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PREFACE

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Special issue "Recent advances in geo-, paleo- and rock-magnetism"

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The special issue of *Earth, Planets and Space* "Recent Advances in Geo-, Paleo- and Rock-Magnetism" was motivated by presentations given in Session S-EM18 "General Contributions in Geomagnetism, Paleomagnetism, and Rock magnetism" held during the Japan Geoscience Union–American Geophysical Union (JpGU–AGU) 2017 Joint Meeting (20–25 May in Chiba, Japan). Contributions span the broad range of topical developments in Earth magnetism including the disciplines of archeomagnetism, paleomagnetism, paleointensity, rock magnetism, crustal magnetism and biogeomagnetism. In addition, several contributions present advances in methods of analysis. These areas are briefly introduced below with an emphasis on the advances represented, current community debates and the motivation the new results provide for further study.

Archeomagnetism and paleomagnetism

Contributions in archeomagnetism and paleomagnetism display the continual advances in the collection of new data recording the history of the geomagnetic field. Kitahara et al. (2018) present Tsunakawa–Shaw paleointensity estimates from a tenth-century kiln from Japan that further demonstrate the viability of this protocol for defining field strength from archeological materials. The field intensity values derived are somewhat lower values than those reported in prior studies in Japan; this should provide motivation for further investigation. Ahn et al. (2018) discuss the potential of sediments from Jeju Island, Korea, for recording young (17–22 kyr) excursions and the challenges of distinguishing these considering rock magnetic complexities. Li et al. (2018) discuss loess and paleosol paleomagnetic records of Brunhes geomagnetic excursions from Central Asia. In particular, they highlight recordings of the Blake and Laschamp geomagnetic excursions.

Global records of the archeomagnetic field and excursions are of crucial importance not only for understanding the past magnetic field but also for providing context on modern changes. Specifically, there is a debate over what excursions tell us about the rapidly diminishing modern dipole field; some analyses of the rate of intensity changes support the idea of an impending reversal or excursion, whereas others argue that the geomagnetic field patterns during recent excursions differ from those of the present-day field. The latter interpretation is highly dependent on the nature of global data coverage. Endeavors of the type defined by Kitahara et al. (2018), Ahn et al. (2018) and Li et al. (2018) can move us closer to global coverage; they are crucial for improving predictions of the future magnetic field and our planetary magnetic shield.

In a Frontier Letter, Kato et al. (2018) present paleointensity results from single silicate crystals separated from Cretaceous granites of Japan. They yield data from plagioclase feldspars that bear on the ongoing debate over the field during Superchrons, periods tens of millions of years long with few (or no) geomagnetic reversals. Numerical simulations, theory and prior paleointensity data from single feldspars argue for a strong field during the Cretaceous Normal Superchron and an inverse relationship between geomagnetic reversal frequency and field strength. However, results from whole rocks fail to show this relationship. The results of Kato et al. (2018) not only highlight the potential of single silicate crystal studies, but also strongly support a high field during the Cretaceous Normal Superchron, representing a major contribution to this fundamental issue.

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Rock magnetism

Rock magnetism describes the basic physics of rock and mineral magnetic recorders and as such underpins our understanding of paleomagnetism. The Verwey transition, the change from cubic to monoclinic crystal structure in magnetite at 120 K, continues to be a focus of interest in the community. Lindquist et al. (2019) use transmission electron microscope imaging to document domain wall motion across the Verwey transition in a magnetite sample deformed in the laboratory. These authors relate these data to the role stress, and dislocations can play in controlling magnetic properties. In contrast, Dunlop and Özdemir (2018) study magnetite annealed to remove the effects of stress. Their rock magnetic data on size-controlled magnetite allow them to study the degree to which remanence memory occurs when cycling across the transition. While the authors conclude that the results are still too scattered to be useful for magnetic granulometry, these results together with the observations of Lindquist et al. (2019) further define the phenomenology of the Verwey transition and may eventually lead to a better understanding of other observations such as magnetic field controls on low-temperature magnetic properties.

Biogeomagnetism

Biogeomagnetism is an expanding field and one in which many discoveries await further research. In an Express Letter, Oda et al. (2018) offer one such discovery. The authors report the first identification of magnetofossils of magnetotactic bacteria in ferromanganese crust from the Pacific Ocean. The report of this occurrence is surprising and has far-reaching implications. Bacterial magnetite has long been known to be concentrated at the modern redox boundary in pelagic sediments (e.g., studies of the Ontong Java Plateau of the Western Pacific Ocean). The observations of Oda et al. (2018), however, reveal that one should not assume that seemingly fully oxic deep-sea ferromanganese crusts are devoid of magnetotactic bacteria. This should motivate studies to define paleomicroenvironments in these crusts. Moreover, these new observations suggest a greater role of ferromanganese crusts and related deposits for global iron cycling. In a Frontier Letter, Zhang and Pan (2018) review the characterization of magnetite associated with magnetoferritins and magnetotactic bacteria. The former relates to important potential biomedical applications, whereas the latter applies to the continued effort to define modern magnetotactic bacteria populations and magnetofossils in deep geologic time.

Marine geology/geophysics

From the earliest definition of the marine magnetic anomalies that were crucial for the plate tectonics scientific revolution, magnetic investigations have been central in marine geology and geophysics. Today there remain unknowns about seafloor magnetization processes. Studies addressing these unknowns take on even greater importance as we look for terrestrial analogs for hydrothermal processes on other planets and satellites. Fujii et al. (2018) discuss the fundamental hydrothermal alteration effects on the magnetic properties of submarine basalts from the Okinawa Trough. Although their data cannot completely exclude effects of alteration-induced self-reversal by ionic recording, available geochemical constraints support a conversion of high magnetic titanomagnetites to non-magnetic phases. Fujii and Okino (2018) combine magnetic mapping with submersible photographic documentation and sampling to study off-axis lava flows of the Central Indian Ridge near hydrothermal fields. This diverse data set allows the authors to draw inferences on the emplacement of altered and less magnetic material versus more highly magnetized recently erupted flows.

Global magnetic field studies and applications

A plethora of new satellite data offer opportunities for analyses of tectonic structure, magnetic anomalies and seismicity. Lei et al. (2018) identify a possible correlation between the vertical component of the lithospheric magnetic field and continental seismicity in Mainland China and surrounding areas and discuss this in terms of lithospheric viscosity and temperature gradients. Roger et al. (2019) discuss the investigation of core flow using Slepian functions. Although the authors conclude that more work is needed to address spectral leakage, potential remains to study features of core flow, including the potential influence of unusual core–mantle features such as large low-shear-velocity provinces that have been proposed to be long-term sites of flux expulsion affecting the most recent and paleofield of the South Atlantic Anomaly region.

Methods

Retrieving pristine rock magnetic and paleomagnetic records from natural samples remains challenging, especially as the discipline seeks records with ever greater spatial and temporal resolution. A number of contributions address advances in techniques of sample preparation and/or data analysis.

Myre et al. (2019) present applications of a fast spatial domain algorithm "TNT-NN" to address the inversion of data sets from scanning SQUID magnetometers (SSMs).

As opposed to ultrasensitive three-component SQUID magnetometers, these magnetometers directly measure only the vertical component on the magnetization, and therefore, the other components must be inferred by an inversion of the data with associated uncertainties. The work of Myre et al. (2019) is an important step forward in providing a robust framework for the analyses of SSM data.

Analyses of data derived from continuous measurements of sedimentary cores using pass-through SQUID magnetometers have also been a target of software development. Yamamoto et al. (2018) present a successful application of a software UDECON (Xuan and Oda 2015) to deconvolve natural remanent magnetization data obtained from such continuous measurements spanning a geomagnetic reversal; tests show that the software can help extract fine-scale features in the data which are in good agreement with discrete paleomagnetic sample measurements.

In technical reports, Hatakeyama (2018) present online plotting options for viewing paleomagnetic and rock magnetic data assisting international collaborations, whereas Anai et al. (2018) discuss a reductive chemical demagnetization approach with the promise of being able to remove secondary minerals and their magnetizations reveals primary recordings of the geomagnetic field from reef limestones and potentially other rock types.

The rock magnetic study of single silicate grains has mainly focused on their use in paleointensity or paleodirections, but their use in provenance studies has only recently been recognized. Usui et al. (2018) present methods of separation and present the first rock magnetic results from quartz and feldspar derived from red clays, presenting their results as a new provenance indicator. Given the areal distribution of red clays, this work opens many new possibilities for future investigations.

Authors' contributions

All authors served as guest editors for this special issue. Lead guest editor John Tarduno drafted the preface which was edited and approved by all authors. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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