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1. Data Report: Mineral Magnetic Properties of Sediments from Site 1144, Northern South China Sea[1]

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INTRODUCTION

Site 1144 is located in the northern reaches of the South China Sea at 20°3.18′N, 117°25.14′E. It is on a sediment drift in 2037 m of water, with sediment sources originating from the Pearl, Mekong, and Red Rivers (Shipboard Scientific Party, 2000). It was cored along with four other sites in the northern South China Sea to study the evolution of the East Asian monsoon. The site was chosen as a high-sedimentation-rate site to study the paleomonsoon history over the mid- to late Pleistocene.

Three holes were cored at Site 1144, using both the advanced piston corer (APC) and extended core barrel (XCB): Hole 1144A to a depth of 453 meters below seafloor (mbsf), Hole 1144B to a depth of 452 mbsf, and Hole 1144C to a depth of 204 mbsf. A splice was constructed from the three holes that provided a continuous composite depth record from 0 to 235.41 meters composite depth (mcd). Beyond 235.41 mcd, there is a discontinuous floating splice from 235 to 519 mcd. The recovered sediments are hemipelagic, consisting of terrigenous material, biogenic carbonate, and opal. Accumulation rates are extremely high in the upper 250 mcd, averaging 870 m/m.y., and decrease to 370 m/m.y. in the lower 250–519 mcd (Shipboard Scientific Party, 2000).

Routine paleomagnetic cube samples (2 cm on a side) were collected at a rate of one to two samples per 1.5-m section. The samples were used on board for paleomagnetic analysis. These samples were then analyzed on shore for various mineral magnetic parameters to determine

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changes in the concentration, composition, and grain size of the magnetic fraction of the sediments.

METHODS

Low-field magnetic susceptibility was measured using a Kappabridge KLY-2 susceptibility bridge operating at an alternating-current (AC) field of 300 A/m at a frequency of 920 Hz. Magnetic susceptibility is a measure of the concentration of paramagnetic (e.g., clays and pyrite), diamagnetic (e.g., quartz and carbonate), and ferromagnetic (which includes ferrimagnetic minerals such as magnetite and maghemite and antiferrimagnetic minerals such as hematite) minerals in the sediment. Ferri- and paramagnetic minerals can contribute strongly to low-field susceptibility. Antiferrimagnetic minerals contribute weakly; diamagnetic minerals contribute weakly negative values and are, in most cases, negligible. A more thorough description of these and the following methods can be found in Thompson and Oldfield (1986) and Dunlop and Özdemir (1997).

Anhysteretic remanent magnetization (ARM) is a measure of the concentration of small single-domain to pseudo–single domain magnetic grains that have a size range between 0.05 and 1 µm. ARM was applied using a Dtech D-2000 alternating-field (AF) demagnetizer fitted with a DC magnetizing coil. The samples were magnetized with a 50-µT DC field superimposed on an AF field decaying from 100 to 0 mT. ARM was then measured on a 2-G three-axis cryogenic magnetometer. Predominantly strong ferrimagnetic grains such as magnetite and maghemite, with grain sizes between 0.05 and 1 µm, contribute to ARM.

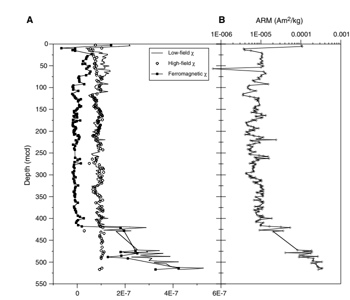
Hysteresis loops were measured for every other sample on a Princeton Instruments vibrating sample magnetometer. The sample is vibrated in a magnetic field that is swept from 0 to +1 to –1 T then back to 0 T; the magnetization of the sample is picked up by a set of coils that are wound to cancel the sweeping DC field. Parameters extracted from the loop are used to determine the concentration and domain state, which is directly related to grain size of ferrimagnetic minerals. High-field magnetic susceptibility is also calculated from the hysteresis loop and is contributed by para- and diamagnetic minerals.

RESULTS

Magnetic Susceptibility

Low-field magnetic susceptibility has a maximum value near the bottom of the core of 5×10^{-7} m^3/kg (Fig. F1). It shows a sharp decrease from the bottom of the core up to 440 mcd. From 440 mcd, it remains relatively constant at 1×10^{-7} m^3/kg to 125 mcd, where it increases slightly. Between 10 and 20 mcd, there is a sharp low, with values of ~0.5×10^{-7} m^3/kg, then an increase to >2×10^{-7} m^3/kg to the core top. High-field magnetic susceptibility remains fairly constant at 1×10^{-7} m^3/kg for the entire interval, with only a slight increase between 120 and 75 mcd and a low from 20 to 10 mcd (Fig. F1). By subtracting the high-field susceptibility from low-field susceptibility ($\chi_{lf} - \chi_{hf}$), ferromagnetic susceptibility can be determined. Ferromagnetic susceptibility ranges from 2×10^{-7} m^3/kg to 4×10^{-7} m^3/kg from the bottom of the core to 440 mcd (Fig. F1). Between 440 and 100 mcd, ferromagnetic sus-

F1. Low-field and paramagnetic susceptibility, p. 6.



ceptibility averages 0, indicating the low-field magnetic susceptibility is mainly contributed by paramagnetic minerals. The slight offset to negative values of ferromagnetic susceptibility is due to calibration problems for sample-shape effects in the high-field susceptibility measurements, whereas the low-field measurements are not affected by sample geometry (Jackson et al., 2001). Because the sample sizes varied a bit as a result of dehydration, it was not possible to apply a correction. Above 100 mcd, ferromagnetic susceptibility increases to ~0.5×10^{-7} m^3/kg, indicating an increase in ferromagnetic content. However, there is again a sharp drop in ferromagnetic content between 20 and 10 mcd.

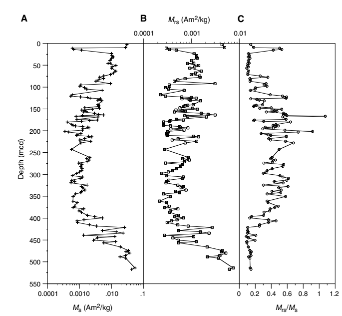
Anhysteretic Remanent Magnetization

ARM values reach a maximum of 1.2×10^{-4} Am^2/kg in the deepest sediments and decrease to an average value of ~1.8×10^{-6} Am^2/kg at 440 mcd (Fig. F1). From 440 to 120 mcd, they remain fairly constant and then increase slightly to 1×10^{-5} Am^2/kg between 120 and 20 mcd. Between 20 and 10 mcd, there is a sharp low that correlates to the drop in magnetic susceptibility with ARM values of 1.25×10^{-6} Am^2/kg. From 10 to near the core top, ARM increases to 1×10^{-4} Am^2/kg, which is similar to the core bottom.

Hysteresis Parameters

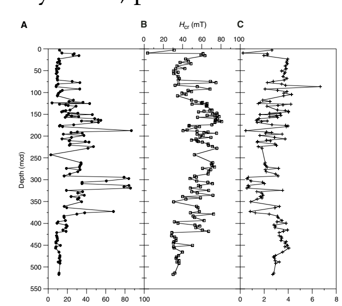
Saturation magnetization (M_s) (Fig. F2) is a function of the concentration and composition of ferromagnetic material in the sediment. Changes in M_s can indicate either a change in the concentration of a single type of mineral or variations in mineralogy because various minerals have different saturation values. M_s is at a maximum of 0.05 Am^2/kg near the core bottom and decreases down to ~1×10^{-3} Am^2/kg between 440 and ~200 mcd. Between 200 and 40 mcd, there is a gradual increase to values of 0.01 Am^2/kg. Between 20 and 10 mcd, M_s spikes sharply to low values of ~6×10^{-4} Am^2/kg. Saturation remanence (M_{rs}), which can also be affected by grain size, generally shows the same trend as M_s (Fig. F2).

F2. Saturation magnetization, saturation remnant magnetization, and calculation of remanence ratio, p. 7.



Coercivity (H_c) and coercivity remanence (H_{cr}) (Fig. F3) are affected by the grain size and mineralogy of the ferromagnetic minerals in the sample. The two parameters have, generally, the same trends with lower values (H_c = ~10 mT and H_{cr} = ~30 mT) from the core bottom to 440 mcd and generally higher values (H_c = ~30 mT and H_{cr} = ~55 mT), with more variability between 440 and ~100 mcd. From 100 mcd to the core top, there is a background value of ~10 mT for H_c and ~65 mT for H_{cr}. Three intervals at 90, 75, and 20–10 mcd have H_c spiking to ~32 mT and H_{cr} to ~70 mcd.

F3. Coercivity, coercivity remanence, and calculation of coercivity ratios, p. 8.



Ratios of hysteresis parameters can be used as an estimation of grain size if the mineralogy of the ferromagnetic fraction remains constant. Generally, H_{cr}/H_c ratios >4 indicate large multidomain grains (>10 µm), ratios between 2 and 4 indicate pseudo–single domain grains (~1 to 10 µm), and ratios <2 indicate single-domain grains (0.05 to ~1 µm) (Day et al., 1977; Dunlop, 1986). From the bottom of the core to 375 mcd, H_{cr}/H_c averages 3.5; at 375 mcd, values drop to ~2 and show more variability (Fig. F3). From 200 mcd, there is a slight increase in values, indicating that grain size is increasing. Between 75 and 20 mcd, H_{cr}/H_c is stable, with an average value of 3.8. Above 20 mcd, the ratio drops to between 2 and 3, indicating finer grains near the surface.

The M_{rs}/M_s ratio also indicates grain size, with lower values indicating larger grains (Fig. F2). M_{rs}/M_s ratios show a pattern similar to H_{cr}/H_c, with coarser grains in the bottom of the core to 420 mcd; between 420 and 75 mcd, grains sizes are smaller with more variability. From 75 to 20 mcd, the ratio again becomes stable and averages 0.1, similar to the bottom. Between 20 and 10 mcd, values increase then drop again near the core top.

The hysteresis parameters indicate that near the bottom and top of the cores the concentration of magnetic material is higher and coarser than in the middle, where the concentration is lower and finer grained. However, it is also possible that the mineralogy of the magnetic material is changing, which could also affect the hysteresis parameters.

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Figure F1. **A.** Measurements of low-field and paramagnetic susceptibility. Closed boxes = ferromagnetic susceptibility ($\chi_{lf} - \chi_{hf}$). **B.** Measurements of anhysteretic remanent magnetization (ARM).

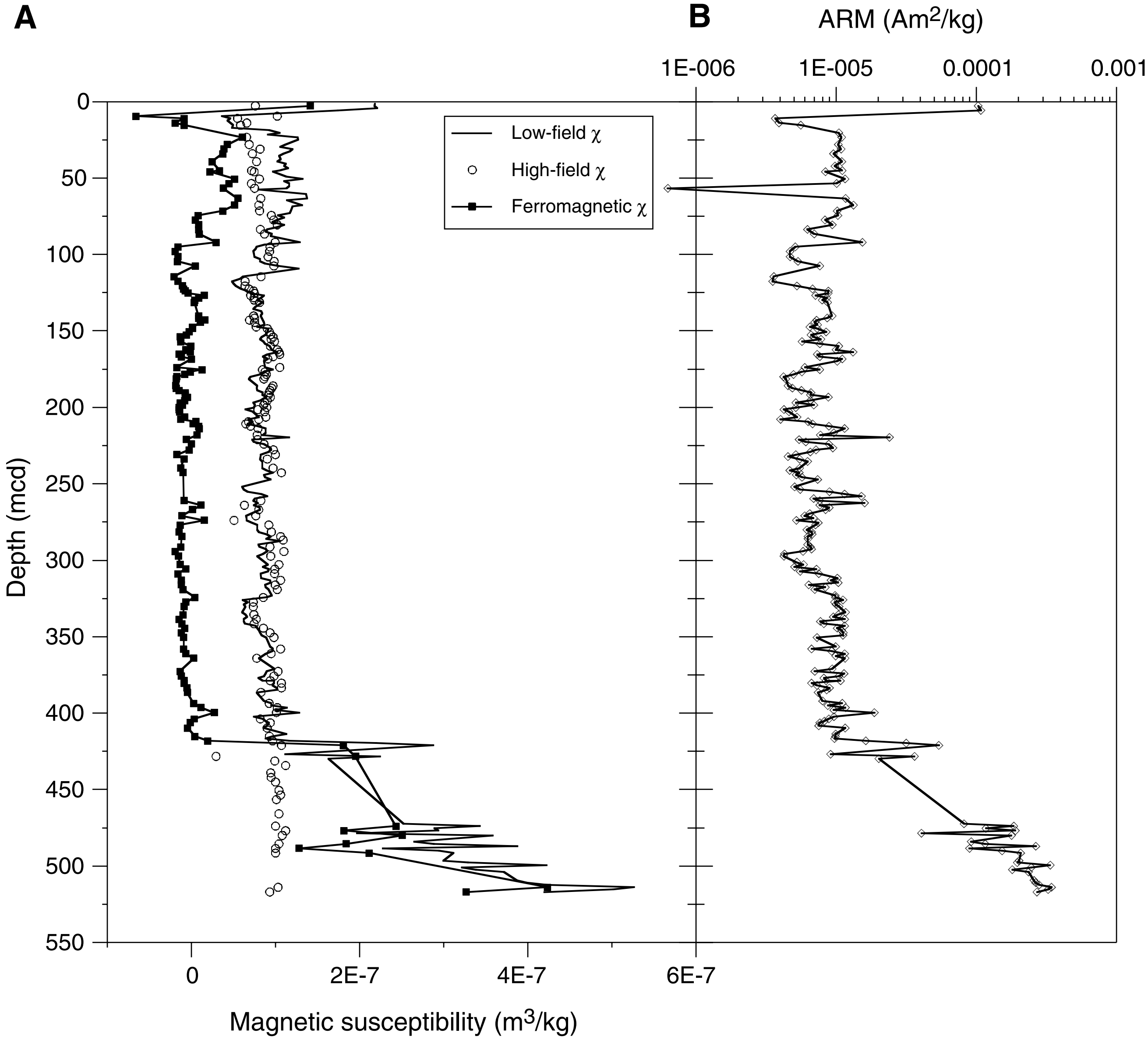

Figure F2. Measurements of (**A**) saturation magnetization (M_s), (**B**) saturation remnant magnetization (M_{rs}) from hysteresis loops, and (**C**) calculation of remanence ratio (M_{rs}/M_s). Higher values indicate finer grain size.

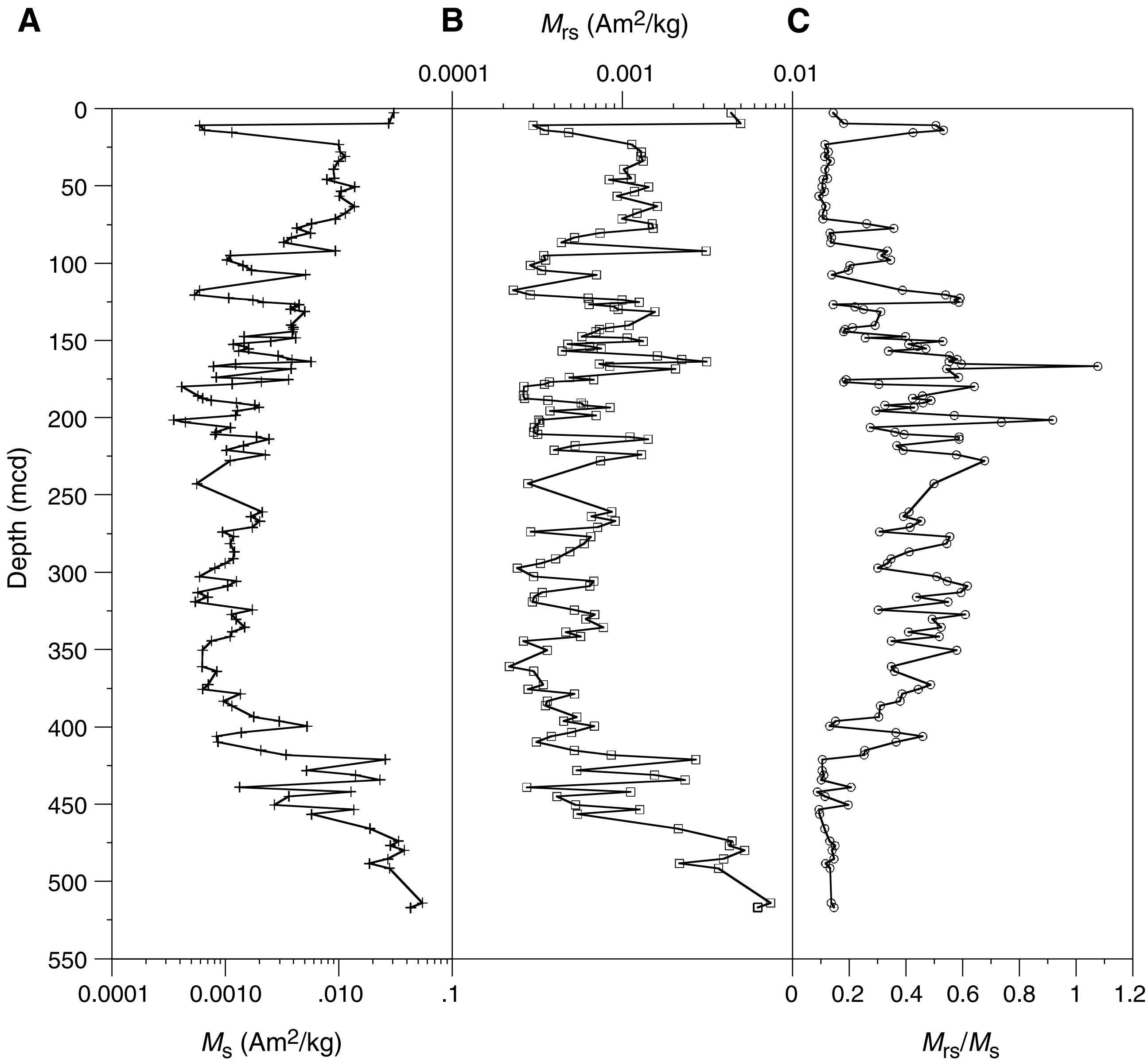

Figure F3. Measurements of (**A**) coercivity (H_c) and (**B**) coercivity remanence (H_{cr}) from hysteresis loops and (**C**) calculation of coercivity ratios (H_{cr}/H_c). Higher values indicate larger grain size.