Appearance of gigantic biogenic magnetite during the PETM: A progress report

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During the Paleocene-Eocene Thermal Maximum (PETM) ~55 Ma, global temperatures jumped 5–9°C within less than 10,000 years (Sluijs et al., 2007; Zachos et al., 2008). Despite the ongoing debate on what triggered the event that lasted ~180 ky, large releases of greenhouse gases, in particular methane from gas hydrates, probably contributed to the rapidity and extent of the warming event. The event 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.

Kaolinite-rich clay sediments deposited during the PETM at subtropical paleolatitude in the Atlantic Coastal Plain at Wilson Lake and the Ancora borehole (ODP Leg 174AX), N.J., contain abundant ~40- to 300-nm cuboidal, elongate-prismatic and bullet-shaped magnetofossils resembling crystals in living magnetotactic bacteria . Kopp et al., (2007) and Lippert & Zachos (2007) used ferromagnetic resonance (FMR) spectroscopy, other rock magnetic methods, and transmission electron microscopy (TEM) of magnetic separates to characterize the sediments. Aside from abundant bacterial magnetofossils, these same sediments also contain exceptionally large 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, up to ten times larger than magnetite produced by magnetotactic bacteria. The giant biogenic magnetite crystals appeared and disappeared during the PETM. Magnetotactic bacteria usually live in the suboxic zone of sediments in fresh, brackish, and marine environments. The development of a meter-scale 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. Using FMR and TEM, we mapped the magnetofossil distribution and identified three magnetic facies in the clay: one characterized by a mix of detrital particles and magnetofossils, a second with a higher magnetofossil-to-detrital ratio, and a third with only transient magnetofossils. The distribution of these facies suggests that suboxic conditions promoting magnetofossil production and preservation occurred throughout inner middle neritic sediments of the Salisbury Embayment of the N.J. paleocoast (Kopp et al., 2009). Such a distribution is consistent with the development of a system resembling a modern tropical river-dominated shelf like the Amazon shelf.