Rock-magnetic Study for Normalization of the Remanent Magnetization Obtained from an Antarctic Deep-sea Sediment Core

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Abstract

In order to estimate the relative variation of the geomagnetic field intensity in the Antarctic region, rock-magnetic experiments have been conducted on a deep-sea sediment core obtained from offshore Wilkes Land, East Antarctica. Acquisition curves of anhysteretic remanent magnetization (ARM) and isothermal remanent magnetization (IRM) indicate that the ARM intensity is not completely saturated even at the maximum alternating-field (AF) field of 100 mT whereas the IRM intensity is saturated. The demagnetization curve of saturation isothermal remanent magnetization (SIRM) is remarkably similar to that of natural remanent magnetization (NRM), while that of ARM depicts definitely different change in AF field. It implies that the coercivity spectrum of NRM is similar to that of SIRM and far from that of ARM.The normalized ratio of NRM to SIRM is remarkably stable over a broad range of demagnetization steps, whereas the normalized ratio of NRM to ARM is unstable. Therefore, in relative paleointensity estimation using the core GC1501, SIRM could be better for normalizing NRM than ARM.

Key words : sediment core, rock-magnetism, relative paleointensity, SIRM

1. Introduction

Deep-sea sediments can provide the continuous records of the past geomagnetic field, and a number of relative paleointensity variations of the geomagnetic field were obtained from sediments for more than the last 0.8 Ma, which allowed the construction of global reference paleointensity curves (e.g., Guyodo and Valet, 1999[1]; Yamazaki and Oda, 2005[2]; Valet *et al*., 2005[3]) by the technical and methodological development of paleointensity determination.

The sediment core used in this study (GC1501) was obtained from a continental rise site 3060 m deep at the western part of the Antarctic Wilkes Land margin during the TH94 cruise

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(1994-1995) of R/V HAKUREI-MARU, which was carried out by the Technology Research Center, Japan National Oil Corporation (Ishihara *et al*., 1996[4]) . The total length of the core is 540 cm. Abundant foraminiferal skeletons in good preservation were observed throughout the core. The sediment material was siliceous silt and showed brownish gray color. They clearly indicate oxidized condition, which gives additional stability of magnetic mineral against alteration throughout burial diagenesis.

A fundamental paleomagnetic studies were conducted on the same core by Sakai *et al*. (1998) [5] and Matsuoka & Funaki (2003)[6]. Matsuoka & Funaki (2003)[6] observed the NRM intensities which are 10-100 times higher than those commonly obtained from different localities and the remarkable high-stability components which survived up to 100 mT in AF demagnetization. The reported anomalous NRM intensity decay plots in AF demagnetization are shown in Figure 1.

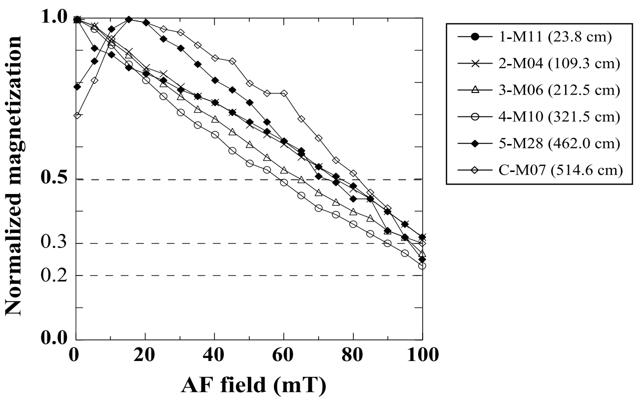

Figure 1. NRM intensity decay plots in AF demagnetization (Matsuoka & Funaki, 2003[6]).

The normalization of NRM with using an appropriate proxy is essential for paleointensity estimates. Sakai *et al*. (1998)[5] attempted to estimate the relative paleointensity of the geomagnetic field with using NRM intensity normalized by susceptibility (χ). However, as pointed out by Levi and Banerjee (1976)[7], susceptibility is hard to relate to remanence and hence much less preferable for paleointensity estimation than some form of room temperature remanence. For detailed discussions, therefore, more reliable paleointensity estimation with using other normalizer such as ARM or IRM is necessary.

Matsuoka & Funaki (2006)[8] performed the measurements of χ and ARM, which demonstrated the rock-magnetic homogeneity by the significant low amplitudes of their overall variations. It commonly allows the relative paleointensity estimation and thus Matsuoka and Funaki (2006)[8]estimated a relative paleointensity variation from NRM intensities remaining after AF demagnetization at 30 mT (NRM_{30mT}) normalized by ARM intensity at 30 mT demagnetization (ARM_{30mT}) with checking the absence of correlation between the normalized intensity (NRM_{30mT}/ARM_{30mT}) and the normalizer (ARM_{30mT}).

For further study, however, other normalizer also should be determined. SIRM has been also commonly used as a normalizer for relative paleointensity estimates (e.g., Channell *et al*., 1997[9]; Sato and Kobayashi, 1998[10]). The magnitude of SIRM is typically thousands of times larger than that of NRM, while the magnitude of ARM is a few tens to hundreds of times that of NRM. Thus SIRM is less preferable than ARM in many cases (e.g., Levi and Banerjee, 1976[7]). However, SIRM is more efficient to estimate the amount of magnetic fractions of high coercivity (e.g., hematite, maghemite, goethite) than ARM. In this study, therefore, SIRM is focused as another normalizer by comparison with ARM.

2. Magnetic Measurements

2.1 ARM Experiment

ARM acquisition experiments were carried out by the ARM acquisition coil in the SQUID magnetometer installed in a low magnetic field room in National Institute of Polar Research in Tokyo, Japan. ARM was imparted on every sample by superimposing a DC biasing field of 0.1 mT on an increasing AF field up to 100 mT in steps of 10 mT. Since the core was obtained from the Antarctic polar region, the dominant NRM component is vertical, as supported by the AF demagnetization results, and it was not demagnetized completely even if the demagnetization field was 100 mT (Matsuoka & Funaki, 2003[6]). Therefore, ARM was imparted toward the horizontal direction of core for minimizing the effect of residual NRM after the demagnetization. After the ARM acquisition experiments, all samples were demagnetized up to 100 mT in steps of 10 mT.

2.1 IRM Experiment

The pilot sediment sample was subjected to IRM acquisition experiments with the NIPR Pulse Magnetizer. IRM was imparted on the sample in the field of 50 mT as the first step, and then in steps of 100 mT up to 800 mT. Same as ARM, IRM was imparted toward the horizontal direction of core for minimizing the effect of residual NRM after the AF demagnetization. The acquired SIRM was AF demagnetized up to 100 mT in steps of 10 mT with using a SQUID magnetometer.

3. Results

A typical result of ARM acquisition experiments was shown in Figure 2a. The obtained ARM intensity was normalized by its maximum ARM intensity. The acquisition curve shows 10-20 % increase at every step up to 50 mT AF field. Though the ARM intensity increases by several percent at every step of over 50 mT AF field, it is not completely saturated even at the AF field of 100 mT.

A typical ARM intensity decay curve in AF demagnetization is shown in Figure 2b. The decay curve shows strongly convex-down shape. Almost 70 % of whole ARM intensity disappears at the AF field of 30 mT.

A typical result of IRM acquisition experiment was shown in Figure 2c. The intensity of IRM was normalized by the IRM intensity that was acquired at the DC field of 800 mT. The acquisition curve shows the drastic increase at every step up to 200 mT AF field. The 92 % of the IRM intensity acquired at the DC field of 800 mT has been gained up to 200 mT step. The IRM intensity was saturated in the DC field of 400 mT and thus can be assumed to be SIRM. The value of SIRM is 22.0 A/m, which is about 200 times larger than the NRM and about 45 times larger than the ARM.

A typical result of AF demagnetization of SIRM was shown in Figure 2d. The decay curve of IRM shows a remarkable linear change against AF field. The 15 % of the SIRM was survived up to 100 mT AF field. The median destructive field of SIRM (MDF_{SIRM}), the value of the peak AF field necessary to reduce the IRM intensity to half of its initial value, was estimated as 57.5 mT.

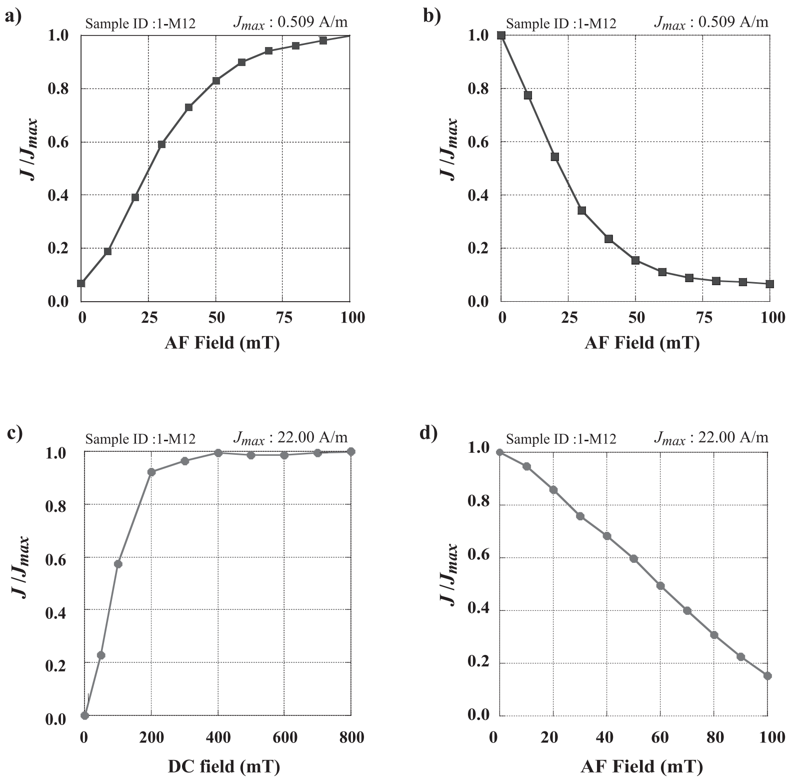

Figure 2. Typical results of ARM and IRM experiments.

(a) ARM acquisition curve on a discrete sample in AF field up to 100 mT.

(b) ARM intensity decay curve in AF demagnetization.

(c) IRM acquisition curve on a discrete sample in DC field up to 800 mT.

(d) IRM intensity decay curve in AF demagnetization.

4. Discussion

The acquisition curves of ARM and IRM are compared in Figure 3a. While the IRM intensity is saturated, the ARM intensity is not completely saturated even at the maximum AF field of 100 mT. Since the main carriers of NRM characterized by remarkably high coercivity may fail to acquire ARM completely, the concentration of NRM carriers cannot be estimated correctly by using ARM. The demagnetization curves of NRM, ARM and SIRM are also compared in Figure 3b. The demagnetization curve of SIRM is remarkably similar to that of NRM, while that of ARM depicts definitely different change in AF field. It indicates that the coercivity spectrum of NRM is similar to that of SIRM and far from that of ARM. A consequence of this dissimilarity in coercivity spectra between ARM and NRM is that the ratio of the two is very unstable during demagnetization.

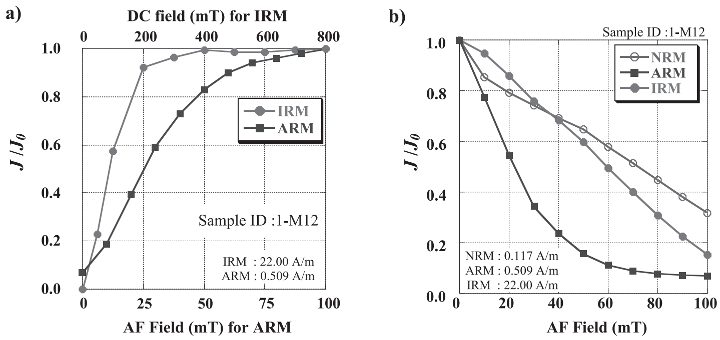

Figure3. Comparison of various remanent magnetizations.
(a) Comparison of acquisition curves of ARM and IRM.
(b) Comparison of the demagnetization curves of NRM, ARM and SIRM.

Figure 4 shows the normalized ratios of NRM to ARM (A*) and of NRM to SIRM (I*) during demagnetization. The I* is quite stable over a broad range of demagnetization steps, whereas A* is unstable. Therefore, the author considers the normalization by using SIRM to be better than ARM for the relative paleointensity estimation.

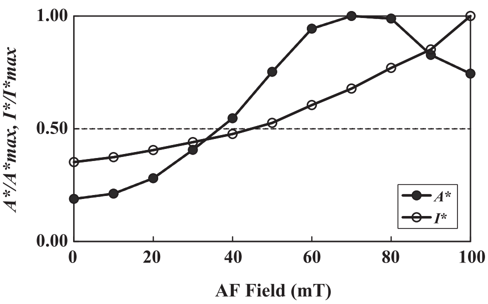

Figure4. Changes of the ratio of NRM to ARM (A*) and the ratio of NRM to SIRM (I*) during demagnetization. Solid/open circles show plots of A*/I*.

5. Conclusion

In order to find the most suitable normalizer for relative paleointensity estimation, two rock-magnetic experiments, ARM experiment and IRM experiment, were carried out. The acquisition curves of ARM and IRM indicated that the ARM intensity is not completely saturated even at the maximum AF field of 100 mT while the IRM intensity is saturated. The comparison of NRM, ARM, and SIRM demagnetization curves revealed that the coercivity spectrum of NRM is similar to that of SIRM and far from that of ARM. The normalized ratio of NRM to SIRM is significantly stable over a broad range of demagnetization steps, whereas the normalized ratio of NRM to ARM is unstable. Thus SIRM could be concluded to be better for normalizing than ARM.

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