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20. *DATA REPORT:* MAGNETIC POLARITY AND SUSCEPTIBILITY MEASUREMENTS FROM THE GEOLOGICAL HIGH-RESOLUTION MAGNETOMETER TOOL AT SITES 984, 986, AND 987[1]

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ABSTRACT

Magnetic field and susceptibility data were collected using the geological high-resolution magnetometer tool string (GHMT) at three sites during Ocean Drilling Program Leg 162. Postcruise processing of the magnetic field data yielded a polarity stratigraphy for Holes 986C and 987E. A magnetic susceptibility record was measured at Hole 984B. Detailed analysis of the core and log susceptibility records at Hole 984B yielded an empirical tool resolution of the susceptibility measurement tool (SUMT) of 53 cm. At Site 984, where sedimentation rates were typically >10 cm/k.y., this gave a resolution of at least ~5000 yr. This data report summarizes the GHMT postcruise processing, method of interpretation, and analysis of the SUMT resolution.

INTRODUCTION

The geological high-resolution magnetometer tool string (GHMT) was first used on sediments and Paris Basin rock cores in the early 1990s (Pozzi et al., 1988, 1993; Bouisset and Augustin, 1993; Pagès et al., 1993). Its use in deep-sea sediments began only in 1993 during Ocean Drilling Program (ODP) Leg 145 (Dubuisson et al., 1995; Thibal et al., 1995). The GHMT has been used during six ODP legs, but these still remain the only published examples of the potential of the GHMT.

On Leg 162, we deployed the GHMT at Sites 984, 986, and 987. The site locations are provided in Table 1. This geophysical wireline logging tool string (see Shipboard Scientific Party 1996, p. 40, for a diagram) consists of three tools, the nuclear magnetic resonance tool (NMRT), a susceptibility measurement tool (SUMT), and a natural gamma tool (NGT). The NGT is run on top of every tool string for the purpose of data and depth integration between all the wireline logs.

GHMT MEASUREMENTS

A full discussion of postcruise processing of the GHMT is provided by Pozzi et al. (1988; 1993) and Etchecopar et al. (1994). A brief summary is given here to make the data more accessible to those not familiar with the terminology. The NMRT takes magnetic field measurements in sediments.

The basic principle of the tool is $T = B + I + R$, where

T = total magnetic field (measured by NMRT);
B = Earth's present magnetic field at a given location (known);
R = remanent magnetic field;
I = induced magnetic field = (ct) (calculated);

Table 1. Site locations and GHMT-logged interval depths.

Hole	Location	GHMT-logged interval	Latitude	Longitude
984B	Bjorn Drift	80 to 501 mbsf	61°25.52′N	24°04.95′W
986C	Svalbard margin	88 to 370 mbsf	77°20.43′N	9°04.66′W
987E	East Greenland margin	77 to 483 mbsf	70°29.79′N	17°56.19′W

Note: mbsf = meters below seafloor.

where

c = magnetic susceptibility measured by SUMT; and
t = transfer coefficient that is a function of borehole location, diameter, and vector trajectory to B.

Knowing T, B, and I, it is possible to determine R, the remanent magnetization of the sediments, which provides the polarity information. However, R cannot be calculated directly because of the vastly different sediment volumes that the NMRT (essentially an infinite volume) and SUMT (~1–2 m^3) measure. Because the relative magnitudes of R and c are constant in a given lithology (Koenigsberger coefficient; Pozzi et al., 1988), estimates of the relative polarity are made by crossplotting the susceptibility data (typically changing with depth) with remanence R. A change in slope from positive to negative indicates a change from normal to reverse polarity and vice versa.

The crossplotting is done using a sliding window technique in which as many as 11 windows varying from 1.5 to 24 m in length are used to make sure all reversals have been identified because the length and duration of a reversal are not known beforehand. The mean square fit, standard deviation, and a correlation coefficient are calculated in each window to filter the data. The limits of these statistics can be changed to ensure data quality. The results of the windows are then combined to provide one interpreted polarity stratigraphy relative to the global polarity time scale.

RESULTS

Polarity stratigraphies were obtained for Hole 986C (Fig. 1) and Hole 987E (Fig. 2). Borehole conditions were poor in Hole 986D below 400 meters below seafloor (mbsf); thus, extending the GHMT coverage was not possible. At Hole 987E, only the upper 500 m could

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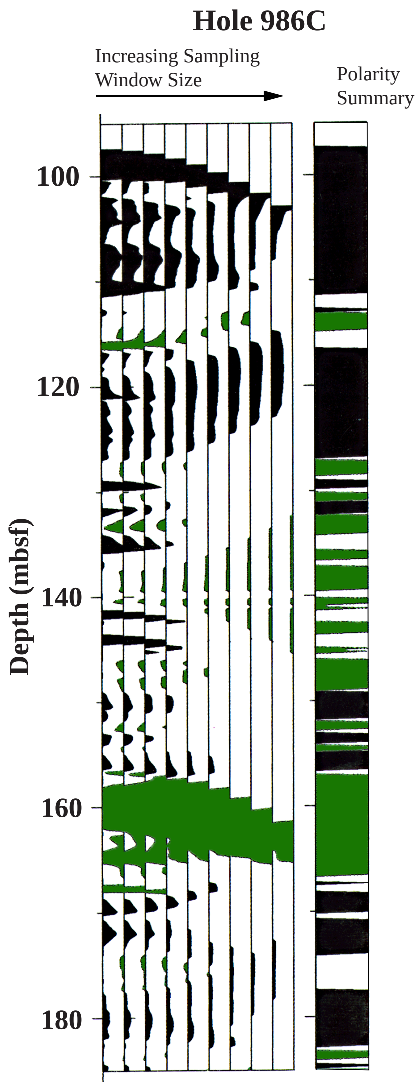

Figure 1. Polarity stratigraphy for Hole 986C from 90 to 200 mbsf. Normal polarity intervals are shown in black, reverse polarity is gray, and undetermined sections are white. Nine sampling windows ranging from 1.5- to 16-m lengths were used to create polarity synthesis for this hole.

be logged because of hole collapse. No interpreted polarity ages are presented with this data. The interpretations are included in Channell et al. (Chap. 10, this volume) as part of the paleomagnetic summaries and age models for Sites 986 and 987. The GHMT data for Hole 986C also provided important age control for a detailed study of Svalbard margin glacial history (Forsberg et al., Chap. 17, this volume).

At Hole 984B, only a magnetic susceptibility record was measured because the magnetic field readings from the basalt-rich sediments were so strong that they overwhelmed the NMRT sensor at that site. A detailed statistical analysis of the magnetic susceptibility was conducted to determine the empirical resolution of the SUMT (Kreitz, 1996). Understanding the resolution of these wireline geophysical tools relative to similar core measurements is critical to establish the correct correlation. The theoretical limits of the tool do not often apply to varying sediment types or enlarged borehole conditions. Also, the limited past usage of the tool provides little information on the typical "field" resolutions that can be expected.

The first step in core-log integration of the susceptibility data was to create a continuous core data set comparable to log data. A spliced section of core data for the upper 260 m was made by stacking all the susceptibility data from the multisensor track (MST) from all four holes (A–D) into the original shipboard meters composite depth (mcd) scale to create a revised mcd (rmcd) that included all the susceptibility data. The difference between the mcd and rmcd is that the former is a spliced record containing the "best representative" sections chosen from any of the drilled holes, whereas the latter contains all the magnetic susceptibility data from each hole that are computationally added to create one curve. This new stacked rmcd record represents the most complete estimate of magnetic susceptibility for 0–260 mbsf for Site 984 (Table 2, on CD-ROM, back pocket, this volume). The overall depth scale of the rmcd and mcd is the same, although the relative depth of features (e.g., an obvious peak or trough) may have been shifted.

This stacked rmcd record was correlated with the log data beginning at ~90 mbsf (logging above this depth was not possible), and a mapping function was created to link the two data sets to a common depth scale (Fig. 3). The correlation function yielded a significant r^2 value of 0.81. Cross-spectral analysis of these two time series provided coherency and gain spectra (Fig. 4A–D) that give tool resolution and signal attenuation information. The interval from 123 to 173 mbsf chosen for the analyses yielded a coherency close to the maximum theoretical resolution of ~50 cm (Fig. 4A, B). The maximum resolution observed in this interval was 53 cm. This represents a minimum of ~5 k.y. resolution at Site 984 where sedimentation rates average >10 cm/k.y. This is ample resolution to resolve orbital precession cycles (3–5 samples/cycle) and obliquity cycles (7–9 samples/cycle) without aliasing our results. Higher frequency climate signals <5 k.y. cannot be resolved with these data. The average resolution of the SUMT logs for all of Hole 984B was ~75 cm. In Figure 4C, the gain spectra for the interval (123–173 mbsf) showed that the logging data are actually amplified over the core data, which may reflect either good borehole conditions, poor core conditions or measurements, or some combination of these factors. However, because of the MST's higher sampling resolution of 5–7 cm (500- to 700-yr resolution), the gain spectra over the whole section from 90 to 260 mbsf shows that the core measurements are amplified relative to log measurements (Fig. 4D).

Analysis of core and logs below 260 mbsf where most of the cores were recovered using the extended core barrel (XCB) was complicated by sparser core recovery. The correlation factor drops to r^2 = 0.65 from 0.81 but is still significant. The cyclicity in both core and log susceptibility measurements appears more pronounced in this lower section. However, there are cycles in the logs that do not appear in the core data. An example is shown in Figure 5 in the interval from 320 to 440 mbsf (note cycle at ~395 mbsf). This figure illustrates that poor core measurements, poor core condition, or, in the worst case, missing sediment may severely affect the susceptibility measurements. Despite their lower resolution, the log data successfully identify these cyclical changes, as well as potential core problems, and provide important constraints that improve both depth scales and estimates of sedimentation rate.

SUMMARY

1. GHMT data provide important polarity stratigraphy information at Sites 986 (Forsberg et al., Chap. 17, this volume) and 987 (Channell et al., Chap. 10, this volume) and facilitate age interpretation of magnetic reversal events and lithologic boundaries.

2. Detailed analysis of Hole 984B magnetic susceptibility record measured by the SUMT yields an empirical maximum resolution of ~53 cm. This corresponds to temporal resolution of ~5 k.y. for Hole 984B.

3. Statistical comparisons of core and log magnetic susceptibility observations for Hole 984B give a r^2 = 0.81 in the upper 260 mbsf. Poor core recovery decreases the correlation to r^2 = 0.65 in the section between 260 and 500 mbsf.

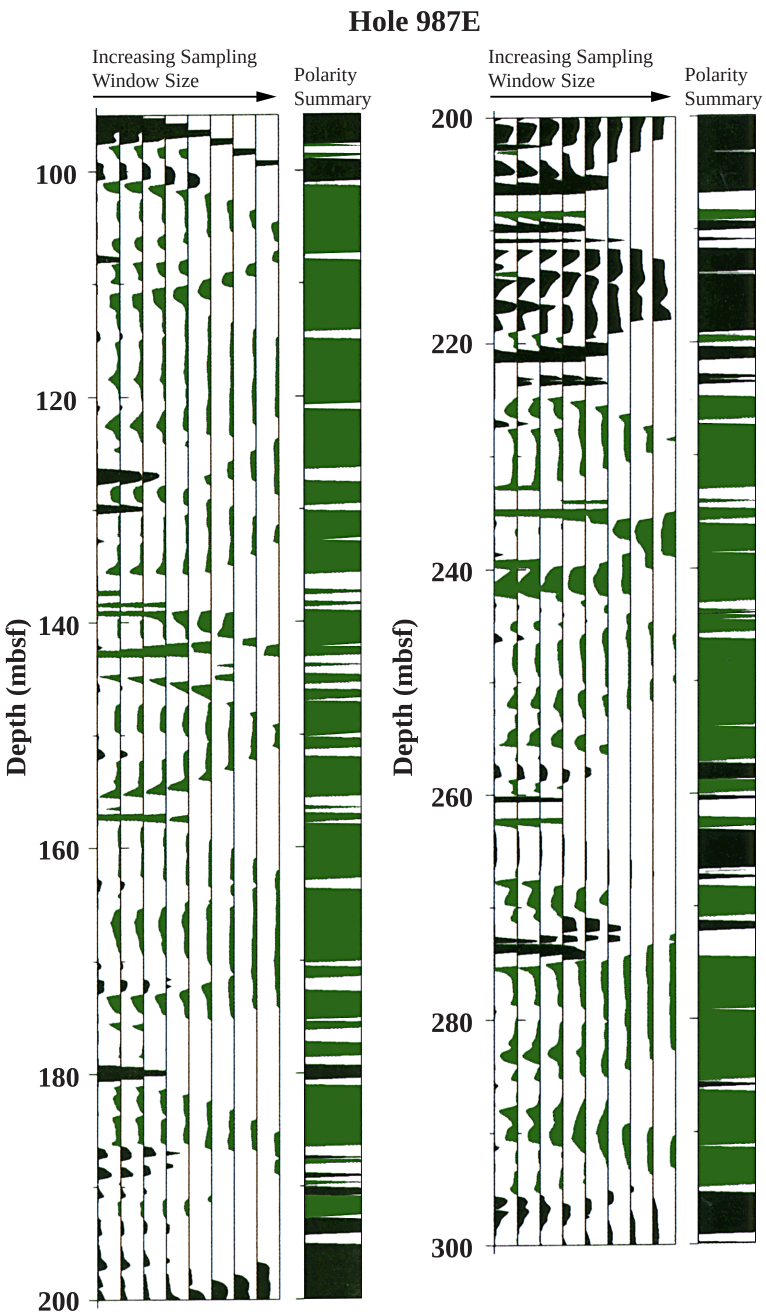

Figure 2. Polarity stratigraphy for Hole 987E from 90 to 300 mbsf. Data collected below this interval were severely disturbed by debris flows and are not shown. Normal polarity intervals are shown in black, reverse polarity is gray, and undetermined sections are white. Eight sampling windows ranging from 1.5- to 12.8-m lengths were used to create polarity synthesis for this hole.

4. Preliminary core-log integration using magnetic susceptibility for Hole 984B demonstrates obvious susceptibility cycles that are missing in the core data from the XCB portion of the hole (>290 mbsf) despite the higher sampling resolution of the MST measurements.

5. A revised mcd core magnetic susceptibility record has been produced for Site 984 over the upper 260 mbsf, which includes all susceptibility measurements from the four holes.

6. Integrating GHMT and core data may help provide both better age and data coverage (which has implications for improved stratigraphy), sedimentation rate estimates, and depth-scale correlation.

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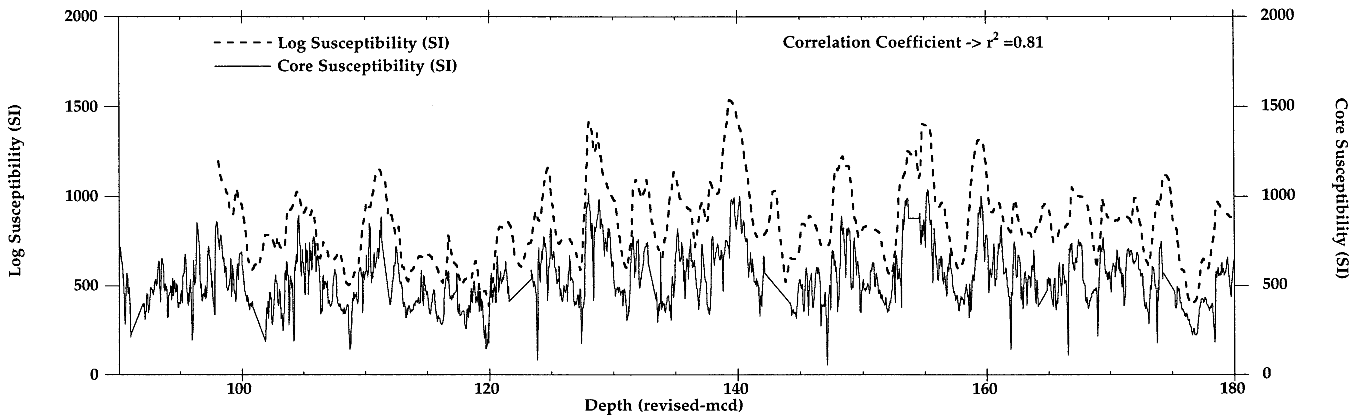

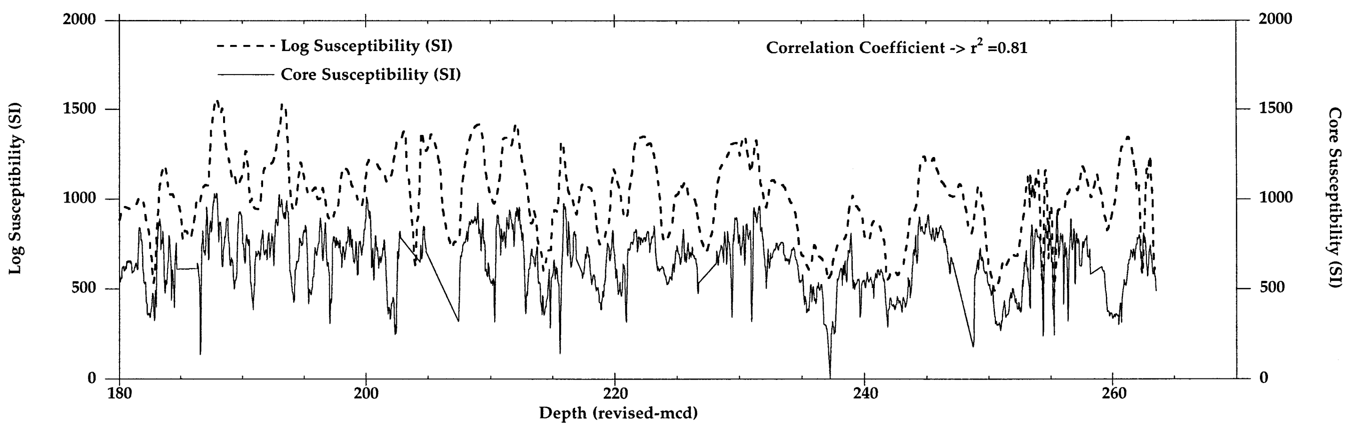

Figure 3. Correlation of revised core magnetic susceptibility stack for Site 984 and comparison with SUMT log data over the interval from 90 to 260 mbsf. Note that the SUMT values have been divided by a factor of four for purposes of the diagram. The revised mcd (rmcd) scale is constructed by computationally stacking (using Fourier transforms) all magnetic susceptibility data from all four holes at Site 984. The resulting curve is mapped into the shipboard mcd depth scale, although individual features of the susceptibility curve may have been shifted from the original depths assigned by the mcd scale. The rmcd, using all the available data, is the most complete magnetic susceptibility record for Site 984.

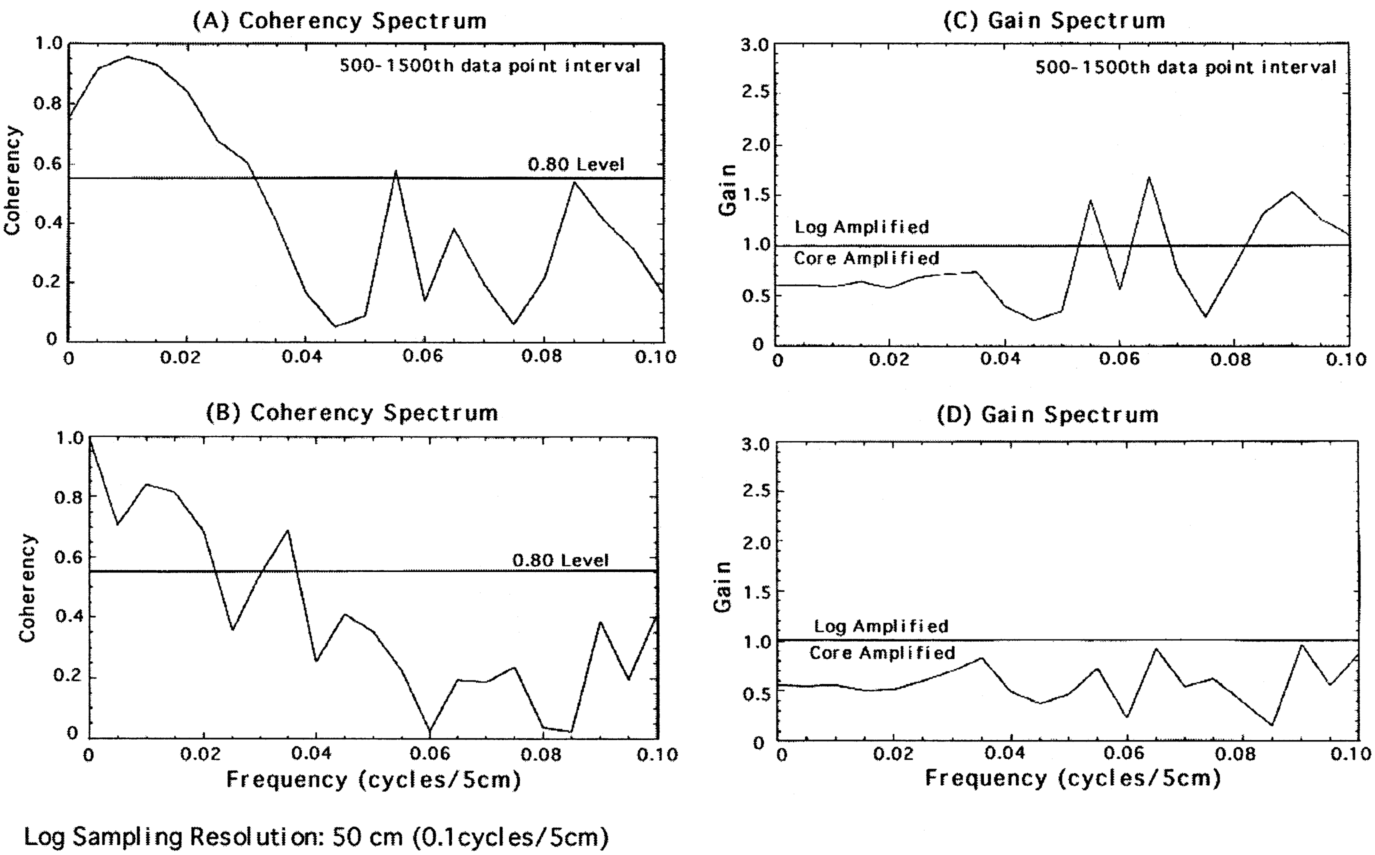

Figure 4. **A.** Coherency spectrum for empirical SUMT resolution of 53 cm for the interval from 123 to 173 mbsf that showed the best mapping between core and log magnetic susceptibility data. **B.** Coherency spectrum for theoretical SUMT resolution of 0.50 m. **C.** Gain spectrum for the interval from 123 to 173 mbsf where log resolution is amplified relative to core magnetic susceptibility. **D.** Gain spectrum for the interval from 90 to 260 mbsf showing typical amplification of core magnetic susceptibility over log data.

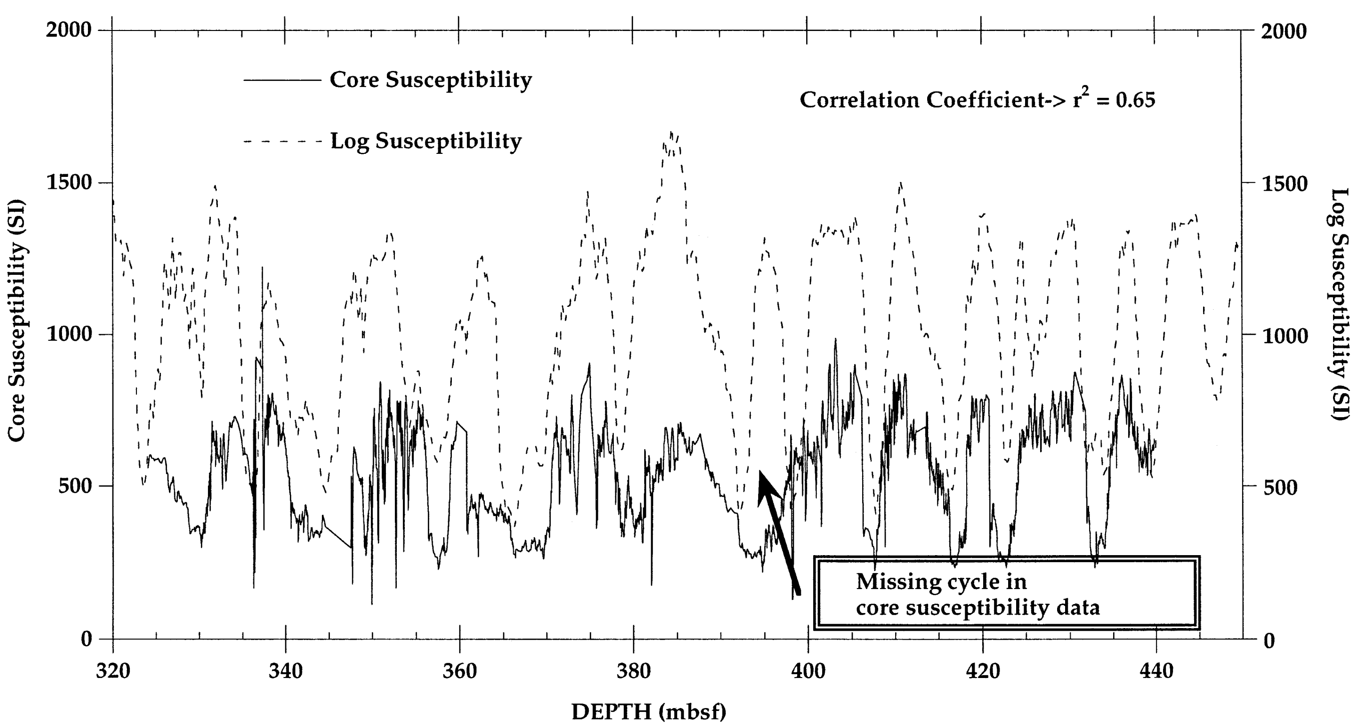

Figure 5. Comparison of core and log magnetic susceptibility over the interval from 320 to 440 mbsf. The missing cycle in core data at ~395 mbsf may result from poor core measurements or core condition, or may represent a small section of missing sediment.