TAO, Vol. 9, No. 1, 143-152, March 1998

NOTE AND CORRESPONDENCE

Late Pleistocene Volcanic Ash Layers in Core MD972142, Offshore From Northwestern Palawan, South China Sea: A Preliminary Report

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(Manuscript received 20 December 1997, in final form 5 February 1998)

ABSTRACT

More than 18 distinct, well-defined ash-rich layers were recognized from the piston core MD972142 raised offshore from northwestern Palawan during the IMAGES III - IPHIS - Leg II Cruise in the South China Sea. The thickness of these macroscopically recognizable ash layers varies from 0.5 cm to 10 cm with a mode of 4 cm. Microscopic examination of the ashes reveals that these ash layers consist of vitric, microlite-bearing and crystalline components.

Strong reflection signals in the 3.5 kHz acoustic stratigraphy were found to be caused by various tephra layers down to 18 m in the upper section of the core. On-board measurement of bulk density confirms that the ash layers are more dense than the hemipelagic sediments. In addition, these layers also show much stronger magnetic susceptibilities than the intervening sediments. It indicates that the ash layers contain more abundant magnetic minerals than the microfossil-bearing hemipelagic sediments.

The last appearance datum of pink *Globigerinoides ruber* (planktic foraminifera) at 9.72 m and the absence of *Pseudoemiliania lacunosa* (calcareous nannofossil) in the core provide good age constraints for a preliminary correlation. The tephra layers in the top 7 meters can be correlated to the Upper, Middle and Lower Units of volcanic layers previously recognized in the northern South China Sea. Our preliminary correlation suggests that these ash-rich layers were deposited at 10 ka, 26-42 ka, 64-79 ka, and probably 110-290 ka, and 390-430 ka during the last 430 kyrs.

(Key Words: South China Sea, Pleistocene, Volcanic ash, Tephrochronology)

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1. INTRODUCTION

Island-arc volcanism along the western Pacific margin represents one of the most unique features characterizing the Pole-Equator-Pole Transect II (PEP-II) of the Past Global Changes (PAGES) Program. During the cruise IMAGES III - IPHIS - Leg II in June 1997 (Chen *et al.*, 1998, this volume), one of the main objectives for coring at Site MD972142 was to obtain a continuous, high-resolution record of volcanic activities of the past 100 - 500 thousand years pertinent to, although not limited to, the Philippine Archipelago. Such a record would not only serve as a good basis for further stratigraphic correlation in this area but also provide an unprecedented data base for evaluating the role of volcanism on local and global climate changes.

Modern volcanic eruptions in the Philippines, such as the 1991 eruption of Mount Pinatubo, have left discernible records in deep-sea surface sediments in a wide westward elongated lobe covering 30% of the bathypelagic South China Sea. The thickness of the ash layer reaches 1 - 2 cm in the area off the Luzon Island (Wiesner *et al.*, 1995). Based upon a broad survey of core-top samples obtained in the northern and central South China Sea, Yang and Fan (1990) documented that the abundance contours of volcanogenous particles in the Recent sediments are shaped like a tongue extending offshore from southern Luzon Island and tapering to the west. The highest concentration is as high as 31% in the bulk sediments at about 14°N and 117°W. Several recent studies of short gravity/piston cores in the northern and central South China Sea have also documented the occurrence of discrete tephra layers in the latest Pleistocene sequences (Feng *et al.*, 1988; Chen and Zhou, 1993; Wang *et al.*, 1992). Three major groups of tephra beds were recognized and dated to be around 10-13 ka, 26-42 ka, and 64-79 ka, respectively (Chen and Zhou, 1993). Limited by the short length of the cores studied (10 m in length was the longest), the oldest record has yet to exceed 80 kyrs in age. Although they cover only a narrow age range, these ash layers attest to their potential as basin-wide stratigraphic markers. Furthermore, the completeness and continuous nature of the deep-sea sedimentary sequences makes the tephra layers an excellent geologic record of past volcanism (Kennett, 1981). Such records may also provide clues for reconstructing the past wind regimes of the upper atmosphere and transportation mechanism in the South China Sea and peripheral areas (e.g., Koyaguchi and Tokuno, 1992).

2. CORE MD972142

The long piston core MD972142 was raised on the continental slope off the northwestern coast of Palawan from a water depth of 1557 m (Figure 1). The coordinates of the site are 12°41.33'N and 119°27.90'E. The core measures 35.91 m in length, consisting mainly of hemipelagic mud/silt sediments enriched with well-preserved calcareous and siliceous microfossils. No turbidites were detected. Intercalated conspicuously in this thick sequence of hemipelagic sediments are more than 18 layers of volcanic ashes. The thickness of the layers is generally larger than 1 cm, with a mode at about 4 cm. The thickest one is as much as 10 cm in length (Figure 2). On-board scientists recorded the position and thickness of the ash layers when core descriptions were made under naked-eye examination and confirmed by light microscopy. These layers consist of pumice, glass shards and phenocrystals of pyroclastic miner-

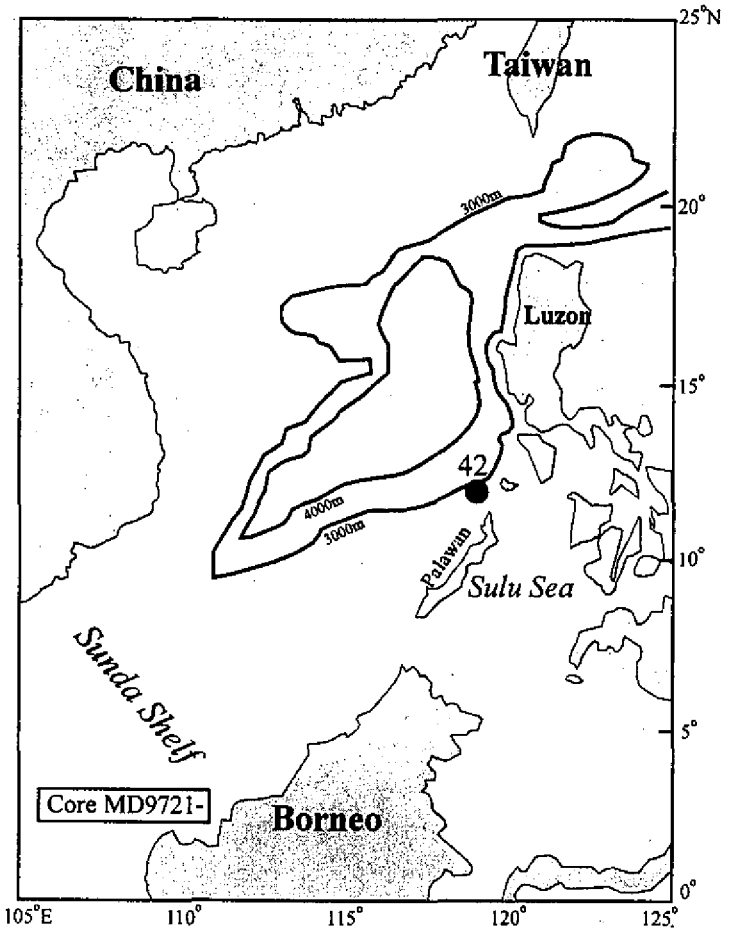

Fig. 1. The locality of Core MD972142 off the northwestern coast of Palawan Island.

als. The position and thickness of these ash layers were checked once again on shore in laboratory when sampling was done.

3. PHYSICAL PROPERTIES

Before opening them up for description, the un-split cores were first passed through a multi-sensor device to measure physical properties, including magnetic susceptibility, bulk density and P-wave velocity. The configuration of the multi-sensor track (MST) system made by the Geotek Ltd. is shown in Figure 3. Three major sensors were installed:

(1) P-wave logger. This consists of two transducers connected to an oscilloscope to measure the travel time of a 500 kHz compressional wave through the core. The travel time is used to calculate P-wave velocity in the sediment.

(2) Gamma ray source (^{137}Cs) and detector. This component measures the bulk density of

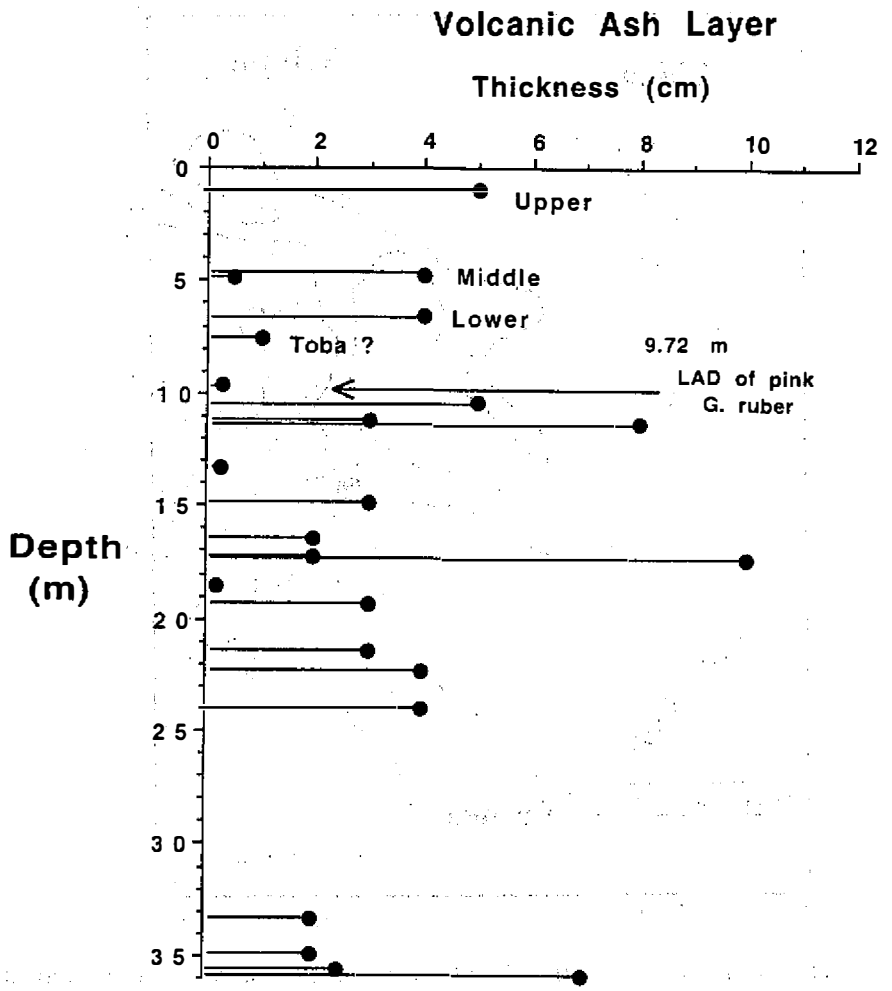

Fig. 2. Positions and thickness of ash layers in Core MD972142. Dashed lines indicate traces of tephras. Based upon the biochronostratigraphic constraint anchored by the last appearance of pink-pigmented *Globigerinoides ruber* at 9.72 m, the volcanic ash layers in the upper 10 meters were correlated to the Upper, Middle and Lower Units of ash beds recognized by Chen and Zhou (1993) and to the Toba eruption of Sumatra (Linsley, 1996)

sediments by comparing the attenuation of gamma rays through the cores with attenuation through aluminum standards.

(3) Magnetic susceptibility meter (Bartington Instruments MS2 loop sensor with an internal diameter of 125 mm). This part gauges the amount of magnetic material existing in the core.

For the MST measurements, the un-split core was first cut into sections of 1.5 meter in length. For the core MD972142, a total of 24 sections were logged. Before delivering these

core sections into the MST system, the temperatures of the laboratory and within the core were measured respectively. Logging was only begun once the core temperature had equilibrated with room temperature. This was to prevent the core temperature from drifting during logging which may result in artificial effects. Measurements were made continuously at increment of 2 cm along the core. The results were automatically stored in a computer.

Figure 4 shows the stratigraphic variation patterns of the bulk density, P-wave velocity and magnetic susceptibility of the studied core. It is found that the three physical parameters show simultaneously high spike values at many levels in the sequences. Compared to the lithology of the core, these levels where high peak signals appeared are coincident with the recorded ash layers (Figure 4). Among the three parameters, the high values of magnetic susceptibility are particularly connected with tephra layers.

Volcanic ash layers are considered to contain much more magnetic minerals than the intervening sediments. Furthermore, magnetite has usually been found to be the major magnetic mineral contained in volcanic ashes. A relatively large amount of magnetite in the ash layers is the main factor causing the extremely high peaks of magnetic susceptibility in the studied core. Samples which show secondary high spiked values in magnetic susceptibility were also examined microscopically. We found that these hemi-pelagic sediment samples contain a high portion of volcanic ashes, especially in the size fraction of 63 - 150 mm.

The profile of the bulk density shows an increasing trend from top to bottom except for two intervals at 17.4 m and 35.7 m where the densities were extremely low. This general increasing trend is considered to reflect the increasing degree of compactness with depth. The two low-density intervals were observed to be soupy sediments with high water content, whereas spiked high values of density are generally associated with volcanic ash layers.

The increasing trend in velocity is less obvious than that in density. High values of velocity are coincident with volcanic ash layers especially in the upper part of the core.

4. ACOUSTIC SUB-BOTTOM PROFILE

A 3.5 kHz acoustic sounding system was used for mapping sedimentation pattern in the deep sea and for selecting appropriate coring localities. Partly due to the shallow depth of the

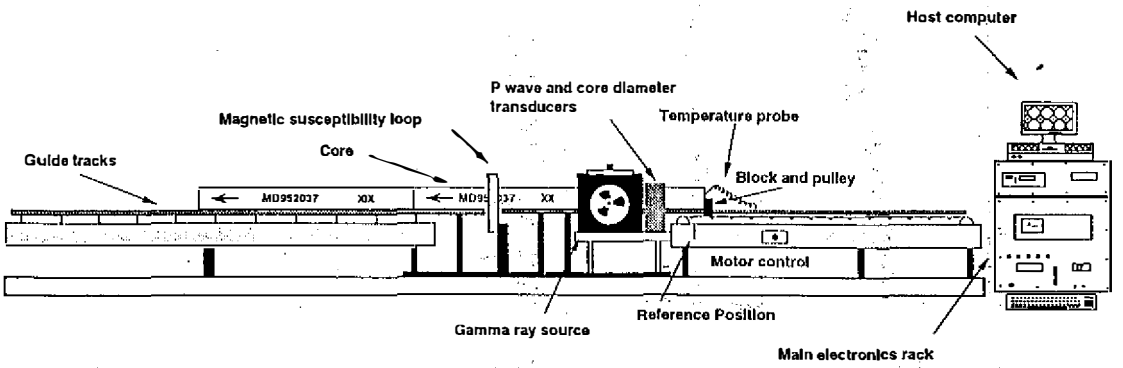

Fig. 3. Configuration of the multi-sensor track installed on the R/V *Marion Dufresne* for the MD106 IMAGES III.

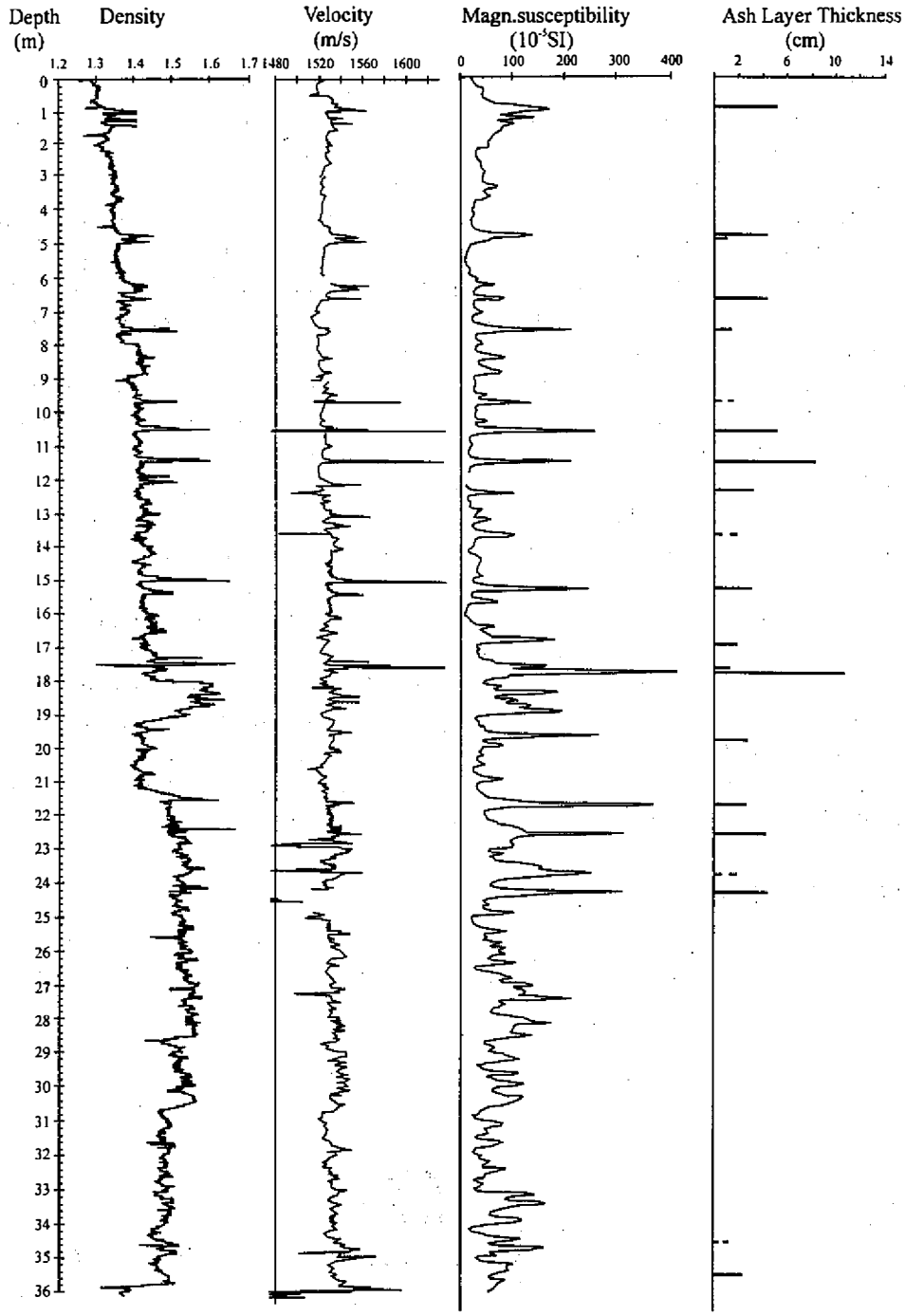

Fig. 4. Time-series of density, P-wave velocity and magnetic susceptibility measured by the multi-sensors installed on board R/V *Marion Dufresne*. Also shown in the right-most column is the thickness of volcanic ash layers.

site of MD972142, the acoustic profile showed excellent resolution with clear reflection signals. We traced the original profile of the site directly onto tracing paper and then enlarged it as shown in Figure 5. Comparing this enlarged acoustic profile to the lithology of the studied core, one can relate the reflection levels to the layers of volcanic ash. The coincidence indicates that the ash layers are distinctively more dense than the intervening sediments and therefore become stronger acoustic reflectors. It implies that the acoustic profiling in this area can be used to identify volcanic ash layers. However, this observation is not applicable to other sites cored during this cruise since some of the reflectors were caused by turbidites.

5. TEPHROCHRONOLOGY

According to our preliminary nannofossil biostratigraphic examination, the absence of *Pseudoemiliania lacunosa* in the core suggests that the base of this core is younger than 461 ka (Thierstein *et al.*, 1977; Takayama, 1993). The last appearance of the pink-pigmented variety of *Globigerinoides ruber* (planktic foraminifera) was found to be at 9.72m. The age of this datum in the Indo-Pacific area has been dated to be near to 120 ka (Thompson *et al.*, 1979). Cang *et al* (1988) confirmed such an age assignment for the datum in the Okinawa Trough area based upon oxygen isotope stratigraphy.

Given 120 Ka as the age of the level at 9.72m, the tephra layers in the upper 7 meters of the core can be correlated to the Upper, Middle and Lower Units of tephras coined by Chen and Zhou (1992) (Figure 2). Based upon their oxygen isotope stratigraphies for two cores, these Units were dated to be 10-13 ka, 26-42 ka and 64ka, respectively (Chen and Zhou, 1993). We adopted their correlation and interpreted the next lower ash layer at 750 cm as likely to be related to the large-scale Toba eruption in Sumatra at ~75 ka (Linsley, 1996). The age assignments of these four ash layers together with the *G. ruber* datum allow us to construct a tentative depth-age model for the sediments in the upper 10 meters of the core (solid curve in the right panel of Figure 6). To make a first approximation of the volcanic episodicity , we extrapolated the general sedimentation rate determined by the Upper Unit (12 ka) and the *G. ruber* datum (120 ka) to the lower part of the core (Figure 6). The age of the bottom of the core is estimated to be 430 ka, consistent with the fact that no *Pseudoemiliania lacunosa* (the youngest occurrence is 460 ka) was found. The volcanic activities appear to be more frequent during the periods from 110 to 290 ka, and from 390 to 430 ka.

6. SUMMARY

On-board examination of Core MD972142 revealed that there are 18 discrete volcanic ash layers which were macroscopically distinguishable. These volcanic ash layers are very good reflectors, as shown on the 3.5 kHz acoustic sub-bottom sediment profile. They show also distinctively high P-wave velocity, density and magnetic susceptibility. These distinctive physical properties, easily measured by a multi-track sensor, render the ash layers potentially very useful stratigraphic correlation markers.

A preliminary examination of planktic foraminifera of the sequence found that the last appearance of pink-pigmented *Globigerinoides ruber* occurred at 9.72 m. The age (120 ka) of

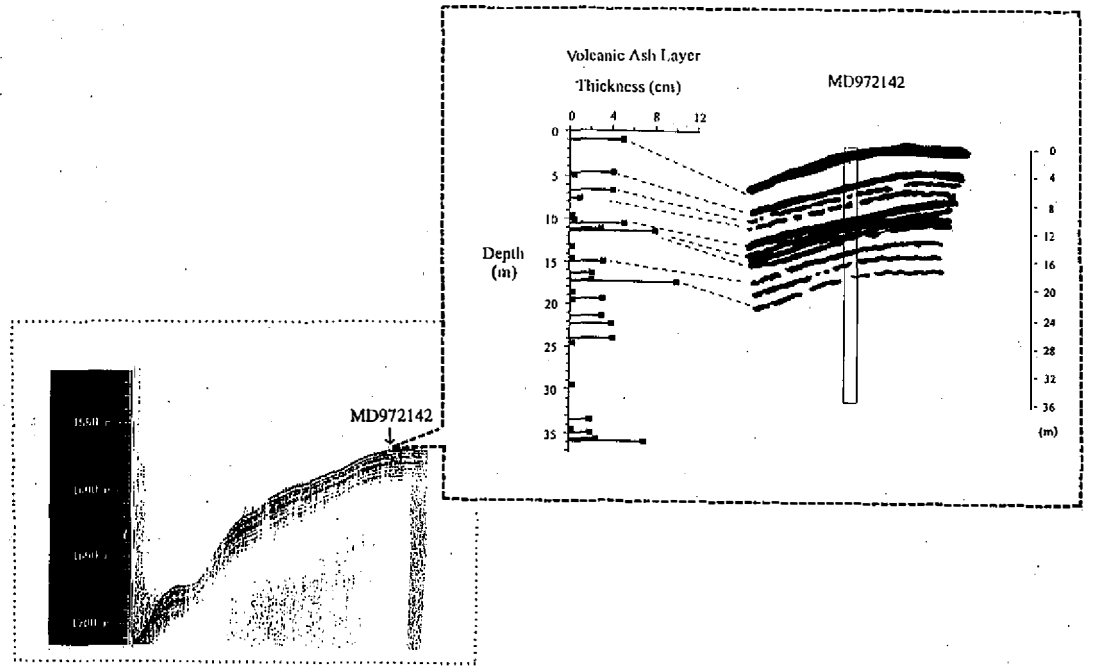

Fig. 5. Acoustic profile of sub-bottom sediments at Site MD972142. Left panel shows the original profile (which is smaller in scale than the hard copy generated by sounding machine) from computer output. Right panel is an enlargement of part of the profile of the site MD972142 traced directly on board from the hard copy of the sounding device.

this datum level in the Pacific Ocean provides us with a reliable controlling point for age correlation. Ash layers in the upper 7 meters can thus be correlated to the Upper, Middle and Lower Units of tephras in the northern South China Sea previously recognized by Chen and Zhou (1993). As *Pseudoemiliania lacunosa* is absent throughout the sequence, the bottom of the core is dated to be younger than 461 ka. An extrapolation of the sedimentation rate from the upper section to the lower allows us to construct a depth-age model for the observed ash layers in the lower part of the core. Our preliminary age correlation suggests that the volcanic activities of the Philippine archipelago and adjacent areas were more frequent during 10-13 ka, 26-42 ka, 64-79 ka, and probably 110-290 ka, and 390-430 ka in the last 430 kyrs.

Acknowledgments This study is a contribution to the Taiwan IMAGES program. The financial support for the participation of Taiwan scientists in the IMAGES-IPHIS-II Cruise was from the National Science Council under grants NSC86-2611-M-002-006 and NSC86-2111-M-019-005. We are grateful for the constructive suggestions made by the five reviewers at TAO. The first author (KYW) has been supported by ROC National Science Foundation Grant NSC-87-2611-M-002-003.

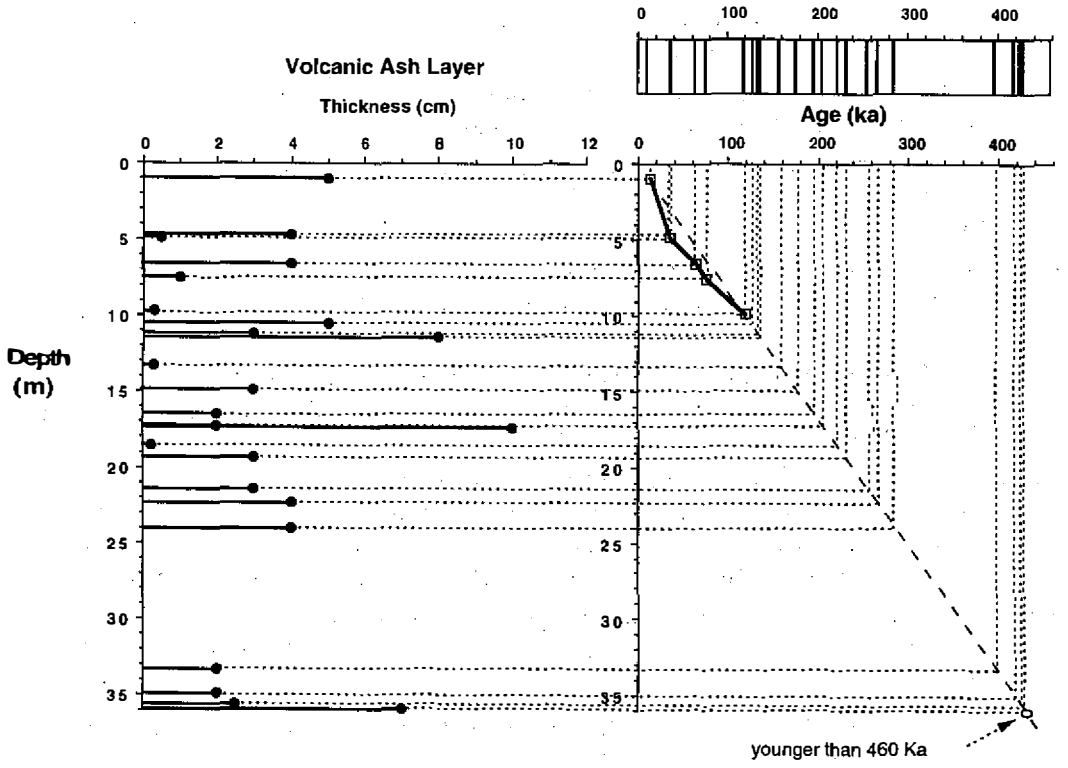

Fig. 6. Depth-age model for volcanic ash layers in MD972142.

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