



# Editorial: Multi-Disciplinary Applications in Magnetic Chronostratigraphy

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## Editorial on the Research Article

### Multi-Disciplinary Applications in Magnetic Chronostratigraphy

Using magnetic methods, it is possible to assign ages to rocks and sedimentary sequences.

Magnetostratigraphy constitutes a standard dating tool in the Earth Sciences, applicable to a wide variety of rock types formed under different environmental conditions (continental, lacustrine, marine and volcanic). Rock samples are capable of retaining a geologically stable magnetization even if it is very weak because of a relatively low concentration of magnetic minerals (e.g., magnetite or hematite). Sediments and sedimentary rocks acquire a primary natural remanent magnetization (NRM), called a detrital remanent magnetization (DRM) when the sub-micron magnetic grains in the sediments settle through the water column or during post-depositional consolidation and align with the geomagnetic field. In igneous rocks, a primary natural remanent magnetization, called a thermoremanent magnetization (TRM) is acquired when the magnetic minerals in a rock cool below a critical temperature (the Curie temperature for ferrimagnetic minerals, like magnetite and the Neel temperature for antiferromagnetic minerals like hematite). Magnetic minerals can be formed due to changes in post-depositional conditions, i.e., biogenic processes, fluid circulation or oxidation/reduction processes which impart a chemical remanent magnetization (CRM) to the rock. This type of magnetization is secondary and can often mask the primary magnetizations in a rock.

During paleomagnetic studies, geological samples are typically subjected to increasing steps of demagnetization, either temperature steps or alternating magnetic field steps, in order to isolate the primary paleomagnetic directions of the rock. In this way it is possible to determine the geomagnetic polarity intervals in a sedimentary sequence.

Those geomagnetic polarity intervals can be normal (usually depicted by a black zone in a plot) when magnetic polarity is the same as today or reversed (depicted by a white zone) when the polarity is the opposite of today. During the Cenozoic patterns of polarity intervals are grouped together and designated as chrons, based initially on their seafloor magnetic anomaly patterns, and labeled by C. For instance, C1 (Chron 1) includes the normal polarity interval of the past 781 ka (called Bruhnes), and the reversed polarity interval immediately preceding it starting at about 1.8 Ma (called Matuyama), including a short normal polarity interval at about 1 Ma (called Jaramillo). Chrons are not the same as polarity intervals. During the Mesozoic, chrons are designated by an M. Polarity intervals last usually between 1 and 10 Ma but on occasion during Earth history, intervals of one polarity are observed that are tens of millions of years long (superchrons). The time to change from normal to reversed polarity is very short (around 5 ka); consequently, the boundary between polarity intervals is very precise in time.

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The sequence of geomagnetic polarity intervals is globally calibrated by the seafloor magnetic anomalies, biostratigraphic zonation and numerical radioisotope dating of sedimentary (marine and continental) and volcanic sections from around the globe.

The resulting magnetic polarity sequence can then be correlated to the Geomagnetic Polarity Time Scale (GPTS), thus tying the sedimentary or igneous rock sequence to numerical time. Magnetostratigraphy can produce precise ages for the samples proximal to polarity interval boundaries and allow the interpolation of mean accumulation rates between boundaries.

This Research Topic volume includes a variety of paleomagnetic and rock magnetic studies (10 papers) which use magnetostratigraphy and subsequent correlation to the GPTS to address a series of important geological problems. Paleomagnetic techniques are used to detect and date the initiation of major deep sea currents, such as the initiation of the Antarctic bottom water (DSDP Site 274) during the Miocene/Oligocene transition (Jovane et al.), and the initiation of the Atlantic Ocean circulation in the Paleogene from samples collected from the São Paulo Plateau (Palcu et al.). Larrasoña et al. investigate the timing of climate variability and early hominid migration out of Africa through the Levantine Corridor from magnetostratigraphic studies of late Cenozoic Lake Kuntula deposits in the Negev Desert of Israel.

Another important magnetic dating tool uses the record of relative paleointensity variations of the geomagnetic field from marine and lacustrine sediments to assign time to the sedimentary sequence. In this case, the intensity of the sediment's magnetization is normalized by the concentration of magnetic minerals by rock magnetic measurements, such as magnetic susceptibility ( $\chi$  when normalized by mass or  $\kappa$  when normalized by volume), anhysteretic remanent magnetization (ARM) or isothermal remanent magnetization (IRM). The resulting normalized paleointensity curve can be correlated to the global paleointensity curves for the last 2 Ma ( $S_{\text{int-2000}}$ ; Valet et al., 2005). Our Research Topic includes a relative paleointensity study of 88 m of lacustrine sediments measured in u-channels from Lake Junin in Peru. After filtering out the low NRM intensity samples a high-quality relative paleointensity record was obtained that allowed correlation to the master relative paleointensity curves for the Brunhes normal polarity interval (subchron C1n) resulting in a high-resolution age model (Hatfield et al.).

Astronomically-forced climate cycles, i.e., Milankovitch cycles, are encoded by the concentration of magnetic minerals of sediments (Kodama and Hinnov, 2015). Measurements of

magnetic susceptibility, ARM and IRM, allow the detection of Milankovitch cycles and hence a high-resolution time calibration of sedimentary sequences from the Precambrian to the present.

Included in our Research Topic are rock magnetic cyclostratigraphy studies of Permian loess in south-central France from equatorial Pangean deposits (Pfeifer et al.) using a portable susceptibility meter, Carboniferous fluvial deposits of red beds from Pennsylvania (Kodama) comparing portable and laboratory susceptibility measurements and Early Cretaceous lacustrine deposits rich in dinosaur/primitive bird fossils of the Jehol Biota (Liu et al.). The magnetic susceptibility cyclostratigraphy in each study was able to identify astronomically-forced global climate change cycles and assign high resolution time to the sequences being studied.

Magnetic chronostratigraphic methods include multidisciplinary approaches to understand the post-depositional changes that occurred to the sediments during climatic changes and sea-level fluctuations. One study in our Research Topic investigates the reliability of magnetic susceptibility for inter-regional correlations in the Ardennes carbonate platform (France) during the Paleozoic (Pas et al.) and another study reports on the link between post-depositional diagenetic changes in magnetic minerals and the manganese cycle in the Arctic Ocean (Wiers et al.).

Finally, the paleomagnetic directions of geochronologically-dated igneous samples from an eastern Australian hotspot track, extending over 34 Ma, delineate the drift of these hotspots with respect to the Earth's spin axis. These results allow an estimate of true polar wander for the last 34 Ma (Hansma and Tohver).

In conclusion, as it is shown by the papers of this Research Topic, magnetic methods, i.e., magnetostratigraphy, rock magnetic cyclostratigraphy, and relative paleointensity records, are currently used to provide high resolution chronostratigraphy for sedimentary sequences and hence the time framework for understanding and correlating ancient paleoclimatic and paleoenvironmental changes both regionally and globally. In the future, these techniques represent robust tools that can be applied to a wide range of stratigraphic sections in order to improve age constraints of past geologic events for better understanding the processes that caused them.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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