Remanent Magnetization Experiments

Remanent magnetization experiments were conducted using a 2G Enterprises SQUID magnetometer equipped with in-line alternating field (AF), anhysteretic remanent mangetization (ARM), and isothermal remanent magnetization (IRM) coils, as described in Kopp et al. [2006]. Parameters determined from these experiments are shown in Table S1 and Figure S1. Coercivity spectra determined from IRM acquisition experiments are shown in Figure S2, and ARM acquisition curves are shown in Figure S3.

Consistent with prior results from hysteresis experiments (Table S1), the IRM strength of samples from the PETM clay are 10-60 times higher than those of samples from underlying and overlying sediments (Figure S1). The coercivity of remanence of the PETM clay, which ranges from 53 to 69 mT, is lower than that of underlying and overlying samples (72-78 mT). Examination of the coercivity spectra (Figure S2) indicates that the increase in bulk coercivity is due to the influence of a high coercivity component, such as goethite or hematite. PETM clay also exhibits high values of anhysteretic susceptibility, consistent with those of magnetotactic bacteria (Figure S3).

First Order Reversal Curve Analysis

First Order Reversal Curves (FORCs) were measured using a Princeton Measurements Alternating Gradient Magnetometer (MicroMag 2900) at Rutgers University. Measurement of a FORC begins by saturating the sample in a large positive magnetic field. Then the field is decreased to a reversal field H_a, and the FORC is defined by the set of induced magnetization measurements as the field is increased from H_a back to saturation. The FORC distribution is defined as a mixed derivative: $\rho(H_a, H_b) \equiv -\partial^2 M(H_a, H_b)/\partial H_a \partial H_b$. where $M(H_a, H_b)$ is the magnetization at an applied field H_b, on the FORC with reversal point H_a ($H_b \geq H_a$) [Pike, et al., 1999]. Quantitatively, the distribution $\rho(H_a, H_b)$ at a point P is calculated by fitting a polynomial surface $a_1 + a_2 H_a + a_3 H_a^2 + a_4 H_b + a_5 H_b^2 + a_6 H_a H_b$ on a local square grid centred at the point P. The value $-a_6$ represents $\rho(H_a, H_b)$ at P. A FORC diagram is a contour plot of $\rho(H_a, H_b)$ with $H_u = (H_b + H_a)/2$ and $H_c' = (H_b - H_a)/2$ on the vertical and horizontal axes, respectively. The smoothing factor (SF) defines the number of points $(2SF + 1)^2$ on the local grid.

The FORC distribution measured for an Ancora sample at 169.53 m (Figure S4) is elongate and roughly symmetric with respect to the H_c' axis. The distribution contours encircling a single maximum at $H_{c,max} \approx$ 22 mT are well separated from the diagram origin, suggesting stable single-domain particles (magnetofossils) with a unimodal grain-size distribution. The observed $H_{c,max}'$ value is smaller than corresponding values observed for natural and cultured magnetosomes elsewhere [Chen, et al., in press; Pan, et al., 2005], consistent with a large mean size of magnetosomes in the Ancora PETM clay. The characteristic interaction field $H_{u1/2}$ = 4.7 mT (Figure S4, right) suggests weak between-chain or between-particle interaction [Pan, et al., 2005]. However, some widening of the outer contours for $H_c' < 20$ mT hints at a stronger interaction, possibly due to minor magnetosome clumping in situ. The FORC data were processed using the “Forcobello” software, courtesy of Michael Winklhofer (Munich University) [Winklhofer and Zimanyi, 2006].