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Last 160 Ka Paleomagnetic Directional Secular Variation Record from Core MD972151, Southwestern South China Sea

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ABSTRACT

This study presents the directional paleomagnetic secular variation pattern of core MD972151 taken from the southwestern South China Sea during the IMAGES III – IPHIS Cruise in 1997. A total of 281 samples taken from this core were subjected to AF demagnetization to analyze their characteristic remanent magnetization.

The results indicated a reversed event at depth of between 21.7 and 23.8 meters. It was identified as the Blake Event, and has an age interval of about 130 ka. Another short reversed event was found near the bottom of the core. This was tentatively described as an excursion that occurred at about 150-160 ka. These assignments were in very close agreement with the results of oxygen isotope analysis. Consequently, the core under study was determined to be presenting a record of perhaps the last 160 ka probably. And the sedimentation rate can thus be estimated to be of about 17-18 cm/ky.

In addition to the reversed events, two excursions were also observed, one at the core top to 3.7 meters, and the other at 15.3-15.5 m in depth. The latter excursion was estimated to be of about 75 ka in age, based on comparing the results of this study to the intensity record made by Valet and Meynadier (1993). However, the former one might well be a recent excursion, under 20 ka in age, because comparison with oxygen isotope data ruled out the possibility of being the 'Laschamp Event'. Another possible cause for this abnormal event might be that it was due to deposition process of the sediments. Of course, this question will require further study.

Finally, the paleo-longitude variation pattern shows that the VGPs seemed to drift eastward at a record rate of over 4 meters in depth. This departs from observations of the present-day geomagnetic field that indicate the magnetic pole is drifting westward. The significance of this discrepancy warrants further study too.

(Key words: Paleomagnetic secular variation, VGP, South China Sea, IMAGES)

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1. INTRODUCTION

Secular variation is one of the major time-spatial dependent behaviors of the earth's magnetic field. It not only plays an important role for investigating the characteristics and origin of the geomagnetic field, but also becomes a very powerful tool for stratigraphic correlation studies. It has been applied broadly in studying marine and lake sediments and yielded many fruitful results (Barton & McElhinny, 1981; Creer, 1974; 1977; Creer et al., 1976; 1980; 1981; Hyodo et al., 1993; Turner and Thompson, 1981). During last two decades, secular variation was applied in paleo-environment change studies. This application provided more precise age data, in addition to the paleontological and isotopic methods, to yield much better age constraints for the observed events.

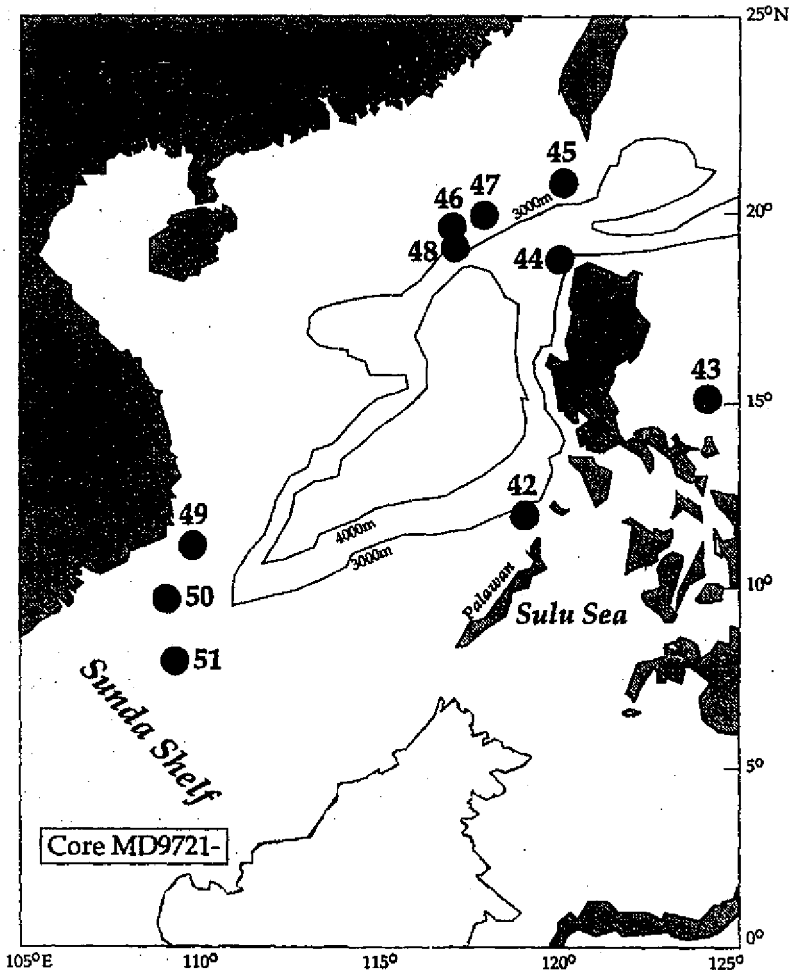

Fig. 1. The sketch map of the South China Sea showing site localities of the cores taken during IMAGES III – IPHIS Cruise in June, 1997.

The South China Sea (SCS; 5~22°N, 110~120°E) located off southeastern Asia (Figure 1) is one of the largest marginal seas in the world. Reports indicate that it has shown a high sedimentation rate, especially since the last glacial period. Very thick sediment depositions were found at its surrounding continental shelf area (Wang et al., 1992). Such thick sediments provide a good opportunity for obtaining high resolution records of paleo-environment changes, paleo-oceanography, paleo-climate et al. In addition, it also provides an excellent chance for paleomagnetic study, including secular variation analysis.

In June 1997, the IMAGES research group of Taiwan joined the IMAGES III Cruise and retrieved 8 giant long piston cores from SCS. The main purpose of this cruise was to study and reconstruct the paleo-oceanography and paleo-climate changes in SCS. To establish good age control, each core was required to undergo paleomagnetic secular variation and rock magnetism studies. In this study, the first secular variation record analyzed from core MD972151 is presented. This will support age data for future stratigraphic correlations and observations about the behavior of the earth magnetic field in the SCS area.

2. GEOLOGICAL SETTING AND LITHOLOGY OF THE CORE

The studied core MD972151 was taken from the southwestern SCS at a location north of the Sunda Shelf. The coordinates of the site position are 109°52.17'E longitude and 8°43.73'N latitude (Figure 1). The water depth of this site is about 1,589 m and the total recovered length of the studied core is 26.72 m. The lithology of this core is shown in Figure 2. Major constituents of this core are very fine grain clay and silty clay. Only very few thin sand laminae could be found at depths between 23 to 24 meters and close to the bottom. This figure indicates the presence of a void of 22.5 cm in length at the depth interval of 1107.5 cm to 1130 cm. So, the actual length of this core is about 26.5 m.

The Sunda Shelf covers an area extending from the Gulf of Siam to the Java Sea. The northern part accesses large amounts of terrigenous sediments delivered from the Indochina Peninsula by the Mekong River. Although it is the major water way between the SCS and the Indian Ocean, the water depth at its southern part is quite shallow, only 30 or 40 meters. So, this waterway might have been closed during the glacial period when the sea level was lower. And, this might have caused the deposition interruption which affected the continuity of the observed data set. However, the coring site of this study is in the northeast part of the Sunda Shelf. The present day water depth and the lithology of the core suggest that the observed record should not have this break in data continuity.

3. SAMPLING AND LABORATORY ANALYSIS

Plastic boxes, 2 by 2 cm in their inner sides, made by the Ginken Co., were used for continuous sampling of core MD972151. A total of 1125 specimens were obtained. For the paleomagnetic study, one fourth of the 1125 samples with equal spacing were chosen for stepwise alternating field (AF) demagnetization from 0 mT to 100 mT with an increment of 10 mT. After each demagnetization step, natural remanent magnetizations (NRM) of the samples

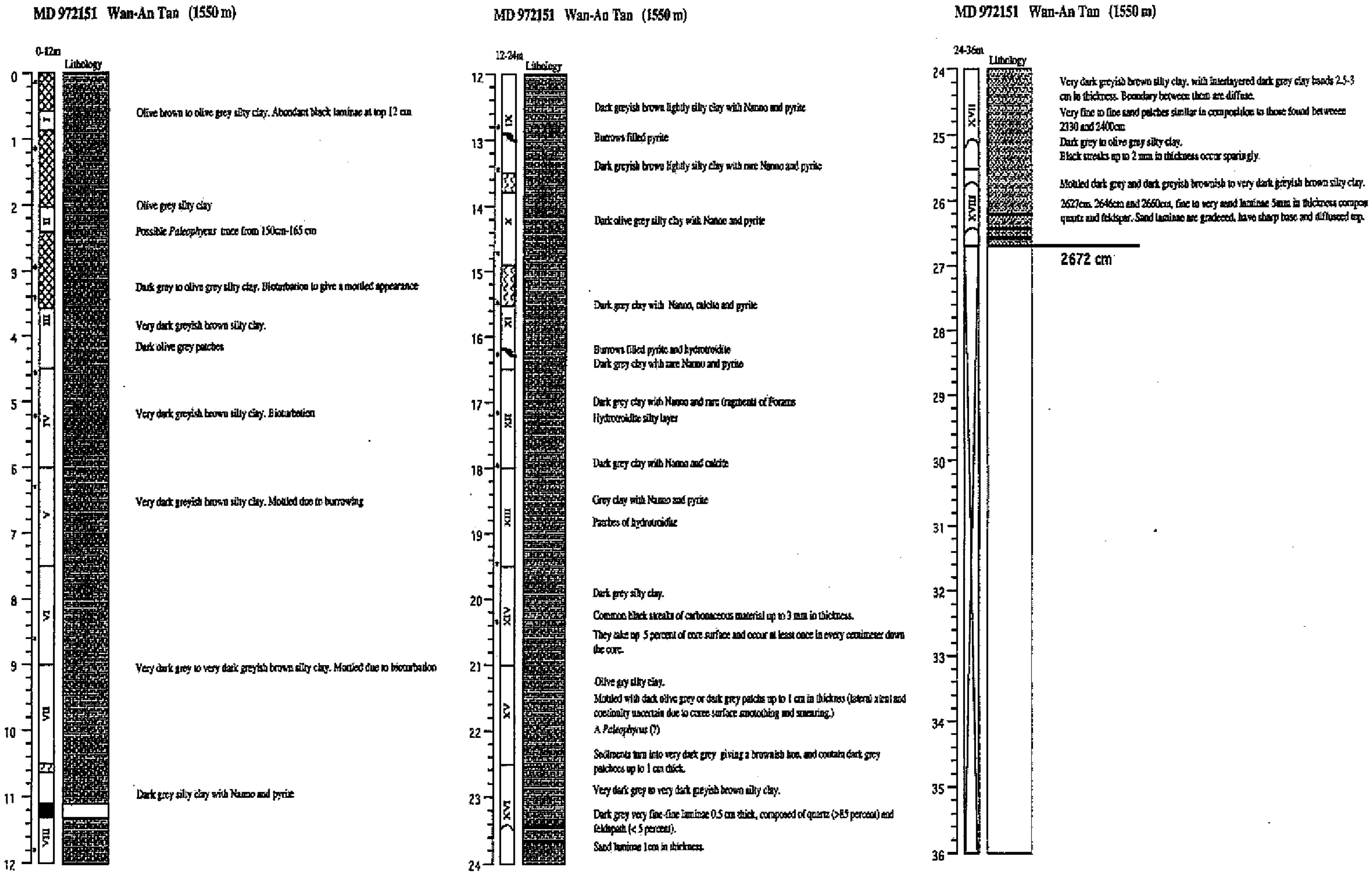

Fig. 2. The lithology of the studied core MD972151.

were measured on a cryogenic magnetometer (2G 755 SRM) installed in our magnetic shielding room. Stable components of NRM of samples were determined by applying the linear regression method according to the several final demagnetization steps shown on the Zijderveld plot (Zijderveld, 1967).

Stratigraphical variation patterns of paleo-declinations and paleo-inclinations were then set up. In order to investigate the principal behavior of the earth magnetic field, the paleo-declinations had to be corrected for calculating the virtual geomagnetic pole (VGP) positions. This was because of the unknown azimuth of the reference line of the core. The method we used in this study was to put the mean declination of the most stable part (4-25 m; flipped 180^0 for the reversed polarity directions) against that of its present day declination. Finally, the stratigraphical secular variation patterns of the paleo-longitude and paleo-latitude of VGP were established. The paleomagnetic data of core MD972151 are available electronically at Paleoceanographic Data Center of Core Laboratory - Center for Ocean Research, NSC, at the Institute of Applied Geophysics, National Taiwan Ocean University, Keelung, Taiwan, R.O.C. (Internet: http://140.121.175.114).

4. PALEOMAGNETIC SECULAR VARIATION PATTERN

The typical orthogonal plots of the samples are shown in Figure 3. Most of the samples show that secondary components of NRM could be completely removed after 40 mT demagnetization. Thus, the characteristic remanent magnetizations could be well delimited.

Secular variation patterns of paleo-declination and paleo-inclination of samples are presented in Figure 4. The corresponding secular variation patterns of paleo-longitude and paleo-longitude of VGP are displayed in Figure 5. From these figures, a reversed polarity event could be determined clearly at depths between 21.7 and 23.8 meters. Another small reversed event located near the bottom of the core was also found. At the depth of 15.3-15.5 meters, an event of negative inclination with north seeking declination occurred. It was most likely an excursion. In addition, an abnormal direction zone appeared at the core top to 3.7 meters: either positive inclination with declination around the NW direction or negative inclination with declination around the NE direction. What these events represent will be discussed below.

In addition, the paleo-declination pattern (Figure 4) showed a continuous counterclockwise variation trend from bottom of the core to 3.7 m in depth, except the reversed events. This trend reflected an eastward drifting phenomenon of VGP at most parts of the core (paleo-longitude pattern in Figure 5). This differs greatly from present-day observations of the geomagnetic field which indicate that the magnetic pole displays a westward drift phenomenon. The significance of this phenomenon requires further study.

5. DISCUSSIONS

Because the reversed polarity event appeared at depths between 21.7 to 23.8 meters indicates it corresponds to the "Blake Event", which has an age interval of about 130-140 ka. This

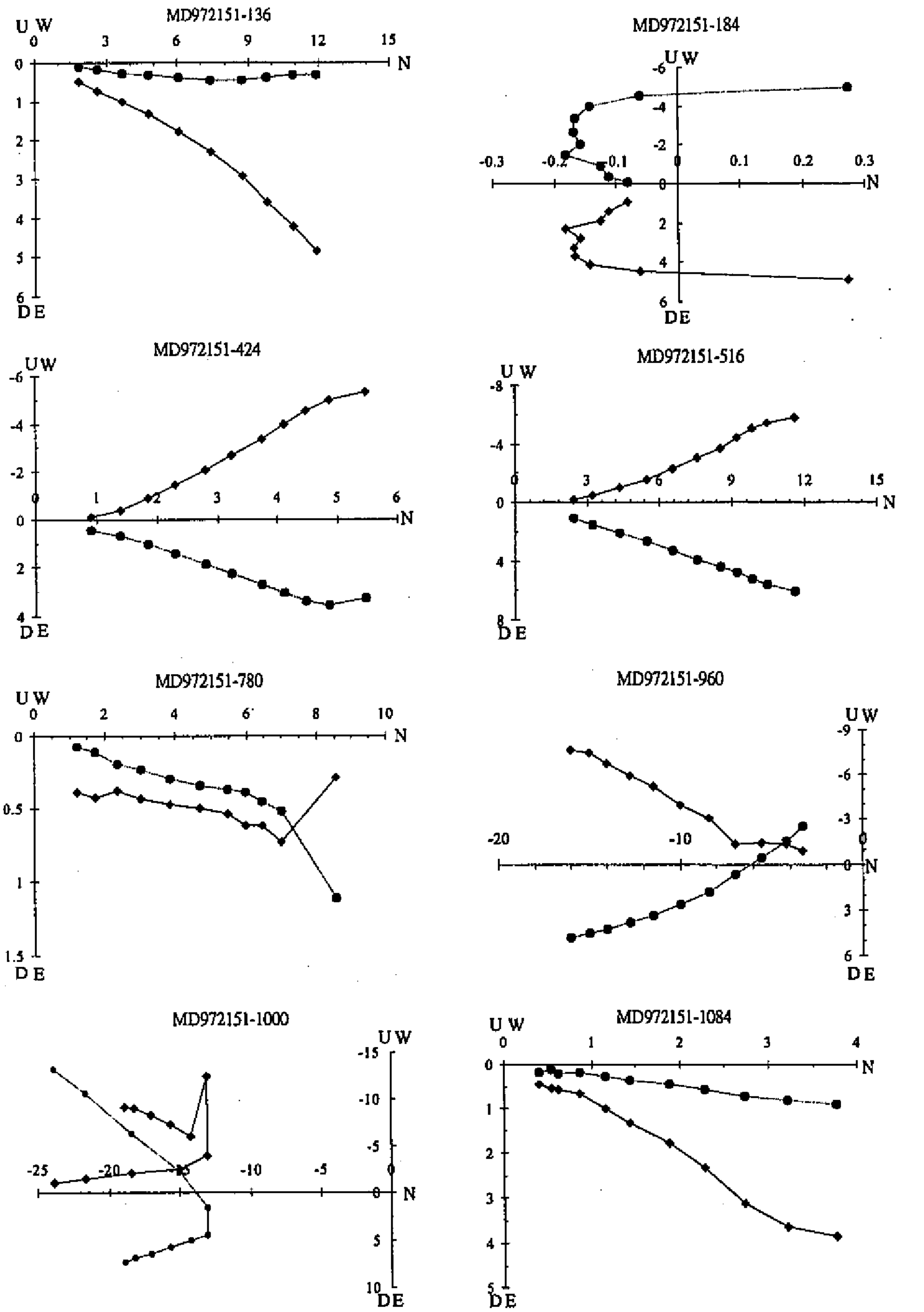

Fig. 3. Typical orthogonal plots of the studied samples showing the variation of NRM during AF demagnetization. (circle: D-N component; rhombus: N-E component).

assignment is in close agreement with the results of the oxygen isotope analysis carried out by Lee et al. (Lee et al., 1999). They report that the boundary of stages 5 and 6, which has an age of about 127 ka, is at about 21.5 m in depth. This confirmation enables us to estimate the average sedimentation rate of this core to be about 17-18 cm/ky.

Based on the estimated sedimentation rate, we concluded that the core under study is able to support information of the last 150-160 ka. In this study, a very short reversed polarity event was also found at the bottom of the core. Past reports made no mention of any polarity reversal during 150-160 ka. However, the paleo-intensity study of the last 4 Ma by Valet and Meynadier (1993) indicated that a low intensity event occurred around 150-160 ka, between the Blake and Jamaica events. We believe that a record of such high resolution as core MD972151 studied in this paper can provide more opportunities to observe the suchshort events. Consequently, we tentatively assign the short reversed polarity event to this low intensity event, and conclude that the core studied will support results for the last 150-160 ka.

The magnetic excursion observed at the depth of 15.3-15.5 m was estimated, by using the estimated sedimentation rate, to have an age of about 80-90 ka. Unfortunately, no such excur-

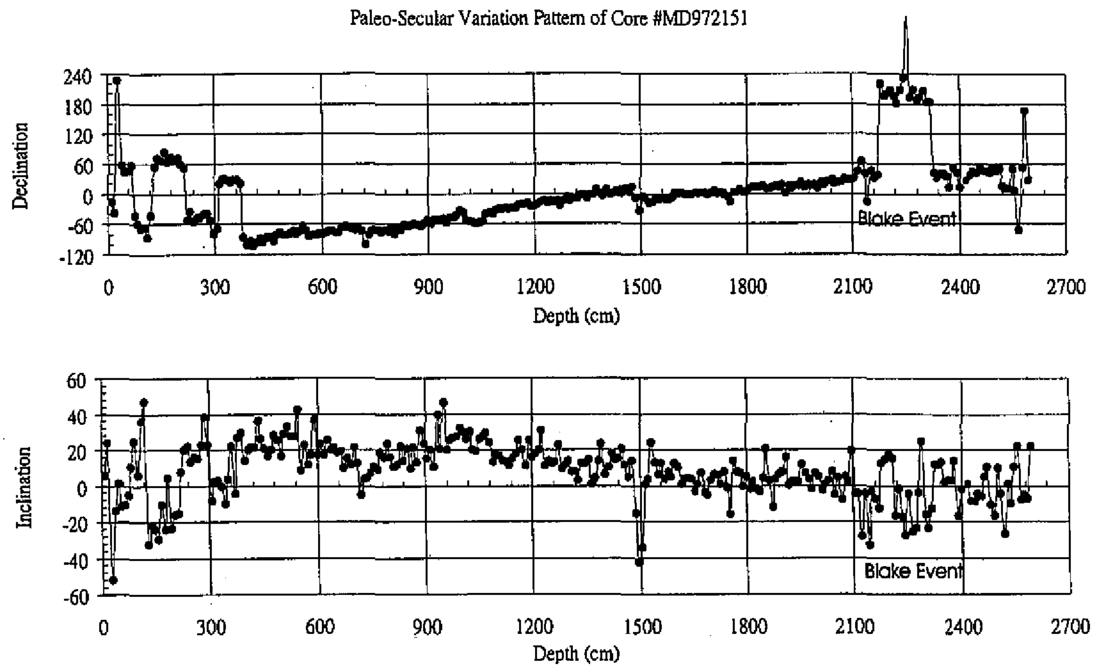

Fig. 4. Stratigraphic variation patterns of paleo-declination and paleo-inclination of core MD972151 showing the directional secular variation pattern in South China Sea during last 160 ka. Reversed polarity of the Blake Event was found to appear at the depth between 21.7 and 24.0 meters. Another short event was observed at the bottom of the core too. In addition, two excursions could be identified at depth of 15.3-15.5 m and the top 3.7 m..

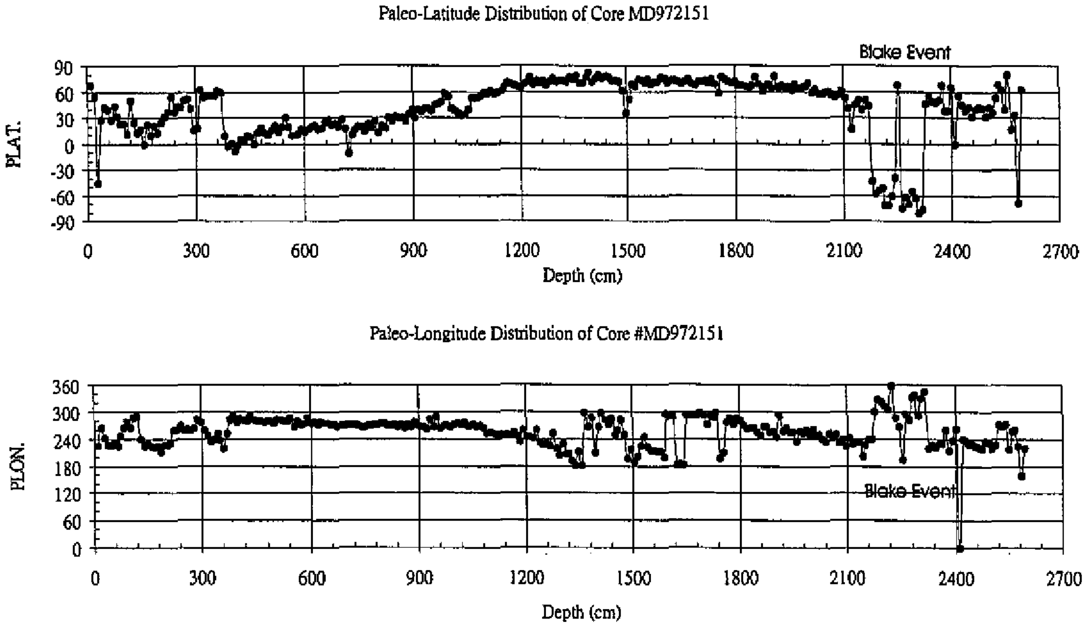

Fig. 5. Stratigraphic variation patterns of paleo-latitude and paleo-longitude of VGP.

sion has been reported for this period in the paleomagnetic direction literatures. Recently, Valet and Meynadier (1993) demonstrated a low intensity event at about 75 ka. Considering that the sedimentation rate might not have been constant in the past, the observed excursion at 15.3-15.5 m in depth in this study could possibly be correlated with this period of low intensity. And this hypothesis could be supported by oxygen isotope data studied by Lee et al. (1999).

Abnormal directions found from the core top to 3.7 m in depth were initially regarded as the Laschamp Event of 40 ka in age. However, this supposition was contradicted by the recent oxygen isotope data studied by Lee et al. (1999). Hence, the initial correlation of this abnormal event to the Laschamp Event was ruled out. According to that this anomaly appeared at the top of the core, two other possible explanations of its formation could be proposed. One is that it was a previously un-reported excursion that occurred at a time less than 20 ka, the other is that the abnormal paleomagnetic directions resulted from depositional process of the sediments. Which phenomenon the abnormal directions actually represent is a question that will require further data, analysis and speculation.

6. CONCLUSIONS

Marine sediment cores taken from South China Sea during the IMAGES III cruise provided a great opportunity for high-resolution study of paleomagnetic secular variation. Through this study, we established a paleomagnetic secular variation pattern for the last 160 ka. One excursions which appeared at the depth of 15.3-15.5 m was determined to have an age of about 75 ka. Another, found at the core top to 3.7 m, was shown not to be the 'Laschamp Event'. Rather, it was tentatively considered a previously un-reported excursion. However, the abnormal directions of this excursion indicate an alternate possible explanation based on the deposition process. Of course, this problem requires further study.

Based on the age assignment, the sedimentation rate of the core studied is estimated to be about 17-18 cm/ky on average. Furthermore, the age model, established from the paleomagnetic secular variation pattern of this study, is highly consistent with the oxygen isotope record. Hence, it should play an important role in future stratigraphic correlation work and age control in environmental and paleo-oceanographic studies of the South China Sea area. In addition, eastward drifting of the VGPs is observed in the paleo-longitude pattern. The significance of this phenomenon warrants further investigation.

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REFERENCES

Barton, C. E. and M. W. McElhinny, 1981: A 10,000-year geomagnetic secular variation record from three Australian maars. *Geophys. J. R. Astro. Soc.*, **67**, 465-485.

Creer, K. M., 1974: Geomagnetic variations for the interval 7000-25000 BP as recorded in a core of sediment from Station 1474 of the Black Sea cruise of "Atlantis II". *Earth Planet. Sci. Lett.*, **23**, 34-42.

Creer, K. M., 1977: Geomagnetic secular variations during the last 25,000 years: an interpretation of data obtained from rapidly deposited sediments. *Geophys. J. R. Astr.Soc.*, **48**, 91-109.

Creer, K. M., T. W. Anderson and C. F. M. Lewis, 1976: Late Quaternary geomagnetic stratigraphy recorded in Lake Erie sediments. *Earth Planet. Sci. Lett.*, **31**, 37-47.

Creer, K. M., P. W. Readman and A. M. Jacobs, 1980: Paleomagnetic and palaeontological dating of a section at Gioia Tauro, Italy: identification of the Blake Event. *Earth Planet. Sci. Lett.*, **50**, 289-300.

Creer, K. M., P. W. Readman and S. Papamarinopoulos, 1981: Geomagnetic secular variations in Greece through the last 6000 years obtained from lake sediment studies. *Geophys. J. R. Astr.Soc.*, **66**, 193-219.

Hyodo, M., C. Itota, and K. Yaskawa, 1993: Geomagnetic secular variation reconstructed from magnetizations of wide-diameter cores of Holocene sediments in Japan. *J. Geomag.*

Geoelectr., **45**, 669-696.

Lee, M. Y., K. Y. Wei and Y. G. Chen, 1999: A high resolution oxygen isotope stratigraphy for the last 150,000 years in the southern South China Sea: Core MD972151. *TAO*, **10**, 239-254.

Valet, J. P. and L. Meynadier, 1993: Geomagnetic field intensity and reversals during the past four million years. *Nature*, **366**, 234-238.

Turner, G. M. and R. Tompson, 1981: Lake sediment records of the geomagnetic secular variation in Britain during Holocene times: Geophys. *J. R. Astr. Soc.*, **65**, 703-725.

Wang, P., Z. Jian and Z. Lin, 1992: Late Quaternary Sedimentation rate in South China Sea. In: "Late Quaternary paleoceanography study in South China Sea", published by Qintao Oceanography Univ., 23-41. (in chinese)

Zijderveld, J. D. A., 1967: AF demagnetization of rocks Analysis of results. In: D. W. Collinson, R. M. Creer and S. K. Runcorn (Eds.), Methods in Paleomagnetism, Elsevier, New York, 254-286.