Rea, D.K., Basov, I.A., Scholl, D.W., and Allan, J.F. (Eds.), 1995
Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 145

31. DETAILED VARIATION OF GEOMAGNETIC FIELD INTENSITY DURING THE LATE PLEISTOCENE AT SITE 882[1]

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ABSTRACT

I present a relative geomagnetic field intensity record during the last 210 k.y. from hemipelagic sediments of Hole 882B on the west side of the Detroit Seamount, northwestern Pacific. The record consists of discrete samples taken at 15-cm intervals, which can be converted to about 4 k.y. using the average sedimentation rate. The time control was provided by a visual comparison between the whole-core magnetic susceptibility record and oxygen isotopes from Site 677. The results of stepwise alternating-field demagnetization experiments show that soft components, probably consisting of viscous remanent magnetization, are removed by 5- to 20-mT AF demagnetization. The ratio of natural/anhysteretic remanent magnetization to a portion of each 10-mT interval up to 50 mT is taken to evaluate VRM contribution to the remanence. This result suggests that VRM does not affect to the remanence of coercivities higher than 20 mT, and the remanence slightly becomes unstable in higher than 40 mT. Thus, I select the NRM/ARM ratio between 20 and 40 mT for relative paleointensity determination. The resultant relative paleointensity record is similar in behavior to the volcanic and archeological data and paleointensity records in sedimentary rocks provided by previous studies. The record is characterized by an approximately 20-k.y. cycle in the intensity variation, and there are prominent intensity drops at 20–25 and 190 ka.

INTRODUCTION

The changes in past geomagnetic field intensity have mainly been derived from lavas and baked archeological materials, as they carry a stable thermal remanent magnetization (TRM) that is detectable quantitatively by means of the remanence acquisition process. Paleointensity data from these kinds of materials are well documented for the last few ten thousand years (e.g., McElhinny and Senanayake, 1982; Tanaka et al., 1994). However, archeological materials are very difficult to find, particularly those aged older than 10 ka, and volcanic materials available are very sporadic.

As opposed to archeological and volcanic materials, sediments provide a continuous paleomagnetic record that goes back in time for many years. Some scientists consider the paleointensity record derived from sediments to be unreliable, because of the difficulty in understanding the remanence acquisition process in sediments and the diagenesis effects for the acquired remanence. Consequently, many researchers do not think even now that sediments are able to carry paleointensity information. However, recent paleomagnetic studies on sediment cores that were dedicated to the extraction of a paleointensity record have shown a reasonable record for the last few hundred thousand years (Tauxe and Valet, 1989; Tauxe and Wu, 1990; Tric et al., 1992).

In this study, I have conducted paleomagnetic measurements on soft sediment samples taken with plastic cubes from Hole 882B, which was drilled at the west side of the Detroit Seamount (50°21.798′N, 167°35.976′E) in a water depth of 3244.2 m (Fig. 1). An advanced hydraulic piston corer (APC) was used to drill Hole 882B, and it penetrated from 0 to 270.4 mbsf (103.9% recovery). The average sedimentation rate for the top 100 m is 3.8 cm/k.y. I present here the preliminary results, which show relative paleointensity changes comparable to both archeological/volcanic and sedimentary records provided by previous studies.

MATERIALS AND METHODS

Measurements of natural remanent magnetization (NRM), magnetic remanence after alternating-field (AF) cleaning at 15-mT peak field, and initial low-field magnetic susceptibility per unit volume were determined at 10-cm intervals on the archive halves of cores by the Shipboard Scientific Party. The results have been reported in the *Initial Reports* volume for Leg 145 (Shipboard Scientific Party, 1993).

To investigate in detail and extract a relative paleointensity record from the sediments, discrete samples were taken by pressing special nonmagnetic plastic cubes (2.2-cm inner height and width) into soft sediments at 15-cm intervals for the top 10 m of Hole 882B. The sediments consist mostly of diatom fossils (about 80% of the total component) as well as some clay minerals and sponge spicules. After being sampled, each cube was wrapped with plastic film to shut out oxygen and water vapors.

Paleomagnetic measurements and AF-demagnetization experiments were performed in all samples using 2G Cryogenic Magnetometer with 2-axis sensor and Natsuhara-Giken AF demagnetizer at Ibaraki University. Anhysteretic remanent magnetization (ARM) acquisition experiments were conducted using a Helmholz coil of 8-cm diameter adapted to the demagnetization coil; ARM was acquired in an AF peak field of 80 mT with a direct-field bias of 0.03 mT. Stepwise AF demagnetization was performed on each sample at 5- to 10-mT intervals up to 50–80 mT. In addition, the same measurement sequence was performed after the ARM acquisition to investigate the coercivity spectrum in each sample.

Low-field magnetic susceptibility per unit volume was also measured in all samples using the Bartington Magnetic Susceptibility System at the Ocean Research Institute, University of Tokyo. Susceptibility was measured at low (0.47 kHz) and high (4.7 kHz) frequencies to obtain a frequency-dependence coefficient (K_{fd}) of magnetic susceptibility in each sample. K_{fd} is expressed as a percentage, and it is defined by

$$K_{fd} = 100 \times (K_{lf} - K_{hf})/K_{lf},$$

where K denotes susceptibility per unit volume, and lf and hf refer to low and high frequencies, respectively.

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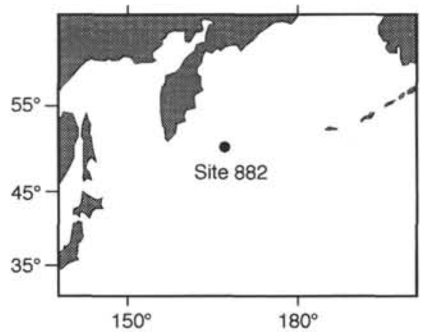

Figure 1. Location map of Site 882.

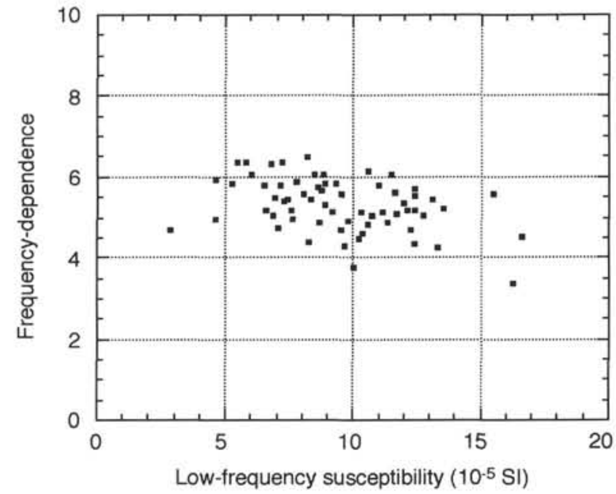

Figure 2. The frequency-dependence of magnetic susceptibility (K_{fd}) as a function of the low-frequency (0.47 kHz) susceptibility (K_{lf}).

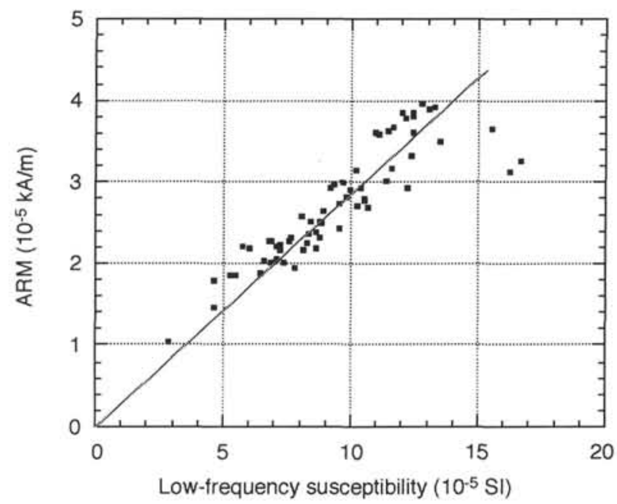

Figure 3. ARM intensity as a function of the low-frequency susceptibility (K_{lf}).

RESULTS

Characteristics and Stability of Magnetic Remanence

To monitor the magnetic grain size of the samples, weak-field susceptibility at both low and high frequencies was measured, and the result provided the frequency-dependence of magnetic susceptibility (K_{fd}). K_{fd} is considered to be highly sensitive to ultrafine grains near the *SD* (single domain) – *SP* (superpara) size threshold (Thompson and Oldfield, 1986, p. 56). This threshold is found at about 0.03 µm for isometric magnetite grains (Dunlop, 1973).

Figure 2 shows the K_{fd} vs. K_{lf} plot, on which there is a weak correlation (R = 0.39) and nearly a constant relation between both factors. The average K_{fd} value with the standard deviation is 5.33 ± 0.65. Yamazaki and Katsura (1990) represented a relationship between the K_{fd} and the mean diameter of magnetic grains in pelagic clay from the South Pacific. According to this relationship, a K_{fd} value of 5.33 can be converted to a mean grain diameter of about 0.1 µm. This and the K_{fd} vs. K_{lf} relation indicate that magnetic grains in the Hole 882B sediments consist mainly of single-domain or pseudo-single-domain magnetic grains.

An ARM-susceptibility diagram is shown in Figure 3, which exhibits clustering points around a straight line through the origin. This indicates that Hole 882B sediments have a common magnetic grain-size distribution with varying concentrations of magnetic mineral.

Figure 4 shows examples of stepwise AF demagnetization plotted on Zijderveld diagrams. These diagrams show that the remanences are quite stable, decaying linearly to the origin. Soft (viscous) components supposed to be contributed by VRM were removed completely by 5- to 20-mT AF. Sample 145-882B-2H-4, 25 cm (Fig. 4C), shows reversed magnetization, which shows that 5-mT AF is enough to extract a primary remanent magnetization. As shown in this figure, a large viscous component is common throughout the whole sequence.

Directions of Remanence

The declination and inclination of discrete samples were derived from regression lines passing through the origins using remanence data from 20 to 40 mT. The resulting directions are plotted vs. depth in Figure 5, which also shows the paleomagnetic directions from the onboard pass-through measurements. In this figure, declinations of both pass-through and discrete data were adjusted by the mean value in each core to 0.

The most prominent characteristic of the paleomagnetic directions is the reversed remanence at 11 mbsf. One sample displays a reversed inclination of –69.5°, but it does not contain a reversed declination. The pass-through data show a complete reversed direction at 10.9 mbsf, however, these results suggest that there is no geomagnetic excursion here but rather a very short geomagnetic reversal event at this level.

The mean value and the standard deviation of the inclination data from discrete samples were calculated, except for data that show intermediate and reversed polarity, as 67.7° ± 6.8°, which includes the axial dipole direction (67.4°) expected at the latitude of this site. This indicates that no significant inclination error caused by compaction of sediments or core disturbance occurs here.

Time Control

Because Site 882 is below the calcium carbonate compensation depth (CCD), there are few planktonic and benthic foraminifers in the sediments. Consequently, an oxygen isotope stratigraphy has not been available. This is necessary for dating during the period after the last geomagnetic polarity transition at 780 ka. Thus, I have used the onboard magnetic susceptibility record to determine detailed ages during the period. Figure 6 shows the Site 677 oxygen isotope record (Shackleton et al., 1990) and the Site 882 susceptibility record for the last 780 k.y. (Brunhes Epoch). Both curves exhibit similar changes, on which higher susceptibility sequences are comparable to lower oxygen isotope (glacial) periods. On the susceptibility record, it is easier to identify variations of an approximately 100-k.y. cycle such as glacial-interglacial changes, although shorter variations are hard to compare with peaks in the oxygen isotope record. In spite of the difficulty, preliminary time controls for the last 250 k.y., established using the comparison, are presented in Table 1.

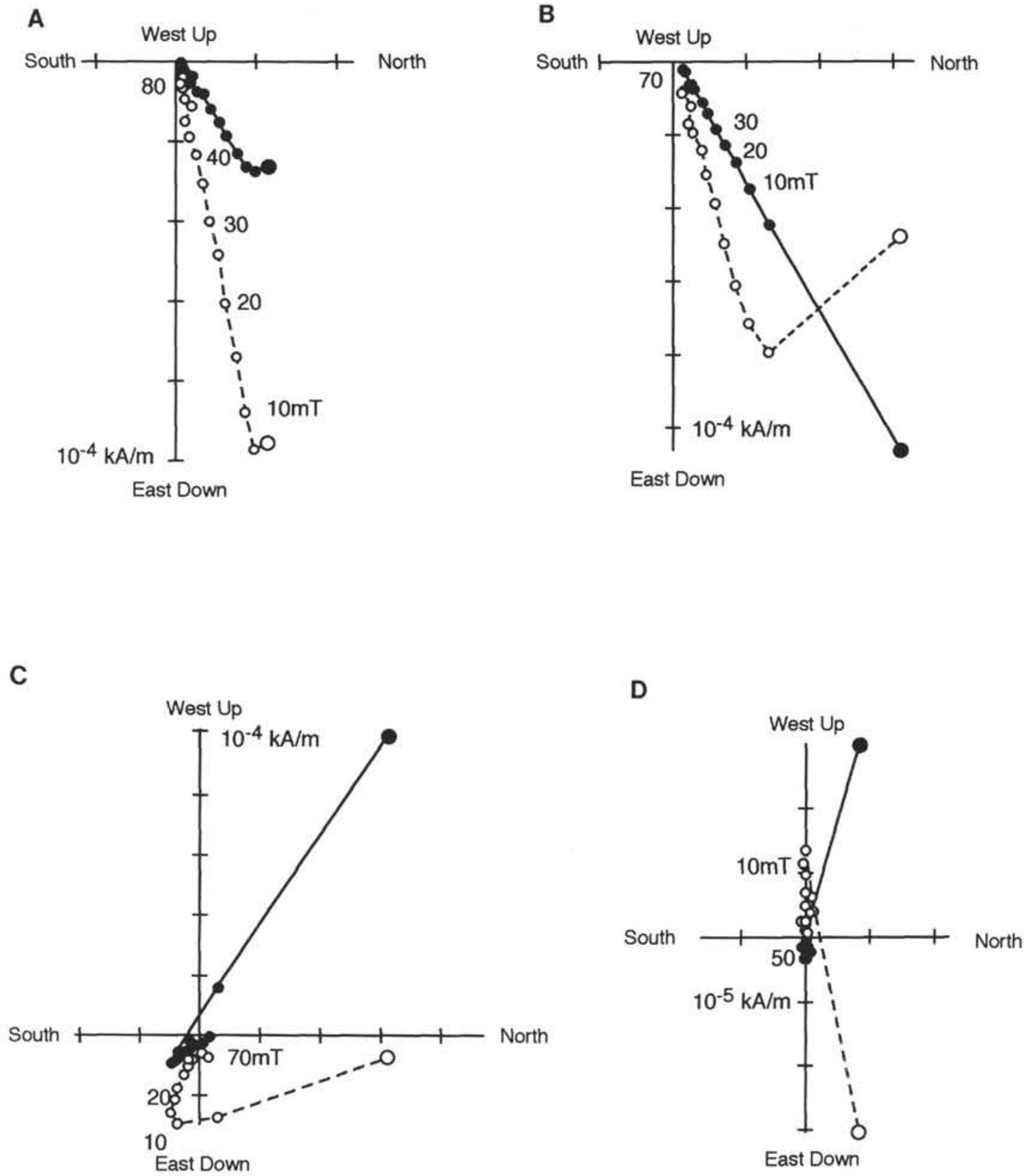

Figure 4. Examples of stepwise AF demagnetization plotted on Zijderveld diagrams. Open circles represent perspective on the vertical plane; solid circles, the horizontal plane. **A.** Sample 145-882B-1H-1, 125 cm. **B.** Sample 145-882B-1H-3, 10 cm. **C.** Sample 145-882B-2H-1, 12 cm. **D.** Sample 145-882B-2H-4, 25 cm.

Relative Paleointensity

To normalize a remanent intensity with the amount of magnetic grains in the sediments, I have conducted a comparison of NRM to ARM within a certain coercivity spectrum. Figure 7 shows examples of the coercivity spectrum in each sample, which was provided by an ARM portion in each 10-mT interval. The same procedure was applied to all samples. The resulting coercivity spectra indicate that magnetic grains with coercivity of 10 to 30 mT contribute most of the ARM component. Because ARM is considered to have similar characteristics to NRM, the coercivity portion of 10 to 30 mT is expected to contribute largely to an NRM component. To examine this issue, an NRM portion in each 10-mT interval was taken for each sample; these examples are shown in Figure 8. This figure shows that similar coercivity spectrum shapes to those from the ARM shown in Figure 7 except for the 0- to 10-mT interval. These soft components are probably caused by VRM acquisition during the period after the detrital remanent magnetization (DRM) was acquired in the sediments.

Figure 9 shows the NRM/ARM ratios in each 10-mT interval for all samples. If the NRM components are derived only from DRM, the NRM/ARM ratios should be common throughout the coercivity. This figure shows that large amounts of VRM have contributed to the softer coercivity components (<10 mT), and the 10- to 20-mT components also have slightly been affected by the VRM. The NRM/ARM ratios take nearly a constant value throughout the coercivities from 20 to 40 mT in most of samples, but some samples show changes in the ratios at the 40- to 50-mT interval. Thus, a coercivity component in the 20- to 40-mT interval is supposed to be derived largely from primary DRM; in turn, an NRM/ARM ratio in the 20- to 40-mT portion is suitable as a reliable indicator of relative paleointensity. The

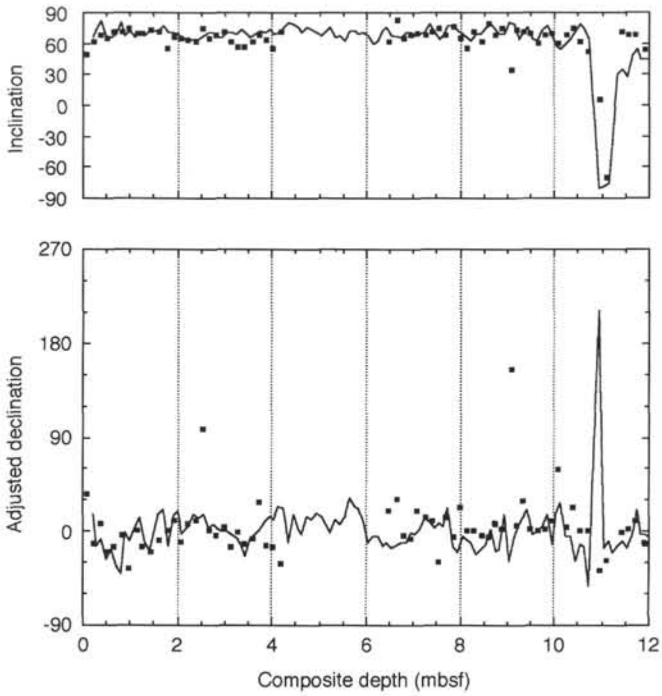

Figure 5. Declination and inclination plots on the depth scale. Solid lines indicate pass-through records, and solid squares indicate discrete data. The directions from discrete samples are derived from regression lines passing through the origins using remanence data from 20 to 40 mT.

NRM/ARM ratio for the 20- to 40-mT portion is shown in Figure 10, plotted on the age scale that was estimated in the previous section. This record shows that the intensity varies within an approximately 20-k.y. cycle, and two prominent intensity minima are present at 20–25 and 190 ka. The sedimentary virtual dipole moment (VDM) records from Mediterranean (Tric et al., 1992) and volcanic data (Tanaka et al., 1994) are plotted simultaneously on the figure with an arbitrary vertical scale. These data sets, provided from completely different environments and areas, match well. This fact strongly suggests that sediments have enough potential to reveal the variability of past geomagnetic intensity.

SUMMARY

1. Hole 882B sediments have a common magnetic grain-size distribution and varying concentrations of magnetic grains.
2. The softer coercivity component (<10 mT) is largely contributed by VRM in most of samples.
3. The NRM/ARM ratio of the 20- to 40-mT portion is suitable as a reliable indicator for relative paleointensity.
4. The Hole 882B paleointensity record shows that the intensity varies within an approximately 20-k.y. cycle, and two prominent intensity minima are evident at 20–25 and 190 ka.

Table 1. Time control of Hole 882B for the last 250 k.y.

Age (ka)	Depth (mbsf)
18	1.25
43.2	2.59
68	3.94
85	4.33
110	4.88
132	6.59
190	10.68
214	12.63
245	13.78

ACKNOWLEDGMENTS

I thank Toshiya Kanomatsu at Ocean Research Institute of the University of Tokyo for his comments and discussion.

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* Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

Date of initial receipt: 6 April 1994
Date of acceptance: 17 October 1994
Ms 145SR-137

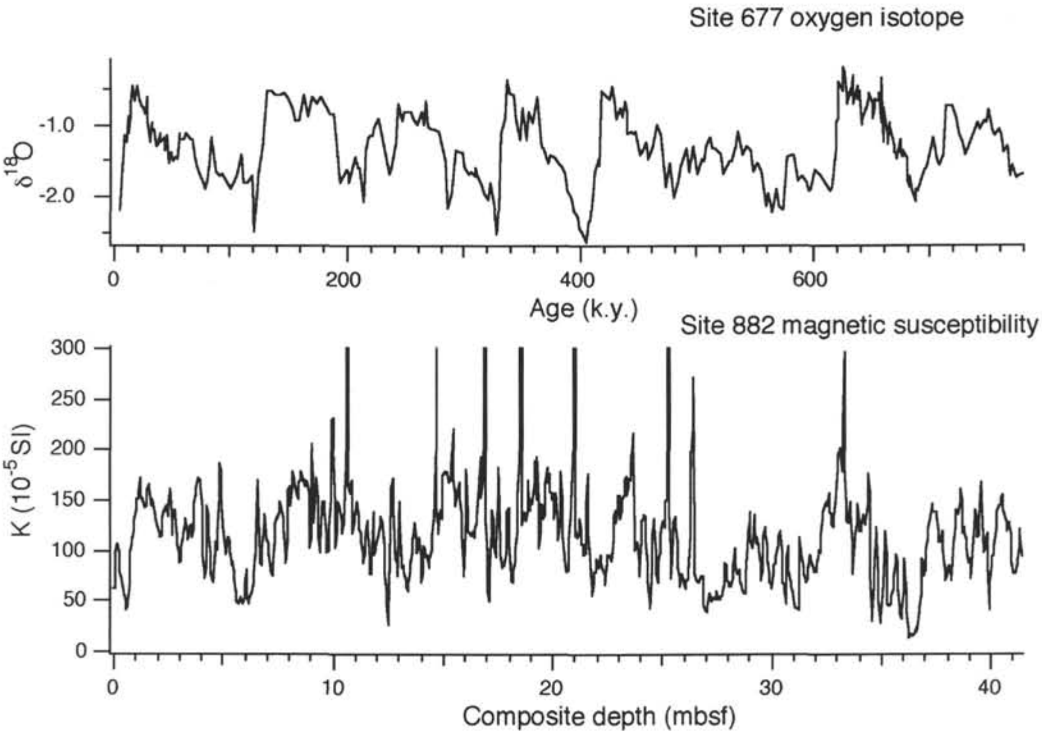

Figure 6. A comparison between the Site 677 oxygen isotope record and the Site 882 susceptibility record for the last 780 k.y.

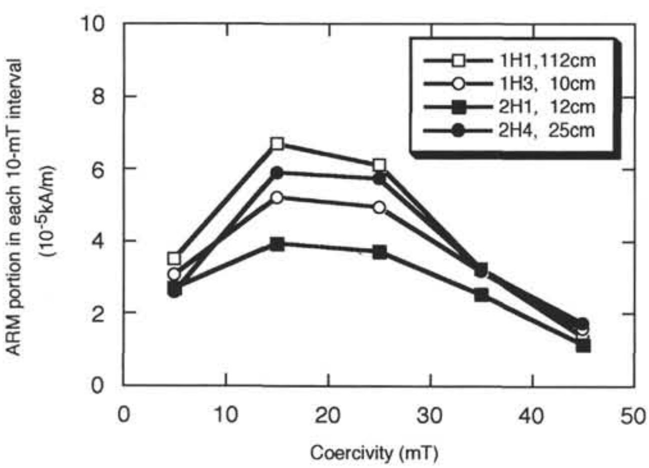

Figure 7. Examples of the coercivity spectrum provided by an ARM portion in each 10-mT interval.

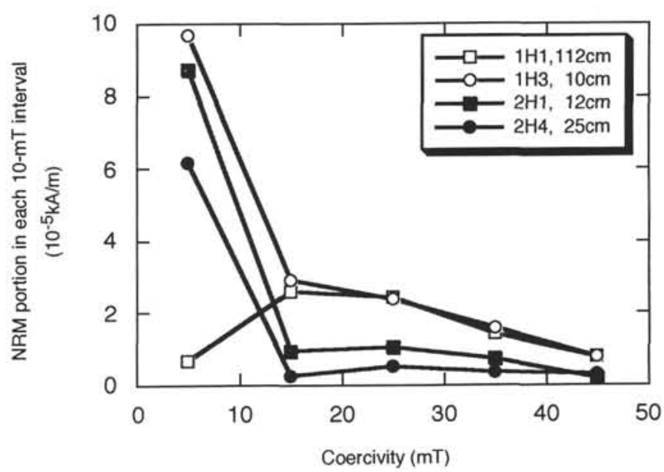

Figure 8. Examples of the coercivity spectrum provided by an NRM portion in each 10-mT interval.

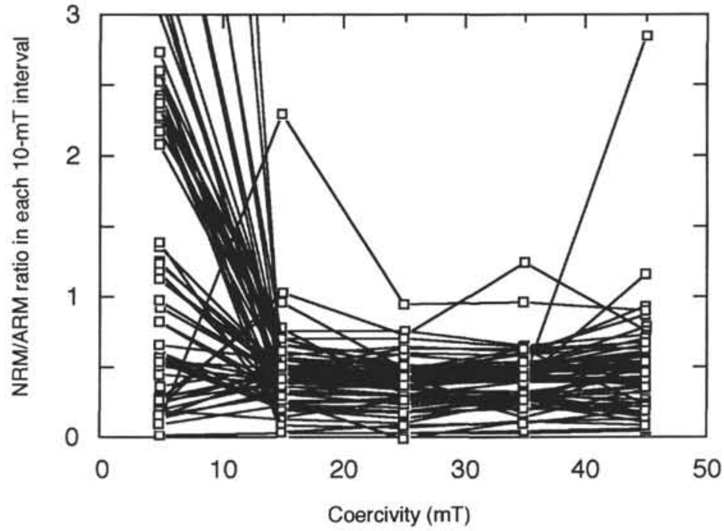

Figure 9. NRM/ARM ratios in each 10-mT interval for all samples.

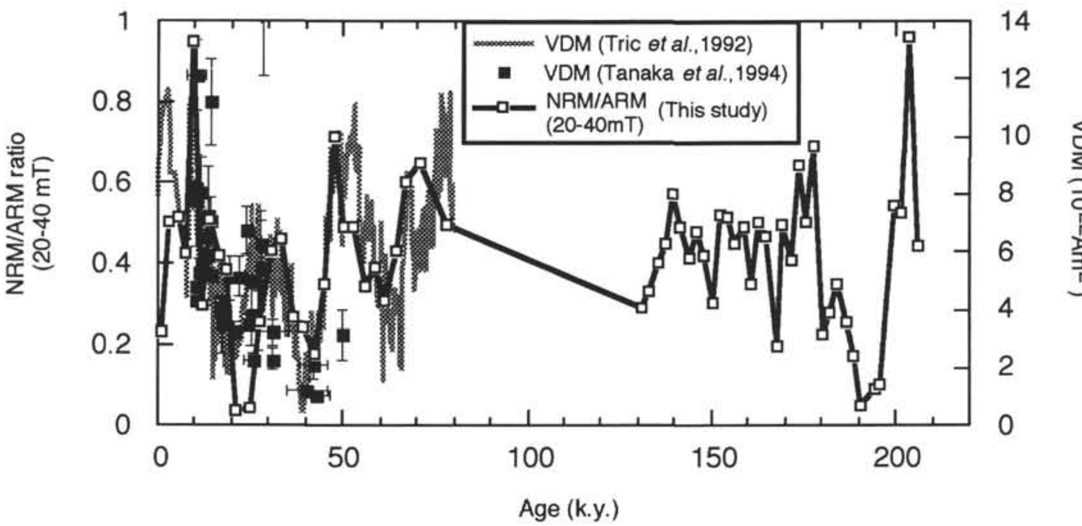

Figure 10. NRM/ARM ratio of the 20- to 40-mT portion as a function of the age scale (k.y.). The sedimentary VDM record (shaded line; Tric et al., 1992) and volcanic VDM data (solid squares with error bars; Tanaka et al., 1994) are plotted using an arbitrary vertical scale for the NRM/ARM ratio.