない、という可能性が考えられる。これらを区別するためにはより詳細な岩石磁氣的検討が必要である。

キーワード：太古代、古地磁気

Keywords: Archean, paleomagnetism



GPS から推定される過去の大陸形状の復元 その2  
Past continental shape inferred from GPS data part 2

\*勝間田 優<sup>1</sup>、原田 靖<sup>1</sup>

\*Yu Katsumata<sup>1</sup>, Yasushi Harada<sup>1</sup>

1.東海大学海洋学部

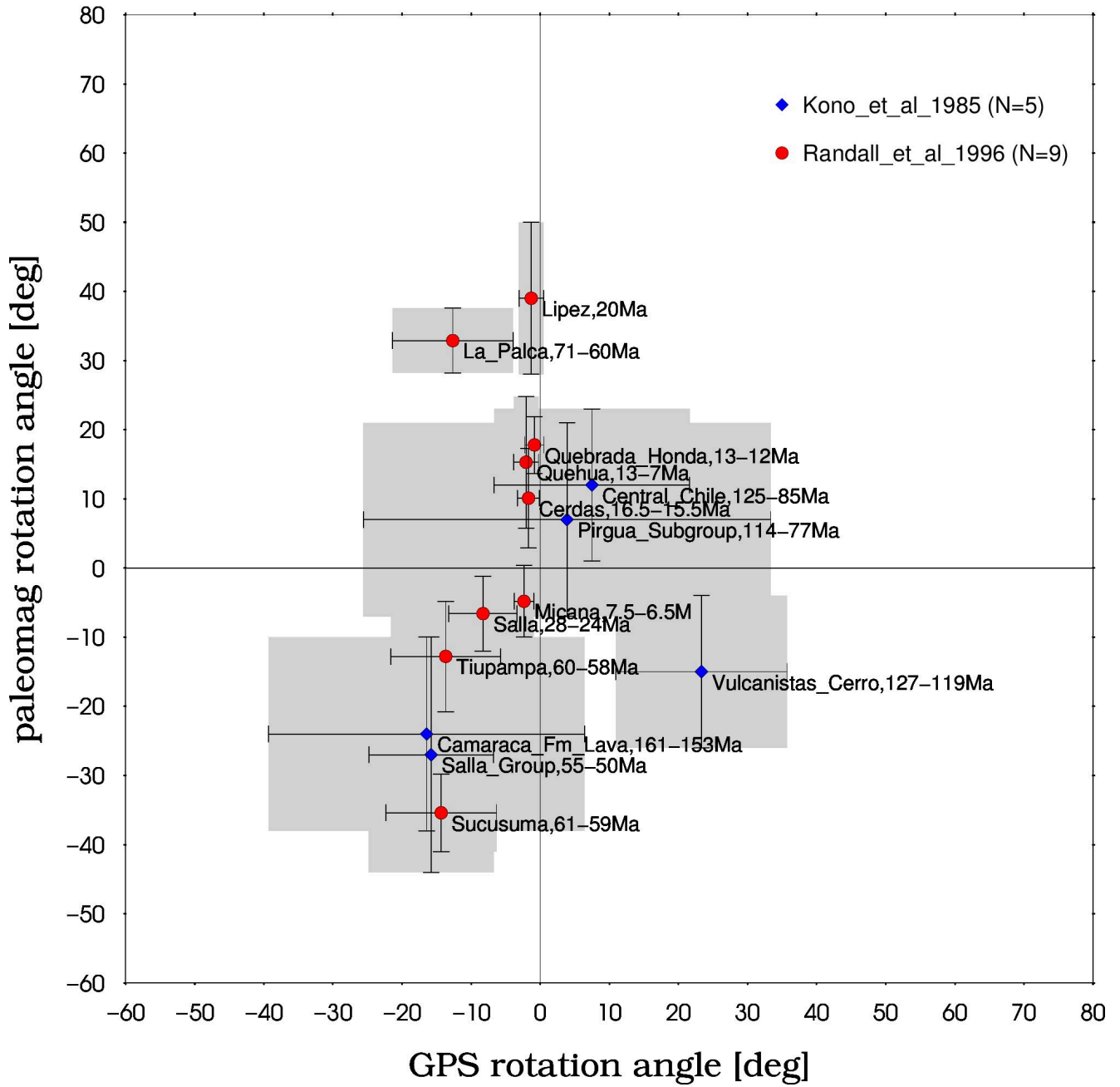
1.Tokai University School of Marine Science and Technology

河合ら(2014連合大会)はGPSのデータによる大陸の内部変形運動を過去に外挿して約50Ma相当の南米大陸の形状を計算し, Kono et al.,1985 が古地磁気学的解析から推定した第三紀前期のアンデス山脈の形状と調和的であることを示した. 本研究では河合ら(2014連合大会)と同様な方法で全地球表面の変形量を計算し,上の Kono et al.,1985 に加えて Randall et al.,1996 の南米大陸の古地磁気データセットを用いてGPSデータから推定される南米大陸の変形による回転量が古地磁気データと比較し得るかどうかを定量的に検証した.用いた古地磁気データは十数点でそれぞれの地点で推定されるGPSからの回転運動量を計算したところ古地磁気データの年代の不確定性起源の誤差やGPS観測点の少なさから来る誤差が大きいものの大局的には正の相関が見られた.

この結果から数十年スケールのGPSで観測されるプレート内部変形は数千万年スケールの大陸の変形運動と比較し得ることを示唆している. しかしながら負の相関を示しているデータも散見され, 必ずしもすべてのデータにおいてGPSのデータと古地磁気データが調和しているわけではないことも分かる.本研究で用いた方法は汎用性が高いのでGPSデータと古地磁気データがある地域ならばどこでも外挿計算による比較が可能である. 今後も他の地域での古地磁気データとGPSから推定される変形量の定量的な比較して行くことによってデータを蓄積し,どのような場所で両者の相関が高いのか, どの程度の過去までGPSデータの外挿が可能なのかを調べていく作業が重要であろう.

キーワード: GPS、過去の大陸形状、古地磁気学データ

Keywords: GPS, Past continental shape, Paleomagnetic data



## 地磁気データから推定されるコア表面渦度の時空間変動

Spatial and temporal variation of vorticity at the core surface estimated from geomagnetic field data

\*松島 政貴<sup>1</sup>

\*Masaki Matsushima<sup>1</sup>

1.東京工業大学理学院地球惑星科学系

1.Department of Earth and Planetary Sciences, School of Science, Tokyo Institute of Technology

Fluid motion near the Earth's core surface provides useful information on core dynamics, and it can be estimated from spatial and temporal distributions of the geomagnetic field. Most of core surface flow models rely on the frozen-flux approximation, in which the magnetic diffusion is neglected for a large-scale magnetic field with time scales much shorter than magnetic diffusion time. It should be noted, however, that there exists a viscous boundary layer at the core-mantle boundary (CMB), where the magnetic diffusion may play an important role in secular variations of geomagnetic field. Keeping this in mind, a new approach to estimation of core surface flow has been devised by Matsushima (2015). That is, the magnetic diffusion is explicitly incorporated within the viscous layer, while it is neglected below the boundary layer.

A core surface flow model between 1840 and 1990 has been derived from a geomagnetic field model, *gufm1* (Jackson et al., 2000). Temporal variations of the flow model contain information on phenomena in relation with core-mantle coupling, such as the LOD (length-of-day), and spin-up/spin-down of core flows. In particular, core surface flows inside the viscous layer at the CMB may reveal an interesting feature in relation with Earth's rotation.

In this paper, we have examined time series of the LOD, kinetic energy of core surface flow, and vorticity derived from the flow model. We could not find any clear correlation between the LOD and kinetic energy of core flow within the boundary layer, and rates of changes in the LOD and the kinetic energy. Also the z-component of global vorticity calculated from core surface flows inside and below the boundary layer was turned out to have little correlation to the LOD. By focusing on a specific longitude or latitude, however, the z-component of local vorticity reveals moderate correlation to the LOD. This result may be explained in terms of conservation of the potential vorticity.

キーワード：渦度、コア表面流、地球磁場

Keywords: vorticity, core surface flow, geomagnetic field

## Thermal structure of the inner core boundary in numerical dynamos

\*Hiroaki Matsui<sup>1</sup>

1.Dept. of Earth and Planetary Sciences, University of California, Davis

Seismic anisotropy through alignment of crystal lattices suggests aspherical growth of the inner core. Slow viscous deformation of the inner core and latent heat distribution by flow motion are expected to be the origin of the aspherical growth of the inner core. A number of dynamo simulations has been performed with prescribed boundary conditions at ICB to take into account the inner core heterogeneity. In the present study, we perform geodynamo simulations with considering the heat equation in the inner core. To compare the results with the simulation without considering the inner core, we assume that the inner core is electrically insulated and co-rotate with mantle. In addition, we set the same thermal diffusivity for the inner core and outer core, and introduce a constant heat source in the inner core to keep the average temperature in the outer core through the simulations. We also set a homogeneous heat flux at the outer boundary of the shell as a thermal boundary condition at CMB. We compare the simulations results with the simulations results using fixed heat flux or temperature condition at ICB. The results show that the time averaged thermal structure at ICB is likely to the homogeneous heat flux boundary conditions. The time averaged lateral temperature variation is approximately 26% of the average temperature difference between ICB and CMB, while lateral heat flux variation is only 6% of the average heat flux at the ICB. We also observe small scale temperature and heat flux variations; however, these components vary with time. In addition, the length scale of the heat flux variation is smaller than the temperature variation at ICB.

Keywords: geodynamo simulations, Inner core boundary

## SVM法による火星磁気異常の表面磁場マッピング

## Regional mapping of the Martian magnetic anomalies on the surface with the SVM method

山口 雅央<sup>1</sup>、\*綱川 秀夫<sup>1</sup>、高橋 太<sup>2</sup>Masao Yamaguchi<sup>1</sup>, \*Hideo Tsunakawa<sup>1</sup>, Futoshi Takahashi<sup>2</sup>

1.東京工業大学大学院理工学研究科地球惑星科学専攻、2.九州大学大学院理学府地球惑星科学専攻

1.Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2.Department of Earth and Planetary Sciences, Kyushu University

The Mars shows strong magnetic anomalies of more than 100 nT at 400 km altitude by the Mars Global Surveyor (MGS) observation during 1997-2006 (e.g. Acuña et al., 1998). The magnetic anomalies indicate existence of the ancient Martian dynamo at about 4Ga, although the present Mars has no global magnetic field. Several previous studies have mapped the magnetic anomalies using the MGS observations at about 400 km altitudes of the mapping phase and at about 120-400 km altitudes of the aerobraking phase. The mapping results show characteristic features: the E-W elongated magnetic anomalies of about 15 degree width, and magnetic reduction/demagnetization at some large craters (e.g. Acuña et al., 1998; Purucker et al., 2000; Connerney et al., 2005; Lillis et al., 2008). However, it is difficult to detect fine structures of the crustal magnetic fields on the maps normalized at high altitudes, since short wavelength components are attenuated. In the present study, we have applied the Surface Vector Mapping (SVM) method (Tsunakawa et al., 2014, 2015) to the Terra Cimmeria region and several craters on the Mars.

Terra Cimmeria is a part of the high land region on the southern hemisphere and one of the strongest magnetic anomaly regions on the Mars. Applying the regional SVM method to the MGS observations in 2005 (30-60 S, 150-180 E; -0.4 ~ 3 km in topographic elevation), the surface magnetic field is estimated to be more than 10000 nT at some areas of the Terra Cimmeria region. The SVM maps show elongated magnetic anomalies with about 5 degree width on the surface, which is much shorter in wavelength than those on the previous maps. These short wavelength components are recognized with relatively smaller amplitudes in the observed magnetic fields. We also have analyzed the magnetic fields observed in 2001. Comparison of the SVM maps between 2005 and 2001 datasets indicates good internal consistency. Based on the SVM results, we have calculated the magnetic field along the pass of about 125-375 km altitudes during the aerobraking phase in 1998, resulting in good agreement of the calculated fields with the observed fields. Thus the Martian magnetic anomalies in the Terra Cimmeria region are successfully mapped on the surface in the present study.

One of the remarkable features on the SVM maps of the Terra Cimmeria region is that total intensities of more than 14000 nT on the surface are restricted at areas with about 2-3 km topographic elevations. The diagram of surface total intensity vs. topographic elevation shows that maximum intensity increases with the elevation in range of -0.4 ~ 2 km. These features suggest that magnetic anomaly sources in this region may be distributed in relatively thin layer near the surface. We also have applied the SVM method to several craters and their surrounding regions. Most of these crater regions show correlations between the the surface total intensity and the topographic elevation, similar to the Terra Cimmeria region. The results from the Terra Cimmeria and crater regions imply that the Martian magnetic anomalies seem to be carried mainly by crustal magnetization of a layer with several kilometer depth.

キーワード：火星、磁気異常、マッピング、地殻

Keywords: Mars, magnetic anomaly, mapping, crust

Rock-magnetic studies concerning source of the Martian magnetic anomaly  
 Rock-magnetic studies concerning source of the Martian magnetic anomaly

\*佐藤 雅彦<sup>1</sup>、潮田 雅司<sup>1</sup>、中田 亮一<sup>2</sup>、山本 裕二<sup>3</sup>、西岡 孝<sup>3</sup>、小玉 一人<sup>3</sup>、綱川 秀夫<sup>4</sup>、望月 伸竜<sup>5</sup>  
 \*Masahiko Sato<sup>1</sup>, Masashi Ushioda<sup>1</sup>, Ryoichi Nakada<sup>2</sup>, Yuhji Yamamoto<sup>3</sup>, Takashi Nishioka<sup>3</sup>, Kazuto KODAMA<sup>3</sup>, Hideo Tsunakawa<sup>4</sup>, Nobutatsu Mochizuki<sup>5</sup>

1.産業技術総合研究所、2.海洋研究開発機構、3.高知大学、4.東京工業大学、5.熊本大学

1.National Institute of Advanced Industrial Science and Technology, 2.Japan Agency for Marine-Earth Science and Technology, 3.Kochi University, 4.Tokyo Institute of Technology, 5.Kumamoto University

Mars Global Surveyor observed the magnetic field of Mars, and revealed that there are many strong magnetic anomalies. The strong magnetic anomalies suggest an active core dynamo of early Mars (about 4 billion years ago), and some mechanism of crustal formation in the dynamo field. Since magnetic properties of crustal rocks depend critically upon the mineralogical form of magnetic particles, the strong magnetic anomalies can give crucial information about the chemical composition and oxidation state prevailing in the early Martian crust. However, source of the Martian magnetic anomalies, which are originated from thick magnetized layers within the crust, have been poorly understood yet because of the lack of basic information concerning magnetic properties of deep crustal rocks. Here, we report the results of rock-magnetic studies to interpret the source of the Martian magnetic anomaly.

To determine magnetic domain state of the source, we conducted in-situ magnetic hysteresis measurement of magnetite under high pressure up to 1 GPa. The results show that magnetite exhibits various pressure dependences of coercivity with respect to magnetic domain states: multidomain (MD) magnetite (linearly increase with pressure at a rate of +91%/GPa), pseudo-single-domain (PSD) magnetite (increases with pressure as a quadratic function), acicular single-domain (SD) magnetite (constant up to 1 GPa), and equidimensional SD magnetite (decrease with pressure at a rate of -15%/GPa). Taking into account these pressure dependences, relaxation time of remanent magnetization in the Martian crust was calculated as a function of depth and age. Remanent magnetizations carried by MD and PSD magnetites have been demagnetized within 4 billion years, except very shallow crustal part. On the other hand, the SD magnetite can stably retain its magnetization in the entire crust. Therefore, the source of the Martian magnetic anomaly is fine-grained SD magnetite.

As the mechanism that crystallize and maintain fine-grained SD magnetite in the deep crustal rocks, we focus on a plagioclase crystal with magnetite inclusions. The plagioclase crystal with magnetite inclusions is ubiquitous in mafic and intermediate terrestrial plutonic rocks, and should play an important role in controlling the magnetic properties of deep crustal rocks. To evaluate the role of the plagioclase crystal, we prepared plagioclase crystals from gabbroic anorthosite of the Duluth complex at Forest Center, Minnesota, USA, and magnetic measurements combined with microscopic observation and synchrotron radiation study were conducted for the single grain plagioclase crystals. The magnetic hysteresis parameters resulted in SD and PSD range on the Day plot. The low-temperature remanence curves showed pronounced remanence reductions at around 100-120 K, indicating that the plagioclase crystals contained nearly pure magnetite. The magnetite contents ranged from 40 to 680 ppm with an average of 270 ppm in weight, which could be sufficient to the source of strong magnetic anomalies. On the basis of the experimental results, we will discuss the chemical composition and oxygen state in the Martian crust, which was suited for bearing fine-grained SD magnetite.

キーワード：Rock-magnetism、Martian magnetic anomaly

Keywords: Rock-magnetism, Martian magnetic anomaly



## SQUID顕微鏡のS/N向上に向けて

## Improvements in Signal-to-Noise Ratio for SQUID microscope

\*小田 啓邦<sup>1</sup>、佐藤 雅彦<sup>1</sup>、野口 敦史<sup>3,1</sup>、高橋 浩規<sup>4,1</sup>、河合 淳<sup>2</sup>、宮本 政和<sup>2</sup>

\*Hirokuni Oda<sup>1</sup>, Masahiko Sato<sup>1</sup>, Atushi Noguchi<sup>3,1</sup>, Hironori Takahashi<sup>4,1</sup>, Jun Kawai<sup>2</sup>, Masakazu Miyamoto<sup>2</sup>

1.産業技術総合研究所地質情報研究部門、2.金沢工業大学、3.高知大学、4.茨城大学

1.Institute of Geology and Geoinformation, Geological Survey of Japan, AIST, 2.Kanazawa Institute of Technology, 3.Kochi University, 4.Ibaraki University

We have been developing scanning SQUID (superconducting quantum interference device) microscope for geological samples. In this presentation, we will demonstrate improvements in our scanning SQUID microscope system. We introduce external magnetic shielding by thin shield film outside of a double-layered PC permalloy magnetic shield box surrounding scanning SQUID microscope. We also develop internal magnetic shield just outside of scanning SQUID microscope with five layered shield film for AC and DC shielding. With this set-up, we also introduce a reference SQUID sensor inside liquid helium dewar in order to compensate noise originated from environmental magnetic field. Resulting signal-to-noise ratio is going to be analyzed and reported. In addition, we show a calibration procedure for our scanning SQUID microscope in terms of its sensitivity and deviation from vertical axis.

キーワード：走査型SQUID顕微鏡、ノイズ、磁気シールド、S/N比、校正

Keywords: scanning SQUID microscope, noise, magnetic shielding, signal-to-noise ratio, calibration

磁化率周波数スペクトルのインバージョンとパルス磁化緩和から得られる磁気緩和時間の比較検討  
Comparison of magnetic relaxation-time distributions derived from measurements in  
frequency-domain and time-domain

\*小玉 一人<sup>1</sup>

\*Kazuto KODAMA<sup>1</sup>

1. 高知大学海洋コア総合研究センター

1.Center for Advanced Marine Core Research

火山岩類から得られる交流磁化率の周波数スペクトルは、SP 粒子の磁気緩和だけでなく、MD 粒子の磁区構造や磁壁のダイナミクスなど多彩な情報を含むと考えられる。本研究では、同一試料について、MPMSによる低温広帯域の複素磁化率と室温におけるパルス磁気緩和を測定し、それらの結果の比較検討から明らかとなった新たな諸現象を紹介する。複素磁化率スペクトルは、室温（300K）から10 K、周波数1 Hzから1 kHzで測定した。パルス磁気緩和はKodama（2015）の方法により、強弱2段階のパルス磁場（7mTと0.7T）と2段階のパルス幅（0.13msと11ms）で行った。測定試料は、ハワイ・伊豆大島・桜島など内外各地のSD~PSD火成岩である。ハワイを除くすべての試料は、130Kから30 Kの範囲で虚数磁化率 $k''$ に顕著なピークを示した。実数磁化率 $k'$ の減衰曲線とあわせると、それらは限られた緩和時間分布をもつ粒子集団のデバイ型緩和スペクトルと解釈できる。一方、 $k''$ のピーク周波数が温度低下につれて低周波側にシフトし、それらピーク周波数と温度の逆数の対数プロット（Neel-Arrhenius plot）が直線となることも、上記の解釈を支持する。さらに、ひとつのスペクトルを複数のDebye型スペクトルに分解するインバージョン法（Debye decomposition）（Nordsiek & Wellner, 2008）を適用することによって緩和時間の離散スペクトルを求めた。それらの結果を室温に外挿した推定値は、パルス磁気緩和測定から直接得られた緩和時間とほぼ一致する。“緩和周波数”（=緩和時間の逆数）は100 kHzから1 MHzで、一般的な強磁性振動や磁壁振動などスピンの動力学が支配する微視的領域の共鳴振動数（数100 MHz~GHz）と比較して著しく低周波である。このことは、今報告の磁気緩和現象が、磁性粒子のサイズ・形状・弾性や磁壁の可逆移動などの巨視的な要因によることを示唆する。

キーワード：磁気緩和時間、周波数スペクトル、インバージョン

Keywords: magnetic relaxation time, frequency spectrum, inversion

## 津波性巨礫の粘性残留磁気を用いた津波年代推定

## Viscous remanent magnetization of tsunamigenic boulders and the age of tsunami events

\*佐藤 哲郎<sup>1</sup>、中村 教博<sup>1,2</sup>、後藤 和久<sup>2</sup>、山田 昌樹<sup>3</sup>、熊谷 祐穂<sup>1</sup>、外崎 貴之<sup>1</sup>、箕浦 幸治<sup>1</sup>

\*Tetsuro Sato<sup>1</sup>, Norihiro Nakamura<sup>1,2</sup>, Kazuhisa Goto<sup>2</sup>, Masaki Yamada<sup>3</sup>, Yuho Kumagai<sup>1</sup>, Takayuki Tonosaki<sup>1</sup>, Koji Minoura<sup>1</sup>

1.東北大学大学院理学研究科地学専攻、2.東北大学災害科学国際研究所、3.筑波大学大学院生命環境科学研究科地球進化科学専攻

1.Graduate School of Earth Science, Tohoku University, 2.International Research Institute of Disaster Science (IRIDeS), Tohoku University, 3.Graduate School of Life and Environmental Science, University of Tsukuba

Along some coastlines in Japan, there are erratic boulders apparently emplaced by tsunamis. The key to understanding of past tsunami events is the ability to accurately date the emplaced age of boulders. Although radiocarbon is one of powerful tools for dating boulders, subsequent movements and non-organic rocks (sedimentary rocks and volcanic rocks) cannot be dated. To overcome this problem, we use viscous remanent magnetization (VRM). Viscous remanent magnetization (VRM) partially overprints original magnetization in rocks displaced by paleotsunami events. If a magnetic-mineral bearing rock is moved or re-oriented, the magnetism of the smaller magnetic grains re-aligns to the direction of the ambient magnetic field with time. This phenomenon is well known as Neel's (1949, 1955) single-domain (SD) relaxation theory. Pullaiah et al. (1975) derived a time-temperature (t-T relation) relation by assuming Neel's theory of magnetite. In principle, an experimental combination of short relaxation time and high temperature for removing VRM can determine the unknown relaxation time (tsunami age) at room temperature. We tested this hypothesis to tsunamigenic boulders consisted of coral limestone in Ishigaki Island, sand stone in Beppu bay and welded tuff in Sanriku coast. The demagnetized paths of all samples have VRM turning points, and their demagnetization temperatures are compatible or higher value of the Neel's hypothesis.

キーワード：津波性巨礫、粘性残留磁化、温度時間関係式

Keywords: tsunamigenic boulder, viscous remanent magnetization, time-temperature relation

## 入戸火砕流堆積物から抽出した粒子の自然残留磁化とその起源の検討

Examination on natural remanent magnetization and its origin of single grains extracted from the Ito pyroclastic flow deposits

\*武田 大海<sup>1</sup>、山本 裕二<sup>2</sup>、佐藤 雅彦<sup>3</sup>、川畑 博<sup>4</sup>

\*hiromi takeda<sup>1</sup>, Yuhji Yamamoto<sup>2</sup>, Masahiko Sato<sup>3</sup>, Hiroshi Kawabata<sup>4</sup>

1.高知大学大学院総合人間自然科学研究科、2.高知大学 海洋コア総合研究センター、3.産業技術総合研究所地質調査総合センター、4.高知大学理学部

1.Graduate school of Integrated Arts and Sciences, Kochi University, 2.Center for Advanced Marine Core Research, Kochi University, 3.Geological Survey of Japan, AIST, 4.Faculty of Science, Kochi University

日本周辺には数多くの広域テフラが分布し、様々な地球科学的研究が行われてきている。古地磁気・岩石磁気学的研究においては、テフラを構成する粒子群が集合体として獲得しているマクロな残留磁化を主な分析対象としているが、個々の粒子は噴出時に熱的なプロセスによる熱残留磁化 (TRM) を獲得している可能性が考えられる。本研究では入戸火砕流堆積物の非溶結部から20~30メッシュ (595~841 $\mu\text{m}$ ) の粒子を抽出し、古地磁気・岩石磁気学的分析を行うことで、NRMの起源を検討した。入戸火砕流堆積物から抽出し、種類別に塊状火山ガラス、軽石型火山ガラス、緑色岩片、黒色岩片、輝石、石英・長石の6種類に分類した646個の粒子の自然残留磁化 (NRM) を測定した。その中で79個の粒子 (12.2%) はブランク平均 (8~17pAm<sup>2</sup>) に比して有意に強いNRM強度を保持していることが分かった。これらの粒子から種類別に各1~2個を選定して段階交流消磁を行ったところ、塊状火山ガラス、軽石型火山ガラス、黒色岩片、緑色岩片については安定な残留磁化を保持していることが分かった。さらにこれらの粒子に対して各種の岩石磁気分析を行ったところ、安定磁化成分は保磁力の高い単磁区サイズのマグネタイトが主なキャリアーであることが分かった。これらの粒子は、非履歴性残留磁化 (ARM)、等温残留磁化 (IRM) の段階交流消磁に対しても安定性を示した。一部を除きNRM/ARM比は1.24~4.07を示し、NRM/IRM比は0.0224~0.0475を示した。これらの比は、Yu (2010)によって単磁区~疑似単磁区サイズのマグネタイトについて報告されているTRM/ARM比 (2.60 $\pm$ 1.32 (1 $\sigma$ )) およびTRM/IRM比 (0.0362 $\pm$ 0.0128 (1 $\sigma$ )) と標準偏差 (1 $\sigma$ ) の範囲内で一致する。したがってNRMの起源は熱残留磁化であることが示唆される。

## 還元化学消磁による磁性鉱物の変化

Changes of magnetic minerals in reductive chemical demagnetization.

\*穴井 千里<sup>1</sup>、望月 伸竜<sup>2</sup>、渋谷 秀敏<sup>1</sup>\*Chisato Anai<sup>1</sup>, Nobutatsu Mochizuki<sup>2</sup>, Hidetoshi Shibuya<sup>1</sup>

1.熊本大学大学院自然科学研究科、2.熊本大学大学院先導機構

1.Dep't of Earth &amp; Environment, Kumamoto Univ., 2.Priority Organization for Innovation and Excellence, Kumamoto Univ.

Demagnetizations are important processes in paleomagnetism studies. Alternating Field demagnetization (AFD) and Thermal demagnetization (ThD) are two of the most popular techniques used. However, there are samples that those techniques would not work for erasing secondary magnetizations. In such a case, Chemical Demagnetization (CD) could be applied. It is widely used for paleomagnetic studies of redbeds, as the post-dated magnetic minerals may dissolve earlier. So it shall be effective for demagnetization of rocks with chemical remanent magnetization (CRM). Chemical demagnetization in most paleomagnetic studies has been performed using concentrated HCl solution, by leaching specimens for several months or for several days in high temperature. Those procedures have not been widely used because the handling of the high temperature HCl is difficult or time consuming for the room temperature. In addition, they destroy limestone samples and any other sedimentary rocks cemented by carbonate materials. In order to apply CD for limestones, we examined reductive etchant of neutral pH under the room temperature.

The magnetostratigraphy of reef limestone (Ryukyu Group) using the Reductive Chemical Demagnetization (RCD) is already reported in the 138<sup>th</sup> Society of Geomagnetism and Earth, Planetary and Space Sciences. Here we focus on the magnetic mineral changes in RCD, and magnetic properties of the minerals charring characteristic remanent magnetization.

The reductive etchants tried are potassium iodide (KI) solution and ascorbic acid (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>) solution. The solutions are prepared in 5-20%, and for ascorbic acid (pH is about 2.4) the pH is buffered to 6.0-6.5 with sodium hydrogen carbonate (NaHCO<sub>3</sub>). The redox potential of those cases is -150\_-10mv. This condition falls in the domain of stable iron ion Fe<sup>2+</sup> in the pH-pE diagram shown in Henshaw and Merrill (1980). After the leaching experiment in this condition, we performed various rock magnetism measurements.

As we wrote above chemical demagnetization in room temperature is very time consuming, drip-feeding of etchant is also tested. Drips of etchant is supplied from the top of the sample, and flows out from the bottom. The solvent (water) removes the solved Fe<sup>2+</sup> faster.

We performed three experiments:

1) RCD of IRM: We compare the efficiency varying the etchants, concentrations and exposure method, in eight kind of solution (KI: 5, 10, 15, 20% ascorbic acid: 5, 10, 15, 20%) which supplied by dripping and dipping. The IRM is measured every 12 hours. The dripping enhances the demagnetization speed significantly, and shortens the duration up to a 9th of dipping RCD. In the eight kinds of solutions, the ascorbic acid 5% + NaHCO<sub>3</sub> (pH=6.52, ORP=-107mv) is the fastest, and the demagnetization is completed in 72 hours. Those experiments indicate RCD dipping the reductive etchant is most effective at least for those limestones.

2) IRM acquisition: The comparison of the IRM acquisition curves between before and after RCD indicate that the significant increase in saturating field, 3T and 1T, respectively, by RCD. It suggest that the RCD removes hematite and/or goethite, and remains magnetite intact.

3) Thermal demagnetization of a three-component IRM: Samples before and after RCD are exposed in 3T, 0.3T and 0.1T in each orthogonal direction, and then thermally demagnetized. It showed that a

high coercivity magnetic minerals was demagnetized by RCD. This indicate that at least considerable portion of the component demagnetized by RCD is carried by hematite. These results showed that the RCD is effective for carbonate rocks. We think that the reductive etchant make CD more versatile, as the ascorbic acid is easy to handle in the laboratory.

キーワード：化学消磁、還元性エッチャント

Keywords: chemical demagnetization, reductive etchant

スランプ褶曲を受けた細粒火山灰層の古地磁気と帯磁率異方性  
Paleomagnetism and AMS of a slumped fine-grained volcanic ash bed

\*星 博幸<sup>1</sup>、新井田 佑太<sup>1</sup>

\*Hiroyuki Hoshi<sup>1</sup>, Yuta Niida<sup>1</sup>

1.愛知教育大学

1.Aichi University of Education

愛知県知多半島には大谷火山灰層とよばれる約4 Ma (鮮新世)の珪長質細粒火山灰層(テフラ層)が分布している。模式地において、この火山灰層は降下堆積物(約5 cm)とラハール堆積物(約3.6 m)のセットからなる。ラハール堆積物は火山ガラスを主とするいわゆる磨き粉火山灰からなり、スランプ褶曲を顕著に受けている。このラハール堆積物は古地磁気方位と帯磁率異方性(AMS)が褶曲形態とどのような関係になっているかを調べる絶好の機会を提供する。

Otofujii et al. (1975)はこの模式地でラハール堆積物の古地磁気方位を調査し、層準によって方位が大きく異なることを報告した。彼らはこの方位の違いについて、堆積時の急速な地磁気変動が記録されたとする可能性を指摘した。しかし残留磁化獲得後にスランプ褶曲が起こったために方位の違いが生じた可能性も疑われる。古地磁気方位とAMSを詳細に調べれば、これらの可能性の真偽も検証できるだろう。

模式地のラハール堆積物の水平方向5 m×5 m、上下方向2 mの範囲内で、ラミナの走向・傾斜が異なる5地点で定方位コアを採取した。岩石磁気測定結果は、試料に含まれる主要な強磁性鉱物がマグネタイトであることを示す。すべての試料に段階交流消磁または段階熱消磁を適用した。ほとんどすべての試料が直交投影図上で原点に向かって減衰する残留磁化成分(特徴磁化成分)を保持していた。すべての地点において、この特徴磁化方位は地点内でよく集中した。地点間で比較すると、褶曲補正前の状態で5つの地点方位はすべて偏角180°前後の上向き方位(逆極性)を示し、互いに類似していた。褶曲補正すると5つの方位は大きく分散した。これらの結果は特徴磁化方位がスランプ褶曲後に獲得されたもの(おそらくpost-depositional DRM)であることを示す。褶曲補正前の状態でOtofujii et al. (1975)が示したような方位の違いは認められなかった。一方AMSは、褶曲補正前と補正後のいずれの場合も、地点内集中度、主軸方位ともに地点によって大きく異なった。この結果は、残留磁化方位を担う強磁性鉱物の配列がAMSには実質的に寄与していないこと、およびAMSに実質的に寄与する鉱物の配列がスランプ褶曲によって乱されていることを示唆する。

以上の結果から、スランプ褶曲を受けた細粒火山灰層は古地磁気方位を利用する研究の測定対象にはなり得るが、AMSを利用する研究(例えば、堆積時古流向の推定)の対象には適さない場合があると言える。

キーワード：スランプ褶曲、火山灰層、テフラ、古地磁気、帯磁率異方性、AMS

Keywords: Slumping, volcanic ash, tephra, paleomagnetism, anisotropy of magnetic susceptibility, AMS

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

\*Myriam Annie Claire Kars<sup>1</sup>, Robert John Musgrave<sup>2,3</sup>, Kazuto KODAMA<sup>1</sup>, Susanne M Straub<sup>4</sup>, Julie Schindlbeck<sup>5</sup>, Maryline Vautravers<sup>6</sup>

1.CMCR, Kochi Univ., 2.Geological Survey of NSW, 3.Univ. of Sydney, 4.Lamont-Doherty Earth Observatory, 5.GEOMAR Helmholtz Centre for Ocean Research Kiel, 6.Univ. of Cambridge

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



## 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

\*佐野 拓郎<sup>1</sup>、兵頭 政幸<sup>1,2</sup>、松本 恵<sup>3</sup>、瀬戸 雄介<sup>1</sup>、楊 天水<sup>4</sup>\*Takuroh Sano<sup>1</sup>, Masayuki Hyodo<sup>1,2</sup>, Megumi Matsumoto<sup>3</sup>, Yusuke Seto<sup>1</sup>, Tianshui Yang<sup>4</sup>

1.神戸大学大学院理学研究科惑星学専攻、2.神戸大学内海域環境教育研究センター、3.神戸大学研究基盤センター、4.中国地質大学

1.Department of Planetology, Kobe University, 2.Research Center for Inland Seas, Kobe University, 3.Center for Supports to Research and Education Activities, Kobe University, 4.State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences

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 investigate 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 ( $29 \times 10^{-8} \text{m}^3 \text{kg}^{-1}$ ) and high ( $116 \times 10^{-8} \text{m}^3 \text{kg}^{-1}$ ) 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, nano-inclusions 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

## 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

\*川村 紀子<sup>1</sup>、山崎 俊嗣<sup>1,2</sup>\*Noriko Kawamura<sup>1</sup>, Toshitsugu Yamazaki<sup>1,2</sup>

1.海上保安大学校 基礎教育講座、2.東京大学 大気海洋研究所

1.Japan Coast Guard Academy, 2.University of Tokyo

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  $\mu\text{m}$ ), 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 ( $<0.45$   $\mu\text{m}$  in diameter) are abundantly 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

## 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

\*熊谷 祐穂<sup>1</sup>、中村 教博<sup>1</sup>、佐藤 哲郎<sup>1</sup>\*Yuho Kumagai<sup>1</sup>, Norihiro Nakamura<sup>1</sup>, Tetsuro Sato<sup>1</sup>

1.東北大学大学院理学研究科地学専攻

1.Department of Earth Science, Tohoku University

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 advantages 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 averaged 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 previous 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 assemblages 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

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.

\*辻本 元博<sup>1</sup>、面谷 明俊<sup>2</sup>、宮内 敏<sup>3</sup>

\*Motohiro Tsujimoto<sup>1</sup>, Akitoshi Omotani<sup>2</sup>, Satoshi Miyauti<sup>3</sup>

1.なし、2.山陰システムコンサルタント、3.伊能忠敬研究会

1.none, 2.San-in System Consultant, 3.Inoh Tadataka Association

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 $0^{\circ}05'$ 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 $0^{\circ}15'$ 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く。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 $0^{\circ}05'$ 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 $0^{\circ}15'$ 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。

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, interdisciplinary

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

\*山本 伸次<sup>1</sup>、佐藤 雅彦<sup>2</sup>、山本 裕二<sup>3</sup>、大野 正夫<sup>4</sup>、綱川 秀夫<sup>5</sup>

\*Shinji Yamamoto<sup>1</sup>, Masahiko Sato<sup>2</sup>, Yuhji Yamamoto<sup>3</sup>, Masao Ohno<sup>4</sup>, Hideo Tsunakawa<sup>5</sup>

1.横浜国立大学、2.産業技術総合研究所、3.高知大学、4.九州大学、5.東京工業大学

1.Yohohama National University, 2.National Institute of Advanced Industrial Science and Technology,  
3.Kochi University, 4.Kyushu University, 5.Tokyo Institute of Technology

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 Hedeian 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  $M_{NRM} \geq 4 \times 10^{-12} \text{ Am}^2$  and  $M_{IRM} \geq 4 \times 10^{-12} \text{ Am}^2$ , 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

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

\*佐藤 雅彦<sup>1</sup>、山本 伸次<sup>2</sup>、山本 裕二<sup>3</sup>、Du Wei<sup>4</sup>、大野 正夫<sup>5</sup>、綱川 秀夫<sup>6</sup>、丸山 茂徳<sup>6</sup>

\*Masahiko Sato<sup>1</sup>, Shinji Yamamoto<sup>2</sup>, Yuhji Yamamoto<sup>3</sup>, Wei Du<sup>4</sup>, Masao Ohno<sup>5</sup>, Hideo Tsunakawa<sup>6</sup>, Shigenori Maruyama<sup>6</sup>

1.産業技術総合研究所、2.横浜国立大学、3.高知大学、4.東京大学、5.九州大学、6.東京工業大学

1.National Institute of Advanced Industrial Science and Technology, 2.Yokohama National University, 3.Kochi University, 4.The University of Tokyo, 5.Kyushu University, 6.Tokyo Institute of Technology

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 ( $M_{\text{NRM}}$ ) was first measured for the 1034 grains of zircon crystals. Then, low-temperature demagnetization (LTD) treatment was further conducted for 85 grains with  $M_{\text{NRM}}$  values larger than  $5 \times 10^{-12} \text{ Am}^2$ , and the memory (NRM intensity after LTD treatment;  $M_{\text{NRM-LTD}}$ ) 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;  $M_{\text{NRM-AFD}}$ ) 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 ( $M_{\text{IRM}}$ ). Subsequently, IRM intensity after LTD treatment ( $M_{\text{IRM-LTD}}$ ) and AFD treatment ( $M_{\text{IRM-AFD}}$ ) were measured for the sample with  $M_{\text{NRM}}$  values larger than  $5 \times 10^{-12} \text{ Am}^2$ .

$M_{\text{NRM}}$  values of the single zircon crystals varied from  $10^{-13}$  to  $10^{-10} \text{ Am}^2$ , and 101 crystals (9.8%) had  $M_{\text{NRM}}$  larger than  $4 \times 10^{-12} \text{ Am}^2$ .  $M_{\text{IRM}}$  values of the single zircon crystals also varied by five orders of magnitude, and 402 crystals (38.9 %) showed  $M_{\text{IRM}}$  larger than  $4 \times 10^{-12} \text{ Am}^2$ . The ratios of  $M_{\text{NRM}}/M_{\text{IRM}}$ ,  $M_{\text{NRM-LTD}}/M_{\text{IRM-LTD}}$ , and  $M_{\text{NRM-AFD}}/M_{\text{IRM-AFD}}$  varied 0.003–2.0, 0.005–2.4, and 0.005–2.4. There were several samples with the  $M_{\text{NRM-AFD}}/M_{\text{IRM-AFD}}$  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.

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

Keywords: Rock-magnetism, Zircon, Paleointensity



## 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

## Abbsolute Paleointensities of about 30Ma from Ethiopian flood basalts

\*吉村 由多加<sup>1</sup>、石川 尚人<sup>1</sup>、山本 裕二<sup>2</sup>、安 鉉善<sup>3</sup>、Tefaye Kidane<sup>4</sup>、乙藤 洋一郎<sup>5</sup>

\*Yutaka Yoshimura<sup>1</sup>, Naoto Ishikawa<sup>1</sup>, Yuhji Yamamoto<sup>2</sup>, Hyeon-seon Ahn<sup>3</sup>, Tefaye Kidane<sup>4</sup>, Yo-ichiro Otofujii<sup>5</sup>

1.京都大学、2.高知大学 海洋コア総合研究センター、3.慶尚大学校、4.アディスアババ大学、5.神戸大学  
1.Kyoto University, 2.Center for Advanced Marine Core Research, Kochi Univ., 3.Research Institute of Natural Science, Gyeongsang National University, 4.Department of Earth Science, Faculty of Science, Addis Ababa University, 5.Kobe University

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<sup>40</sup>Ar/<sup>39</sup>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、不確かさの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ジ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回加熱シヨウ法(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 $1.21\sim 7.28\times 10^{22}\text{Am}^2$ )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: $3.40\times 10^{22}\text{Am}^2$ )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 $8\times 10^{22}\text{Am}^2$ で、0.3Ma~300Maのそれは約 $5\times 10^{22}\text{Am}^2$ 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

## 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

\*福間 浩司<sup>1</sup>、村松 哲夫<sup>1</sup>

\*Koji Fukuma<sup>1</sup>, Tetsuo Muramatsu<sup>1</sup>

## 1.同志社大学理工学部環境システム学科

1.Department of Environmental System Science, Faculty of Science and Engineering, Doshisha University

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

## 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

\*外崎 貴之<sup>1</sup>、中村 教博<sup>1</sup>、後藤 和久<sup>2</sup>、佐藤 哲郎<sup>1</sup>、渡部 真史<sup>3</sup>

\*Takayuki Tonosaki<sup>1</sup>, Norihiro Nakamura<sup>1</sup>, Kazuhisa Goto<sup>2</sup>, Tetsuro Sato<sup>1</sup>, Masashi Watanabe<sup>3</sup>

1.東北大学大学院理学研究科地学専攻、2.東北大学災害科学国際研究所、3.東北大学大学院工学研究科

1.Department of Earth Science, Tohoku University, 2.International Research Institute of Disaster Science (IRIDeS), Tohoku University, 3.Graduate School of Engineering, Tohoku University

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. Especially, 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.

## 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

\*小玉 一人<sup>1</sup>

\*Kazuto KODAMA<sup>1</sup>

1. 高知大学海洋コア総合研究センター

1.Center for Advanced Marine Core Research

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

## 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

\*中島 涼輔<sup>1</sup>、吉田 茂生<sup>2</sup>

\*Ryosuke Nakashima<sup>1</sup>, Shigeo Yoshida<sup>2</sup>

1.九州大学 大学院理学府 地球惑星科学専攻、2.九州大学 大学院理学研究院 地球惑星科学部門

1.Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University,

2.Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University

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

## Constraint of magnetic models using seismic tomography in Taiwan

\*Chieh-Hung Chen<sup>1</sup>, Chun-Rong Chen<sup>2</sup>, Strong Wen<sup>3</sup>, Yi-Hsuan Huang<sup>1</sup>

1.Department of Earth and Environmental Sciences, National Chung Cheng University, Taiwan,

2.Department of Earth Sciences, National Central University, Taiwan, 3.National Center for Research on Earthquake Engineering, Taiwan

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 ( $V_p$ ) together with ( $V_p/V_s$  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