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Editorial: Advances in Magnetism of Soils and Sediments

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Editorial on the Research Topic

Advances in Magnetism of Soils and Sediments

Our understanding of how rock magnetism records sedimentary and environmental processes, along with the refinement of analytical methods, has substantially improved in the last decade. In addition, there is an increasing appreciation of the strong interaction between (bio)geochemical and physical systems and their preservation in the sedimentary record. These developments hold great promise for a better comprehension of the evolution of our planet through time. In this Special Issue, we highlight some of the most significant advances to the topic of sedimentary and soil magnetism and their impact on several related domains.

The Advances in Magnetism of Soil and Sediments Special Issue focuses on identifying and assessing the impact of processes that occur throughout the entire sedimentary and soil cycle on rock magnetic, paleomagnetic, and environmental records (**Figure 1**). Magnetic mineral assemblages are affected by a wide range of chemical, physical and biological processes at different scales in depth and through time, and therefore are good indicators of environmental changes. In terrestrial environments (e.g., soil, sediment, speleothem), the magnetic mineralogy is dominated by detrital particles, mostly iron oxy-hydroxides and iron oxides, which are eroded and transported by wind or water. Some of these minerals are further altered by weathering and diagenetic processes at depth, related to the degradation and fermentation of the organic matter. Biological activity is responsible for the formation of authigenic minerals, either intracellularly or extracellularly, in oxic sedimentary environment. Other constituents of the magnetic assemblage can include atmospheric particles from volcanic ash and anthropogenic aerosols, and to a lesser extent extraterrestrial input. Particles from land are then transported and deposited in aqueous environments and constitute the main magnetic component in marine sediments. Eolian particles (dust), volcanic ash, biogenic magnetic particles from biomineralization, and extraterrestrial input also contribute to magnetic minerals in marine sediments. Post-depositional alteration due to burial, diagenetic processes or fluid and gas circulation, in anoxic conditions, leads to a drastic change in the magnetic mineral assemblages with the reduction of iron oxy-hydroxides and iron oxides to form iron sulfides. Because of magnetic minerals sensitivity to (bio)geochemical conditions, investigating the changes in the magnetic mineral assemblages and associated mechanisms in a diversity of environments leads to new insights on past environmental and paleoceanographic conditions.

With that perspective in mind, a broad range of natural materials are investigated by fourteen original contributions: speleothems, ocean surface and deep sediments, methane- and gas hydrate-bearing sediments, estuarine sediments, sandstone, particulate matter, ice cores, plant ash, soil, paleosols, and microbialites.

Rock magnetic and paleomagnetic approaches can provide highly sensitive and unique information on mineral changes, particularly in fine grained materials, and constrain the relative timing and duration of mineralogical processes during sedimentation and their impact on the environment. In this Volume, classic rock magnetic and paleomagnetic techniques, are combined

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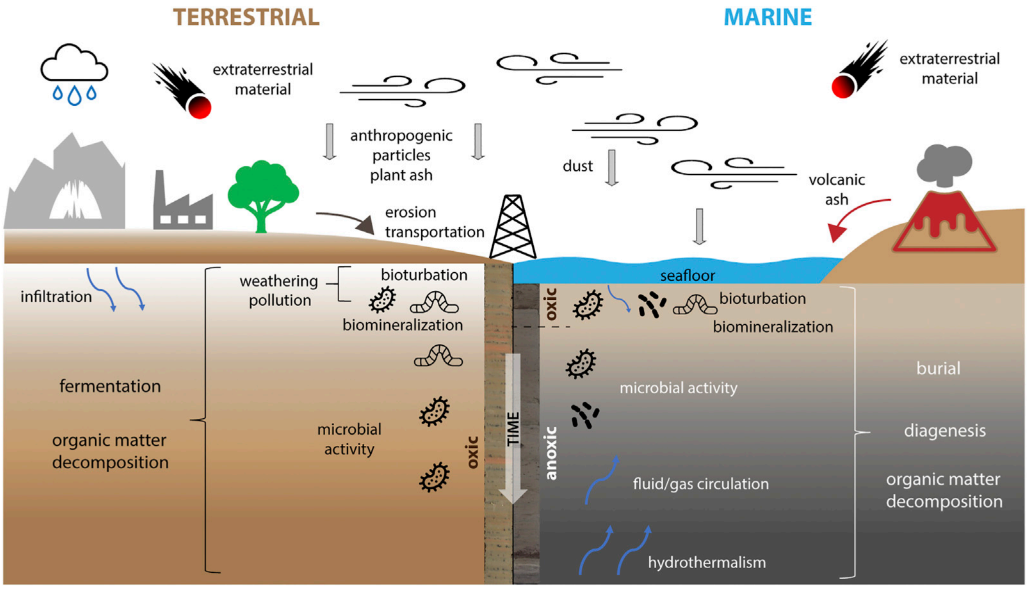

FIGURE 1 | Graphical synthesis of contributions to this Special Issue, highlighting the main sources of magnetic material in terrestrial and marine environments, the physiochemical conditions at the burial site, and the depositional and post-depositional processes that affect the magnetic signal in the geological environment.

with other analytical methods (i.e., Quantum Diamond Microscope magnetic field imaging, electron microscopy, Mössbauer and X-ray spectroscopy, X-ray and electron diffraction, geochemical analyses) yielding strong constraints on several processes, including climatic conditions, diagenesis, post-depositional effects, chemical magnetization, and their effect on the magnetic signal.

Two contributions discuss the advances in the characterization of magnetic minerals in sediments, combining classic rock magnetism with new techniques. Fu et al. show new methods to investigate the magnetic mineralogy of speleothems using magnetic microscopy via Quantum Diamond Microscope magnetic field imaging. This recently developed technique provides high-resolution time-series of detrital input which the authors associate to paleoprecipitation, thus providing useful paleoenvironmental information. Li et al. report a case where deep-sea surface sediments show a complex magnetic mineralogy indicating multiple different sources (distal and local igneous rocks as well as minor magnetofossil and superparamagnetic contributions) identified by scanning and transmission electron microscopy and magnetic methods.

Three contributions explore diagenesis in the context of methanogenesis. Amiel et al. connect early diagenetic processes and sedimentary magnetism using a composite high-resolution sedimentary record of pore-water chemistry, solid phase chemical measurements and mineral-magnetic parameters; they note a strong correlation between increase in the magnetic signal and the precipitation of authigenic magnetic minerals. Badesab et al. integrate rock magnetic, mineralogical, and microscopic analyses to investigate the linkage between greigite magnetism, methane seepage dynamics, and evolution of shallow gas hydrate system. Finally, Kars et al. investigate authigenic ferrimagnetic iron sulfides in gas-hydrate-bearing marine sediments, highlighting a close linkage between greigite, methane hydrate and microbial activity.

Another two contributions explore post-depositional effects on the magnetic mineralogy.

Ahn et al. is related to diagenetic effects on environmental magnetic parameters in an estuarine setting. They support rock magnetic analysis with electron microscopy to evaluate paleoenvironmental proxies and highlight a set of potentially robust magnetic proxies for sea-level change in the Holocene. Ejembi et al. show the profound effects of secondary, post-depositional fluid flow on the magnetic fabric of sandstones using anisotropy of magnetic susceptibility, rock magnetism and electron microscopy.

Three contributions detail advances in measurements of atmospheric magnetic particulate matter. Lanci et al. explore the nature and provenance of dust in Antarctic ice cores, finding undocumented complex behavior possibly due to post-depositional alteration. Till et al. deal with a usually neglected source of magnetic particles in atmosphetic dust, which is plant ash. They investigate through rock magnetic and geochemical characterization factors affecting the soils magnetic response to fire. Shin et al. show the importance of volcanic contributions to sedimentary magnetism, pointing out the close relation between magnetic susceptibility and volcanic proportions in terrigenous sediments.

Another two contributions explore advances in the magnetism of soils and paleosols. In particular, von Dobeneck et al. illustrate that ground magnetic surveys can delineate the structural characteristics of an intrusive basaltic dike, and also reflect the subsurface deformation of its weathering products. Stine et al. analyze the effects of weathering on paleosol magnetic properties using rock-magnetic experiments, scanning electron microscopy, and Mössbauer spectroscopy. These detailed analyses were able to build on prior geochemical and magnetic analyses and suggest complicated interactions between changing provenance and precipitation levels affecting the magnetic signals.

The last two contributions bear on advances in the paleomagnetism of sediments. These papers deal with the quality of the paleomagnetic record in sedimentary rocks. Jung and Bowles investigate the potential of microbialites as a paleomagnetic recorder, proving modern microbialites and an ancient example can carry a consistent magnetization with timing of acquisition close to that of sediment deposition. Finally, Dallanave and Kirscher assess the reliability of the sedimentary record for paleogeographic reconstructions. By simulating geomagnetic directions at different latitudes, they highlight the value of utilizing anisotropy of magnetic susceptibility to assess sedimentary paleomagnetic data before use in paleogeographic reconstructions.

Although open to the larger community, the Special Issue stems from an engaging session on the topic of soil and sediment magnetism during American Geophysical Union's Fall Meeting in 2019. The diversity of the field as it stands now are shown throughout this collection along with the promise of new directions for the future.

AUTHOR CONTRIBUTIONS

All Authors have equally contributed to the Editorial.

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