Environmental change during the PETM drives formation of gigantic biogenic magnetite

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About 55 Ma at the Paleocene /Eocene boundary, the planet experienced a 5-9°C jump in global temperatures within less than 10,000 years known as the Paleocene-Eocene Thermal Maximum (PETM). Debate is still ongoing on what triggered the event that lasted ~180,000 years. However, several lines of evidence suggest that large releases of greenhouse gases, in particular methane from gas hydrates, contributed to the rapidity and extent of the warming event. The event reflects a drastic perturbation of the Earth's ocean and atmospheric systems and was associated with a significant diversification of the terrestrial fauna and flora but also of marine life. Numerous deep-sea benthic foraminifera species disappeared and new forms evolved.

The sediments deposited during the PETM serve as archives that contain distinct paleontological, mineralogical, magnetic, chemical and isotopic evidence of these climatic changes. Kopp et al., (2007) and Lippert & Zachos (2007) report an extraordinary magnetofossil 'Lagerstätte' in kaolinite-rich clay sediments deposited during the PETM at subtropical paleolatitude in the Atlantic Coastal Plain of New Jersey. They used ferromagnetic resonance (FMR) spectroscopy, other rock magnetic methods, and transmission electron microscopy (TEM) of magnetic separates to characterize sediments from boreholes at Ancora (ODP Leg 174AX) and Wilson Lake, NJ, respectively. These sediments contain abundant ~40- to 300-nm cuboidal, elongate-prismatic and bullet-shaped magnetofossils, sometimes arranged in short chains, resembling crystals in living magnetotactic bacteria. Aside from abundant bacterial magnetofossils, these same sediments also contain exceptionally large and novel biogenic magnetite crystals unlike any previously reported from living organisms or from sediments (Schumann et al., 2008).

The spearhead-like, spindle-like and elongated hexaoctahedra magnetite crystals exhibit chemical composition, lattice perfection and oxygen isotopic composition consistent with a biogenic origin. The spearheads and spindles can be up to 4000 nm long (8 times larger than magnetite produced by magnetotactic bacteria). The elongated hexaoctahedra may be up to 1400 nm long and are thus "giant" magnetofossils. They are probably too big to be produced intracellular by prokaryotes, although exceptionally large prokaryotes having cellular diameters up to 750 μm have been reported. In a few cases, we observed apparently intact, tip-outward spherical assemblages of spearhead-like particles that possibly represent the preserved original biological arrangement of these crystals in a hitherto unknown magnetite producing organism.

The discovery of these exceptionally large biogenic magnetite crystals that possibly represent the remains of new micro-organisms that appeared and disappeared with the PETM sheds some light upon the ecological response to biogeochemical changes that occurred during the warming event. Magnetotactic bacteria usually live in the oxic-anoxic transition zone of fresh, brackish, and marine environments including the suboxic zone of

sediments. The occurrence of these new forms together with conventional magnetofossils suggests that they shared a similar ecological niche. The development of a thick suboxic zone with high iron bioavailability – a product of dramatic changes in weathering and sedimentation patterns driven by severe global warming – may have resulted in diversification of magnetite-forming organisms, likely including eukaryotes.
In this study we extended the search for these new magnetofossils to other PETM locations of the Atlantic margin and to a possible modern analog environment in the Amazon delta system.

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