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MAGNETIC NANOPARTICLES IN THE ENVIRONMENT: ORIGIN, IDENTIFICATION; AND APPLICATIONS

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Iron is the fourth most abundant element in the Earth crust, where it occurs as constituent of various minerals such as silicates, oxides, and sulphides. A small fraction of such minerals has ferrimagnetic properties and is responsible for the recording of the Earth magnetic field in past epochs. Such so-called paleomagnetic records play a fundamental role in the reconstruction of the dynamic history of our planet.

Of particular interest for Earth scientists are nano-sized ferrimagneitc iron minerals produced by environmental processes on land and in the oceans. These nanoparticles can provide very stable paleomagnetic records. Furthermore, they represent the signature of specific biogeochemical processes that are modulated by the geologic and climatic history of our planet. Notable examples are (1) the formation of maghemite (γ-Fe_2O_3) nanoparticles in soils, whose concentration in continental dust deposits reflects the alternation of cold-dry and warm-humid climates, and (2) the production of magnetite (Fe_3O_4) in freshwater and marine sediments, inorganically and by so-called magnetotactic bacteria, which is modulated by variations of the sedimentary environment, e.g. in terms of organic matter and oxygen availability.

The study of natural magnetic nanoparticles is extremely challenging because of low concentrations (1 ppm to ~1%) and co-existence of different groups of particles in terms of composition, domain states (i.e. single-domain vs. pseudo-single domain and multidomain), shape, and dispersion in a non-magnetic matrix. Recent techniques based on high-resolution first-order reversal curves (FORC) provided important improvements in the characterization of highly disordered dispersions of magnetic particles as they occur in nature. Such techniques are important for discriminating different magnetic mineral sources and the processes responsible for their formation, transport, and accumulation.

Special focus is given to some topic examples demonstrating the interdisciplinary approach needed to understand natural magnetic nanoparticles - from Earth processes to magnetic property models.