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PALEOMAGNETIC TRANSITION RECORDS OF THE COBB MOUNTAIN EVENT FROM SEDIMENTS OF THE CELEBES AND SULU SEAS

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Abstract. The Cobb Mountain (CM) event is a short normal polarity interval within the Matuyama Chron just before the Jaramillo Subchron. This event was found in the sediments of Site 767 in the Celebes Sea and Site 768 in the Sulu Sea during ODP Leg 124. Reversal depth and age relation analysis gave ages of 1.11 and 1.10 m.y. ago for the onset and termination of this event. We used discrete samples and high-density pass-through measurements to study the behavior of the geomagnetic field crossing this event. Although the two sites are very close to each other, the records of the transitional fields were found to be quite different. They are also very different from another CM event record from the North Atlantic Ocean. Based on the transition data we conclude that the transitional fields for the CM event were non-axisymmetric. One brief reverse in direction, called rebound, was found within the onset reversal at Site 767. The absence of this feature at Site 768 raises an interesting question concerning the source for rebounds.

Introduction

ODP Leg 124 drilled in the Celebes and Sulu seas to investigate the origin of marginal basins [Leg 124 Scientific Party, 1989a and b]. During the ship-board paleomagnetic measurement of the sediment cores, a short normal polarity event within the Matuyama reversed Chron occurring just before the Jaramillo Subchron was recognized at both Site 767 in the Celebes Sea and Site 768 in the Sulu Sea (see Silver et al. 1990). The age of this event based on magnetic reversal sequence indicated that this is the Cobb Mountain (CM) event found in lava flows in California [Mankinen, et al. 1978; Mankinen and Grommè, 1982] and other places around the world (e.g. Watkins, 1968).

Paleomagnetic Data

For detailed study of the CM event, we have used discrete samples (7 cc cubes) taken at 5 cm intervals from the working halves of the sections containing the CM event. The archive halves were pass-through measured at 0.5 cm intervals in order to obtain high resolution data. A total of 39 discrete samples were taken from Sections 2 and 3 of Core 124-767B-009 (Celebes Sea) and 27 discrete samples were taken from Section 3 of Core 124-768B-011 (Sulu Sea). Discrete samples were stepwise AF demagnetized and the archive halves were demagnetized at 20 mT. Discrete sample demagnetization result suggests that 20 mT was enough to reveal the primary components.

Because of the broad sensor region (25 cm long and bell shaped for X, Y, and Z axes) of the pass-through cryogenic magnetometer, the high-density pass-through measurement data required deconvolution to recover the high frequency variations. Standard FFT (Fast Fourier Transform) technique was used for this purpose. We first examined the power spectra of the data and the impulse response functions of each of the 3 axes. We then eliminated the frequencies higher than the instrument responses using a cosine taper window [Yuen and Fraser, 1979]. The deconvolved data were then obtained by taking inverse FFT of the ratio of the power of the data and the instrument response. The deconvolution was performed for each 1.5 m section for each of the 3 axes. Deconvolved X, Y, and Z data were then used to calculate the declination, inclination and intensity. Figure 1 shows the deconvolved data along with results of discrete samples.

Transition Records

Both discrete sample and deconvolved pass-through data were corrected for core orientations (using the multishot core orientation device data) so that declinations are relative to the present day magnetic north. Core 124-768B-11 was also corrected for core barrel penetration rotation. This rotation, indicated by a linear change of declinations from top to bottom of a core with correct declination at bottom, is very common for Leg 124 APC cores.

The sediments covering the CM event were quite uniform except for 2 thin ash layers at Site 767 (Figure 1). At Site 767 sediments were mainly gray clayey silt with one clay size ash layer (10 cm thick, 73.65-73.75 mbsf) after the CM event and another one (12 cm thick, 74.20-74.32 mbsf) inside the CM event. At Site 768 the sedi-

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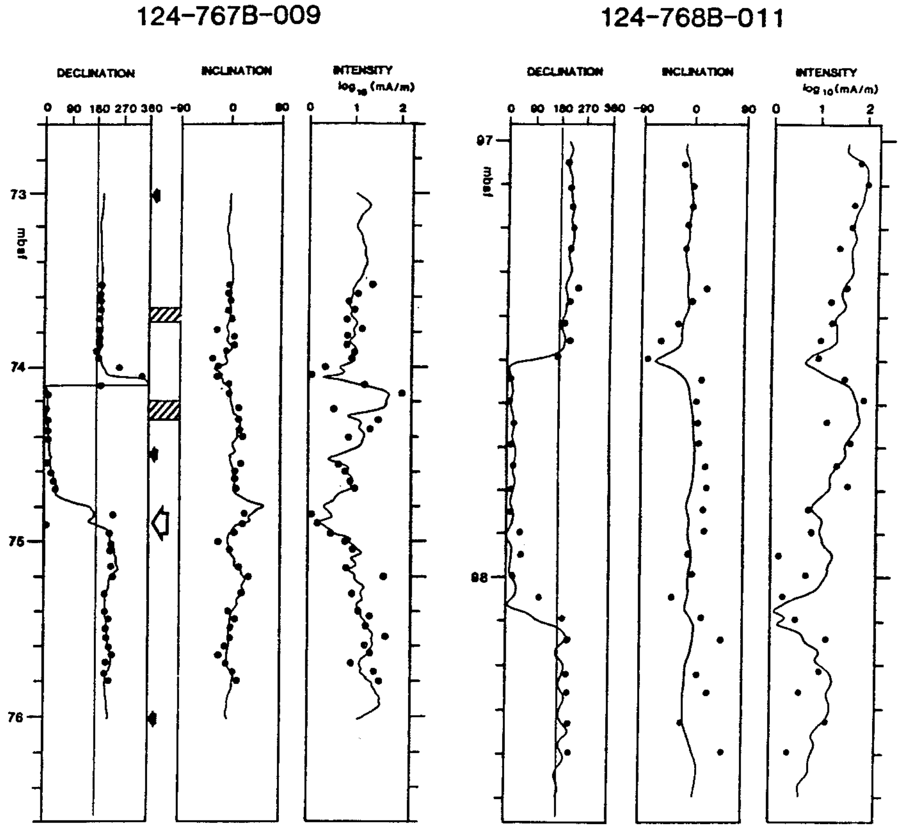

Fig. 1. Stratigraphic plots of declination, inclination, and intensity for discrete samples (solid circles) and deconvolved high-density pass-through measurements (solid lines) for the interval containing the CM event. Site 767 includes Sections 2 and 3 (3 m) of Core 124-767B-009 and Site 768 includes Section 6 (1.5 m) of Core 124-768B-011. The two shaded areas between the declination and inclination columns of Site 767 indicate the positions of 2 thin ash layers. Solid arrows indicate section cuts. The large open arrow indicates the rebound within the CM event onset.

ments were nanno-foram ooze uniformly throughout. How the ash layers in the Celebes and Sulu seas were deposited is not yet investigated. But the abundant ash layers (and turbidite layers) found in the Celebes and Sulu seas seem not to affect the very linear relation between reversal depths and ages [Silver et al., 1990]. Magnetically, the ash layers usually had higher intensity (not very clear for the 2 ash layers shown in Figure 1) but carried consistent directions with those of adjacent sediments.

In general, the agreement between the discrete sample results and the deconvolved pass-through data is quite good in the normal and the reversed sections (Figure 1). It, however, should be noted that deconvolved pass-through data still contain the averaging effect of the instrument and therefore tend to be smoothed out. This may explain the large directional and intensity differences for a few samples within the transition zones. Intensity data have somewhat larger differences between the two types of data due to the different AF levels selected for the discrete samples. Also intensity at Site 768 decreases with depth (Figure 1), probably due to change in concentration of magnetic minerals, causing the near bottom small discrete samples (7 cc) to show larger variations in intensity and direction. The pass through measurements (with about 1,000 cc inside the sensor region) are not affected as much.

Because only very few discrete samples are located within the transition zones, we based our examination of the transitional fields mainly on the deconvolved pass-through data. Figure 2 shows the VGP paths for data of Sites 767 and 768.

At Site 767, pre-CM event declination and inclination showed a period (75-76 mbsf) of large variation (compared with those after the CM event), with VGPs showing large movement between Antarctica and southeastern Africa (Figure 2). The onset reversal of the CM event had a VGP path through the middle Pacific just west of Hawaii (slightly near-sided), with a wandering loop between Australia and Antarctica. The VGPs stayed more or less stationary just north of Alaska during the CM event normal period before taking a path through central Africa (CM event termination, slightly far-sided) and back to western Antarctica where it stayed in one small region.

Site 768 (Sulu Sea) has less pre-CM event variation in

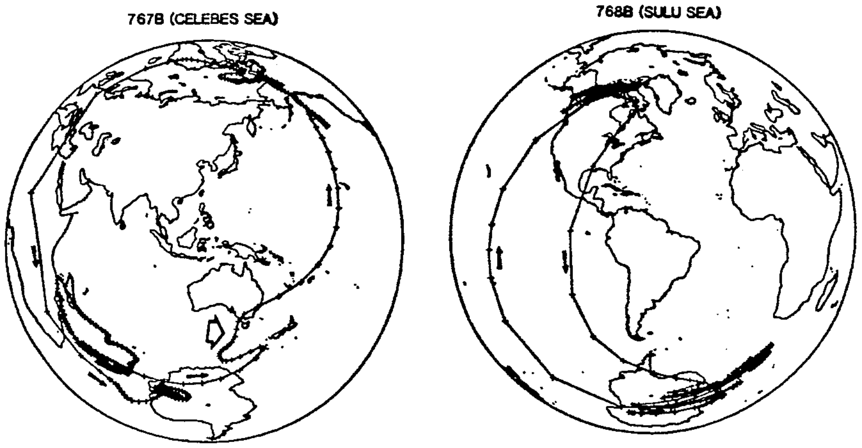

Fig. 2. VGP paths (connected crosses) for the entire CM event at Sites 767 and 768. The maps are equal-area equatorial projection showing a 120^o radius coverage. Site 767 is a near-sided plot and Site 768 is a far-sided plot. The open arrow indicates the rebound within the CM event onset.

directions (Figures 1) with VGPs showing east-west oscillation (caused by the sinusoidal change of declination, Figure 1) in eastern Antarctica (Figure 2). The onset reversal took a nearly non-sided (90^o from the site) VGP path through the eastern Pacific without the wandering loop observed in Site 767. VGPs then stayed near Alaska and northwestern Canada during the CM event normal period before taking a far-sided path through the U.S. and western Pacific back to eastern Antarctica.

Discussions

Routine pass-through measurement (at 10 cm intervals) on board the R/V *Resolution* allowed us to determine the depths of most reversals with an accuracy of 0.1 m. For the CM event, we picked depths based on the high-density pass-through data at mid-point of transitions. We used the 3 most recent well dated reversals to estimate the ages of the CM event reversals. The depth-age relation at Site 767 gives a sedimentation rate of 69.4 m/m.y. and ages of 1.11 and 1.10 m.y. ago for the onset and termination of the CM event. Independent estimates for Site 768 give a sedimentation rate of 56.8 m/m.y. and ages of 1.11 and 1.10 m.y. ago for the CM event reversals. We also plotted the reversal depths from Site 767 against the depths at Site 768 (Figure 3). The very linear relation (with a correlation coefficient of 0.9997) suggests that the sedimentation rates were essentially linear at both sites during the plotted interval. Another possibility is that the sedimentation rates at the two sites changed at the same rate during this time period. This, however, seems very unlikely. Our estimated ages of 1.10 and 1.11 m.y. are in good agreement with the radiometric ages at Cobb Mountain (1.12 ± 0.02 m.y., Mankinen et al., 1978) and the age from a DSDP site in the north Atlantic Ocean (1.12 m.y., Clement et al., 1986/1987).

The most interesting finding of this study is probably that the two reversals bounding the CM event showed very different transitional behaviors at the two sites that are only 3.9^o apart. Several differences were obvious.

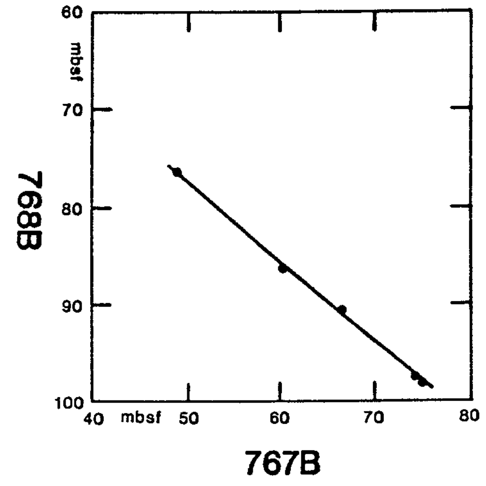

Fig. 3. Depth vs. depth plot for the most recent 5 reversals (B-M boundary and onsets and terminations of Jaramillo and Cobb Mountain events) from Sites 767 and 768.

First, there is a greater dispersion of directions before the onset of the CM event at Site 767 (Figures 1, also clear in the VGP path in Figure 2). Second, the onset transition is more complicated in Site 767 with a reverse in direction accompanied by a small increase in intensity in the middle. This resembles a feature called rebound (or partial recovery and oscillation) commonly observed in other transition records (e.g. Prèvot et al., 1985a and b; Laj. et al., 1988). Third, for the CM event termination, declination swings to the west at Site 767 while it swings to the east at Site 768 (Figure 1), with inclination becoming much steeper (more far sided VGPs) at Site 768.

Clement and Kent [1986/1987] also did a detailed study of the CM event recorded in DSDP cores at Site 609 in the north Atlantic using U-channel sampled discrete samples. They found rebounds of directions at the beginning of onsets and near the end of the termination reversals. Based on this finding, they argued for antisymmetric behaviors of the transitional fields which were largely dependent on sense of reversals without significant non-dipole changes. This, however, is certainly not the case at Sites 767 and 768 at low latitude SE Asia. The onset and terminations at Sites 767 and 768 are very asymmetric, with the onset lasting longer than the terminations (Figure 1). The VGP paths were all close to or nearly 90° from the sites (except 768 termination which is far-sided) so that no near- or far-sided pattern could be found. In addition, the only rebound observed is at Site 767 for the CM event onset (Figure 1). These transition records are not antisymmetric and suggest non-axisymmetric transitional fields.

The rebound within the CM event onset at Site 767 must have been a quicker and higher amplitude change than that shown by the pass-through data as the discrete samples show (Figure 1). There is a slight increase in intensity associated with it. Such rebounds within transition records have been observed for other reversals such as the Steens Mountain record [Prèvot et al., 1985a and b] and those at Zackinthos Island [Laj et al., 1988]. Prèvot et al., [1985b] and Coe and Prèvot [1989] have documented very fast rates of change (they called these transitional impulses) of the geomagnetic field during the Steens Mountain transition and argued for a more turbulent (higher velocity) outer core during transitions. The absence of a rebound, or presence of one much smaller in magnitude and therefore missed by the pass-through data at Site 768, however, raises the question concerning the origin of this fast change feature, because an outer core process ought to affect a much larger area on the earth surface. Our data tend to favor the involvement of some very high order non-dipole terms [Williams and Fuller, 1981] during the CM event onset transition. However, because there are still very few transition records for the CM event (in fact, only this study and that by Clement and Kent, 1986/1987), we believe more data are needed to draw a conclusion. Future studies concentrated on documenting one reversal at widespread sites would be critical to this problem.

Conclusions

Based on paleomagnetic studies of discrete samples and high-density pass-through measurement of sediments from Site 767 and 768, we conclude that the CM event is a true short polarity interval occurred from about 1.11 to 1.10 m.y. ago. The directions remained normal for the entire interval. Its onset and termination reversals appear to be similar to other reversals for major Chron and Subchron boundaries, with transitions lasting several thousand years and complicated structures such as rebounds. The different behaviors of the transitional fields between the onset and the termination argue for non-axisymmetric fields, which is different than what was found in the North Atlantic. Very different transition records at these two close sites also raise the question concerning whether the rebound is an outer core generated feature.

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