LATE QUATERNARY PALEOENVIRONMENTAL RECONSTRUCTION OF THE SUNDA RIVERS DELTA SYSTEM, SUNDA SHELF, SOUTH CHINA SEA: TIMING OF DROWNING AND SEA-LEVEL CHANGES

by

Charu Sharma

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

at

Dalhousie University
Halifax, Nova Scotia
September 2002

National Library
of Canada

Acquisitions and
Bibliographic Services

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale
du Canada

Acquisitions et
services bibliographiques

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence

Our file Notre référence

0-612-75722-6

DALHOUSIE UNIVERSITY

FACULTY OF GRADUATE STUDIES

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "Late Quaternary Paleoenvironmental Reconstruction of the Sunda Rivers Delta System, Sunda Shelf, South China Sea: Timing of Drowning and Sea-Level Changes", by Charu Sharma, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Dated: July 8, 2002

External Examiner:

Research Supervisor:

Examining Committee:

[redacted]

DALHOUSIE UNIVERSITY

DATE: 29 July 2002

AUTHOR: Charu Sharma

TITLE: Late Quaternary Paleoenvironmental Reconstruction of the Sunda Rivers Delta System, Sunda Shelf, South China Sea: Timing of drowning and sea-level changes.

DEPARTMENT OR SCHOOL: Department of Earth Sciences

DEGREE: Doctor of Philosophy CONVOCATION: October YEAR: 2002

Permission is herewith granted to Dalhousie University to circulate and have to copied for non-commercial purposes, at its discretion, the above title upon request of individuals or institutions.

[redacted]

Signature of Author

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

The author attests that permission has been obtained for the use of any copyrighted material appearing in this thesis (other than brief excerpts requiring only proper acknowledgements in scholarly writing), and that all such use is clearly acknowledged.

LATE QUATERNARY PALEOENVIRONMENTAL RECONSTRUCTION OF THE SUNDA RIVERS DELTA SYSTEM, SUNDA SHELF, SOUTH CHINA SEA: TIMING OF DROWNING AND SEA-LEVEL CHANGES

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES AND TABLES

List of Figures

List of Tables

ABSTRACT

The Late Quaternary Paleoenvironmental reconstruction of the Sunda Shelf, South China Sea, was achieved using combined techniques employing foraminifera, radiocarbon chronology, sedimentology, and reflection seismics. Sixteen sediment-cores in modern water depths ranging from 71 – 151 m were used to reconstruct the evolution of the paleo-Sunda Rivers Delta from the time when the Shelf was subaerially exposed during low sea levels, up to the time when the delta was flooded by post-glacial sea-level rise.

A comparison of previous works that document foraminiferal distributions from the Sunda Shelf and its coastline, with the foraminiferal assemblages identified in the sediment-cores in this study, allowed the delineation of paleoenvironments such as mangrove marsh, estuarine delta, shallow marine delta, bay-lagoon, coastal, and nearshore zones. AMS radiocarbon ages obtained from faunally defined levels in the sediment-cores were used for reconstructing and revising the sea-level curve for the Sunda Shelf.

A shallow marine (-76 m to –77 m), and a deltaic (-71 m to –76 m) foraminiferal assemblage from a sediment-core in the inner Shelf area was indicative of an open Borneo Strait, thus, an active southwest monsoon, during Marine Isotope Stage 5. An estuarine-deltaic faunal assemblage from the central Shelf at a depth from –134 m to –138 m indicated a shallow marine setting and an active northeast monsoon during Marine Isotope Stage 3. The inner and central Shelf remained subaerially exposed during the Last Glacial Maximum (cal BP 19, 250 years) to a depth of at least –115 m below present mean sea level. Evidence exists for an abrupt termination of the LGM, documented by the sharp transition from a subaerial to a nearshore environment, and indicated by a sea-level rise of at least 1.7 m per 100 years. The sea-level rise in response to the input of glacial melt water, from cal BP 14, 700 years (+/- 500 years) to cal BP 14, 400 years (+/- 560 years) was at a rate which allowed a mangrove-marsh delta to be maintained from –95 m to –87 m below present mean sea level. Gradual flooding of the delta led to the formation of shallow coastal environments. Complete flooding of the shelf occurred at about cal BP 11, 000 years, which led to drowning and reorganization of the Sunda Rivers Delta System, and re-activated the southwest monsoon through the opening of the Borneo Strait.

The study revises a previous existing sea-level curve for the Sunda Shelf in two main ways:

a. It documents the abrupt termination of the LGM, thus, an early deglacial melt water pulse, an event overlooked previously.
b. It re-interprets the evolution of the Shelf for the time period from cal BP 14, 700 years (+/- 500 yrs.) to cal BP 14, 400 years (+/- 560 years) as a case of delta development through the formation of a mangrove marsh environment, rather than a case of rapid flooding, as proposed previously.

ACKNOWLEDGEMENTS

I would like to thank Dr. D.B. Scott for supervising my thesis. Dr. F.S. Medioli, is thanked for helping in various ways, towards the completion of the thesis. The time and space given by both of them for working independently is gratefully acknowledged. They are thanked for being available for discussions, for reading versions of manuscripts, and for making valuable suggestions towards improving my work.

The following colleagues at the Geologisch-Paläontologisches Institut und Museum, at the Christian-Albrechts-Universität Kiel, Germany, contributed in various ways towards my thesis: My two trips to Kiel, in connection with sample collection and participation on an oceanographic cruise to the South China Sea, were made possible by collaboration with Dr. W. Kuhnt, and Dr. K. Stattegger. They provided all possible facilities to make my trips smooth and productive. Discussions on taxonomy with R. Szarek helped resolve the identification crisis with many specimens. R. Szarek also provided invaluable assistance with sampling of the cores, as did another student (Cily). T. Hanebuth was readily available for discussions on the chronological and sedimentological aspects of the Sunda Shelf sediment cores. S. Steinke provided discussion on the outer shelf sediment cores and their chronology. H. Kawamura, S. Hesse, A. Richter, A. Schimanski, S. Rothe, U. Kreuger provided help in many ways, especially during the cruise SO-140 to the South China Sea. Ana Putar, (Dalhousie U.) supplied the first sediment samples from the study area, through her participation on the SONNE cruise SO-115. The SONNE-115 crew is thanked for sampling the sediment cores. Some of the cores that were sampled by the crew were used in this study.

Discussions with Dr. Y. Yokoyama and Dr. J. Gosse helped in understanding the ^{14}C age model for the sediment cores.

Dr. M. Gibling is thanked for taking an interest in this study, and for his suggestions. Dr. N. King (Bedford Institute of Oceanography) provided discussion for the Parasound seismic records.

Chloe Younger (Curator of the micropaleontology lab) helped in processing and cataloguing the samples. Tom Duffett (Marine Technician) provided technical assistance in various ways, with shipping of the Vibracorer for the cruise, and scanning seismic records. T. Duffett, Jen and Todd Russel-Houston, Eugene MacDonald, and Elisabeth Levac are thanked for help related to computer hardware and software.

Drs. K. Stattegger, S. Steinke, T. Hanebuth, and I. Fokins are thanked for helping me with accomodation, during my attendance of the AGU conference in San Francisco (2000). Funds received from the Faculty of Graduate Studies, Chair of the Earth Sciences Department (Dr. P. Reynolds), and a small grant received from the Dalhousie Association of Graduate Students, made a poster presentation possible, at the meeting of the Geological Association of Canada, GEOCANADA 2000, in Calgary (2000). A reduced conference registration rate offered by Dr. M. Melchin (St. FX U.) helped in presenting a paper at the 10th Canadian Paleontology Conference in Antigonish, (2000). Travel funds received through the Society of Sedimentary Geology (Dr. Tim Carr, SEPM, U. Kansas), a smaller grant by the Dalhousie Student Union, and accomodation provided by Dr. F. McCarthy, made the presentation of a paper possible at the meeting of the American Association of Petroleum Geologists (AAPG) in Houston, (2002).

Dr. D.B. Scott's operating NSERC grant, and a Dalhousie Graduate Student Fellowship (1997 – 2001) funded this study. Two Graduate Bursaries received from the Faculty of Graduate Studies (December, 2001 and April, 2002) are acknowledged. Andy Henry is thanked for the part time employment made possible with the Ocean Drilling Program.

Cheer and encouragement was provided by the following colleagues that I had met at the Australian National University: Yusuke Yokoyama, Tim Barrows, Joe Cali, Louis Shue, and Dan Sinclair.

My family is thanked for providing support and encouragement throughout the study period. Thanks go to my sister for making my get-away trips to visit her during Christmas breaks possible.

The graduate student community is thanked for their cheer, support, and help. Special thanks go to Heidi McDonald and Joyia Chakungal for being great 4th floor colleagues. Dr. Anna Metaxas is thanked for her cheerfulness and encouragement.

Dr. Dorothy I. Godfrey-Smith is thanked for providing the much needed accommodation during the last stage of thesis writing. Without her help with accomodation, this thesis would not have been completed on time.

CHAPTER I

INTRODUCTION

1.1 The Late Quaternary time interval - Sunda Shelf, southwestern South China Sea

The Late Quaternary is a time interval that has experienced rapid climate changes (Kennett, 1982). Fluctuations in sea level (e.g., Hanebuth et al., 2000; Yokoyama et al., 2000), and sea surface temperature (Kienast et al., 2001; Steinke et al., 2001) in the South China Sea (SCS) have significant impacts on climate dynamics. Modern shelf areas of the SCS were subaerially exposed during the sea-level lowstand of the Last Glacial Maximum (cal BP 17, 000 – 23, 000 years), which may have been as low as 135 – 143 metres (m) below present mean sea level (e.g. Camoin et al., 2001). The lower sea levels allowed extensive drainage systems to develop on the Sunda Shelf (Stattegger et al., 1997). Sea-level rise due to deglaciation inundated the exposed shelf areas, causing rapid changes in the pre-existing drainage systems, as the shorelines migrated landwards.

Sea-level changes during the last glacial-interglacial cycle significantly altered the land-sea configuration in the marginal seas of the western Pacific, where the largest shelf area, the Sunda Shelf, is located (Pelejero et al., 1999) (Figure 1). Recent studies suggest a critical linkage between the hydrological phenomena in the Western Pacific Warm Pool (WPWP) and global climate variability (Yan et al., 1992; Martinez et al., 1997; McGregor

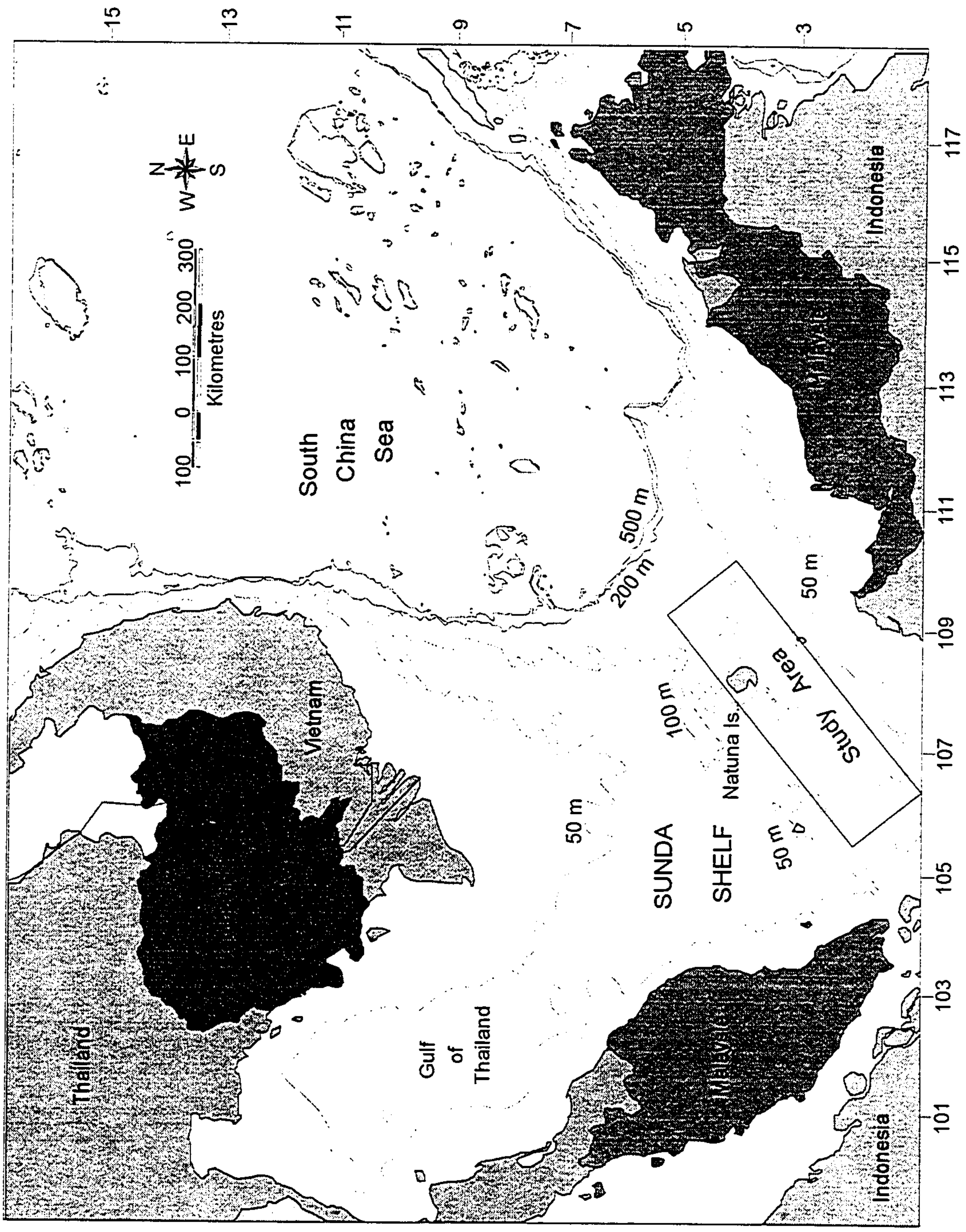


Figure 1. Location of the study area, Sunda Shelf, South China Sea

and Gagan, 2001). Accordingly, the emergence and drowning of the modern Sunda Shelf (paleo-Sundaland), which today comprises roughly 5 % of the areal extent of the WPWP, potentially had a significant impact on the monsoonal transport of moisture, and the hydrological cycles of the western Pacific, and consequently on the global climate (Pelejero et al., 1999). Moreover, the opening and closing of the important oceanic gateways between the western subtropical Pacific and the tropical Indo-Pacific probably led to strong feedbacks and modification of the hydrological conditions of the northwestern subtropical Pacific during the Quaternary. Hence, knowledge about the timing and effects of the drowning of Sundaland is fundamental to the understanding of global climate change during deglaciation (Pelejero et al., 1999).

This study deals with the deltaic response of the Sundaland (modern Sunda Shelf) to Late Quaternary rapid changes, especially sea-level fluctuations. This has direct implications for the coastal response to future sea-level rise, due to natural or anthropogenic effects. Deltaic systems are dynamic environments that respond to climate and sea-level change, which in the case of broad shelves, involves significant migrations of the shoreline as the sea oscillates during glacial/interglacial periods (Woodroffe, 2000). Studying past response of deltaic-estuarine environments provides a basis from which to assess the probable direction of response to future changes in coastlines (Woodroffe, 2000). Furthermore, this study is important because of the following factors: the

Southeast Asian deltaic coastlines are amongst the most heavily populated areas (e.g. Stanley and Warne, 1994), and from a hydrocarbon exploration perspective, paleo-deltas have high potential as hydrocarbon reservoirs, thus, distinguishing the various environments within a deltaic setting is of vital importance for reservoir characterization (Simmons et al., 1999).

1.2 Benthic foraminifera – indicators of the paleoenvironment

The objective of my study was to use benthic foraminifera in combination with techniques being employed by the SONNE-115 working group, such as shallow reflection seismics, sedimentology and ^{14}C chronology, for reconstructing the Late Quaternary paleoenvironment of the paleo-delta on the Sunda Shelf. As examples of a similar methodology, Chivas et al. (2001) demonstrated the Quaternary paleoenvironmental changes of the Gulf of Carpentaria, Australia, showing sea-level/lake-level changes, evidenced by microfossil assemblages, sedimentology, ^{14}C, optical, and thermoluminescence age chronology, in sediment-cores from the area. Yokoyama et al. (2000, 2001) constrained the sea level during the Last Glacial Maximum from the Bonaparte Gulf in northwestern Australia using a combination of microfossil analysis and ^{14}C chronology of sediment cores from the area.

In particular, marginal marine benthic foraminifera have been effectively used for paleo-environmental reconstruction, especially sea-level studies the world over, due to their sensitivity to changes of exposure time in intertidal environments (e.g. Scott and Medioli, 1980; Scott et al., 1990; Scott et al., 1991; Hayward et al., 1999a, b; Yokoyama et al., 2000).

Foraminifera are reliable, cost effective indicators of the paleoenvironment in that they have a good fossilization potential, which permits reconstruction of the environment (Scott et al., 2001). They occur in large numbers, so small samples (<10 cc) usually contain statistically significant populations (Scott et al., 2001).

The study area is ideal for Late Quaternary sea-level studies mainly due to its tectonic stability, as elaborated by Tjia (1980), and more recently by Hanebuth et al. (2000). Moreover, a paleo-delta records a variety of depositional facies changes with the shifting shoreline. Foraminiferal analysis of sediment cores from paleo-deltas provides records of the facies changes associated with the changing boundary conditions.

By combining the results from the foraminiferal analyses with the AMS ^{14}C age dates, sedimentology, and Parasound seismics, this study reconstructed the paleoenvironment of the Sunda Shelf, from subaerial exposure of the delta, to its complete flooding. Such a methodology allowed the revision of the existing Late Quaternary sea-level curve (Hanebuth et al., 2000) for the Sunda Shelf.

1.3 The study area

1.3.1 Location

The Sunda Shelf, one of the most extensive shelf areas in the world, covering an area of 1.8 X 10^6 km^2, lies in the south western part of the South China Sea (SCS) (Tjia, 1980; Stattegger et al., 1997), (Figure 1). It is a flat-lying, semi-enclosed shallow sea, with the Southeast Asian peninsula and the Indonesian archipelago surrounding it along its western margin, and the SCS basin to its east. The straits of Bashi and Taiwan are its marine entrances to the Pacific Ocean via the SCS, while the straits of Malacca, Sunda, and Borneo (Karimata) are its marine entrances to the Indian Ocean (Wyrtki, 1961).

1.3.2 Shelf Physiography

Three regions may be distinguished on the Sunda Shelf: (1) the northern Sunda Shelf, (2) the Singapore Platform in the centre, and (3) the Java Sea Shelf to the south. The Shelf, together with the relatively stable land areas comprising Peninsular Malaysia, the islands of Bangka and Belitung, and the western part of Borneo, is know as Sundaland (Tjia, 1980). The southern part of the Shelf has an average water depth of 40 m; depths of 100 m are reached in its central part, while the adjoining Gulf of Thailand is about 70 m deep in its central part (Wyrtki, 1961). The shelf break is at a depth of 200 m. Land based geological information of Sundaland suggests that the region has been tectonically stable since the Early Tertiary (Tjia, 1980).

1.3.3 Water circulation – Modern system

The Sunda Shelf, and the SCS (the largest marginal basin in the western Pacific) lie under the influence of the Western Pacific Warm Pool, an area with important feedback to the Asian monsoon system (Wang and Wang, 1990). The area is dominated by a typical northeast-southwest monsoonal climate, thus the water currents in the shelf area, and the SCS vary with the wind (Wyrtki, 1961). In the summer, surface waters of the tropical Indian Ocean are driven to the Sunda Shelf from the Malacca and Borneo Straits following the south-westerlies, and flow out into the Pacific Ocean through the Taiwan and Luzon Straits. In the winter, the northeast winds drive the tropical and subtropical Pacific waters together with the colder water of the longshore current to the SCS through the Luzon and Taiwan Straits, across the Sunda Shelf, into the Indian Ocean.

The tidal pattern is predominantly diurnal, with a tidal range from 1.5 – 3 m (Wyrtki, 1961). The sea surface temperatures on the Sunda Shelf range from 20 – 28.8 ° C during the winter monsoon, and from 27 – 29 ° C during the summer monsoon season (Szarek, 2001). The sea surface salinity range is from 32.8 – 34.6 ‰ in the winter, and 33 – 33.8 ‰ in the summer (Szarek, 2001). Salinity values below 33 ‰ are recorded near river deltas throughout the year, whereas values are reduced to 30 ‰ near the mouths of big rivers off Borneo at the end of the rainy season (Szarek, 2001).

1.3.4 Water circulation - Late Quaternary system

During the lower sea level in the Late Pleistocene, the monsoon-driven sea surface circulation was shut down on the Sunda Shelf due to the closure of the Borneo Strait, and the emergence of the Sundaland (Wang et al., 1999). The emerged land supported an active drainage system of the Sunda Rivers (Wyrtki, 1961; Tjia, 1980), (Figure 2). Glacial melting and subsequent rise in sea level led to the inundation of this active drainage system on Sundaland. The Mekong Delta receded to the modern coastline of Vietnam, and has been prograding out on the Shelf again, since the mid-Holocene (Nguyen et al., 2000; Ta et al., 2001). The present day rivers of the east coast of Sumatra and those of the south and west coasts of Borneo generally empty into swampy estuaries. The monsoon dominated continental areas of Southeast Asia and bordering regions are known to deliver large volumes of sediment to the oceans (Milliman, 1999). For instance, rates of sediment removal by the Solo and Brantas Rivers in Indonesia (1200-1600 t km^{-2} yr^{-1}) are amongst the highest anywhere (Hoekstra, 1993a).

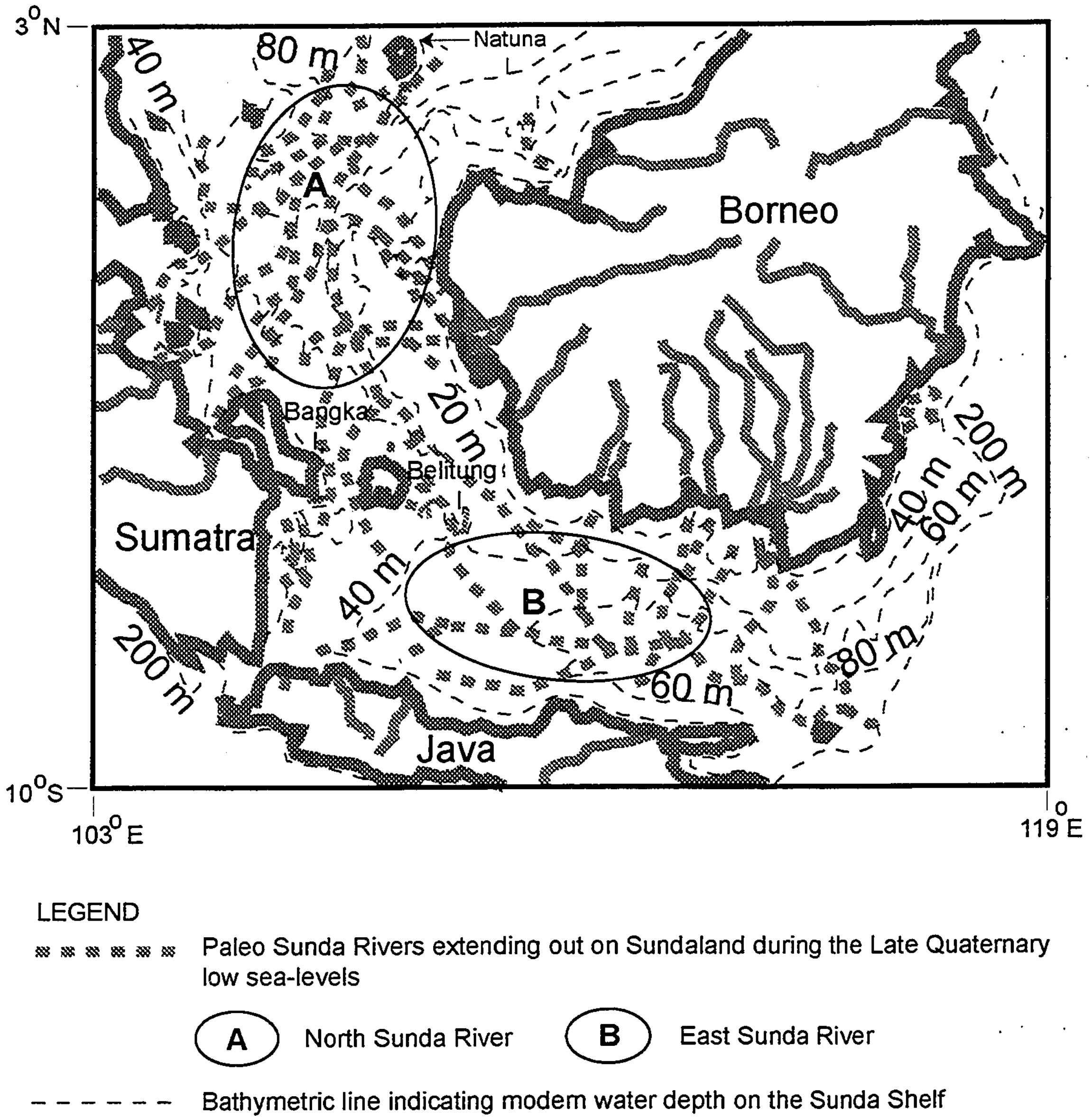


Figure 2. Late Quaternary drainage on Sundaland (modified from Wyrtki, 1961)

CHAPTER II

PREVIOUS STUDIES

2.1 Late Quaternary paleoceanography of the South China Sea – evidence for global teleconnections

Studies from the SCS area showed that this tropical area responded to climate change in the Late Quaternary in a similar way as the other parts of the globe (Broecker et al., 1988; Hanebuth et al., 2000; Kienast et al., 2001; Steinke et al., 2001).

The termination of the Last Glacial Period (Termination 1) in the SCS was demonstrated by an abrupt change in the rate and character of sedimentation (Broecker et al., 1988). The flooding of Sundaland, attributed to glacial meltwater discharge following Termination 1, was also demonstrated by a sudden change in the sedimentation rate of hemipelagic sediments in two cores retrieved from the Sunda Shelf continental slope and the central part of the SCS basin respectively (Pelejero et al., 1999).

In a more recent study, Hanebuth et al. (2000) attributed the flooding of Sundaland to MeltWater Pulse 1A (MWP1A), an event relating to the melting of glacial ice (Bard et al., 1996), following Termination 1. The sea-level curve of the Sunda Shelf following the LGM, constructed by Hanebuth et al. (2000), follows the trend of the sea-level curve obtained from the Barbados coral records (Fairbanks, 1989).

Sea surface temperatures from the SCS, obtained through the alkenone technique, recorded the warming observed in the Greenland Ice Sheet Project 2 (GISP2) ice core record, following the termination of the LGM, as well as the cooling synchronous with the Younger Dryas stadial (Kienast et al, 2001; Steinke et al, 2001). Paleo-monsoonal studies from the SCS showed evidence for strong seasonality during the past two glacial periods, and low seasonality during the interglacials (Wang et al., 1999). Upwelling proxies from the paleo-monsoonal study by Jian et al. (2001) showed that over the last 220, 000 years, the summer monsoon in the SCS area strengthened mainly during interglacial ages, whereas the winter monsoon intensified during the glacial ages. Jian et al. (2001) also showed that the summer monsoon decreased gradually since Marine Isotope Stage 5 while the winter monsoon increased in intensity.

Thus, the Late Quaternary paleoceanography of the SCS has been well documented in recent studies. A special issue of Marine Geology edited by Sarnthein and Wang (1999), entitled 'Response of West Pacific Marginal Seas to Global Climate Change', was dedicated to the paleoceanography of the SCS basin. In contrast, studies documenting the response of the subaerially exposed Sundaland (modern Sunda Shelf) to Late Quaternary climatic fluctuations are relatively few (e.g. Stattegger et al., 1997; Hanebuth, 2000; Hanebuth et al., 2000).

2.2 Late Quaternary drainage and sea-level studies of Sundaland

Previous studies from the Sunda Shelf dealing with the Pleistocene time interval were based on shallow seismic surveys and bathymetric maps (Molengraaff, 1921; Tjia, 1970; Evans et al., 1995), and onshore field studies (e.g. Gupta et al., 1987). Offshore seismic studies identified stratigraphic units and correlated them with equivalent units onshore. These studies concluded that the Sunda craton had been tectonically stable since the Late Cenozoic times.

The study by Molengraaff (1921) revealed that the numerous depth soundings indicated a drowned drainage systems on the Sunda Shelf. This study was later elaborated in the work by Tjia (1980), as follows:

Broad valleys of very low gradients, valley terraces and extensive flat areas upon rises indicated sea-level changes of presumed eustatic character. Other relief features on the shelf included blind channels within and at entrances to narrow straits; often linear, blind valleys crossed the drowned major divide of the Sunda Rivers. Scouring by marine and tidal currents during low sea levels was considered responsible for the development of these blind channels and furrows.

The East Sunda River system occupied the floor of the Java Sea and rose in south Borneo and Java (Fig. 2). In the proximity of both coasts, the connecting segments between the drowned valleys and their onshore upper reaches have been obscured or even obliterated by young sediments. On the whole, however, the relationships between the onshore and the drowned drainage tracts are clear. The East Sunda River debouched at the south end of the Strait of Makassar.

The East Sunda River System was separated from the North Sunda River System by the main drainage divide that ran from Sumatra over Bangka and Belitung to Borneo (Fig. 2). The headwaters of the North Sunda River system were the present major rivers that reached the eastern shore of Sumatra and the west coast of Borneo.

A third large drainage system was interpreted from British Admiralty navigational charts that occupied the bottom of the Gulf of Thailand and the northern Sunda Shelf. The drainage divide between this system and the North Sunda River System was formed by the islands of Tioman, Anambas, and Natuna. Smaller drainage systems were also traced off the Mekong Delta, to the east of southern Sumatra, debouching into the Sunda Strait, and a S-N trending valley to the north of Sarawak (NE Borneo) and named as the Proto-Lupar (Tjia, 1980). Dickerson (1941) proposed to name the river systems of the shelf as the 'Molengraaff Rivers' after G.A.F. Molengraaff, one of the first workers in the study area.

Based on lithologic, foraminiferal, and spore-pollen evidence from punch cores off the east coast of Peninsular Malaysia, and off the coast of Sabah (northwest Borneo) Biswas (1973, 1976) documented three Quaternary cycles of eustatic changes in sea-level on the Sunda Shelf. An accurate age chronology for the sea-level events was not established in his study.

The Holocene sea-level curve of the past 6, 000 years BP, reconstructed from ^{14}C age dates obtained from shoreline deposits of Peninsular Malaysia, indicated a sea-level highstand of +3 to +4 m above mean sea level (Tjia and Fuji, 1992; Hesp et al., 1998). The sea-level curve by Hesp et al. (1998), although tentative, showed that the Holocene post-glacial marine transgression reached present mean sea level around 6, 500 – 7, 000 years BP, rose to nearly 3 m above present, and began to fall to present mean sea level around 3, 000 or less years ago.

The most recent sea-level curve by Hanebuth et al. (2000) constrained the sea-level history of the Sunda Shelf from cal BP 21, 000 – 13, 440 years, through Accelerator Mass Spectrometre (AMS) derived ^{14}C age chronology. Their work also included the sea-level history for the Vietnamese Shelf (northern extension of the Sunda Shelf, which was constrained from cal BP 10, 760 – 13, 155 years. This chronology was obtained using as a carbon source, organic macro-fossils such as mangrove root, plant debris, and wood pieces, as well as bulk sediment, from sediment cores obtained from the central Sunda Shelf, and the Vietnamese Shelf (*Sonne*– 115 cruise, Stattegger et al., 1997). Their study interpreted a slow rise in sea level at the end of the LGM, a rapid rise from cal BP 14, 300 – 14, 100 years, followed by a slowing down of sea-level rise. They attributed the time interval from cal BP 14.3 – 14 kyr. to the glacial meltwater event (MeltWater Pulse 1A, Bard et al., 1996), and to the flooding of the subaerial Sundaland.

Except for the work by Biswas (1976), none of the above mentioned sea-level curves from the Sunda Shelf area were corroborated by microfossil analyses. The interpretation of the sea-level history by Hanebuth et al. (2000), pertaining to delta evolution and flooding of the Shelf, is revised in the present study.

2.3. Foraminiferal studies

To recognize the Late Quaternary paleoenvironments of Sundaland from sediment cores using foraminifera, it was necessary to review the modern distribution patterns of foraminifera in the coastal, and subaerial deltaic zones of the Sunda Shelf coastline. This section is presented in detail in Chapter III.

Studies on the modern distribution of foraminifera in the coastal areas of the Sunda Shelf are relatively few. Moreover, some of these studies could not be used for direct comparison with my results due to incompatible methodology. The main problem arose in that some of the existing studies did not use a finer sieve size (63 – 125 μm) to process their samples, but only examined the coarser size fraction (e.g. Polski, 1959; Waller, 1960). As I elaborate in Chapter IV (Methodology), and show in Chapter V (Results), in many of the sediment samples that I examined for foraminifera, the finer size fraction (63

– 125 μm) contained the bulk of the foraminiferal population. Thus, some of the documented faunal patterns in previous works from the area could not be used for comparison with my study.

Quantitative foraminiferal studies exist from the estuarine areas of Borneo and Malaysia (Dhillon, 1968a; Hofker, 1968; Ho, 1971; Biswas, 1976; Appendix C, Tables), which have been useful as modern analogues for identifying paleoenvironments in the sediment cores in this study. Other studies documenting foraminiferal distribution from shallow coastal areas in the tropical western Pacific region (Graham and Militante, 1959, Appendix C-Table 5), and the coastal areas of the East China Sea (Wang et al, 1985b, c, d), have also been used for comparisons. Some studies on paleo-deltas of the area using microfossils, such as the Late Pleistocene Mekong River Delta (Ta et al., 2001, Table 2), and a study from coastal Cenozoic deposits of Taiwan (Huang, 1964) have also been used for comparison.

2.4 The *Sonne*-115 cruise

The main objective of the German oceanographic expedition, *Sonne*-115 (Stattegger et al., 1997), was a high resolution reconstruction of the post-glacial transgression on the Sunda Shelf and Slope. This was planned to be achieved through the sub-objectives mentioned below. The status of each of these sub-objectives is indicated within brackets:-

1) Reconstruction and comparison of the geometries of the Late Pleistocene and Holocene delta complexes of the Molengraaff and Mekong Rivers, including their fluviatile-marine transition – (addressed in Hanebuth et al., submitted a, b; Hanebuth and Stattegger, submitted; and in this study).

2) Building of a high resolution stratigraphic framework based on AMS ^{14}C dates, and stable isotope stratigraphy – (first half of this sub-objective was achieved through the work of Hanebuth et al., 2000; Steinke et al., submitted).

3) Usage of benthic foraminifera as regression/transgression indicators within the prodelta-area, and examination of their distribution patterns from the prograding phase of the delta system to the end of the transgressive phase – (first half of this sub-objective is addressed in this Ph.D. study, whereas a study of the modern distribution patterns of benthic foraminifera on the Shelf was done by Szarek, 2001).

4) Calculation of accumulation rates of terrigenous sediment and organic matter during the different transgressive stages and examination of their influence on the marine ecosystem – (unaddressed as yet).

5) Testing the sequence stratigraphy concept using a combination of seismic and high resolution stratigraphy, focussing on the development from the ‘transgressive systems tract’ to the ‘maximum flooding surface’ – (addressed in Hanebuth et al., submitted a, b; Hanebuth and Stattegger, submitted).

6) Development of a high resolution sea-level curve for the Late Pleistocene and Holocene of the southwestern SCS – (Hanebuth et al., 2000; revision of their work is demonstrated in the present study).

CHAPTER III

COMPARISONS AND INTERPRETATIONS

3.1 Comparison of previous studies of foraminiferal assemblages from the Sunda Shelf area to this study.

To delineate the Late Quaternary environments of the Sunda Shelf in the sediment cores that were analyzed for foraminifera, a review of the works dealing with the distribution of benthic foraminifera in modern coastal and shelf environment of the Sunda Shelf was undertaken. Distribution patterns from other deltaic areas with similar settings such as a monsoonal climate and a microtidal range were also reviewed.

As mentioned earlier, problems existed with comparing data from this study with previous works, in that the methodology was not entirely compatible. Works by Waller (1960) and Polski (1959) did not include the 63 – 125 um size fraction of the sample in their foraminiferal analyses. The study by Szarek (2001) on the Recent distribution of foraminifera on the Sunda Shelf also did not include the 63 – 125 um size fraction but because the Recent distribution patterns on the Shelf were not examined in detail in this study, comparison was still possible. The study by Graham and Militante (1959) was not quantitative, hence the information on distribution and abundance of foraminifera in the coastal environment of their study area in the Philippines was limited to terms such as 'abundant', 'common', 'rare', and 'very rare'. A common trend observed in all of the previous studies, however, was that in the marginal marine environments of the modern Sunda Shelf coastline the foraminiferal fauna was predominantly benthonic and faunal abundance was low, whereas it increased towards the seaward end (Graham and

Militante, 1959; Dhillon, 1968a; Ho, 1971; Biswas, 1976; Wang et al., 1985a, b, c, d, e). Such a feature is characteristic worldwide of estuarine environments (Scott et al., 2001).

3.1.1 Mangrove Marsh – Estuary Zone

The foraminiferal assemblage from the mangrove swamp-intertidal banks of the Lupar and Labuk Estuaries from Sabah, in East Malaysia (Dhillon, 1968a) was documented to define a zone of coarse resolution, with regards to the degree of tidal influence. The fauna from the Labuk Estuary zone, which was less tidally influenced, was predominantly arenaceous, whereas the fauna from the Lupar Estuary zone, which was more open to marine influence, contained a swept-in mixed calcareous-arenaceous assemblage (Appendix C, Tables 1, 2). The mangrove swamps of Belawan, Sumatra contained an arenaceous fauna as well (Biswas, 1976; Appendix C, Table 3). In the tidal inlets of the Brunei, Limbang, and Trusan Rivers of the Inner Brunei Bay (northern coast of the island of Borneo), with high organic content, fine silt and mud, Ho (1971) documented a purely arenaceous fauna (Appendix C, Table 4). In the Varadero Bay area of Northern Mindoro Bay, Philippines, which had freshwater input from a local river, Graham and Militante (1959) documented a mixed arenaceous - calcareous fauna (Appendix C, Table 5). The arenaceous fauna contained *Haplophragmoides canariensis* and *Trochammina nana*. In their study from the surrounding areas of the Northern Mindoro Bay, which had no significant freshwater input, Graham and Militante (1959) documented a purely calcareous fauna.

The mangrove estuary fauna documented by the various workers along the Sunda Shelf coastline was composed of the common forms such as *Ammobaculites exiguus*, *Ammotium salsum*, *Arenoparrella mexicana*, *Trochammina* spp., *Haplophragmoides* spp., *Elphidium advenum*, *Ammonia beccarii*, *Quinqueloculina seminulum*. An arenaceous fauna similar to the one documented in previous works was identified in specific intervals of the Sunda Shelf cores; accordingly, they are defined herein as a Mangrove Marsh Zone (Table 3).

Similarities in fauna were noted from mangrove swamp areas outside of the Sunda Shelf coastline. A low abundance arenaceous fauna defined the mangrove swamp of the Whangaparapara inlet, Great Barrier Island, New Zealand (Gregory, 1973). The dominant form was *Miliammina pelita,* followed by *Jadammina macrescens*, *Haplophragmoides canariense*, *Trochammina inflata*, and other *Trochammina* spp. A high resolution study from the mangrove-marsh areas of North Island, New Zealand, demonstrated a *Trochammina* fauna as defining the high tide zone of the tidal range of the area (Hayward et al., 1999b). The *Trochammina* fauna was documented to have a world-wide distribution within the narrow vertical tidal range of an area, and shown to be an accurate sea-level indicator, in studies from tropical and temperate mangrove-marsh areas (southern California, Scott et al., 1976; Greece, Scott et al., 1979; Chezzetcook Inlet, Canada, Scott and Medioli, 1980; South America, Scott et al., 1990; Mississippi River Delta, Scott et al., 1991; South Carolina, Collins, 1996; areas of the Pacific rim, Scott et al., 1996; New Zealand, Hayward et al., 1999b; Bermuda, Javaux, 1999).

Previous works from the Sunda Shelf coastline that were discussed above did not specify their sample distribution in the mangrove-swamps. Hence, any existing zonation of the fauna within the tidal range, which may have been an accurate sea-level indicator, was not documented.

3.1.2 Lower Estuary – Bay Zone

The seaward end of the Lupar and Labuk Estuaries, East Malaysia, contained a mixed calcareous-arenaceous fauna (Dhillon, 1968) (Appendix C, Tables 1, 2), as did the seaward part of the Inner Brunei Bay (Ho, 1971) (Appendix C, Table 4). Although the faunal abundance increased towards the seaward end, the total population in the estuaries was low. Out of the lower estuary forms documented in these studies, the following common forms were identified in the Sunda Shelf sediment cores and these intervals were identified accordingly (Table 3): *Ammonia* spp., *Asterorotalia pulchella*, *Bolivina* spp., *Quinqueloculina* spp., *Triloculina* spp., *Cibicides* spp., *Elphidium advenum*, *Nonion* spp., *Pararotalia* sp., and *Pseudorotalia schroeteriana*.

Haig (1993) reported a lagoonal fauna from New Guinea, which contained *Amphimorphina virgula* and *Operculina* sp. Ujjié and Rifardi (1993) documented a mangrove estuary fauna from the Ôura River Estuary of southern Okinawa Island, Japan, which contained *Amphimorphina virgula*, *Pararotalia nipponica*, *Elphidium* spp., *Quinqueloculina* spp., *Bolivina robusta*, *Triloculina* sp., *Spiroloculina* sp., *Textularia* sp., *Ammonia beccarii*, and *Pseudononion japonicum*.

These lower estuary and bay – lagoon forms documented from the vicinity of the Sunda Shelf coastline were identified in specific intervals of the sediment cores, and were thus delineated as a Bay – Lagoon zone (Table 3). The bay area in Northern Mindoro, Philippines, was bordered by fringing reefs, and contained a fauna with larger, symbiont bearing forms (including *Operculina* sp.), in addition to common forms that occurred in other bay areas with clastic discharge (Graham and Militante, 1959; Appendix C, Table 5).

In a study of foraminiferal distribution in the inter-tidal zones of the Sunda Shelf coastline, Biswas (1976) found *Ammonia beccarii* and *Elphidium* spp. to be the commonly occurring forms (e.g. beach zones of Malacca Strait, Singapore, Kudat, Bali) (Appendix C, Table 6). Larger forms such as *Operculina* sp. and *Amphistegina* sp. were common in areas with low clastic discharge.

Sediment intervals bearing fauna such as *Ammonia beccarii* were abundant in almost all of the Sunda Shelf core samples examined. Specifically, *Operculina* sp. and *Elphidium advenum* were common in certain intervals such as in Core 18302-2 (Fig. 5 B), thus these intervals were identified accordingly (Table 3).

In the Bay of Jakarta, there was a difference in fauna, between the part of the bay influenced by river discharge, high organic content and fine silts, and the part of the bay under marine influence (Hofker, 1968). The common forms in the bay comprised *Asterorotalia pulchella, Elphidium batavum, Operculina complanata, Pseudorotalia schroeteriana, Ammonia* sp., and *Quinqueloculina* spp. Forms such as *Bigenerina nodosaria, Textularia* spp., *Spiroloculina communis, Heterostegina* sp., *Amphistegina* sp., and *Operculina complanata* showed a preference for the aerated, marine part of the bay, whereas, *Asterorotalia pulchella* and *Pseudorotalia schroeteriana* showed a preference for the organic rich, muddy substrate influenced by river discharge. Accordingly, specific intervals in the Sunda Shelf sediment cores that comprised a similar fauna were identified as estuarine (Table 3).

Huang (1964) identified estuarine deposits from Miocene formations and Recent sediments of Taiwan based on a faunal assemblage comprising *Ammonia beccarii, A. japonica, Pararotalia ozawai, Pseudorotalia gaimardii, Pseudorotalia schroeteriana* and *Asterorotalia pulchella.*

The commonly occurring forms in the estuaries bordering the East China Sea bore similarity to the estuary zones identified in the Sunda Shelf sediment cores. The Changjian (Yangtze) River Estuary with a tidal range of 2.6 m included a larger variety of *Ammonia* species, whereas, the micro-tidal estuaries contained mainly *Ammonia beccarii* (varieties) and *Elphidium* spp (Wang et al., 1985c). The arenaceous form *Ammobaculites* sp. was documented only from a small microtidal creek on Hainan Island, along with *Elphidium gunteri* and *Quinqueloculina* spp. (Wang et al., 1985c).

A high abundance fauna containing *Ammonia beccarii, Elphidium* spp. and *Discorbis dimidiatus* dominated the inter- to subtidal mud and sand flat environments of the mangrove swamp of the Whangaparapara inlet, Great Barrier Island, New Zealand (Gregory, 1973). *Quinqueloculina seminulum* and other miliolids dominate the beach environment, while forms such as *Cibicides* sp., *Discorbis dimidiatus, Nonion* sp. and

Rosalina sp. were presumed to have been derived from nearby sub-tidal environments (Gregory, 1973).

A mixed benthonic assemblage characterised the intertidal zone of the *Corallina officinalis* (calcareous alga) zone of New Zealand (Hedley et al., 1967). Arenaceous forms included *Haplophragmoides canariense*, *Ammobaculites exiguus*, *Textularia* spp., *Siphotextularia* sp., *Trochammina* spp., *Gaudryina convexa.* Calcareous forms included *Cyclogyra involvens*, miliolids (*Quinqueloculina* spp., *Massilina* spp.), *Bolivina* spp., *Cassidulina* spp., *Discorbis* sp., *Planulinoides* sp., *Rosalina* sp., *Ammonia* sp., *Elphidium* spp. and *Nonion* spp.

3.1.3 Deltaic zone

In the modern coastal area of the Sunda Shelf coastline, this zone may be comprised of inter- to subtidal areas, mangrove marshes, tidal inlets and channels etc. Thus, using the term 'deltaic' for zonation is equivocal. Despite the ambiguity, this term has been used by me in the recognition of certain intervals as 'deltaic' where forms such as *Pararotalia* sp., *Hanzawaia nipponica, Bolivina glutinata*, *Quinqueloculina auberiana* were predominant, accompanied by the presence of planktonic foraminifera.

As discussed above in the 'Lower Estuary – Bay ' section, *Pararotalia* sp. was found to have a distribution in mangrove areas, in the estuary and in the coastal zone closer to the shoreline.

Pararotalia nipponica was documented from the mangrove estuary of the Ôura River in Okinawa, Japan (Ujjié and Rifardi, 1993), the mangrove estuary of Port Darwin, northern Australia (Mitchie, 1987), and from the rocky inter-tidal zone of Shimoda Bay, Japan (Murray, 1991). Studies from other tropical areas, such as the Santos-Sao Vincete Estuarine System of Brazil, documented the distribution of *Pararotalia cananeiaensis* (Debenay, 2001). This form occurred with *Pseudononion atlanticum* and had a maximum abundance in the lower estuary – bay area, where the environment was more protected from longshore currents (Debenay, 2001).

Thus, the abundant occurrence of *Pararotalia* sp. in certain intervals of the Sunda Shelf sediment cores was interpreted to be a deltaic zone (Table 3). This was further corroborated by the presence of other species indicative of an estuarine influence, such as *Hanzawaia nipponica*, *Nonionella turgida*, and *Bolivina glutinata*. (Table 3).

Hanzawaia nipponica in association with *Nonionella* sp. and *Brizalina striatula*, was documented from the Pearl River Delta, Hong Kong (Huang, 2000).

3.1.4 Shelf Zone

Distribution patterns documented from the Sunda Shelf show the absence of planktonic foraminifera up to a water depth of 40 – 50 m (Biswas, 1976). The shallowest surface samples of Szarek (2001), from 69 – 75 m water depth, recorded the lowest total abundance of planktonic foraminifera, compared to the abundance in the outer shelf and bathyal zones (Appendix C, Table 7 A). This is one of the factors that clearly defined the open ocean influenced Shelf assemblage from a coastal zone, in the identification of the paleoenvironments in the sediment cores. Another factor that defined an open ocean type

(Shelf) zone was the high abundance of individuals, as contrasted against a moderate to low number in the coastal paleo-zones identified.

The most recent study of modern foraminiferal distribution on the Sunda Shelf by Szarek (2001) revealed four depth related associations (Appendix C, 7 A, B). Forms of the neritic zone, and some forms of the uppermost bathyal zone defined by Szarek (2001), were documented in specific intervals of the Sunda Shelf cores (Table 3).

3.1.1.6. Mekong Delta Paleoenvironments

In a Late Quaternary paleoenvironmental analysis of a 71 m long core from an incised valley sequence from the Mekong River Delta, using microfossils (Ta et al., 2001; Table 2), the correlation of faunal assemblages with environments was found to be similar to the results from the present study (Table 3).

3.1.1.7. Late Quaternary Paleoenvironments of the Sunda Shelf

A review of the modern distribution patterns along the Sunda Shelf coastline and on the Shelf, led to the following conclusions regarding the shallow coastal environments, and the fauna characterizing them (Table 3). This was the basis for drawing analogies with the Late Quaternary paleoenvironments in the Sunda Shelf sediment cores.

3.1.2. Implications of Foraminiferal Abundance

In general, an anomalous peak in the total abundance of individuals at any given level in the cores is recognized to be indicative of a strong marine influence, or in the general context, a change from the marginal marine setting. Typically high abundance values occur in the upper sediment intervals of most of the cores examined, indicating modern shelf conditions, such as Cores 18277-2 (Fig. 11 B), 18282-2 (Fig. 12), 18300-2 (Fig. 6 B), 18305-2 (Fig. 10 B), 18298-2 (Fig. 9 B). Cores with upper intervals showing low abundances were obtained from erosional areas of the shelf, with higher energy, due to active currents. Such cores were Cores 18316-2 (Fig. 4 B), 18274-3 (Appendix A, Table 9), 18302-2 (moderate abundance in the uppermost intervals, Fig. 5 B).

3.1.3. Implications of Foraminiferal Size Fractions

Benthic individuals were predominantly distributed in the fine (63 – 125 μm) and intermediate (125 – 250 μm) size fractions in all of the Sunda Shelf sediment-core samples examined. Specifically, individuals defining the Mangrove Marsh interval (*Trochammina* fauna) had their maximum distribution in the fine size fraction (Figs. 5 C, 6 C). Similarly, individuals in the Shelf environment (open ocean influenced) were predominantly distributed in the fine size fraction (Figs. 9 C, 10 C). The coastal (estuarine, deltaic) environments were characterised by a varied distribution of individuals in the fine, intermediate and coarse size fractions. Generally, environments which were turbulent, and dynamic, (corresponding with the sandy lithology in the cores) were defined by individual distribution in the coarser size fractions (Figs. 4 C, 5 C, 9 C).

Quiet, sheltered, or less energetic environments were defined by individuals in the fine size fractions (Fig 6 C, 11 C).

PALEOENVIRONMENT	FAUNA
Estuarine channel/tidal river	*Ammonia* spp., *Asterorotalia* spp., *Bulimina* sp., *Brizalina* spp., *Elphidium* sp., *Pararotalia* sp.
Muddy tidal flat/salt marsh	*Pararotalia* sp., *Ammonia* spp., *Quinqueloculina* spp., *Bulimina* sp.
Estuarine-marine	*Ammonia* spp., *Asterorotalia* sp., *Quinqueloculina* spp., *Brizalina* spp., *Pseudogyroidina* spp., *Lagena* sp., *Elphidium* sp., *Triloculina* sp. Brackish water environments within this zone are represented by *Quinqueloculina seminula* and *Ammonia tepida.*
Transitional zone (shallow marine)	Planktonic spp.
Open Bay	*Hopkinsina pacifica*, *Bulimina* sp., *Bolivina* sp., *Brizalina* spp., *Textularia* sp., *Rosalina* sp., *Quinqueloculina* spp., *Fursenkoina* sp., *Fissurina* sp., *Lagena* sp., *Nonion* sp., *Pararotalia* sp.
Pro-delta	Similar as Open Bay assemblage
Delta front	*Ammonia* spp., *Bolivina* spp., *Asterorotalia* sp.,
Sub to inter tidal flat	*Ammonia* sp.
Subaerial delta plain	Barren

Table 1. Late Quaternary Mekong Delta paleoenvironments based on foraminiferal assemblages (Ta et al., 2001)

PALEO-ENVIRONMENT	PALEO ASSEMBLAGES
Shelf (open marine)	Planktonic foraminifera (main indicator) [Surface distribution study done by Szarek (2001) Appendix C, Table 7A, Appendix C, 7B]
Near shore	*Quinqueloculina auberiana*, *Q.* spp., *Bolivina glutinata*, *Textularia* spp., *Bigenerina* sp., *Ammomassilina alveoliniformis*, *Heterolepa subhaidingeri* Planktonic foraminifera
Bay, Lagoon	*Ammonia beccarii*, *Amphimorphina virgula*, *Asterorotalia pulchella*, *Hanzawaia nipponica*, *Pseudorotalia schroeteriana*, *Operculina* sp., *Elphidium advenum*, *Quinqueloculina auberiana*
Estuary (inter, sub tidal)	*Ammonia beccarii*, *Ammotium salsum*, *Asterorotalia pulchella*
Mangrove Marsh (inter-tidal)	*Trochammina macrescens* forma *polystoma*, *Trochammina inflata*, (*Ammotium salsum* – low proportion)
Deltaic	*Pararotalia* sp., *Ammotium salsum*, *Asterorotalia pulchella*, *Ammonia beccarii*, *Hanzawaia nipponica*, *Nonion* sp., *Elphidium advenum*, *Pseudorotalia schroeteriana*, *Bolivina glutinata*, *Nonionella turgida*, *Quinqueloculina auberiana*
Subaerial	Barren

Table 2. Sunda Shelf paleo assemblages and associated paleoenvironments – inferred from drawing analogies from modern distributions, and from results of foraminiferal analyses of the Sunda Shelf sediment-cores.

CHAPTER IV

METHODS

4.1 Data collection

The following methods were employed by the German vessel R/V *Sonne*, during its cruise –115, from Kota Kinabalu, Sarawak, to Singapore (Dec 1996 – Jan 1997) (Stattegger et al., 1997):

1. Reflection seismics

The seismic investigation concentrated on an East-West and North-South transect across the former Molengraaff and Mekong River Delta Systems. Seismic profiling was done using Parasound, Air Gun, and Boomer seismic surveying systems. These profiles were used for selecting core locations that spanned the various zones of the paleo-delta system. Parasound records were obtained on almost all the profiles. A brief description of the Parasound seismic system is attached in Appendix B.

2. Sediment Coring

The sediment coring operation was done by deploying a Giant Box Corer, Multicorer, Vibracorer, and Gravity / Piston corer. Stations were selected according to the following criteria:

(1) equidistant sampling from the seismic transects along the postglacial transgression surface.

(2) Closely spaced samples in the key areas, where shelf unconformities grade into basinal continuous sedimentation.

(3) Stations on pelagic highs with little terrigenous influence were sampled as paleoceanographic reference sites. Parallel to these reference sites, cores were taken within the channel and fan systems to monitor qualitative and quantitative changes in terrigenous sediment fluxes.

More than 40 sediment-cores comprising gravity, vibra, piston, and box cores were thus collected along the two transects. The modern water depths of the coring stations ranged from 34 – 2, 000 metres.

The combined gravity and piston corer comprised a 15 m long gravity coring device and a 26 m long piston coring device. The Rossfelder P-5 Vibracorer, a lightweight corer, was deployed for coring unconsolidated water logged sediment that could not be penetrated with gravity devices. After each core was retrieved, it was labelled, and cut into sections of 1.5 m. Each section was sealed at the top and bottom by a plastic cap. After magnetic susceptibility logging of the core section, it was split longitudinally into the working and archive halves. Colour code logging of the core sections was done using the Geological Society of America Rock Colour Chart. The working section was photographed.

All cores were photographed, described and sampled for micropaleontology palynology, stable isotope analysis, inorganic and organic geochemistry, sedimentology and clay mineralogy on board the ship (Stattegger et al., 1997).

4.2. Laboratory methods

After a review of the Parasound seismic records, core descriptions, and the ^{14}C age dates available at the time, 17 sediment cores that were assumed to span a range of Late Quaternary paleoenvironments were selected for foraminiferal studies (Figure 3; Appendix A, Table. 1). The water depths from which they were raised, range from 71 m - 151 m. About 10 cc sediment samples were collected from these selected cores (following the methodology of Scott et al., 2001), at unequal intervals down-core, based on lithologic changes, using plastic syringes.

Laboratory methods of foraminiferal separation and concentration as documented by Scott et al. (2001) were followed. The sediment samples were washed using a 63 μm sieve. The washed samples were preserved in alcohol. A modified plankton splitter (Scott & Hermelin, 1993) was used to wet split the samples containing large populations of foraminifera; splits usually contained 300 or more specimens. The split sample was

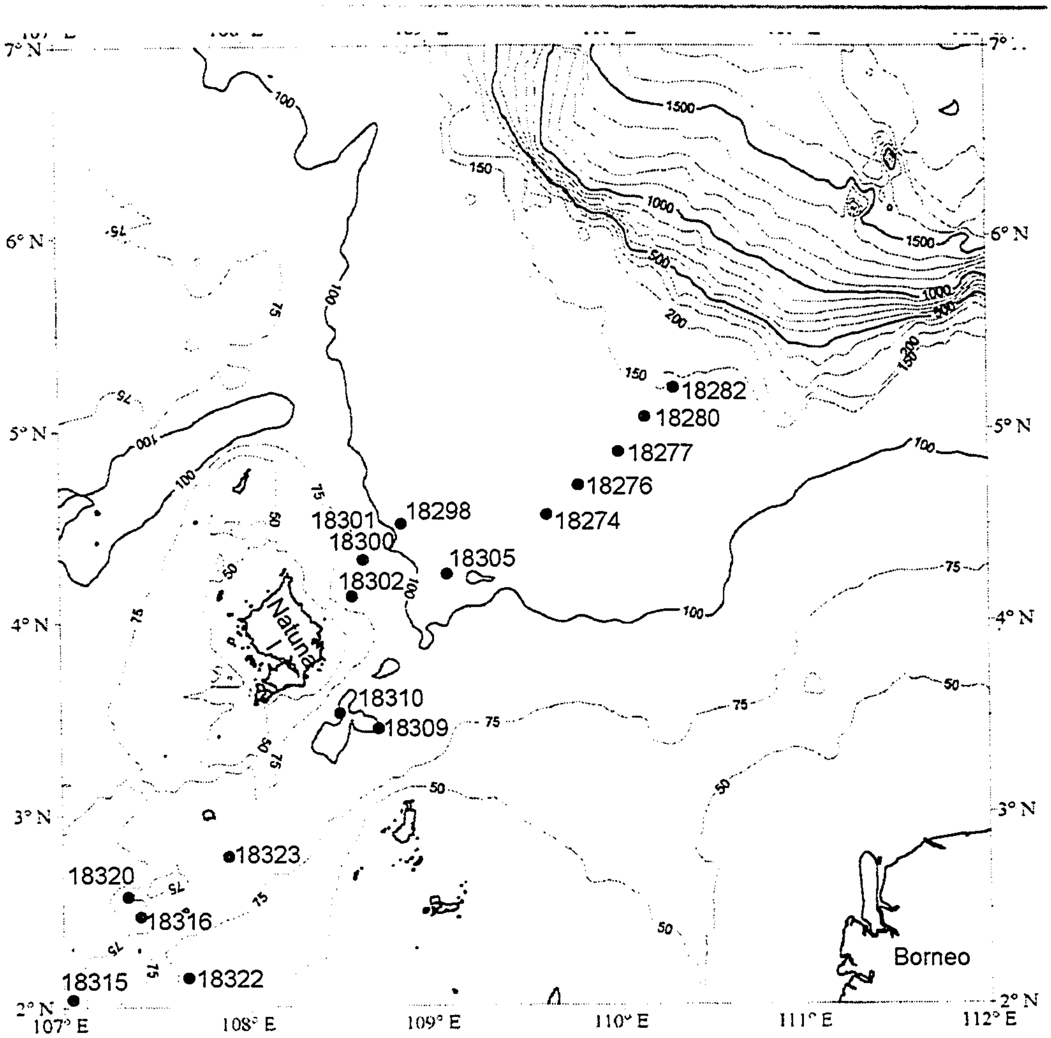


Figure 3. Bathymetric map of the Sunda Shelf showing locations of the sediment-cores used in this study.

then separated into the following size fractions using sieves, such as: > 500 μm, 250 – 500 μm, 125 – 250 μm, and 63 – 125 μm. Each of these sub-sets of a sample was then examined wet, under a reflecting-light microscope. Examining the samples wet allowed the organic inner linings of foraminiferal tests, (and organic walled tests), which were important paleoenvironmental indicators, to stay intact for microscopic examination.

The importance of including the 63 - 125 μm size fraction of the sample was demonstrated by Schröder et al. (1987) who showed that excluding this size fraction caused a significant loss of specimens, including environmental index species, thus creating artificial barren zones in sequences dominated by small-sized species.

Separating the sample into its various size fractions was done to observe any existing trend in the size range of the faunal population, corresponding to a given paleoenvironment. This size range data is presented in the Chapter V (Results). About 300 specimens were identified and counted whenever possible (Scott et al., 2001). Identification was done based on works by Graham and Militante (1959), Matsunaga (1963), Hofker (1968, 1978), Scott et al. (1980), Wang et al. (1985a, b, c, d), Van Marle (1991), Haig (1988, 1993), Jones (1994), Loeblich and Tappan (1994), Huang (2000), Scott et al. (2000), and Szarek (2001).

^{14}C dates were calibrated using the Radiocarbon Calibration Program Rev 4.3 based on Stuiver and Reimer (1993). Delta ^{13}C values were taken from the work by Hanebuth (2000).

CHAPTER V

RESULTS

5.1. Sunda Shelf sediment cores: foraminifera, lithology, and ^{14}C age dates

The results of the foraminiferal analyses of the cores are described below, including description of lithology, foraminiferal content, and the Accelerator Mass Spectrometer (AMS) ^{14}C age date (calibrated, BP). Species with a minimum abundance of 3 % and above were included in the results.

Significant species were represented as discrete percentage abundances in graph format. Percentage abundances of all species are listed in Appendix A, Tables 2 – 16. (unless specified, the term 'individuals' refers to benthic foraminifera). Core locations are shown in Figure 3.

5.1.1. Vibracore 18316-2

This 5. 97 m long vibracore was raised from a water depth of 71 m. The Parasound profile suggested that the core location was from the Late Pleistocene erosional surface. The profile showed a patchy sediment structure and a strong acoustic bottom reflector, characteristic of areas lacking stratified marine Holocene sediments on the Sunda Shelf (Fig. 4 A). A greenish gray clay comprised the lithology of this core, with sandy pockets at the uppermost (0-43 cm) and the lower (400-597 cm) end (Fig. 4 B).

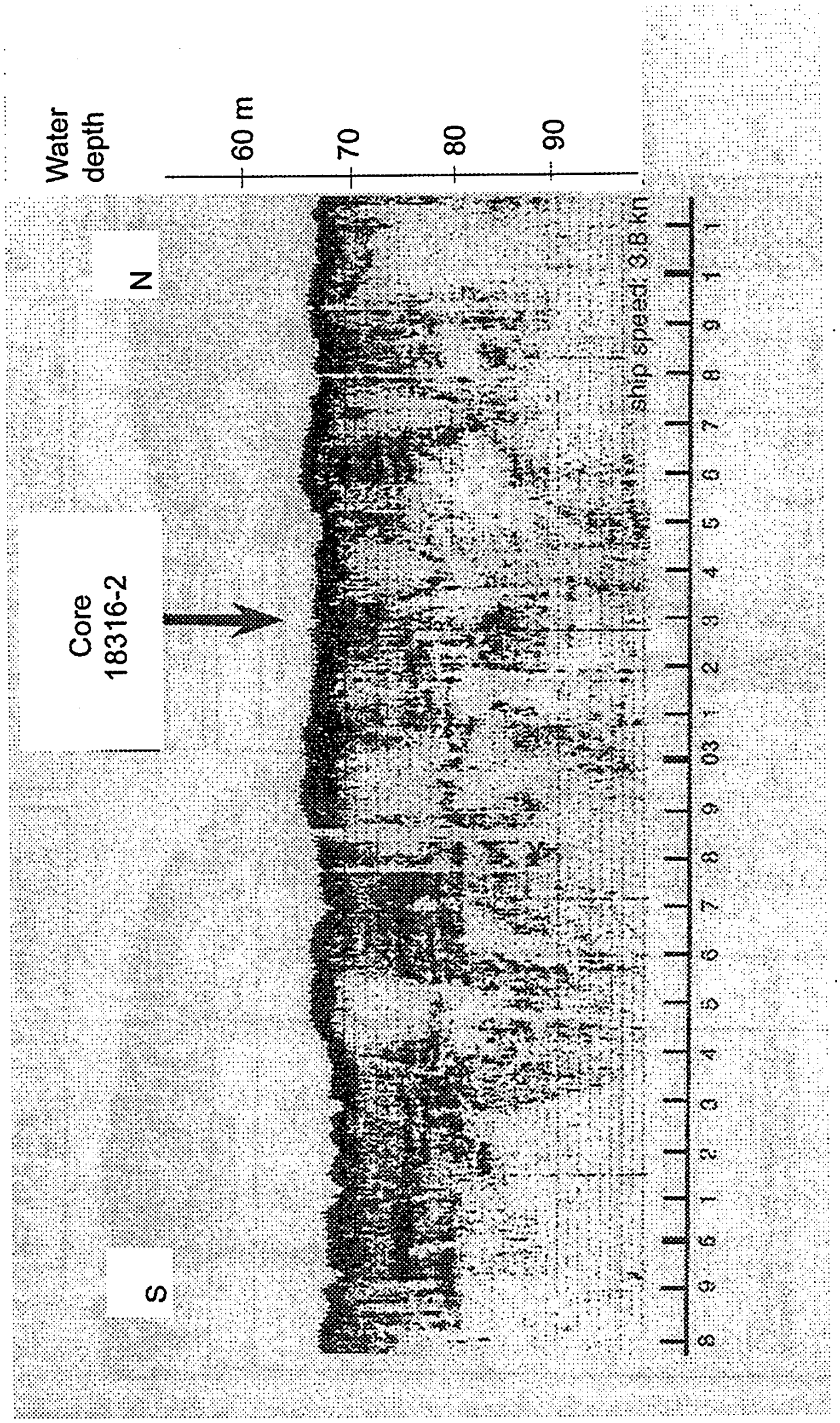


Figure 4 A. Parasound seismic section showing the location of Vibracore 18316-2

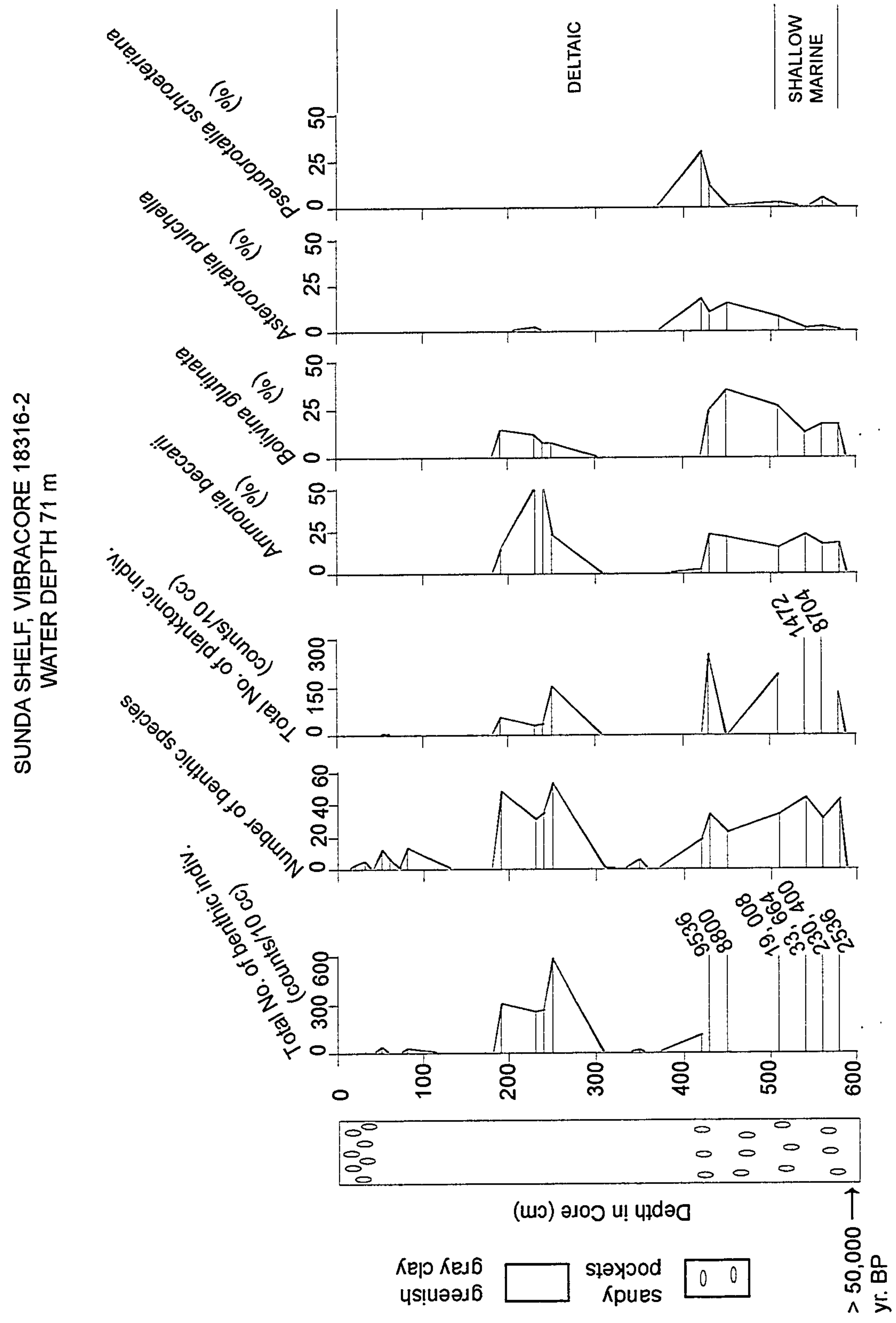


Figure 4 B. Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Vibracore 18316-2.

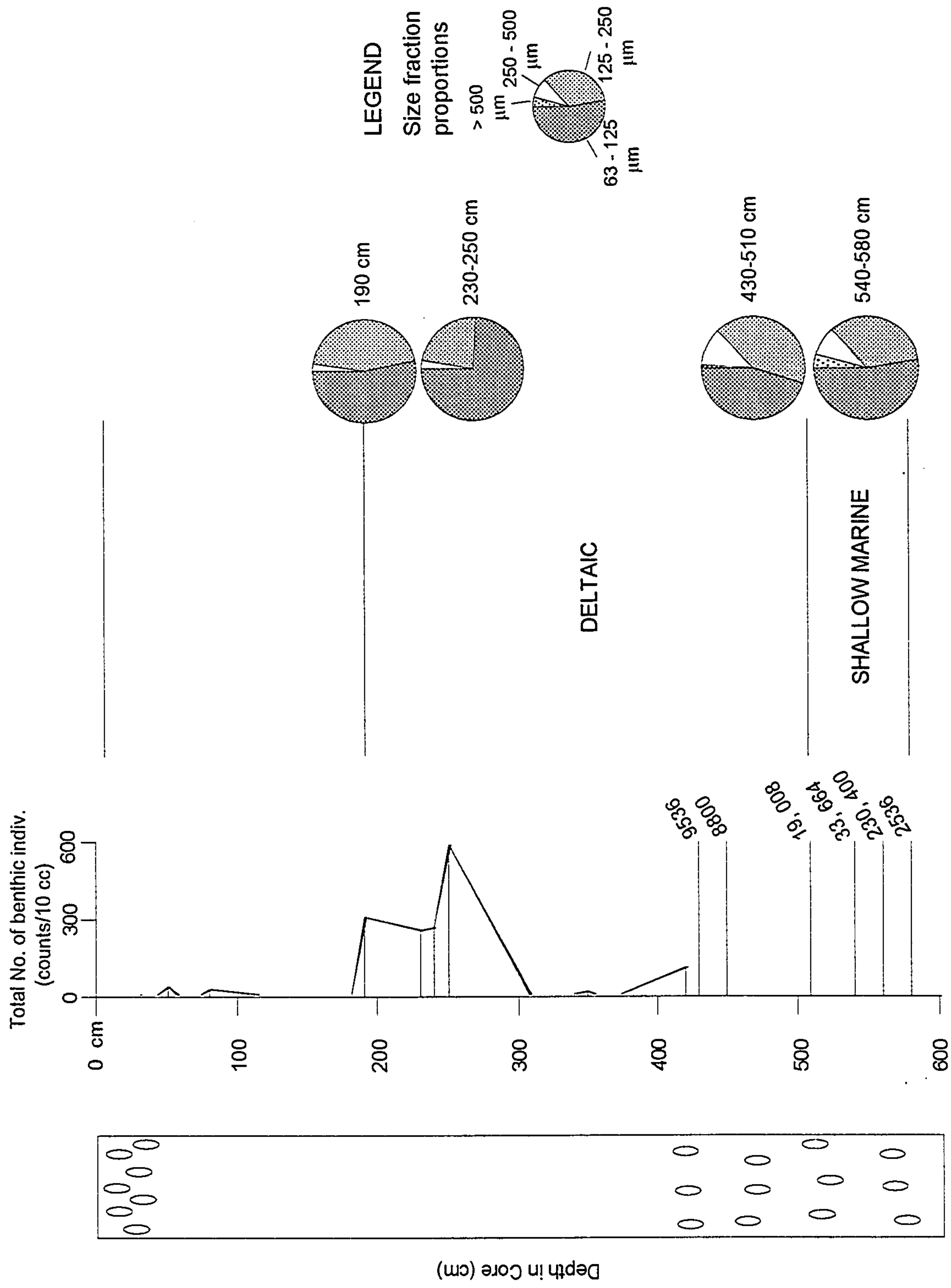


Figure 4 C. Correlation of abundance of benthic individuals with the paleoenvironments within three size fractions in Core 18316-2.

Out of the 32 samples examined from this core, 9 samples were barren, 11 samples yielded very low counts (1 - 40 indiv./10 cc), while 11 samples yielded moderate to very high counts (116 - 230, 400 indiv./10 cc) (Fig. 4 B; Appendix A, Table 2). Foraminiferal abundance was concentrated in clayey sand layers and sandy pockets in the lower half of the core. The fauna was exclusively calcareous.

Predominant species were *Ammonia beccarii* and *Bolivina glutinata*. *Asterorotalia pulchella* occurred in significant proportions in the interval from 420-510 cm, and *Pseudorotalia schroeteriana*, from 370-430 cm.

Secondary species included *Hanzawaia* spp., *Ammomassilina alveoliniformis*, *Cibicides* spp., *Rosalina columbiensis*, *Elphidium advenum*, *Epistominella pulchra*, *Fissurina* sp., *Heterolepa* spp., *Reussella* sp. *Textularia* spp., *Nonion* sp., *Pararotalia* sp., and *Quinqueloculina auberiana*.

In all intervals examined barring one, most of the foraminifera were in the 250 – 125 μm and the 125 – 63 μm size fractions (Fig. 4 C). In the interval from 230 – 250 cm, the majority of individuals belonged to the 125 – 63 μm size fraction.

AMS ^{14}C age date obtained from foraminifera (rotaliids) at 587 cm, yielded an age of > 50, 000 years BP (Table 3 A).

5.1.2. Gravity core 18302-2

Gravity core 18302-2, recovered to a length of 5.98 m, was raised from a water depth of 83 m. The Parasound seismic profile showed the core location to have a wavy surface, indicative of sand waves, underlain by an acoustically transparent layer, which in turn was underlain by a strong reflector (Fig. 5 A). The main lithology of the core comprised clay, with variations in colour, sand, and organic content through the core length (Fig. 5 B).

Out of a total of 25 samples examined for foraminifera from 50-590 cm, 6 were barren, and 19 samples yielded total abundances in the range of 6 – 29, 056 indiv./10 cc (Fig. 5 B; Appendix A, Table 3) . Abundances were highest from 270 – 330 cm, and low from 420 - 590 cm.

Ammonia beccarii was primarily dominant from 50 - 400 cm; other species included *Bolivina glutinata* and *Hanzawaia nipponica*. *Asterorotalia pulchella* was co-dominant from 150 – 400 cm. *Quinqueloculina* spp. was dominant in the uppermost part, and in the interval from 270 – 300 cm. *Amphimorphina virgula, Nonion* sp.(50 – 200 cm), and *Operculina* sp. (150 – 360 cm) were secondarily dominant. *Elphidium* sp., *Nonionella* sp. (50 – 400 cm), and *Pararotalia* sp. (150 – 400 cm) occurred in minor proportions. From 400 – 490 cm, a *Trochammina* fauna was dominant, while *Ammotium salsum* and organic linings were sub-dominant.

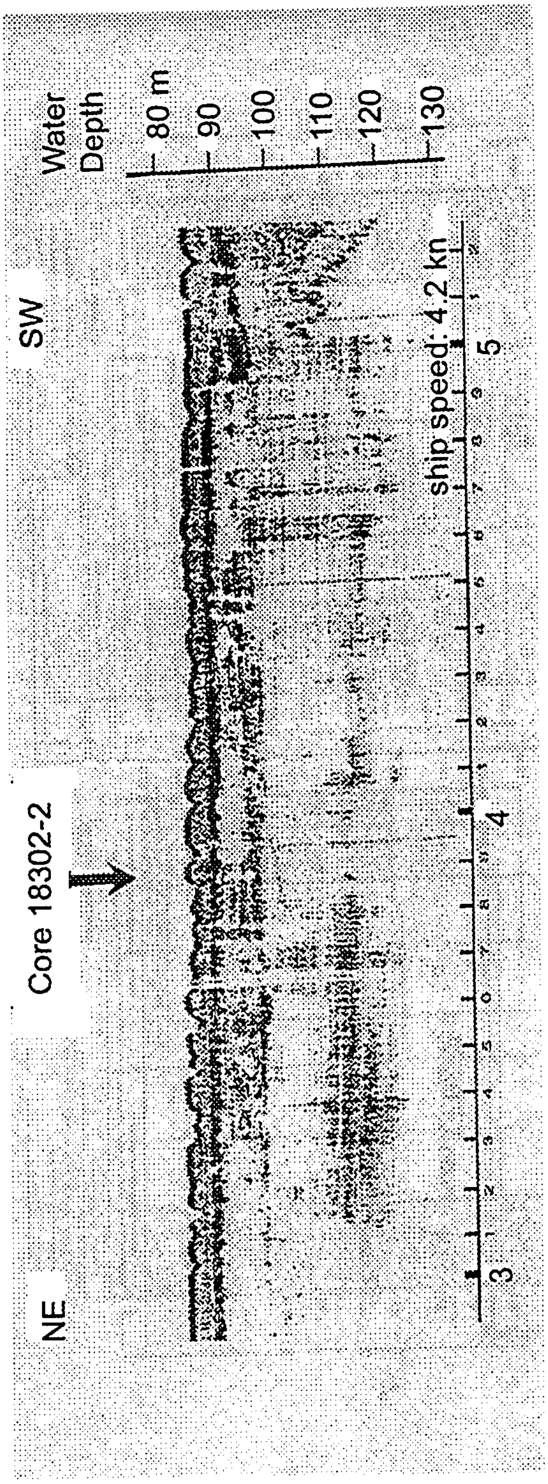


Figure 5 A. Parasound seismic section showing the location of Gravity core 18302-2

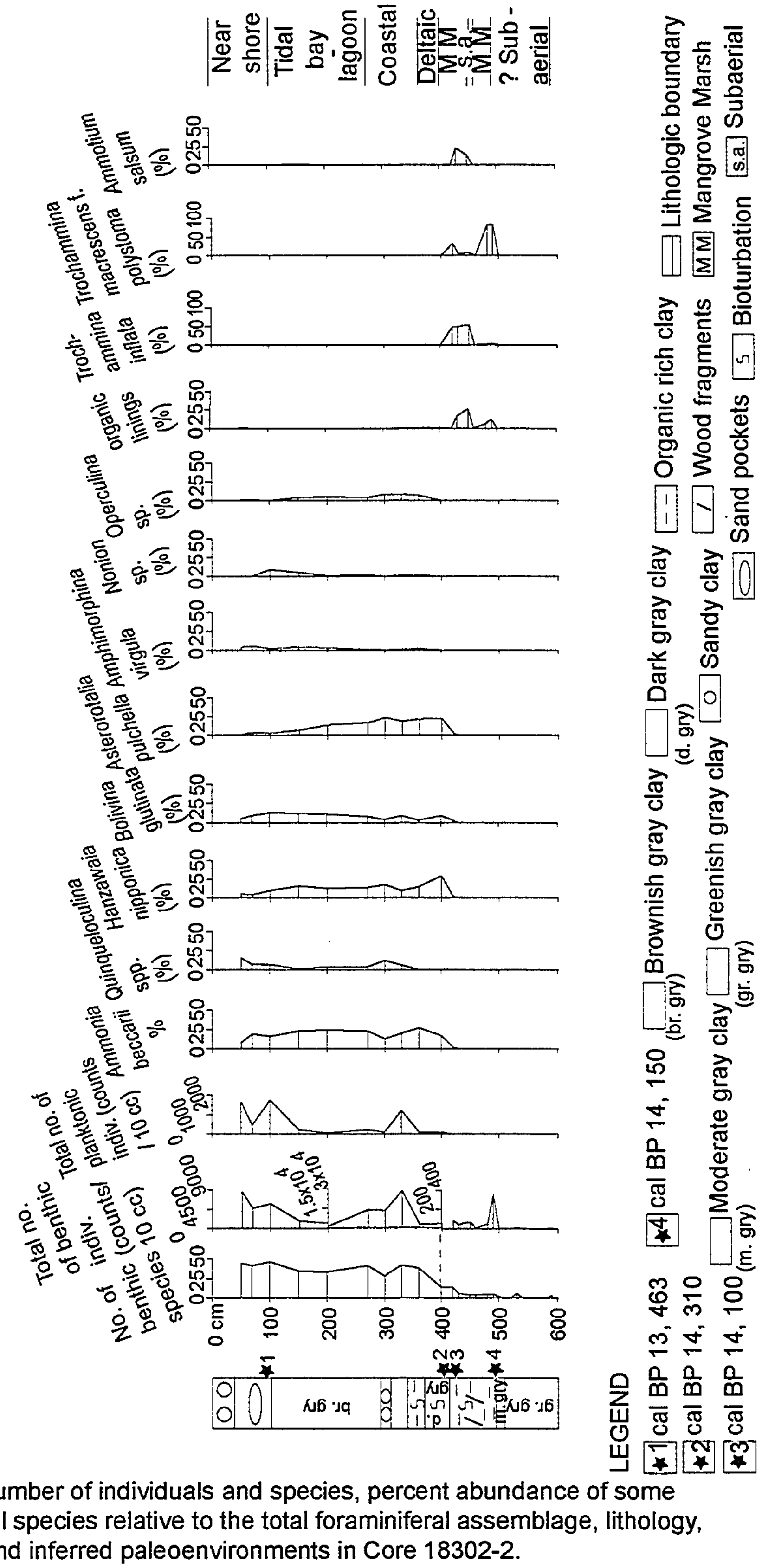


Figure 5 B. Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Core 18302-2.

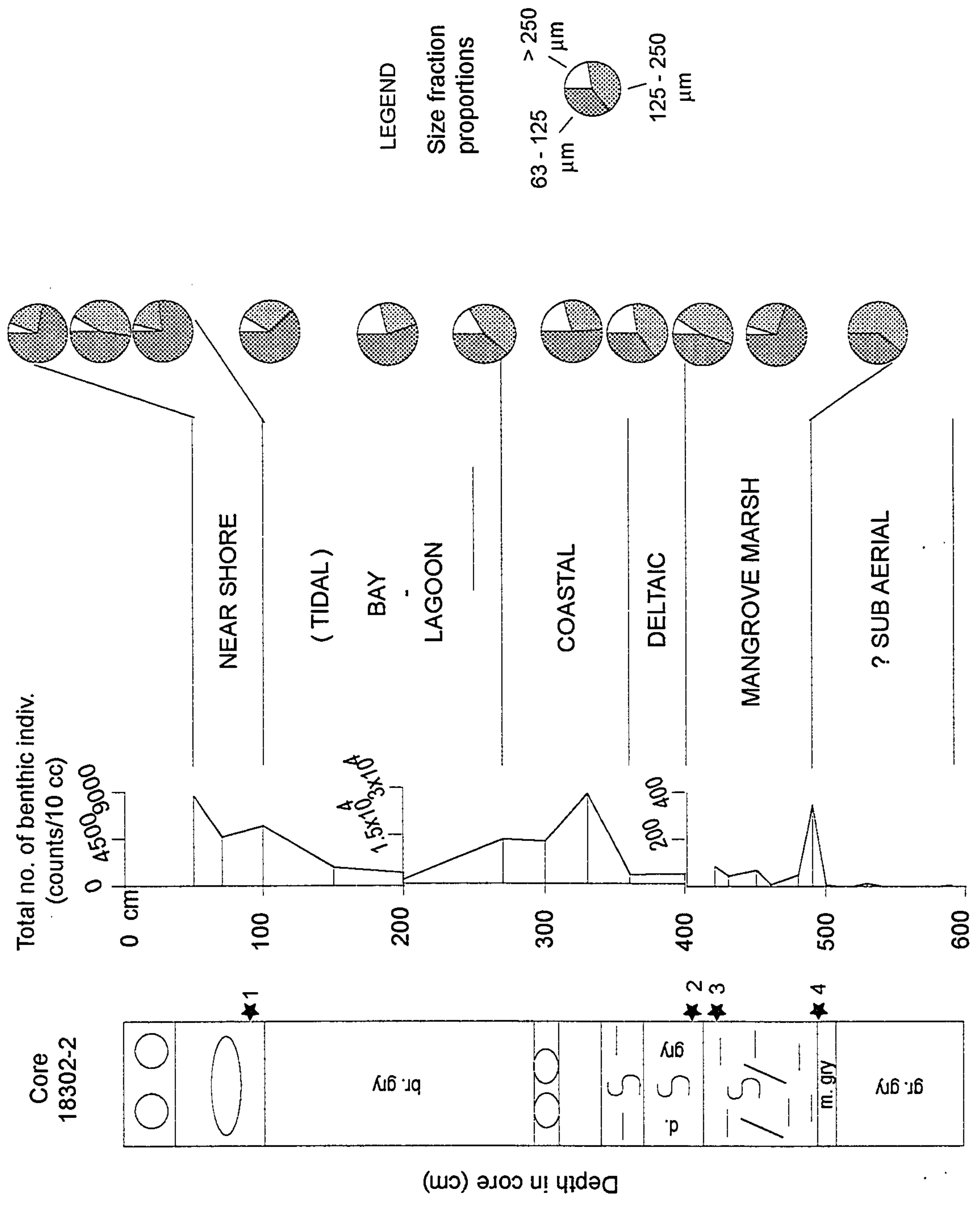


Figure 5 C. Correlation of abundance of benthic individuals with the paleoenvironments within three size fractions in Core 18302-2.

The intervals spanning the central part of the core-length (150 – 400 cm) comprised individuals in the coarser (> 250 μm), intermediate (125 – 250 μm), and the fine (63 – 125 μm) size fractions (Fig. 5 C). Individuals in the upper part of the core (50 – 100 cm) mostly comprised the fine size fraction, while those in the in lower part of the core (400 – 580 cm) comprised the intermediate and fine size fractions (Fig. 5 C).

Four ^{14} C ages were obtained i.e. cal BP 13, 640 yrs. at 85 cm; cal BP 14, 310 yrs. at 410 cm; cal BP 14, 100 yrs. at 415 cm; and cal BP 14, 150 yrs. at 490 cm (Table 3 A).

5.1.3. Vibracore 18309-2

This 5.97 m long core was raised from a water depth of 83 m. The Parasound seismic profile showed the core location to be the eastern shoulder of the Molengraaff Valley. The core lithology consisted of a dark greenish gray clay.

Out of the 4 samples examined for foraminifera, 3 were barren, while 1 sample yielded a total of 2 individuals (Appendix A, Table 13).

A piece of root (*in situ*), AMS ^{14}C age dated from the 178 cm interval, yielded an age of cal BP 14, 340 yrs., while mangrove macro-fibres from the same horizon yielded an age of cal BP 14, 350 yrs (Table 3 A).

5.1.4. Gravity core 18300-2

This 8.85 m long core was raised from a water depth of 91 m. The Parasound seismic profile showed the core location to be the margin of an infilled channel (Fig. 6 A). The lithology of the core comprised clay, with varying colour, sand, and organic content through the core length (Fig. 6 B).

A total of 24 samples were examined for foraminifera, from 30 – 860 cm (Fig. 6 B). Barring the first level examined (30 cm), which yielded very high total abundance (18, 368 indiv. / 10 cc), 12 samples yielded total abundances in the range from 18 – 359 indiv. / 10 cc sediment, while 11 samples yielded very low abundances (0 – 4 indiv. / 10 cc) (Fig. 6 B; Appendix A, Table 4).

A calcareous fauna predominated at 30 cm. Primary dominance was shared by *Bolivina glutinata* and *Quinqueloculina* spp. Secondary dominance was shared by *Ammonia beccarii, Bolivina* spp., *Hanzawaia nipponica, Uvigerina* spp., *Cassidulina* sp., *Bulimina marginata, Epistominella* sp., *Cibicides* sp. (3 %), *Heterolepa praecincta,* and *Textularia* sp. (3 %). Planktonic foraminifera occurred in high abundance only at this level (30 cm). An arenaceous *Trochammina* fauna defined the interval from 30-500 cm. From 500 – 860 cm, the interval was faunally poor.

Individuals in the fine size fraction (63 – 125 μm) dominated the size distribution (Fig. 6 C).

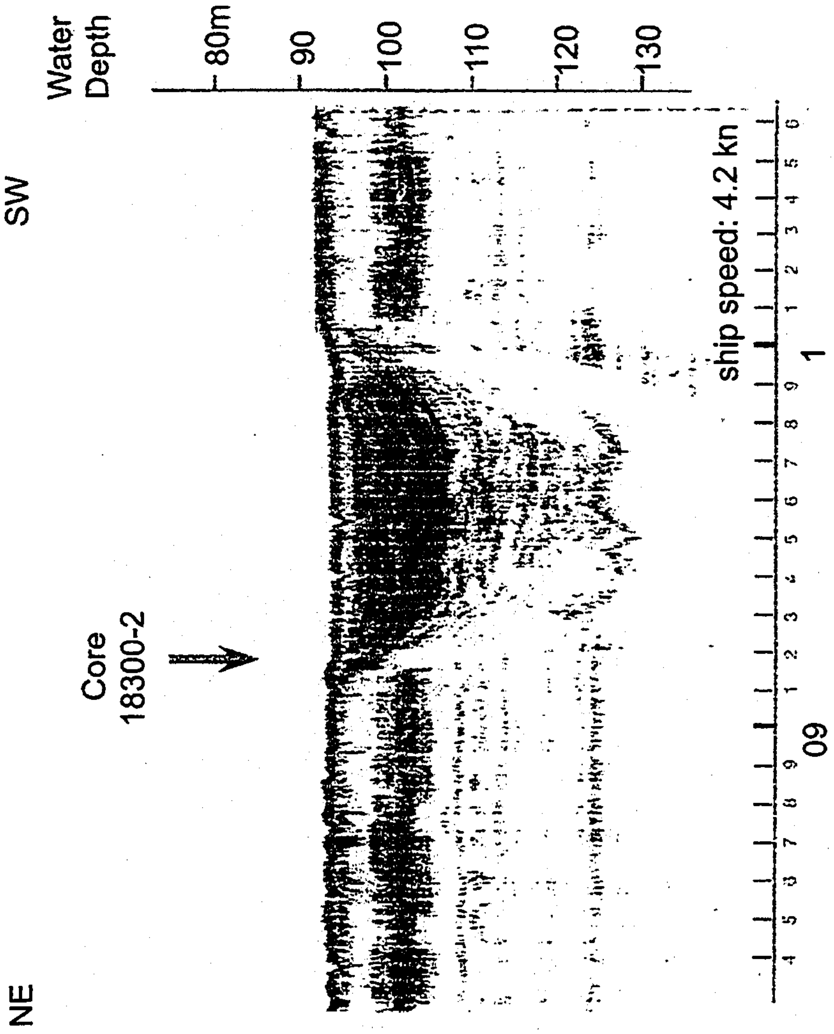


Figure 6 A. Parasound seismic section showing the location of Gravity core 18300-2

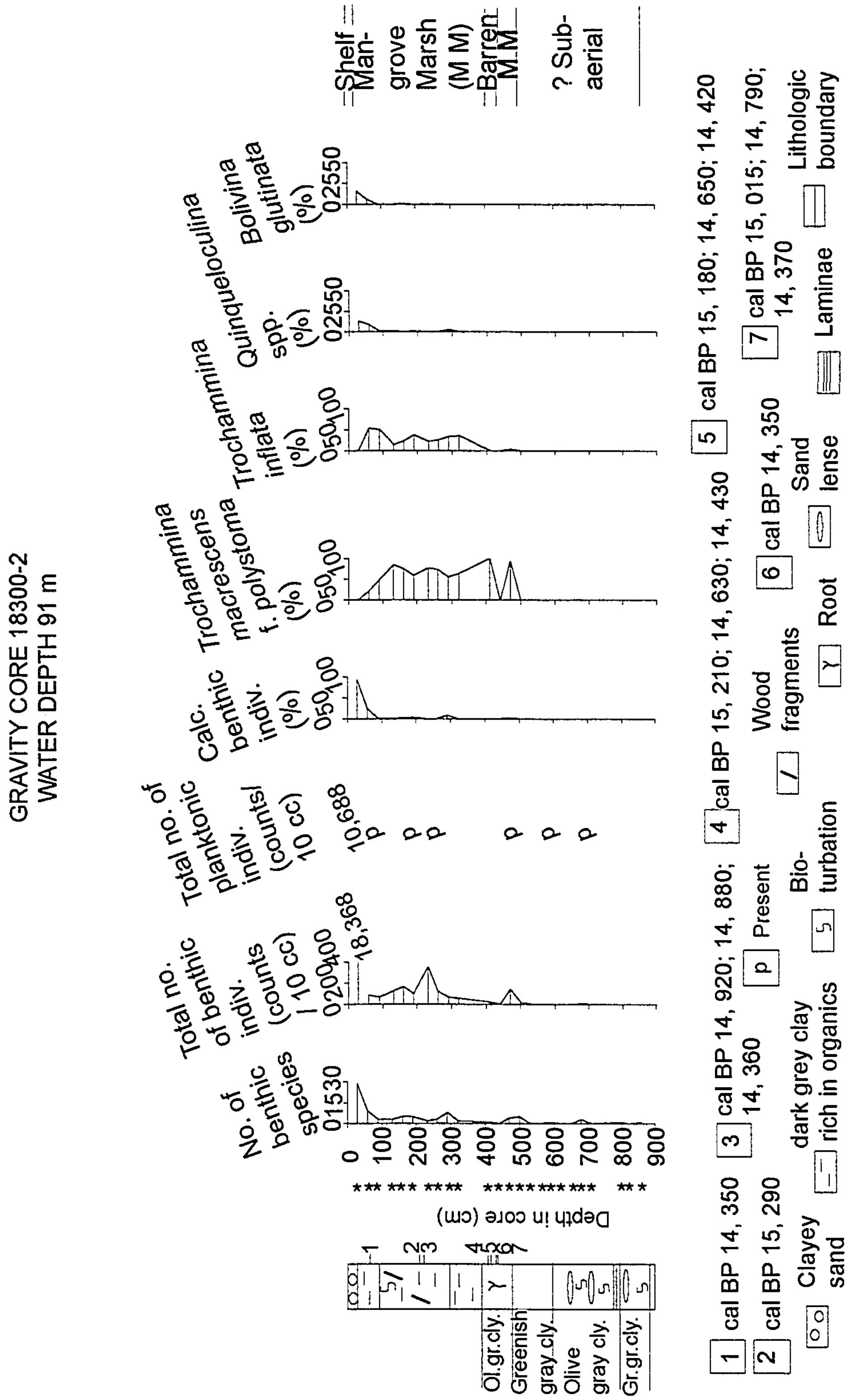


Figure 6 B. Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Gravity core 18300-2.

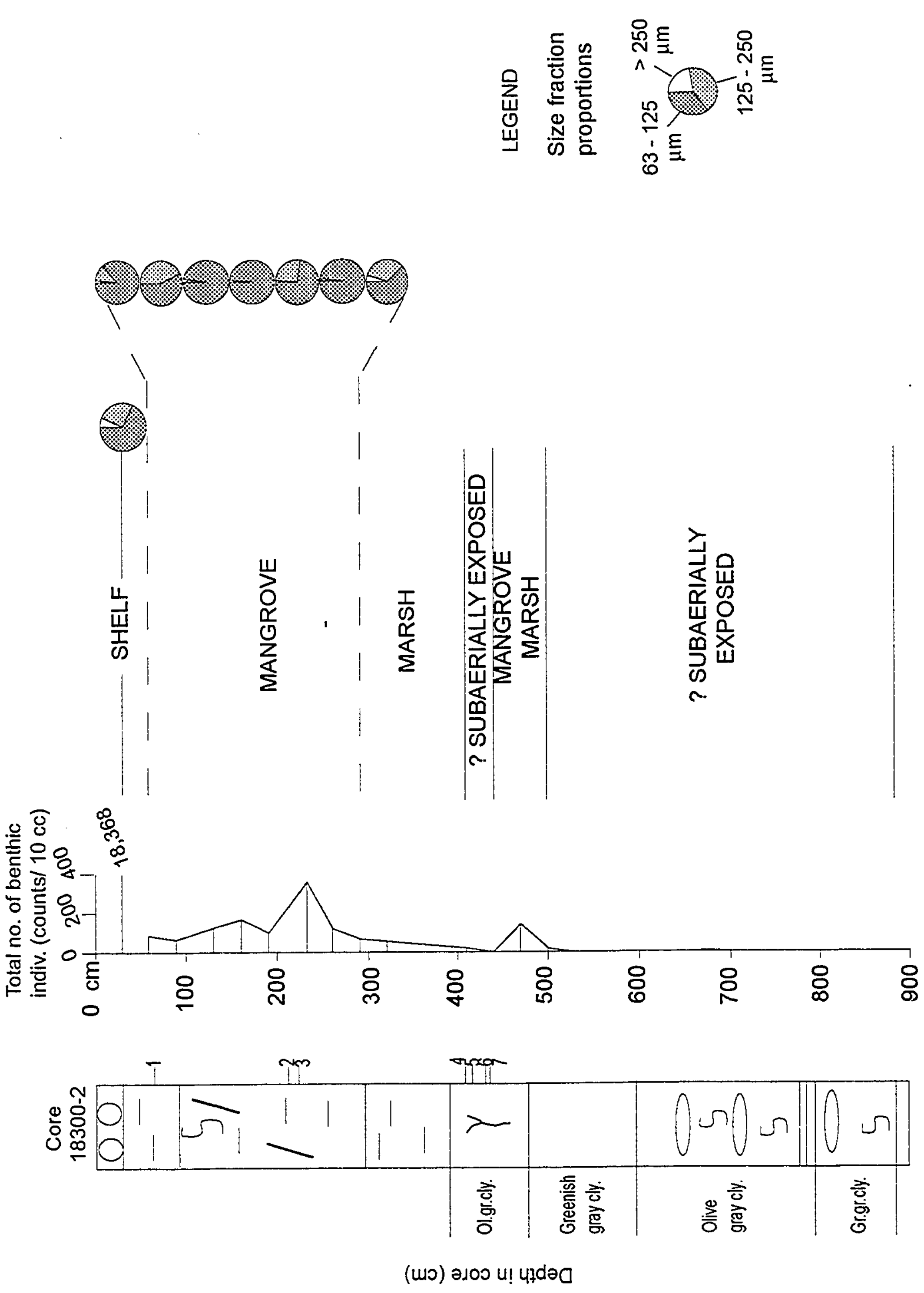


Figure 6 C. Correlation of abundance of benthic individuals with the paleoenvironments within three size fractions in Gravity core 18300-2.

Plant macrofibres, root fibres, and wood pieces from the organic rich clay were AMS ^{14}C age dated to obtain the following ages (Table 3 A): 61 cm: cal BP 14, 350 yrs; 206 cm: cal BP 15, 290 yrs; 223 cm: cal BP 14, 920 / 14, 880 / 14, 360 yrs; 404 cm: cal BP 15, 210 / 14, 630 / 14, 430 yrs; 415 cm: cal BP 15, 180 / 14, 650 / 14, 420 yrs; 428 cm: cal BP 14, 350 yrs; 431 cm: cal BP 15, 015 / 14, 790 / 14, 370 yrs.

5.1.5. Vibracore 18301-2

This 5.82 m long core was raised from a water depth of 93 m. The Parasound seismic profile indicated that the core location was at the margin of an incised channel-fill structure (Fig. 7 A). The lithology of the core comprised clay, with varying shades of colours, and proportions of silt, sand, and organic content (Fig. 7 B).

A total of 6 samples were examined for foraminifera, from 250 – 560 cm (Fig. 7 B). Total abundance was highest at 250 cm (274 indiv. / 10 cc), while it ranged from 1 – 19 indiv. / 10 cc in the rest of the samples. At 250 cm, dominance was established by *Ammonia beccarii*. Secondarily dominant species included *Pararotalia* sp., *Asterorotalia pulchella, Bolivina glutinata, Hanzawaia nipponica, Bulimina marginata, Cassidulina laevigata, Fissurina* sp. From 251-560 cm, a *Trochammina* fauna dominated the interval (Fig. 7 B; Appendix A, Table 5).

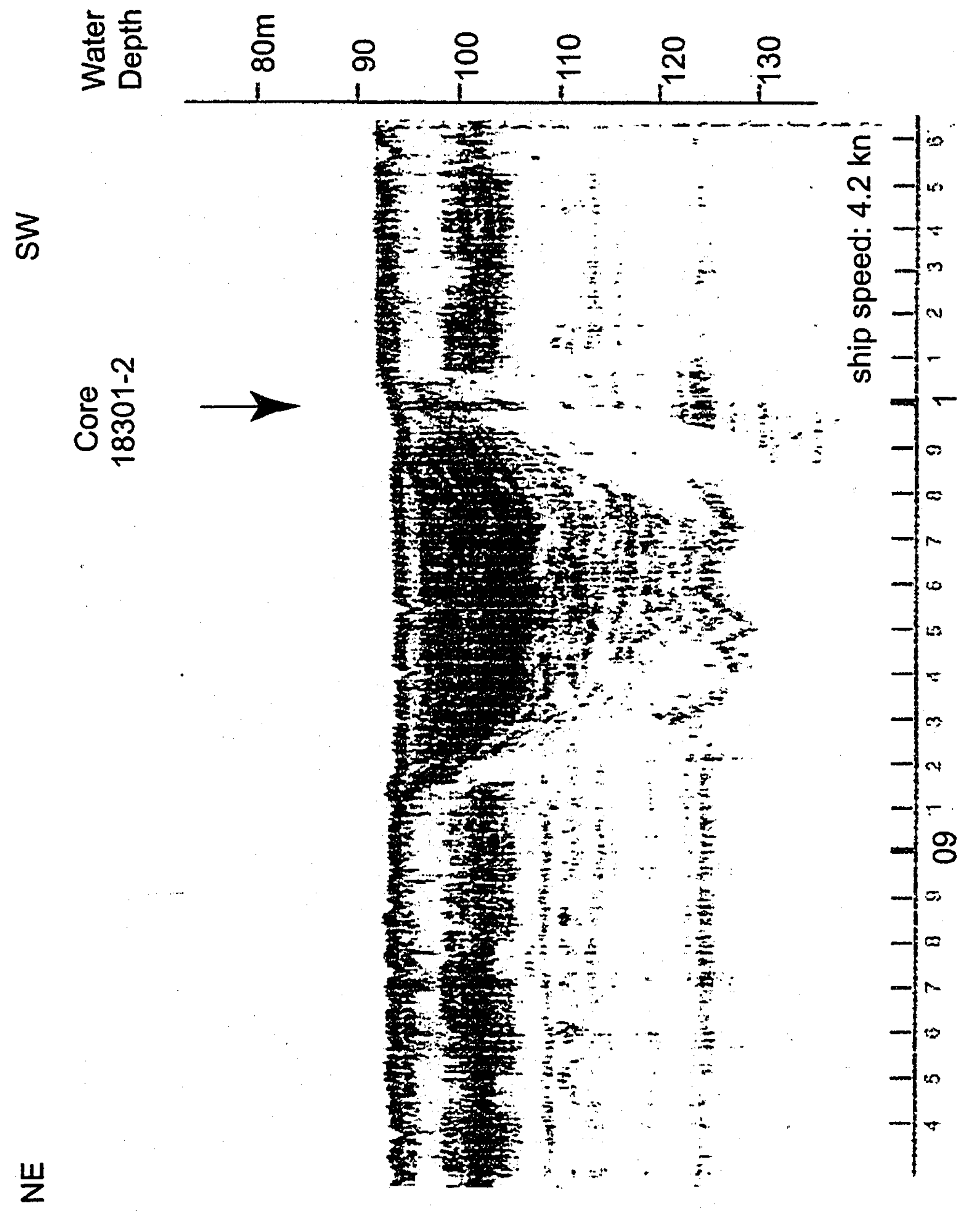


Figure 7 A. Parasound seismic section showing the location of Gravity core 18301-2

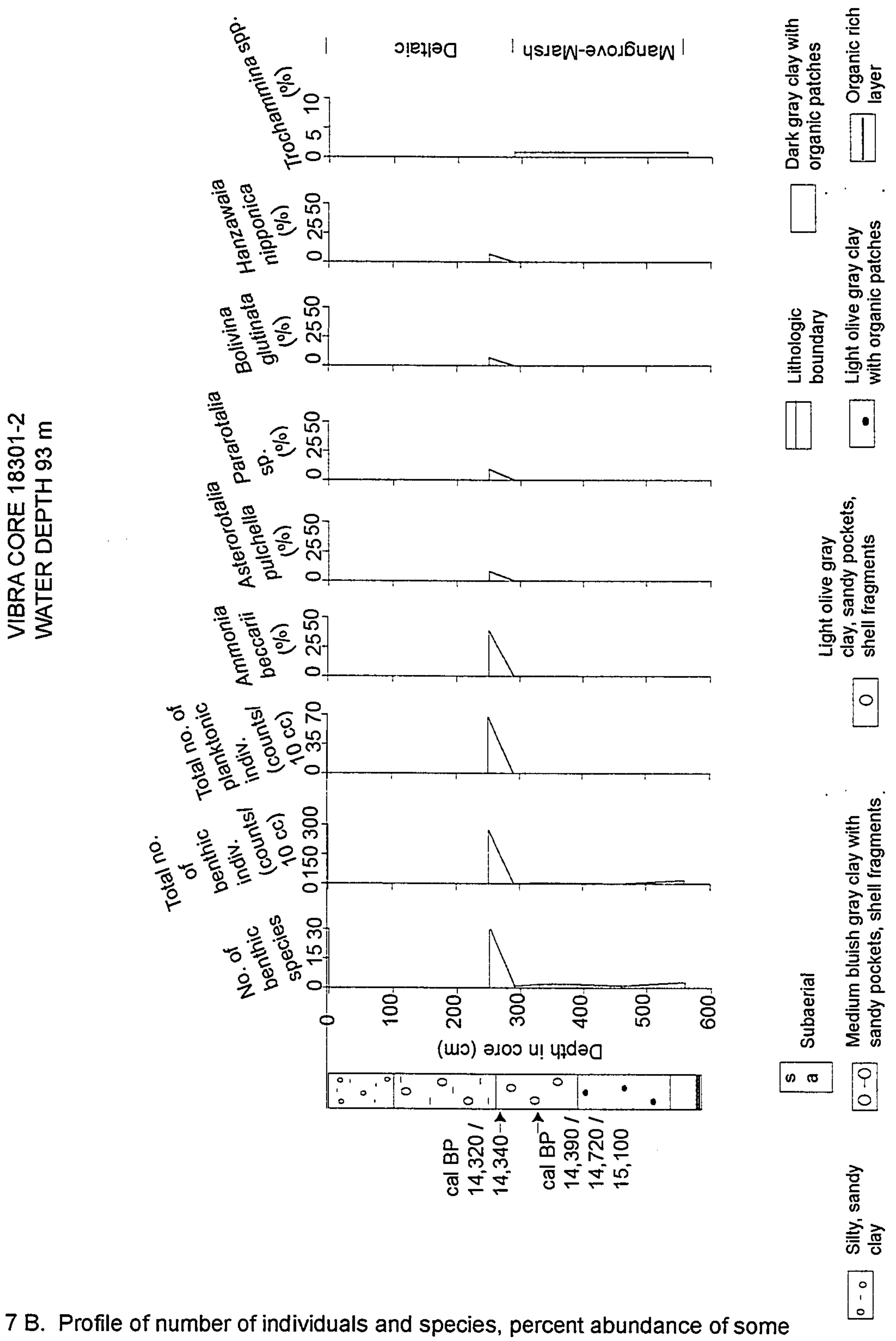


Figure 7 B. Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Vibracore 18301-2.

A piece of wood AMS ^{14}C age dated at 277 cm yielded ages of cal BP 14, 320 / 14, 340 yrs. A piece of wood AMS ^{14}C age dated at 331 cm yielded the following ages (Table 3 A): cal BP 14, 390 / 14, 720 / 15,100 yrs.

5.1.6. Vibracore 18310-2

This 5.68 m long core was raised from a water depth of 100 m (Fig. 8 A). The lithology of the core comprised clay with proportions of sand, water, organic content, and macro fossils (wood fragments) (Fig. 8 B).

A total of 7 samples were examined for foraminifera, from 119 – 567 cm (Fig. 8 B). Two samples yielded total abundances in the range of 113 – 8, 408 indiv. / 10 cc, while the remaining 5 samples were almost barren (Fig. 8 B; Appendix A, Table 6).

At 119 cm, *Quinqueloculina* spp. and *Ammonia beccarii* co-dominated, followed closely in dominance by *Bolivina glutinata* and *Heterolepa* sp. A secondary fauna consisted of *Ammomassilina alveoliniformis*, *Asterorotalia pulchella*, *Cassidulina* spp., *Bulimina marginata*, *Textularia* spp, *Uvigerina* sp, *Cibicides* sp, *Astrononion* sp., *Triloculina* spp. Planktonic foraminiferal abundance was relatively high (2, 168 indiv./10 cc).

From 119-151 cm, *Ammonia beccarii* and *Bulimina marginata* co-dominated, followed closely by *Hanzawaia nipponica*, *Bolivina* spp. (mainly *B. glutinata*), *Heterolepa* sp., and *Asterorotalia pulchella* in dominance. Secondarily dominant fauna

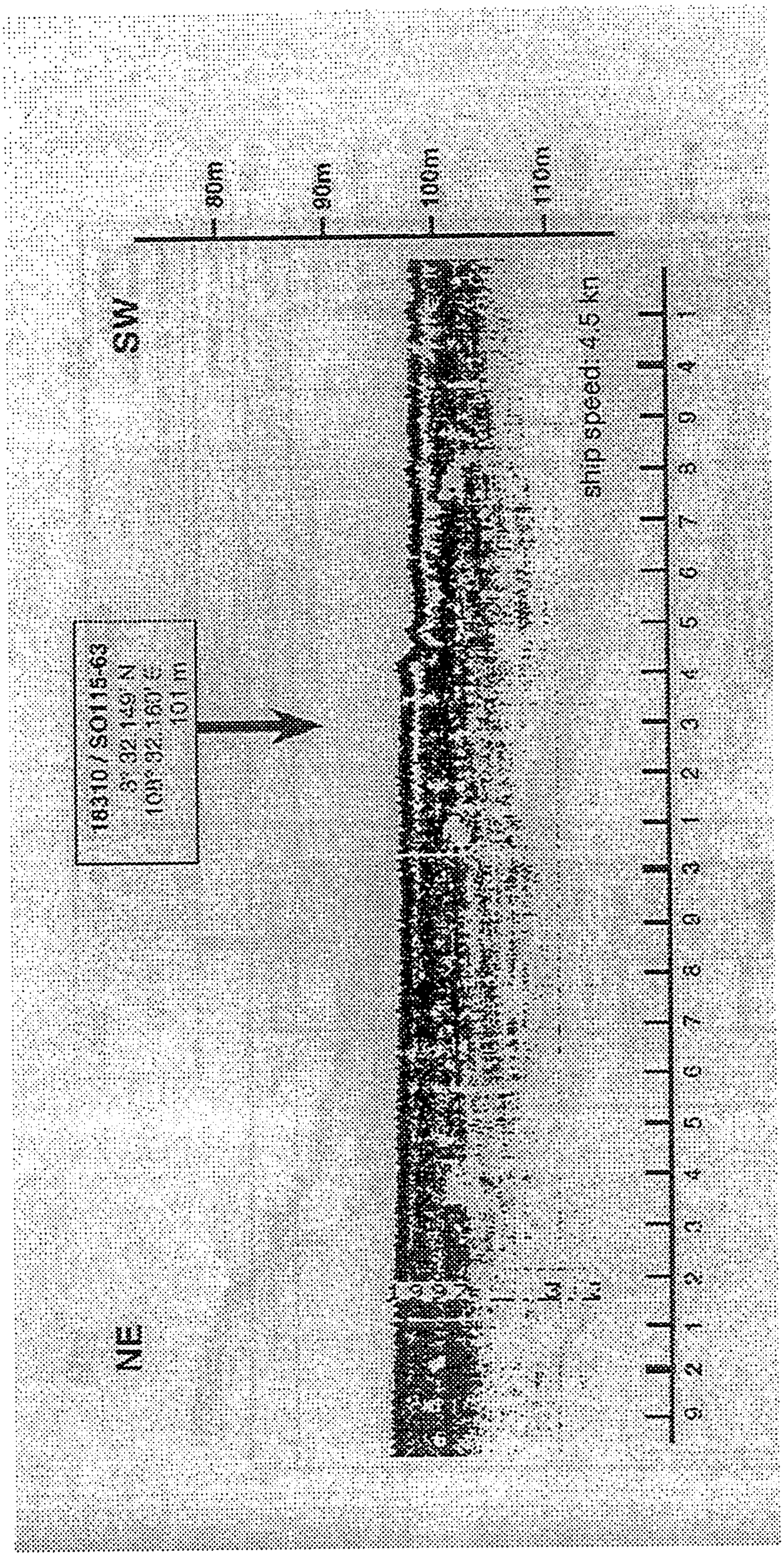


Figure 8 A. Parasound seismic section showing the location of Gravity core 18310-2

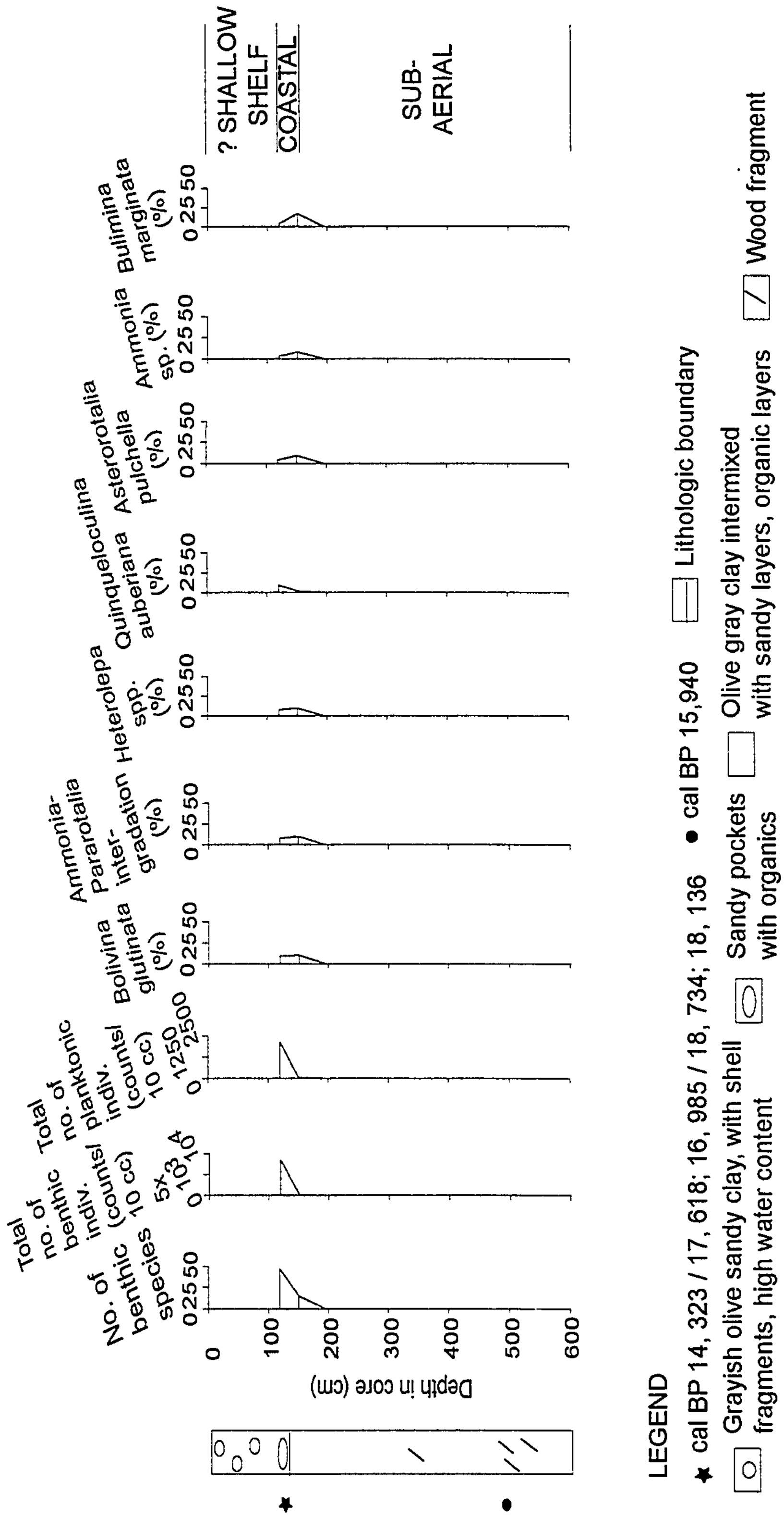


Figure 8 B. Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Vibracore 18310-2.

included *Pseudorotalia schroeteriana*, and *Uvigerina* sp. Planktonic foraminiferal counts were low (46 indiv./10cc). The foraminiferal tests, although well recognizable in morphology, bore signs of corrosion, indicating subaerial exposure, or reworking. The core interval from 151-568 cm (core bottom) was barren of foraminifera.

The following ages were obtained at the interval from 121 – 123 cm by AMS ^{14}C age dating organic matter (Table 3 A): cal BP 14, 323 ; 17, 618; 16, 985; 18, 734; 18, 136 yrs. An age of cal BP 15, 940 yrs. at 490 cm was obtained from a piece of wood, using conventional ^{14}C dating technique.

5.1.7. Vibracore 18298-2

This 5.87 m long core was raised from a water depth of 102 m. The Parasound seismic profile showed the core location to be at the margin of a channel-fill structure (Fig. 9 A). The lithology of the core consisted of clay with varying proportions of sand and organic matter (Fig. 9 B).

From 150 – 587 cm, 18 samples were examined for foraminifera (Fig. 9 B). Total abundances ranged from 106 – 12, 832 indiv. / 10 cc, while 4 samples yielded low abundances from 0 – 26 indiv. / 10 cc (Fig. 9 B; Appendix A, Table 7).

Throughout the examined intervals, dominance was shared by *Ammonia beccarii*, *Bolivina glutinata*, *Asterorotalia pulchella*, *Hanzawaia nipponica*, and *Quinqueloculina* spp. Species establishing secondary dominance included *Pseudorotalia schroeteriana*, *P.*

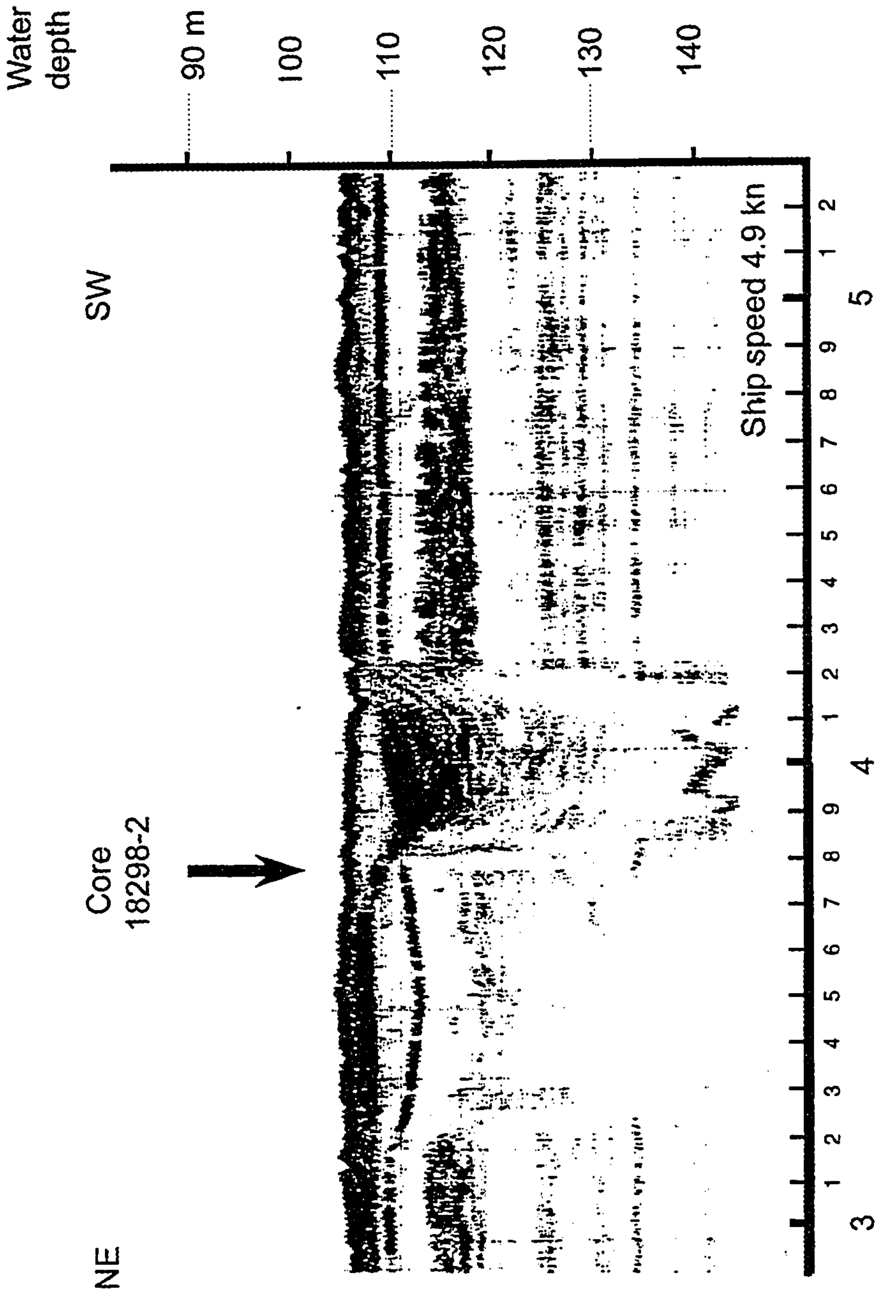


Figure 9 A. Parasound seismic section showing the location of Vibracore 18298-2

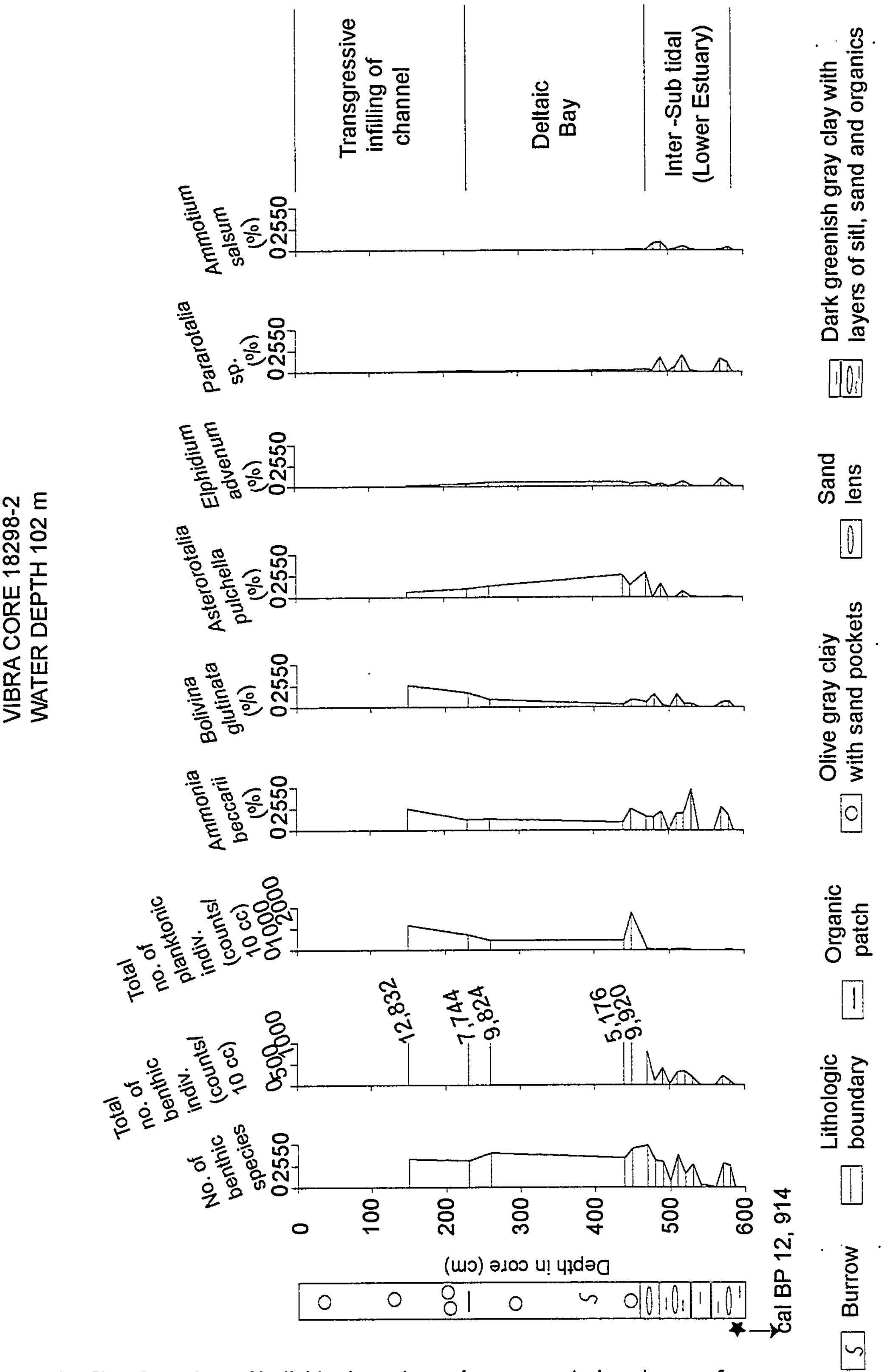


Figure 9 B. Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Vibracore 18298-2.

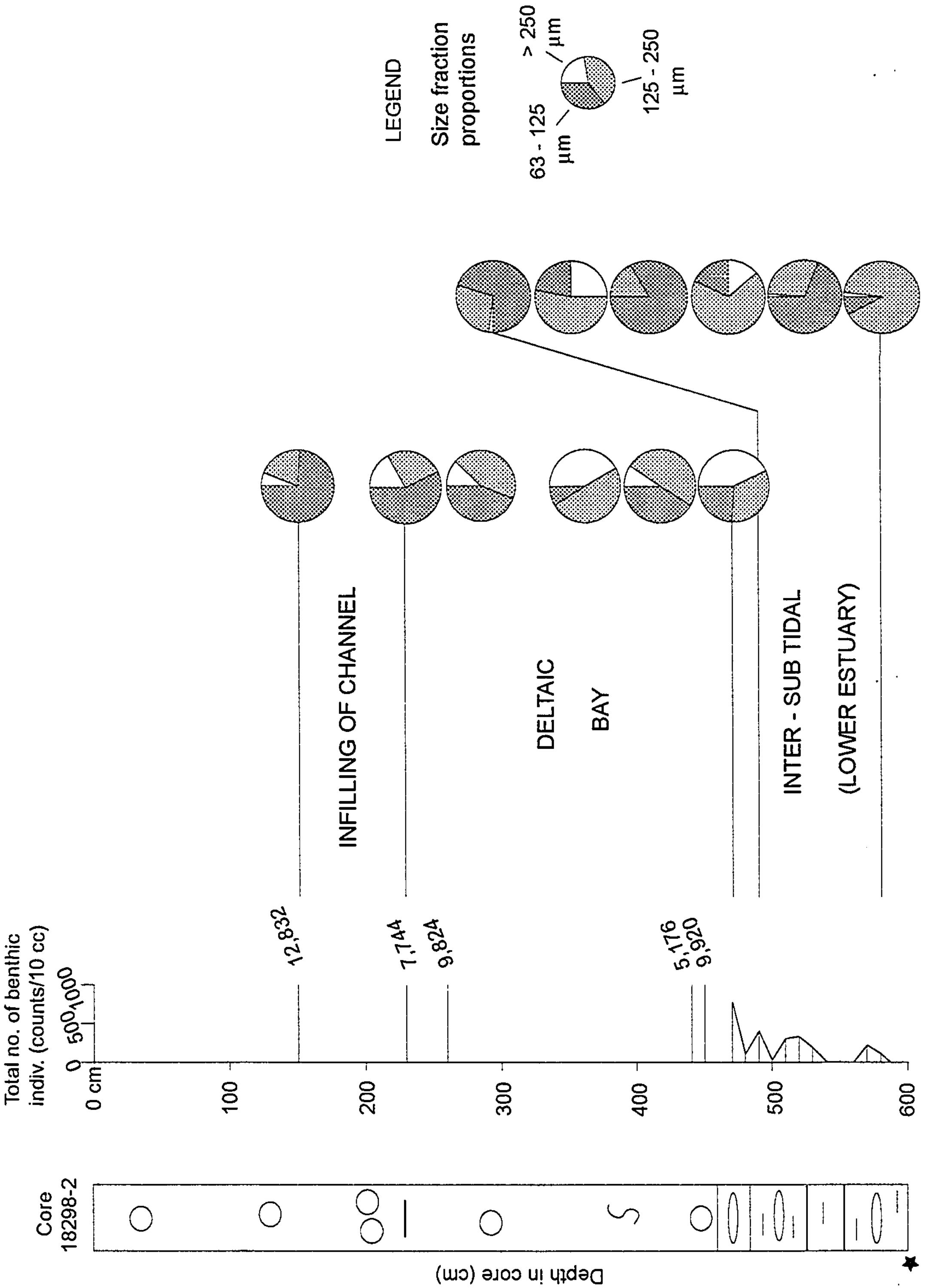


Figure 9 C. Correlation of abundance of benthic individuals with the paleoenvironments within three size fractions in Vibracore 18298-2.

indopacifica, Elphidium spp. Specifically from 490 – 587 cm, *Pararotalia* sp. and *Ammotium salsum* occurred in significant proportions. Planktonic foraminifera occurred in significant proportions from 150 – 450 cm.

Individuals showed varied distribution in size fraction throughout the core length (Fig. 9 C). In the upper part of the core (150 - 260 cm), individuals occurred in the fine size fraction (63 – 125 μm) in dominant proportions; in the central part of the core (260 – 490 cm), the intermediate (125 – 250 μm) and coarse (> 250 μm) fractions were dominant, and in the bottom part of the core, the size distribution, although varied, was concentrated in the intermediate and fine size fractions.

An AMS ^{14}C age of cal BP 12, 910 years was obtained from the bottom of the core (598 cm) by dating a foraminiferan specimen (Table 3 A).

5.1.8. Vibracore 18305-2

This 5.14 m long core was raised from a water depth of 109 m. The Parasound seismic profile showed the core location to be at the shoulder of a large channel-fill structure (Fig. 10 A). The lithology of the core comprised an upper sandy unit, and a lower clayey unit with some organic rich layers (Fig. 10 B).

Five samples were examined for foraminifera, from 124 – 401 cm (Fig. 10 B). Two samples (124 – 183 cm) yielded total abundances from 1, 744 – 19, 328 indiv. / 10

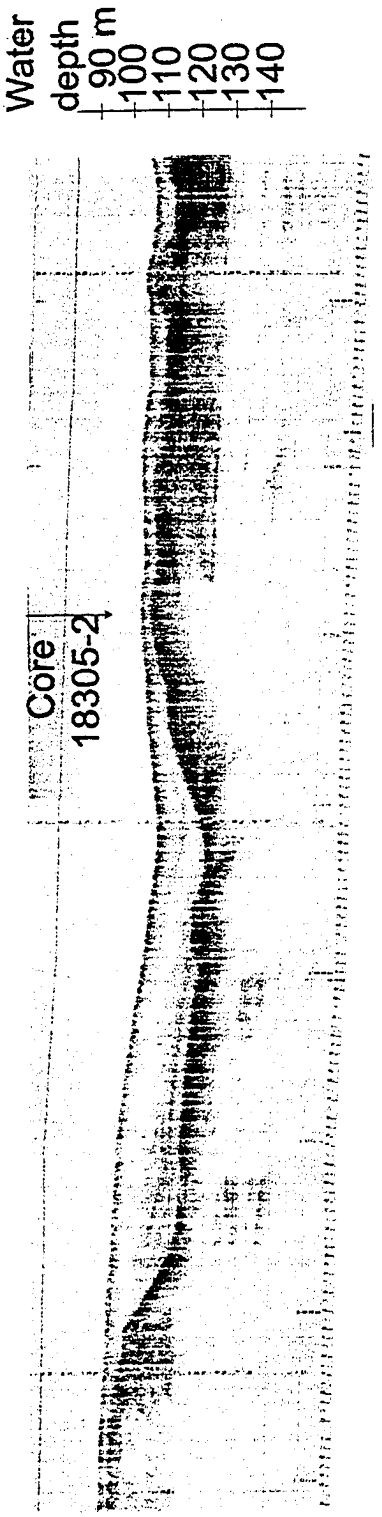


Figure 10 A. Parasound seismic section showing the location of Vibracore 18305-2

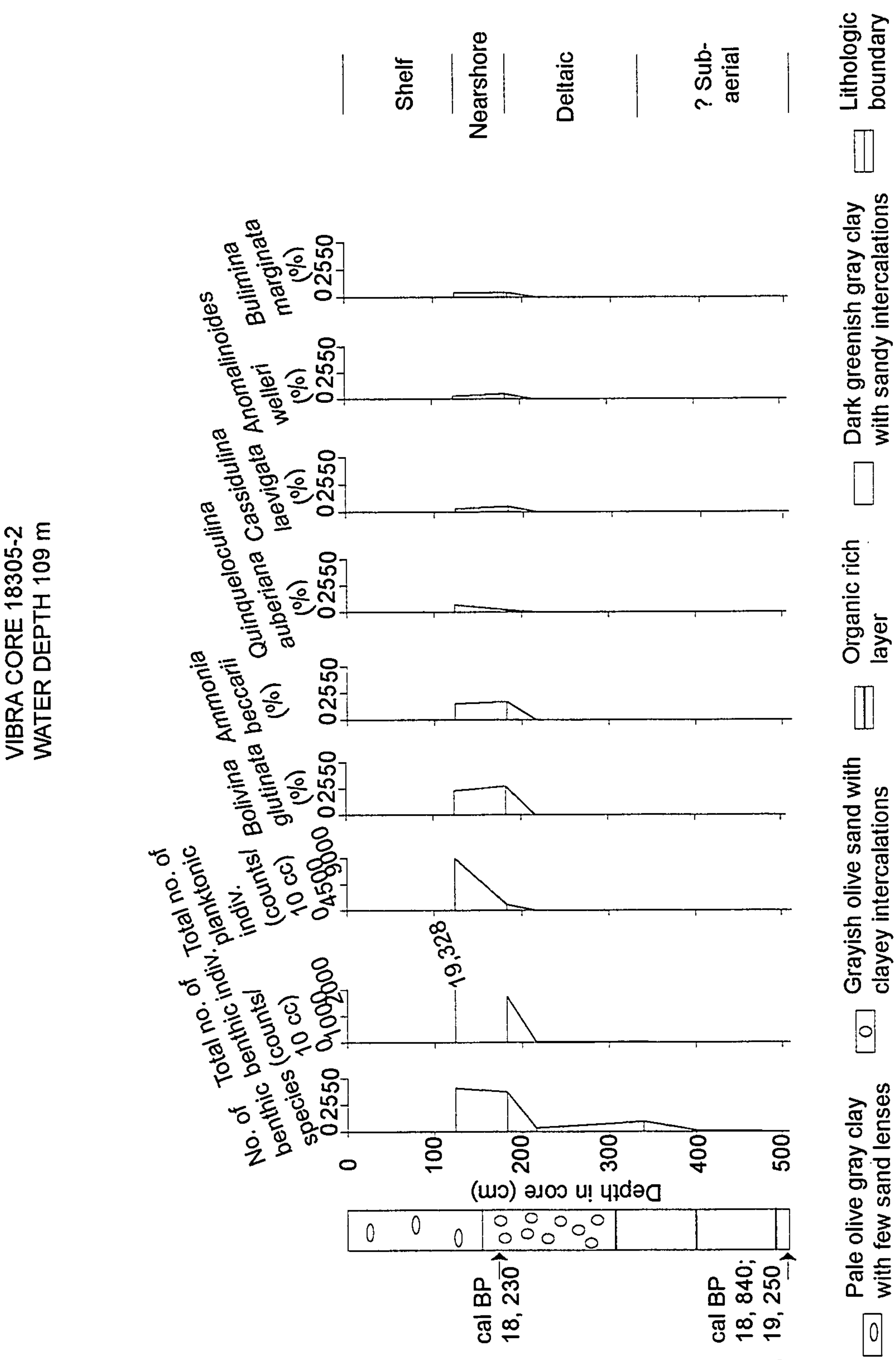


Figure 10 B. Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Vibracore 18305-2.

cc, while the remaining three samples (184 – 401 cm) yielded low abundances, ranging from 2 – 21 indiv. / 10 cc (Fig. 10 B; Appendix A, Table 8).

In the upper two intervals examined, the dominant species was *Bolivina glutinata*, followed by *Ammonia beccarii*. Species establishing secondary dominance included *Quinqueloculina auberiana, Rosalina columbiensis, Bulimina marginata, Ammomassilina alveoliniformis, Anomalinoides welleri, Cassidulina laevigata, Heterolepa subhaidingeri, Quinqueloculina sulcata, Neouvigerina ampullacea.* Planktonic foraminifera occurred in significant proportions in the upper two intervals. Individuals mostly belonged to the fine (63 – 125 µm) size fraction (Fig. 10 C).

The lower two intervals commonly contained *Ammonia* sp., *Pseudorotalia indopacifica, Quinqueloculina* spp. The interval from 216 – 339 cm specifically contained *Asterorotalia pulchella, Bolivina* spp., *Heterolepa subhaidingeri, Pararotalia* sp., *Pseudorotalia schroeteriana*, and *Triloculinella pseudooblonga.* The bottom most interval (339 – 401 cm) was barren of foraminifera.

An age date of cal BP 18, 230 years was obtained at 171 cm by dating leach residue using AMS technique (Table 3 A). Age dates of cal BP 18, 840 years and 19, 250 years were obtained at 511 cm by dating leach residue and wood respectively, using AMS technique (Table 3 A).

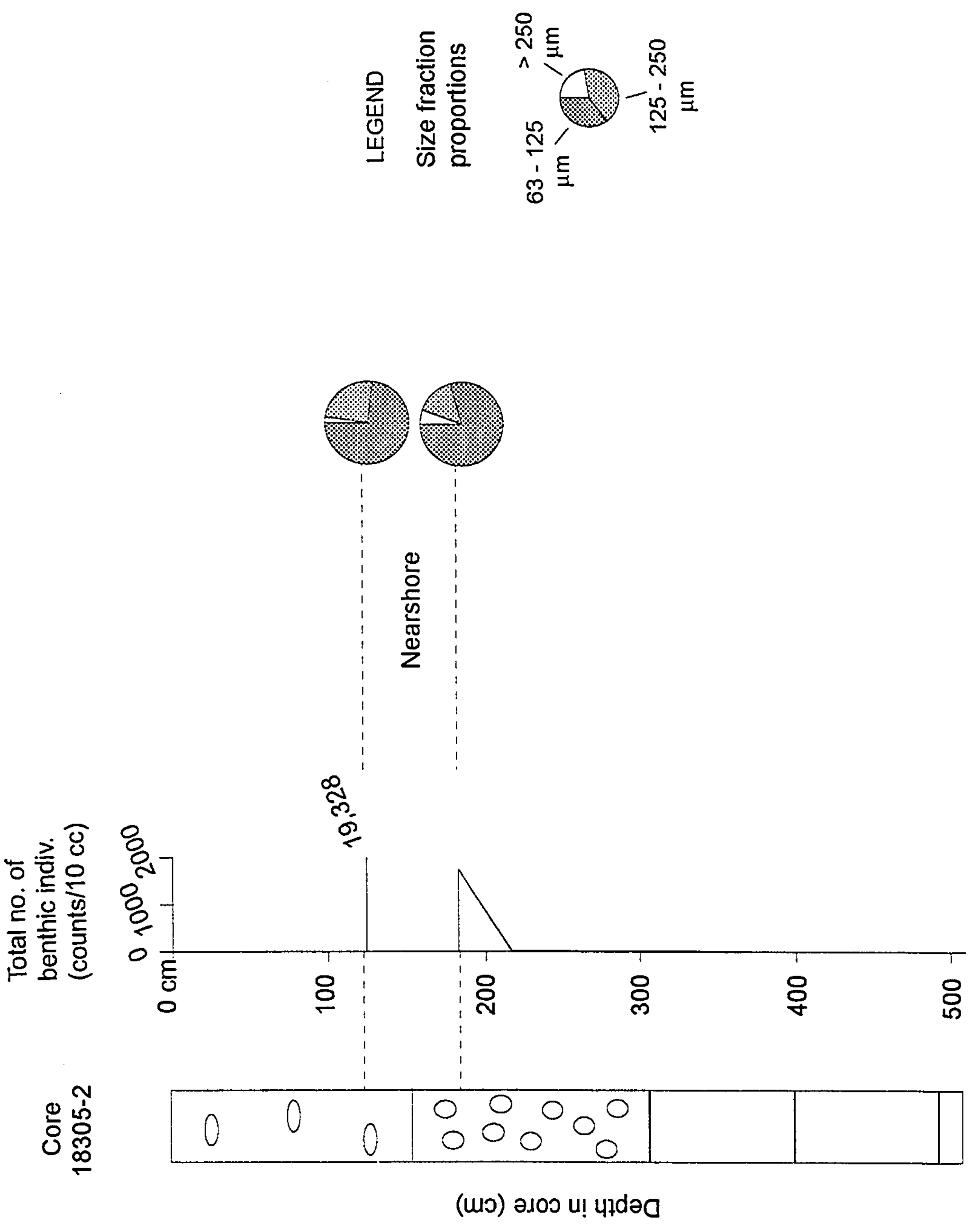


Figure 10 C. Correlation of abundance of benthic individuals with the paleoenvironments within three size fractions in Vibracore 18305-2.

5.1.9. Gravity core 18274-3

This 7.55 m long core was raised from a water depth of 117 m. The Parasound seismic profile showed the core location to be at the proximity of a large erosional channel. The predominant lithology of the core was a dark greenish gray clay with intercalations of silty, organic rich, and clayey layers.

Out of the 69 samples examined for foraminifera, 63 samples were barren, while the remaining 6 samples yielded total abundances from 1 – 62 indiv. / 10 cc. The dominant species consisted of *Ammonia beccarii, Bolivina glutinata, Hanzawaia nipponica, Heterolepa subhaidingeri* (Appendix A, Table 9)

AMS ^{14}C age dating of organic rich material at 145 cm, yielded the following ages (Table 3 A): cal BP 18, 895 years ; 19, 632 years. A piece of wood dated at 743 cm yielded an age of cal BP 17, 526 years.

5.1.10. Gravity core 18277-2

This 4.9 m long core was raised from a water depth of 133 m. The Parasound seismic profile showed a relatively homogenous profile (Fig. 11 A). The core lithology comprised a medium bluish gray homogeneous clay for the most part of the core length (Fig. 11 B). A clayey sand comprised the upper part (0 – 70 cm); two organic rich layers were concentrated in the central part of the core (Fig. 11 B).

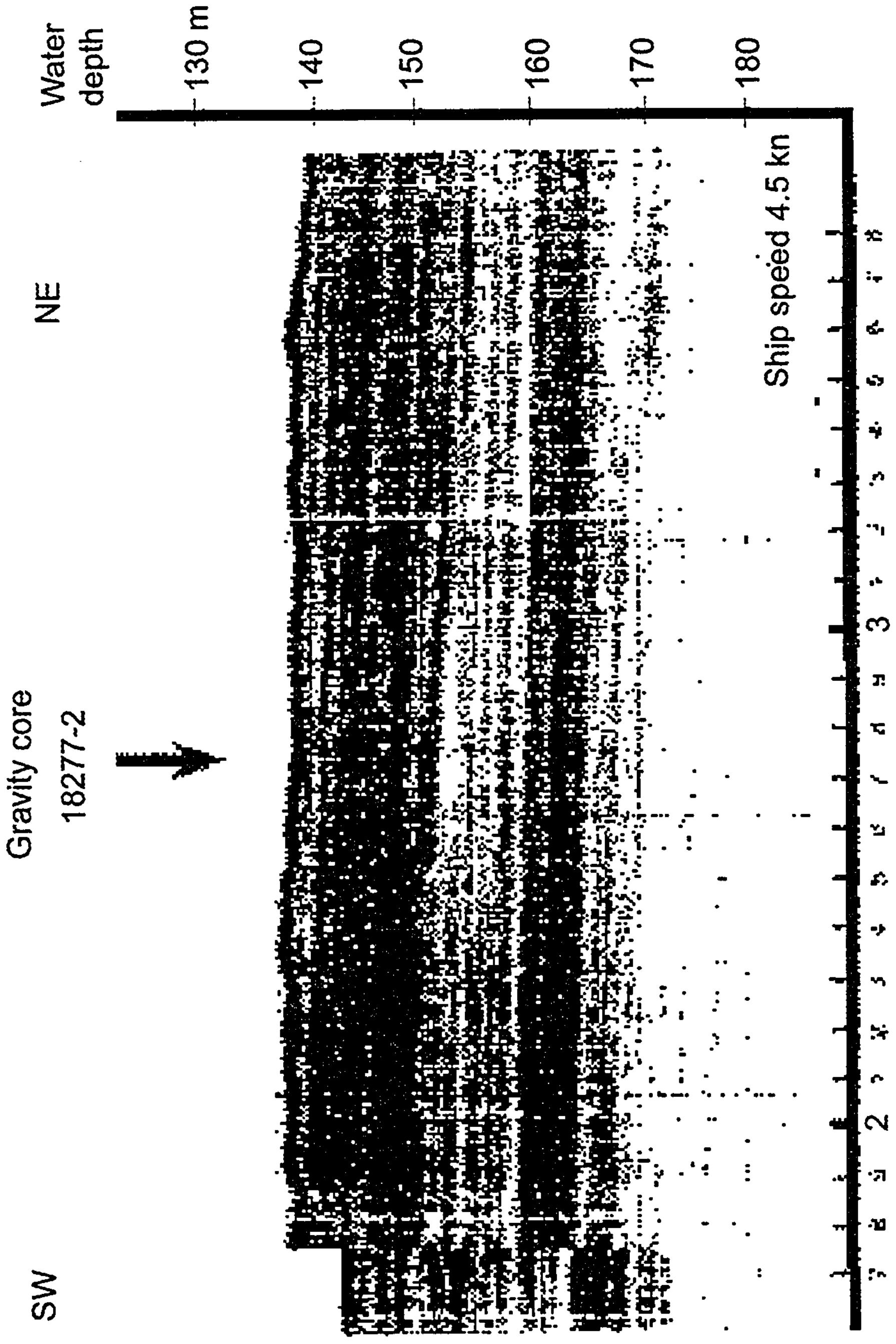


Figure 11 A. Parasound seismic section showing the location of Gravity core 18277-2

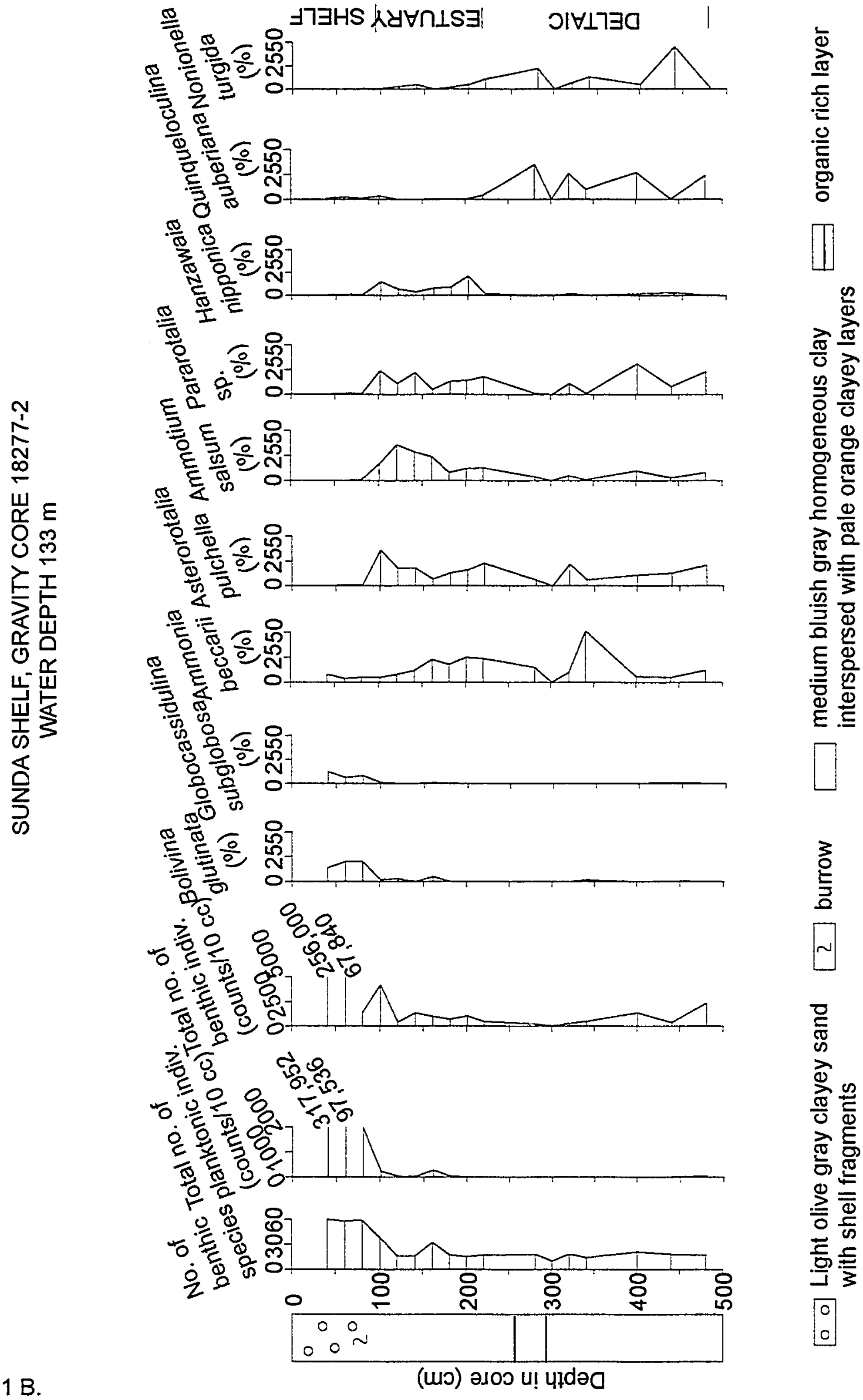


Fig. 11 B.

Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Gravity core 18277-2.

Seventeen samples were examined for foraminifera, from 41 – 481 cm (Fig. 11 B). Total abundances ranged from 29 – 256, 000 indiv. / 10 cc. Planktonic foraminifera occurred in significant proportions from 41 – 161 cm. The upper sandy part of the core was faunally the richest, while abundances were the lowest in the central part (Figs. 11 B; Appendix A, Table 10).

Ammonia beccarii was ubiquitously present at all the examined intervals along the core length. From 41 – 81 cm, *Bolivina glutinata* was the dominant species. Secondarily dominant species included *Globocassidulina subglobosa, Cassidulina laevigata, Ammonia beccarii, Bulimina marginata, Eponides* sp., *Neouvigerina ampullacea.*

From 81 – 481 cm, species dominance was taken over by *Asterorotalia pulchella, Ammotium salsum*, and *Pararotalia* sp. From 221 – 481 cm, dominance was shared by *Quinqueloculina auberiana* and *Nonionella turgida*. From 81 – 200 cm, *Hanzawaia nipponica* was secondarily dominant, along with a minor occurrence of *Nonionella turgida*. *Elphidium advenum* occurred in insignificant proportions at all the intervals examined.

Individuals mostly comprised the fine (63 – 125 μm) and intermediate (125 – 250 μm) size fractions along the core length (Fig. 11 C).

An AMS ^{14}C date obtained from the 100 cm interval, yielded an age of > 38, 000 yrs. BP (Table 3 A).

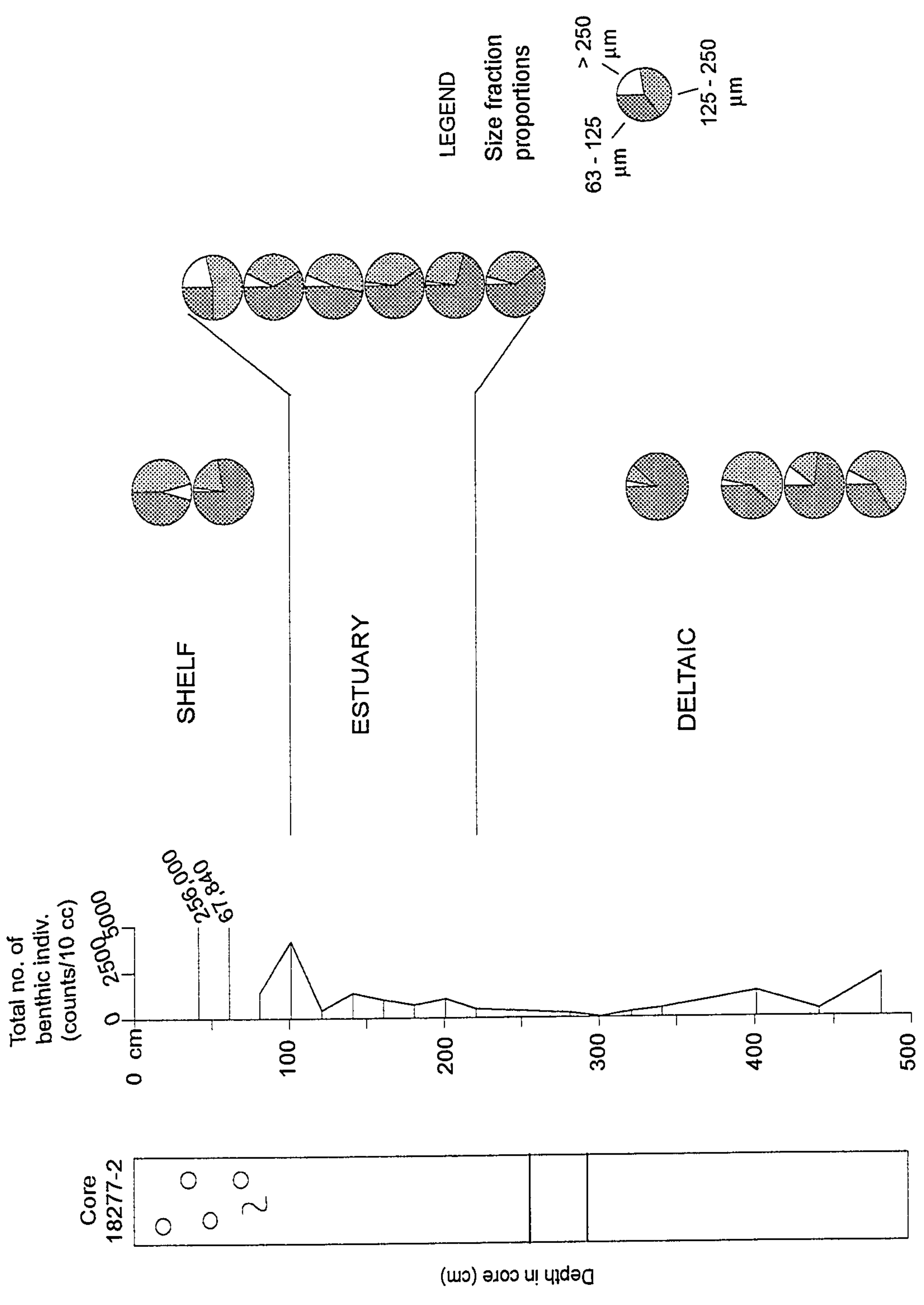


Figure 11 C. Correlation of abundance of benthic individuals with the paleoenvironments within three size fractions in Core 18277-2.

5.1.11. Gravity core 18280-2

This 5.56 m long core was raised from a water depth of 144 m. The Parasound seismic profile showed a relatively homogeneous section. The core lithology comprised two types of clayey units; a clayey sand with shell fragments (0 - 214 cm), and a blue green homogeneous clay (214 - 556 cm).

Out of the 2 samples examined for foraminifera, from 300 – 320 cm, total abundances ranged from 47 – 907 indiv. / 10 cc. Planktonic foraminifera occurred in insignificant proportions.

Dominant species included *Ammonia beccarii*, *Asterorotalia pulchella*, *Nonionella turgida*, *Ammotium salsum*, *Pararotalia* sp., *Pseudorotalia indopacifica*. Minor species included *Quinqueloculina* spp., *Elphidium advenum*, *Hanzawaia* sp., *Bolivina glutinata*.

5.1.12. Gravity core 18282-2

This 6.34 m long core was raised from a water depth of 151 m. The Parasound seismic profile showed a relatively homogenous profile. The lithology consisted of a medium gray homogenous clay for the most part of the core length (Fig. 12).

Out of the 6 samples examined for foraminifera, from 33 – 564 cm, total abundances ranged from 1, 285 – 26, 112 indiv. / 10 cc. Planktonic foraminifera occurred in high proportions from 33 – 262 cm (Fig. 12; Appendix A, Table 11).

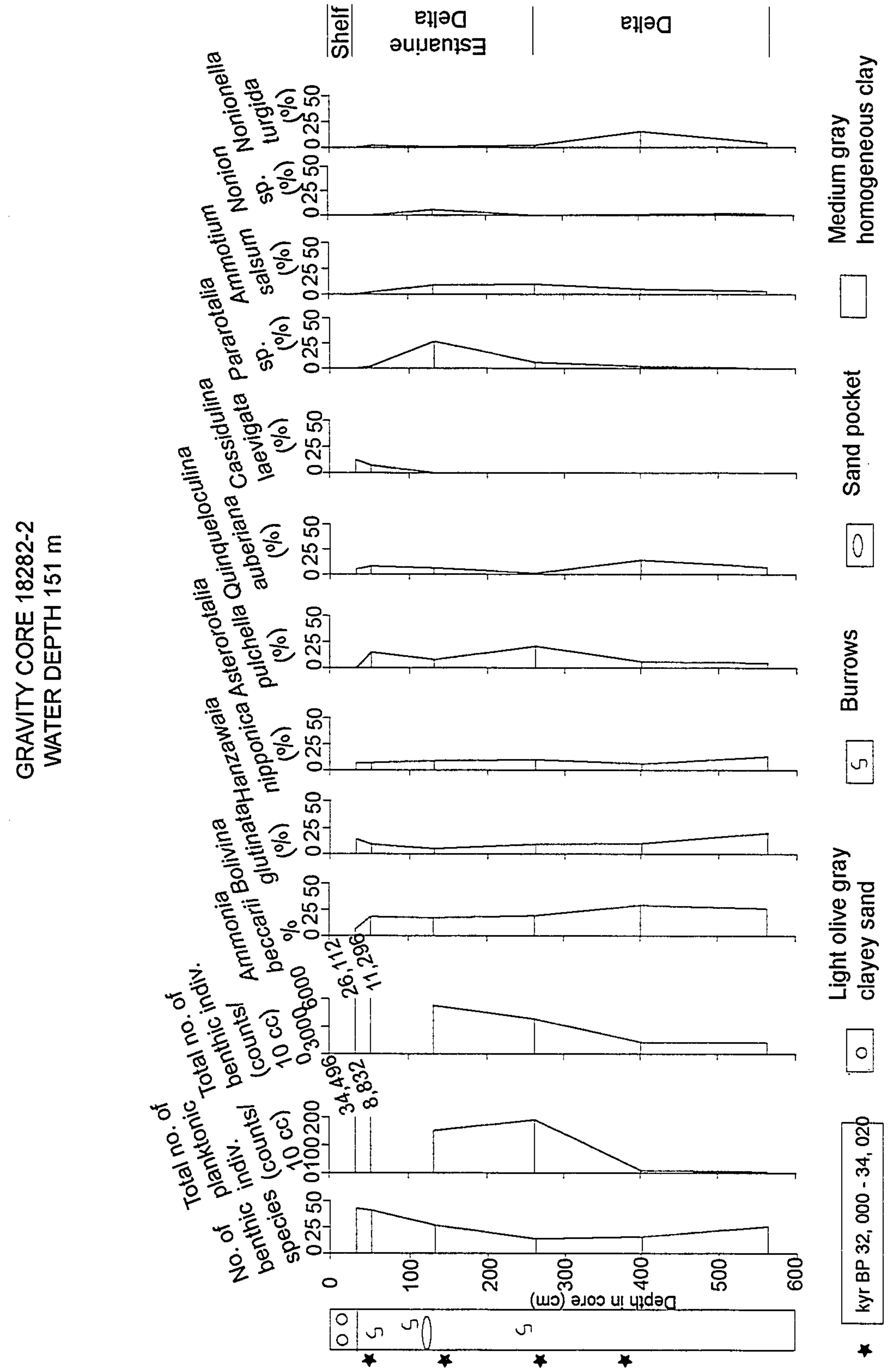


Figure 12. Profile of number of individuals and species, percent abundance of some foraminiferal species relative to the total foraminiferal assemblage, lithology, ^{14}C age, and inferred paleoenvironments in Gravity Core 18282-2.

Ammonia beccarii, *Bolivina glutinata*, *Hanzawaia nipponica*, *Asterorotalia pulchella*, and *Ammotium salsum* occurred in all the samples examined along the core length. *Pararotalia* sp. dominated as the main species in the upper half of the core. *Cassidulina laevigata* showed a peak in abundance from 33 – 52 cm. *Quinqueloculina auberiana* and *Nonionella turgida* occurred in higher proportions in the bottom half of the core. *Elphidium advenum* occurred in insignificant proportions in all the samples examined.

AMS ^{14}C dates obtained from the various intervals down-core yielded ages in the range from 32, 000 – 34, 000 yrs BP (Table 3 A).

5.2. SUNDA SHELF SEA-LEVEL CURVE

For plotting the Late Quaternary sea-level curve for the Sunda Shelf, out of the numerous Accelerator Mass Spectrometric radiocarbon age dates that were available through the work by Hanebuth (2000), and Hanebuth et al. (2000), (Table 3 A), only the dates obtained from faunally defined intervals were considered accurate. Using these ages (Table 3 B), the Sunda Shelf sea-level curve was derived (Figure 13 B). A discussion for this sea-level curve follows in Chapters VI and VII.

Table 3 A. ^{14}C age dates.

LAB NUMBER (KIA)	CORE	WATER DEPTH (m)	SAMPLE DEPTH IN CORE (cm)	MATERIAL DATED	AMS 14C age (years BP)	1 s (yr) (+) (-)	Calibrated age (cal yr. BP)	1 sigma ranges (cal yr. BP)	Delta R (for marine samples) (Regional average value for south/central South China Sea)	Uncertainty in delta R	AMS d 13C	sigma range (+) (-)
5617	18315-2	69	38 - 40	foraminifer (*Rotalia*)	8, 630	55	9, 038	9, 258 - 9, 230; 9, 100 - 8, 976	-17	17		
5619	18322-2	70	49 - 51	foraminifer (*Rotalia*)	4, 495	40	4, 720	4, 788 - 4, 652	-17	17		
5620	18322-2	70	67 - 69	piece of wood	11, 460	55	13, 440	13, 490 - 13, 180	-	-	-	-
2479	18316-2	71	597	foraminifer (transported during coring)	> 50, 000	-	-	-	-	-	-	-
4646	18320-2	76	10 - 12	foraminifer	6, 420	50	6, 904	6, 984 - 6, 846	-17	17		
3540	18320-2	76	10 - 12	bulk sediment	11, 060	80	13, 021	13, 153 - 12, 969	-	-	-20.79	0.12
3541	18320-2	76	200 - 202	wood fragment (from organic material)	> 46, 670	-	-	-	-	-	-28.63	0.11

Table 3 A. (continued).

LAB NUMBER (KIA)	CORE	WATER DEPTH (m)	SAMPLE DEPTH IN CORE (cm)	MATERIAL DATED	AMS 14C age (years BP)	1 s (yr) (+) (-)	Calibrated age (cal yr. BP)	1 sigma ranges (cal yr. BP)	Delta R (for marine samples) (Regional average value for south/central South China Sea)	Uncertainty in delta R	AMS d 13C	sigma range (+) (-)
3542	18320-2	76	484 - 486	organic (peaty) material, fungi?	48, 830	-	-	-	-	-	-28.9	0.13
5610	18309-2	83	175 - 181	piece of root, *in situ*	12, 415	55	14, 340	14, 390 - 14, 100; 15, 170 - 15, 150; 14, 990 - 14, 540; 14, 460 - 14, 150	-	-	-	-
5611	18309-2	83	178 - 179	plant macro fibres	12, 440	80	14, 350	15, 215 - 15, 190	-	-	-	-
5983	18302-2	83	85	piece of wood	11, 520	55	13, 463	13, 790 - 13, 680; 13, 520 - 13, 390; 13, 370; 13, 360 - 13, 330	-	-	-	-
5986	18302-2	83	410	piece of wood	12, 335	60	14, 310	15, 030 - 14, 620; 14, 410 - 14, 120	-	-	-	-

Table 3 A. (continued).

LAB NUMBER (KIA)	CORE	WATER DEPTH (m)	SAMPLE DEPTH IN CORE (cm)	MATERIAL DATED	AMS 14C age (years BP)	1 s (yr) (+) (-)	Calibrated age (cal yr. BP)	1 sigma ranges (cal yr. BP)	Delta R (for marine samples) (Regional average value for south/central South China Sea)	Uncertainty in delta R	AMS d 13C	sigma range (+) (-)
3113	18302-2	83	415	root fibres, *in situ*	12, 100	70	14, 100	14, 960 - 14, 820; 14, 320 - 14, 020; 13, 960 - 13, 830	-	-	-27.84	0.15
3530	18302-2	83	490	plant macro fibres	12, 230	60	14, 150	15, 025 - 14, 690; 14, 360 - 14, 080	-	-	-	-
3531	18302-2	83	590	bulk sediment	20, 160	+330, -310	-	-	-	-	-	-
3527	18300-2	91	61	plant macro fibres	12, 440	70	14, 350	15, 220 - 15, 190; 14, 930 - 14, 160	-	-	-27.9	0.1
2567	18300-2	91	206	macro fibres	12, 650	60	15, 290	15, 520 - 15, 190; 14, 770 - 14, 350	-	-	-27.14	0.05
2568	18300-2	91	223	plant macro fibres	12, 450	+100, -90	14, 920; 14, 880; 14, 360	15, 240 - 15, 190; 14, 915 - 14, 155	-	-	-28.53	0.07

Table 3 A. (continued).

LAB NUMBER (KIA)	CORE	WATER DEPTH (m)	SAMPLE DEPTH IN CORE (cm)	MATERIAL DATED	AMS 14C age (years BP)	1 s (yr) (+) (-)	Calibrated age (cal yr. BP)	1 sigma ranges (cal yr. BP)	Delta R (for marine samples) (Regional average value for south/central South China Sea)	Uncertainty in delta R	AMS d 13C	sigma range (+) (-)
3111	18300-2	91	404	piece of wood	12, 580	60	15, 210; 14, 630; 14, 430	15, 445 - 15, 190; 14, 810 - 14, 320	-	-	-27.76	0.13
2569	18300-2	91	415	plant macro fibres	12, 560	100	15, 180; 14, 650; 14, 420	15, 420 - 15, 190; 14, 820 - 14, 310	-	-	-27.64	0.17
3112	18300-2	91	428	root fibres, in situ	12, 440	80	14, 350	15, 220 - 15, 190; 14, 930 - 14, 160	-	-	-27.9	0.1
2570	18300-2	91	431	piece of wood	12, 470	60	15, 015; 14, 790; 14, 370	15, 300 - 15, 170; 14, 900 - 14, 230	-	-	-27.96	0.1
3528	18300-2	91	590 - 592	bulk sediment	21, 490	+330, -320	-	-	-	-	-22.56	0.29
3529	18300-2	91	879 - 881	bulk sediment	>33, 210	-	-	-	-	-	-30.08	0.23
3529	18300-2	91	879 - 881	bulk sediment	>41, 510	-	-	-	-	-	-	-
3529	18300-2	91	879 - 881	bulk sediment	39, 210	+3, 190, -2, 280	-	-	-	-	-25.6	0.1

Table 3 A. (continued).

LAB NUMBER (KIA)	CORE	WATER DEPTH (m)	SAMPLE DEPTH IN CORE (cm)	MATERIAL DATED	AMS 14C age (years BP)	1 s (yr) (+) (-)	Calibrated age (cal yr. BP)	1 sigma ranges (cal yr. BP)	Delta R (for marine samples) (Regional average value for south/central South China Sea)	Uncertainty in delta R	AMS d 13C	sigma range (+) (-)
3543	18323-2	92	190 - 192	bulk sediment	14, 180	60	17, 000	17, 241 - 16, 752	-	-	-29.35	0.24
3544	18323-2	92	380 - 382	bulk sediment	23, 460	+160, -150	-	-	-	-	-23.03	0.16
3545	18323-2	92	534 - 536	bulk sediment	22, 810	120	-	-	-	-	-25.02	0.22
5606	18301-2	93	277 - 278	piece of wood	12, 410	110	14, 340	14, 950 - 14, 130	-	-	-	-
5605	18301-2	93	277 - 278	piece of wood	12, 370	55	14, 320	15, 035 - 14, 590; 14, 425 - 14, 130	-	-	-	-
5981	18301-2	93	331	piece of wood	12, 510	55	15, 100; 14, 720; 14, 390	15, 360 - 15, 180; 14, 860 - 14, 280	-	-	-	-

Table 3 A. (continued).

LAB NUMBER (KIA)	CORE	WATER DEPTH (m)	SAMPLE DEPTH IN CORE (cm)	MATERIAL DATED	AMS 14C age (years BP)	1 s (yr) (+) (-)	Calibrated age (cal yr. BP)	1 sigma ranges (cal yr. BP)	delta R (for marine samples) (Regional average value for south/central South China Sea)	Uncertainty in delta R	AMS d 13C	sigma range (+) (-)
3114	18310-2	100	121 - 123	organic material (peaty)	12, 370	70	14, 323	15, 040 - 14, 590; 14, 430 - 14, 130	-	-	-29.36	0.08
3822	18310-2	100	121 - 123	organic material (peaty)	15, 690	90	18, 734	19, 035 - 18, 432	-	-	-28.99	0.19
4178.02	18310-2	100	490	piece of wood	13, 260 (conventional)	120	15, 940	16, 240 - 15, 640	-	-	-28.84	-
2487	18298-2	102	587	foraminifer	11, 350	60	12, 910	13, 080 - 13, 060; 12, 990 - 12, 860; 12, 710 - 12, 680	-17	17	-	-
3532	18305-2	109	170 - 172	leach residue (bulk sediment)	15, 250	150	18, 230	18, 550 - 17, 910	-	-	-27.27	0.09
3533	18305-2	109	510 - 512	leach residue (sediment with organic material)	15, 780	80	18, 840	19, 140 - 18, 540	-	-	-	-
3533	18305-2	109	511	piece of wood	16, 140	140	19, 250	19, 590 - 18, 920	-	-	-27.78	0.17

LAB NUMBER (KIA)	CORE	WATER DEPTH (m)	SAMPLE DEPTH IN CORE (cm)	MATERIAL DATED	AMS 14C age (years BP)	1 s (yr) (+) (-)	Calibrated age (cal yr. BP)	1 sigma ranges (cal yr. BP)	delta R (for marine samples) (Regional average value for south/central South China Sea)	Uncertainty in delta R	AMS d 13C	sigma range (+) (-)
5980	18276-2	116	60	leach residue	17, 680	80	21, 020	21, 350 - 20, 690	-	-	-	-
3832	18274-3	117	145 - 149	organic layer (peaty)	16, 470	100	19, 630	19, 950 - 19, 310	-	-	-27.92	0.15
3110	18274-3	117	742 - 744	piece of wood	14, 640	90	17, 530	17, 800 - 17, 260	-	-	-30.51	0.08
-	18277-2	133	105	?	>38, 820	-	-	-	-	-	-	-
3620	18282-2	151	50	foraminifer (*A. pulchella*)	32, 240	+660 / - 610	37, 440	38, 260 - 36, 770	-	-	-	-

Table 3 A. (continued).

Core	Age (cal kyr BP)	Depth (metres below present mean sea level)	Age error (+/-) (cal kyr BP)
18302	14.575	87.1	0.455
18302	14.395	87.15	0.565
18302	14.55	87.9	0.4725
18300	14.69	91.61	0.53
18300	14.93	93.06	0.585
18300	14.7	93.23	0.54
18300	14.88	95.04	0.56
18300	14.86	95.15	0.555
18300	14.69	95.28	0.53
18300	14.76	95.31	0.53

Table 3 B. Faunally defined sea-level points selected from the present study for the Sunda Shelf sea-level curve.

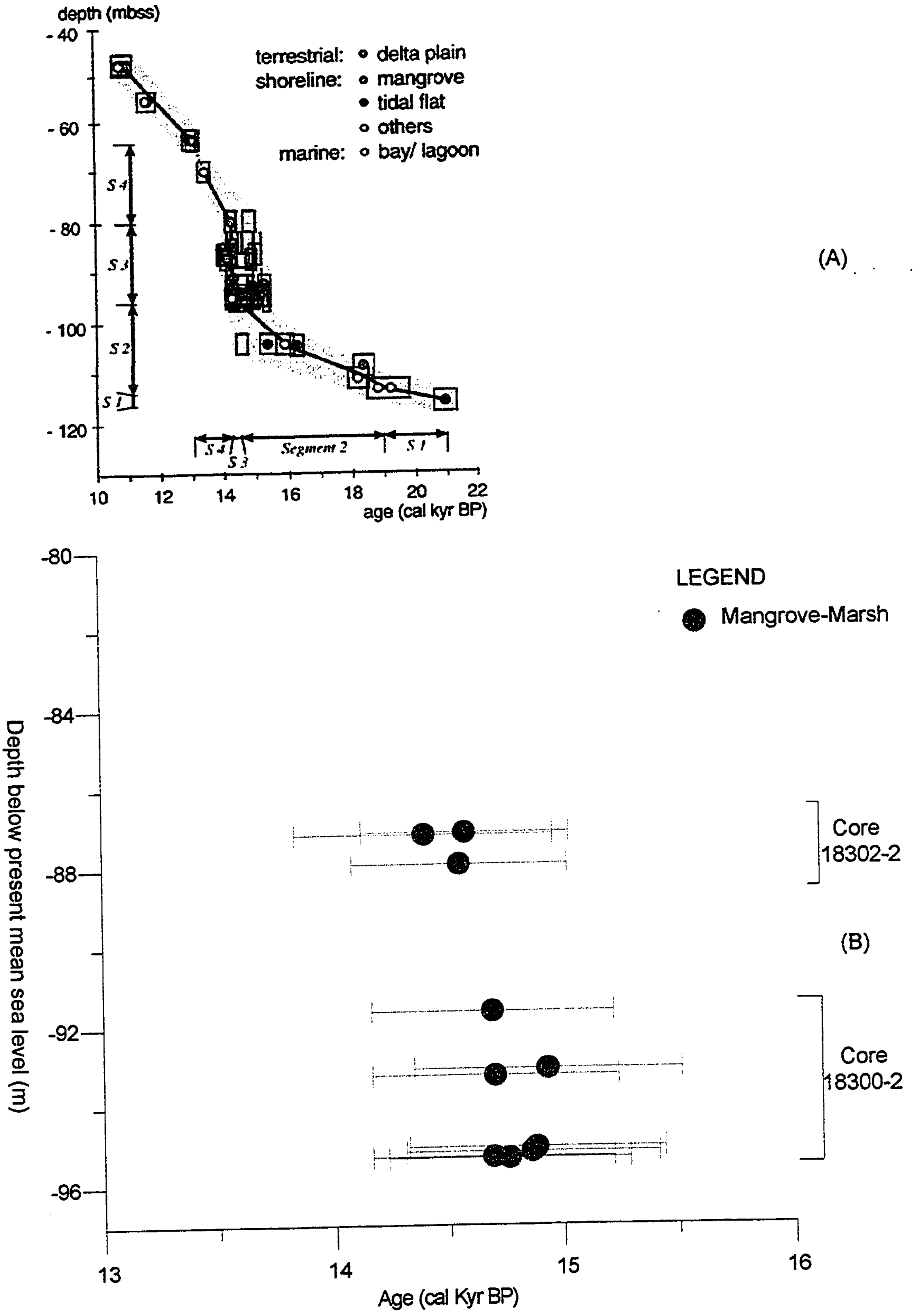


Figure 13. (A) Sunda Shelf sea-level curve by Hanebuth et al. (2000).
(B) Faunally defined sea-level points selected from the present study for the Sunda Shelf sea-level curve.

CHAPTER VI

SYNTHESIS

6.1 Late Quaternary paleoenvironments on Sundaland

Following the delineation of Late Quaternary environments in the Sunda Shelf sediment cores, a synthesis of the results was done, linking the paleoenvironments with the ^{14}C ages (calibrated, BP).

6.1.1 A Marine Isotope Stage 5 shallow marine setting of the Sunda River Delta, comparable to the post cal BP 13, 000 years setting

A Marine Isotope Stage 5 time interval (> 50, 000 years) was represented in Core 18316-2, in the southwestern part of the Shelf, by a deltaic environment, that was faunally well defined (Fig. 4 A). The deltaic fauna from –73 to –76 m below present MSL was indicative of a shoreline at about –50 m below present MSL (Fig. 14). Such a depth was consistent with previous studies of the Marine Isotope Stage 5 shoreline (e.g. Esat et al., 1999; Chivas et al., 2001).

The environmental setting defined by this paleo-delta was assumed to be similar to the present day environment that is prevalent on the Shelf. Such a setting is definitive of an active southwest monsoon, with the Borneo Strait allowing the passage of water from the Indian Ocean, across the Sunda Shelf, to the Pacific Ocean, and vice versa (Wyrtki, 1961) (Fig. 15 A, B).

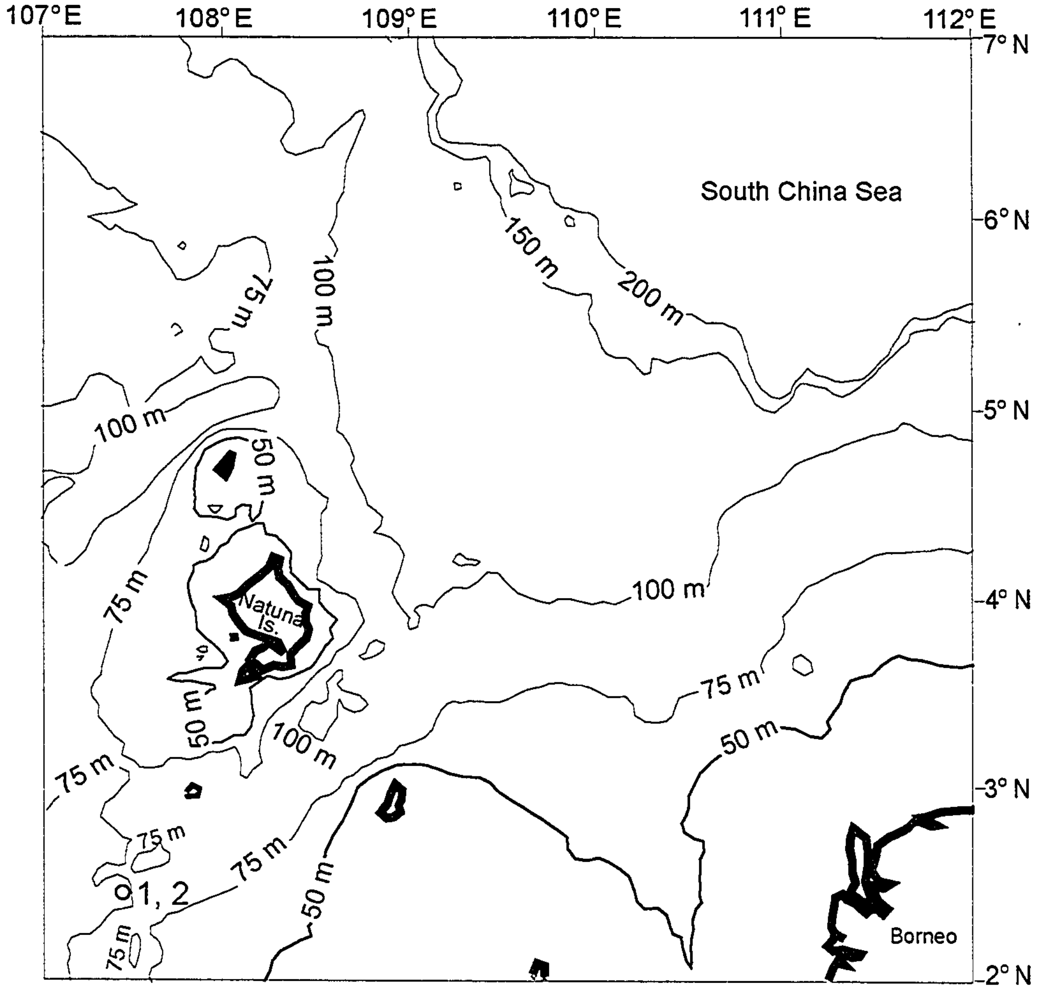


Figure 14. Sundaland at Marine Isotope Stage 5 (> 50, 000 yrs. BP), and at post cal BP 13, 000 years

Symbols:

o Core 18316-2

▲ Present day land mass

1 Deltaic from -72.9 m to -76 m

2 Shallow marine from -76.1 m to -76.8 m; > 50, 000 yrs. BP at -77 m

━━━	Modern bathymetric line indicating the probable position of the shoreline at the time interval under discussion	───	Modern bathymetric line indicating the area under sea level at the time interval under discussion

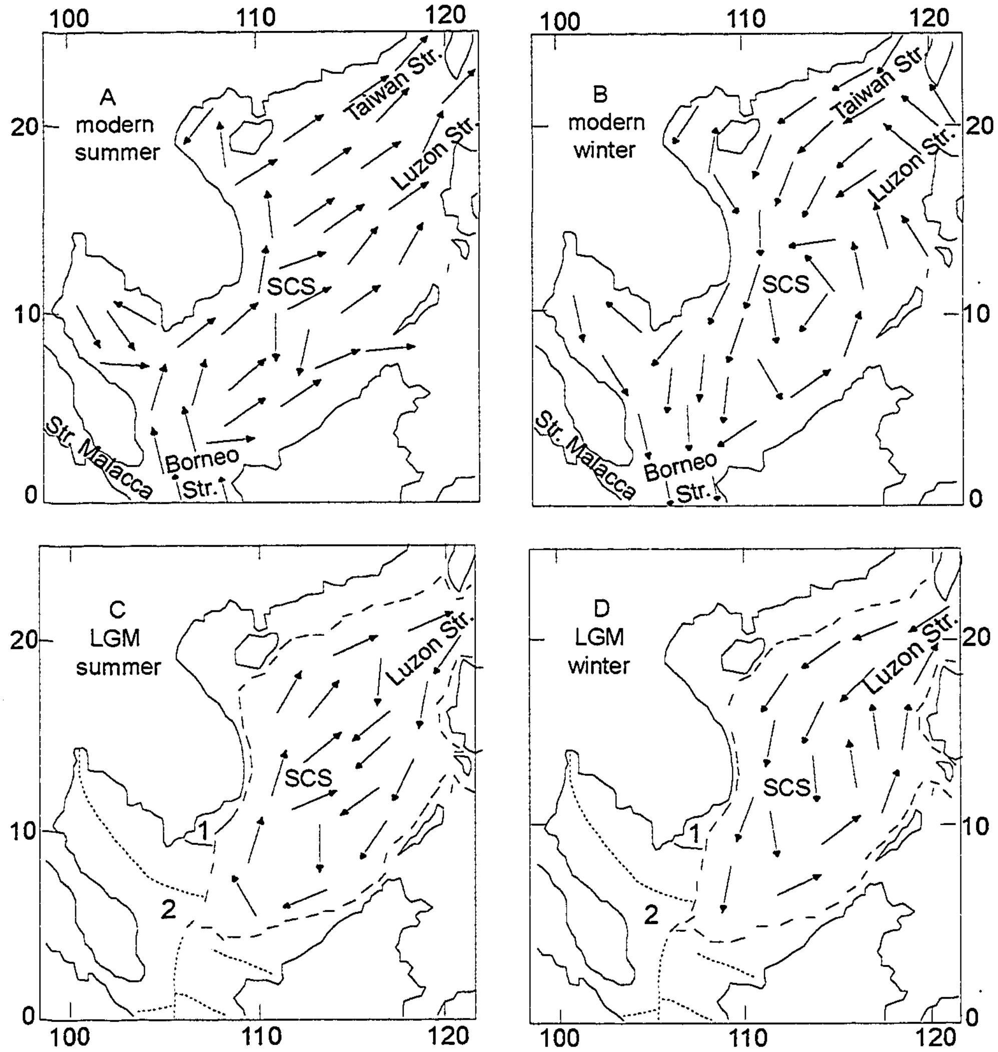


Figure 15. Monsoon influenced water circulation on the Sunda Shelf (modified from Wyrtki, 1961; Tjia, 1980; Wang and Wang, 1990).
A, B: Modern water circulation during summer and winter.
C, D: Water circulation during the Last Glacial Maximum showing the subaerially exposed Sundaland, the paleo-Sunda (2), and the paleo-Mekong (1) Rivers.

6.1.2 The Paleo-North Sunda River Delta: a Marine Isotope Stage 3 setting

A paleo-delta in the northeastern part of the Shelf was defined by a low salinity fauna (Figs. 11 B, 12). ^{14}C age dates from Core 18282-2 (Steinke et al., submitted), and from Core 18277-2 (A. Bojanowski, Kiel University, Germany, written comm.) indicated the time interval of the deltaic setting in that core to belong to Marine Isotope Stage 3. This is one of the few indications of a Stage 3 setting documented so far. The location of the paleo-shoreline remains enigmatic (Fig. 16), a discussion for which follows in Chapter VII.

6.1.3 Marine Isotope Stage 2: Last Glacial Maximum (cal BP 19, 000 – 18, 230 years): subaerial to nearshore environments

At about cal BP 19, 000 years, Sundaland was subaerially exposed to a depth of -114 m below present mean sea level (Fig. 10 A). At cal BP 18, 230 years, a marine transgressive event was identified, which was defined by a near-shore fauna (Figure 10 A), at a depth of –111 m below present mean sea level. The abrupt increase in abundance of this nearshore fauna overlying a faunally barren zone was indicative of a rise in sea level (discussed in Chapter V, section 5.3). Accordingly, the LGM shoreline was inferred at an elevation of –100 m (Fig. 17).

6.1.4 Sundaland from cal BP 15, 290 – 13, 000 years

From cal BP 14, 800 (+/- 530) years to 14, 400 (+/- 560) years, a mangrove marsh environment developed on Sundaland, evidence for which was found in the northeastern

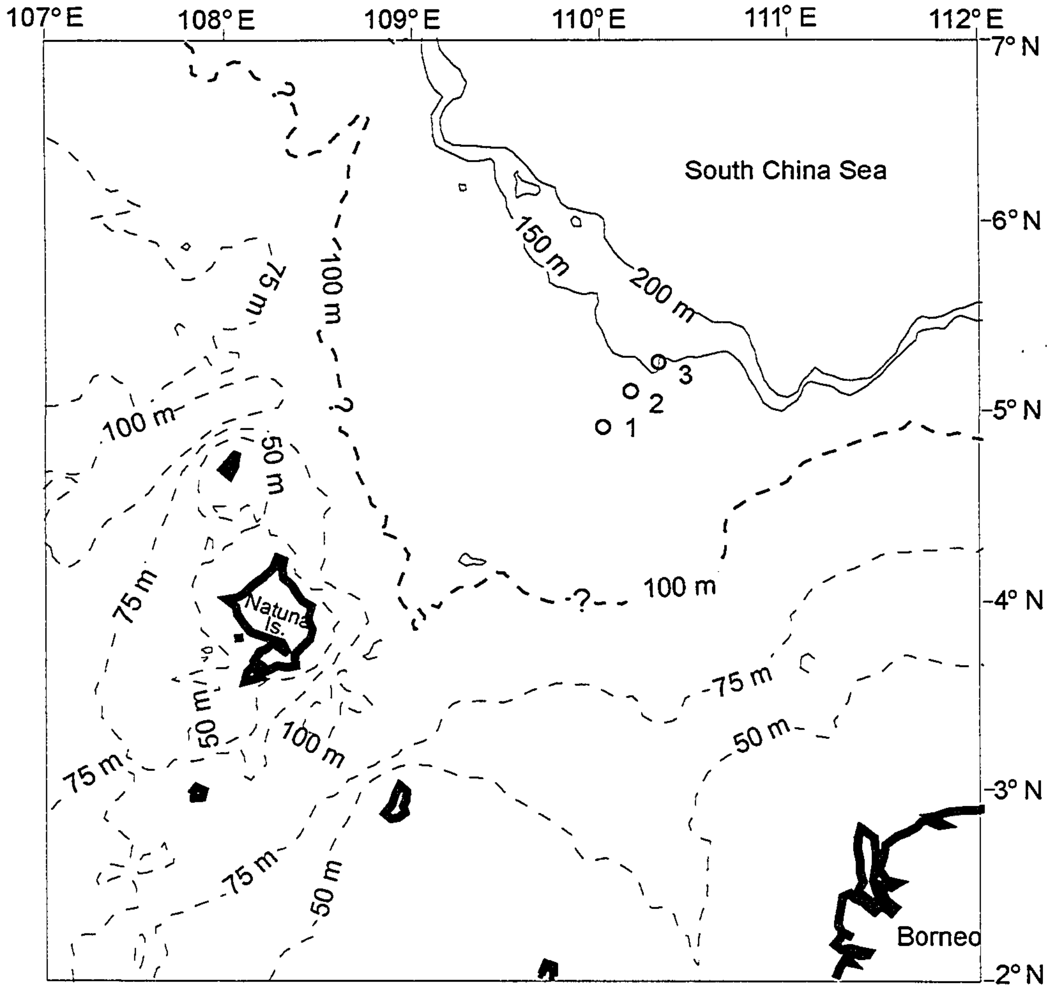


Figure 16. Sundaland at Marine Isotope Stage 3 (cal BP 38, 950 - 36, 080 years)

Symbols:

○ 1 Deltaic interval from -133.8 m to -137.8 m in Core 18277-2
○ 2 Deltaic interval from -147 m to -147.2 m in Core 18280-2
○ 3 Deltaic interval from -151.5 m to -156.6 m in Core 18282-2

– – – – – Modern bathymetric line; subaerial at the time interval under discussion

– – –?– – Modern bathymetric line indicating the possible position of the shoreline during Marine Isotope Stage 3

——— Modern bathymetic line indicating the area under sea level at the time interval under discussion

Present day land mass

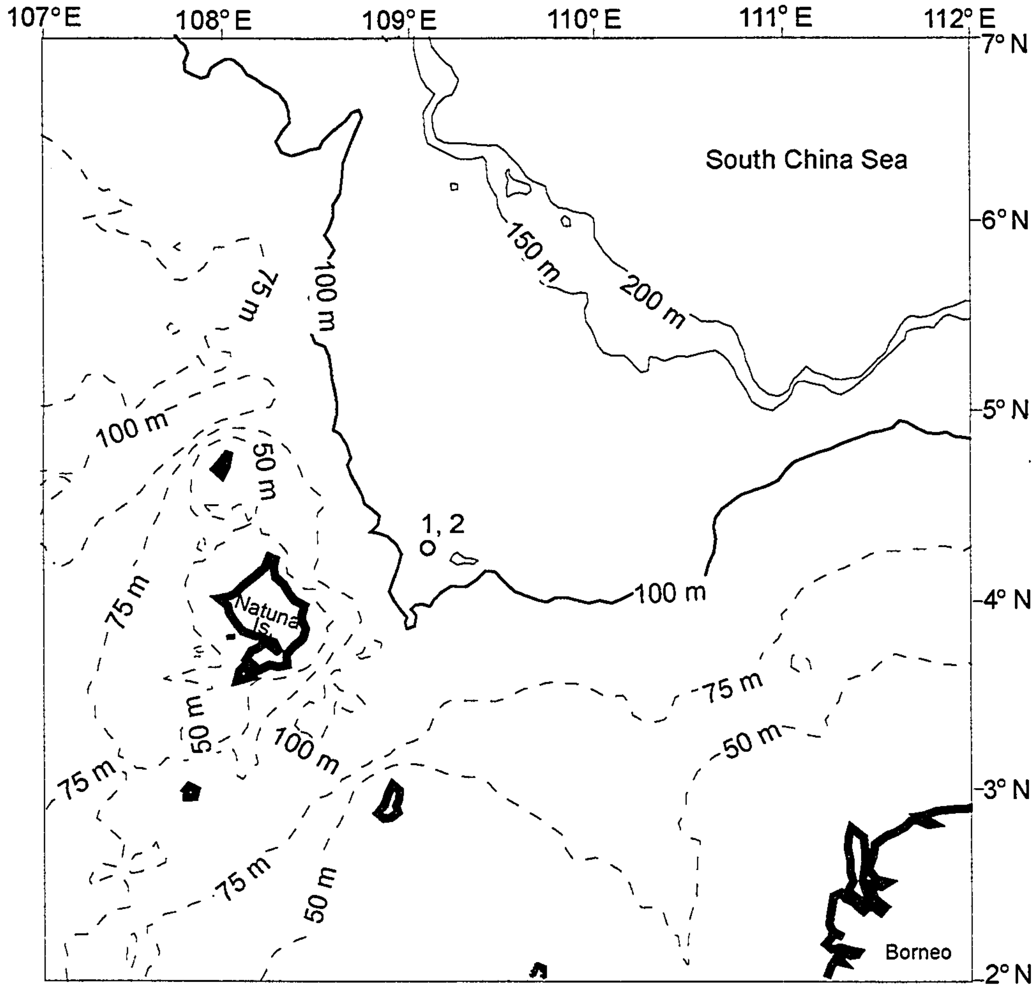


Figure 17. Sundaland during the Last Glacial Maximum (cal BP 19,000 - 18, 000 years)

Symbols:

○ Core 18305-2

1 Subaerial at -114 m at cal BP 19, 250 years

2 Nearshore at -110.7 m at cal BP 18, 230 years

- - - - Modern bathymetric line, subaerial at the time interval under discussion

■ Present day land mass

━━━ Modern bathymetric line indicating the shoreline during the time interval under discussion

——— Modern bathymetric line indicating the area under sea level during the time interval under discussion part of Natuna Island (Figs. 5 A, 6 A, 7). Due to the accuracy of this marginal marine environment in defining the sea level (see Chapter V, section 5.1.1), this paleoenvironment constrained the sea-level history of the Sundaland most accurately. Thus, from cal BP 14, 800 – 14, 400 years, the sea level occurred between –95.3 m to –87.1 m (discussion follows in Chapter VII). Gradual flooding of the Mangrove Marsh was marked by the formation of shallow coastal environments. Core 18302-2 (Fig. 5 A), recorded these coastal zones between cal BP 14, 400 (+/- 560) years and cal BP 13, 500 (+/- 200) years. Core 18298-2 (Fig. 9 A) recorded various coastal environments starting from cal BP 12, 900 (+/- 200) years. The shoreline during this time period, was inferred from –100 to –75 m (Fig. 18).

6.1.5 Flooding of the delta system (post cal BP 13, 000 years)

Complete flooding of the delta system was marked by the sharp transition from coastal-estuarine type to Shelf type faunal assemblage (Figs. 6 A, 9 A). The Shelf must have been flooded to its average modern water depth of -50 m at its stage of complete flooding (Fig. 14). This, in turn, would have led to the re-opening of the Borneo Strait, allowing the exchange of the Indian Ocean and the Pacific Ocean waters (Fig. 15 A, B), thus re-activating the monsoonal pattern.

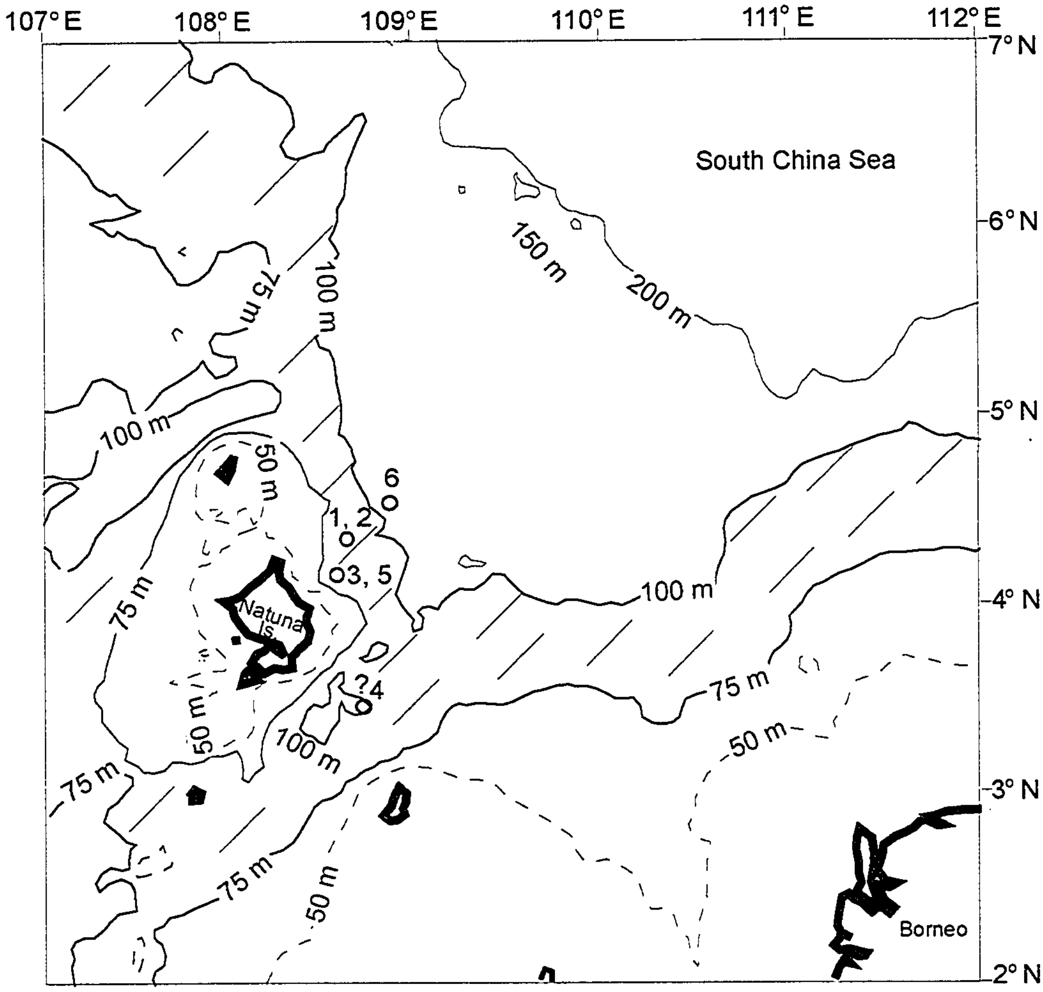


Figure 18. Sundaland from cal BP 15, 290 - 13, 000 years

Symbols:

○ Mangrove Marsh ▲ Land mass ▨ Possible extent of Mangrove Marsh Zone

- - - - - Modern bathymetric line, subaerial during the time interval under discussion

——— Modern bathymetric line, indicating the area under sea level during the time interval under discussion

——— Modern bathymetric lines indicating the positions of the shoreline during the time interval under discussion

1 Core 18300-2: Mangrove Marsh from -95.3 m to -91.6 m, at cal BP 15, 290 - 14, 350 years
2 Core 18301-2: Mangrove Marsh from -96.3 m to -95.8 m, at cal BP 15, 100 - 14, 320 years
3 Core 18302-2: Mangrove Marsh from -87.9 m to -87.1 m, at cal BP 14, 310 - 14, 100 years
?4 Core 18309-2: ?Mangrove Marsh from -84.8 m to -84.7 m, at cal BP 14, 350 years
5 Core 18302-2: Near-shore at -83.8 m, at cal BP 13, 460 years
6 Core 18298-2: Lower Estuary, at -107.9 m, at cal BP 12, 910 years

CHAPTER VII

DISCUSSION

7.1 Paleogeographic and Paleoclimatological Implications

7.1.1. Marine Isotope Stage 5

The Marine Isotope Stage 5 delta in the southwestern part of the Shelf (Fig. 14) was indicative of the connection of Sundaland with the Pacific and the Indian Ocean waters, through an open Borneao Strait, as with the modern oceanographic setting of the Shelf (Fig. 15 A, B). Such a hydrological regime would have allowed the southwestern monsoon to prevail (see Chapter I, section 1.3.3, for an explanation of the monsoonal pattern).

7.1.2. Marine Isotope Stage 3

7.1.2.1. Shoreline position

The Marine Isotope Stage 3 delta in the northeastern part of the Sunda Shelf (Fig. 16) allowed a discussion for the sea-level stand at the time. The relatively thick (5 m), vertically aggraded deltaic interval in Core 18277-2 (Fig. 11 B), suggests that a sea-level rise of a relatively steady nature would have allowed delta aggradation to keep up with it.

The position of the Stage 3 shoreline remains enigmatic. The elevation of the paleo-North Sunda River Delta (Fig. 16) is anomalously low (the top of the deltaic interval occurring at -134 m) for the Stage 3 shoreline to occur at such a depth. Previous studies of the Stage 3 shoreline have documented an elevation of –80 m (Yokoyama et al., 2001).

For understanding the settings of the North Sunda River paleo-delta, an analogy was drawn with the modern prodeltas of the Javanese rivers (e.g. Solo River Delta, East Java, Hoekstra, 1993b). The river mouths of these modern Javanese rivers are sediment depocentres, which have been demonstrated to maintain a strong freshwater plume during the wet monsoon seasons, marking a reduced salinity environment in the prodelta area (Hoekstra, 1993b). The upper boundary of the Solo River Delta Front was marked by the 2 m depth contour and the front extended to at least a depth of 20 – 25 m below mean sea level (Hoekstra, 1993b).

Thus, although the depth range of the low salinity faunal assemblage of the paleo-North Sunda River Delta is not precisely known, a monsoonally induced fresh-water plume corresponding to the low salinity faunal assemblage may be accounted for, at the time. Such a plume would allow placing the sea level at least 20 – 25 m higher than the top of the deltaic interval. Thus, a sea-level elevation of at least about -100 m may be safely inferred for the Stage 3 time interval. Documenting the depth ranges of estuarine foraminiferal assemblages from the modern deltas of these rivers would serve well to ground-truth the interpretations.

7.1.2.2. An active northeast monsoon

The low salinity fauna defining the North Sunda River Delta provided evidence for an active northeast monsoon during the Stage 3 time interval.

7.1.3. Stage 2: Last Glacial Maximum and an early deglacial meltwater pulse

From the existing evidence in the faunally barren sediment intervals, the Last Glacial Maximum time period (cal BP 19, 250 +/- 330 years) on Sundaland was marked by subaerial exposure up to a depth of at least –114 m (Fig. 15 C, D). Marginal marine environments, if any, at that time interval, must have been removed by exposure and erosion.

The presence of a nearshore fauna of high abundance at cal BP 18, 230 years, directly overlying a subaerial interval, was indicative of an abrupt, rapid rise in sea-level (Fig. 19), which led to the infilling of the channel (channel structure shown in Fig. 20 A). This event was considered analogous to the early meltwater spike recorded at cal BP 19, 000 years from the Bonaparte Gulf, Australia (Yokoyama et al., 2001) (Fig. 20 B).

7.1.4. Stage 2: Deglaciation and Meltwater Pulse 1 A

7.1.4.1. Mangrove Marsh – a case of delta development

The Mangrove-Marsh zone of the paleo North Sunda River Delta was interpreted as a stage of delta development, where delta build-out could keep up with the rising sea level. An examination of some studies of the deltaic environments of the Sunda Shelf coastline showed that mangrove-marsh formation took place in response to delta progradation (Gagliano and McIntyre, 1968; Nguyen et al., 2000). The Holocene deltaic plain of the Mekong River Delta may be considered analogous to the paleo Sunda River Delta. Studies by Gagliano and McIntyre (1968), and by Nguyen et al. (2000), showed that the Holocene history of the Mekong Delta was one of coastal build-out. The process

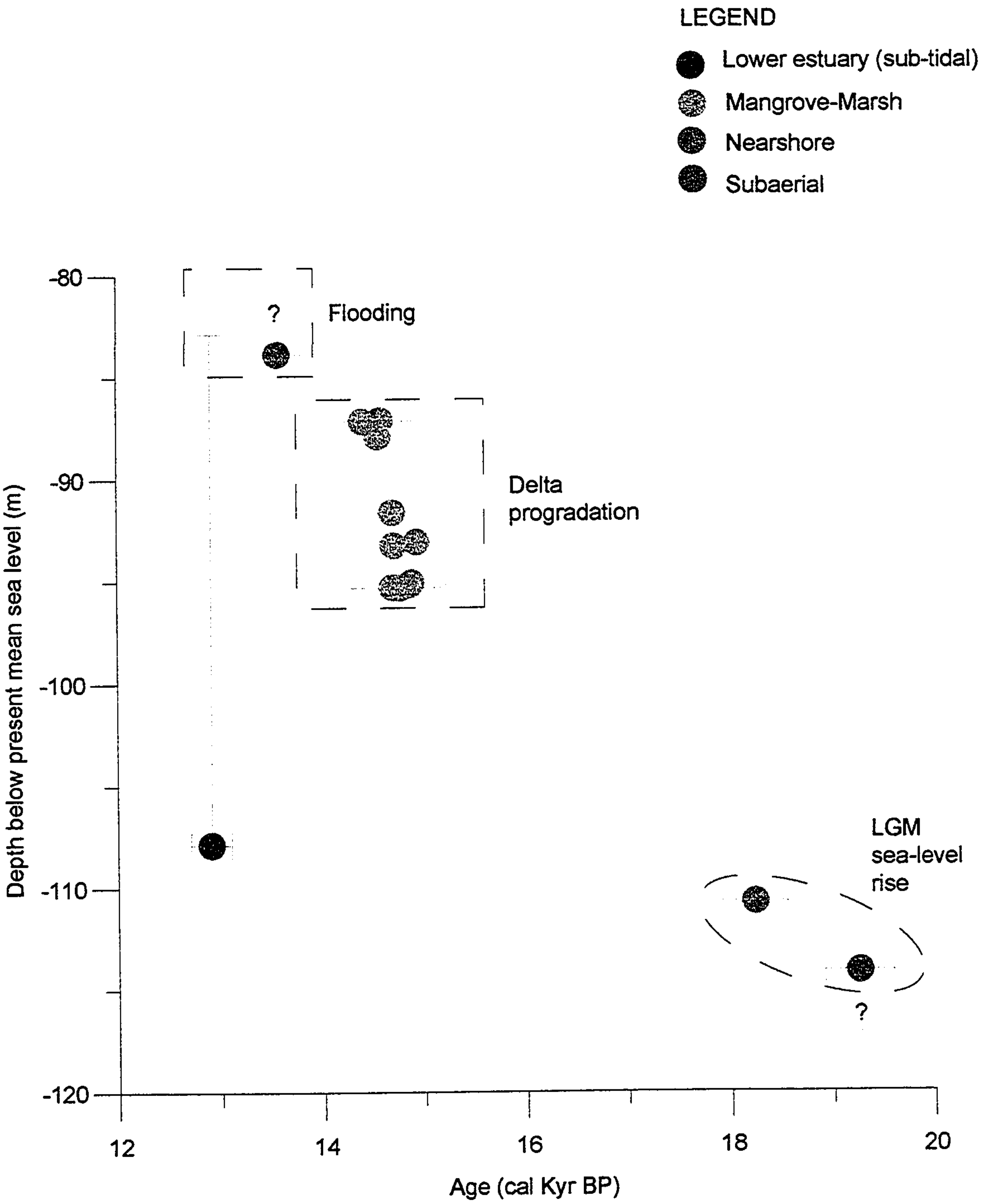
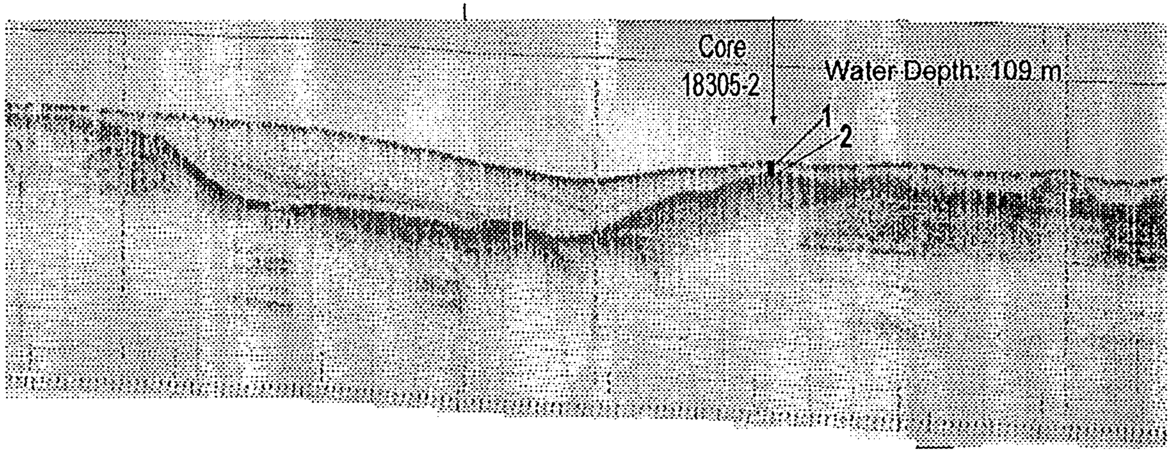


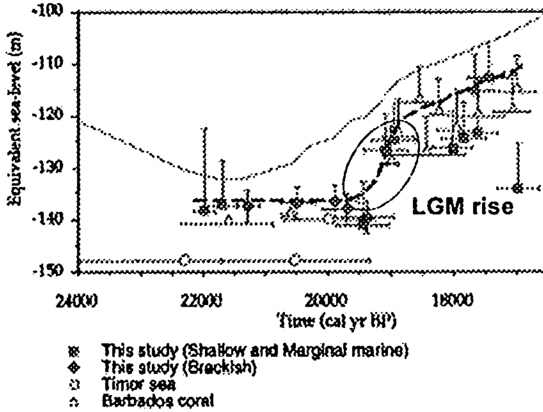
Figure 19. Sunda Shelf sea-level points and associated paleoenvironments

Figure 20. A compilation of figures to show the early meltwater spike at the end of the Last Glacial Maximum, evidenced from the Sunda Shelf (A, C, D) and the Sahul Shelf (B).

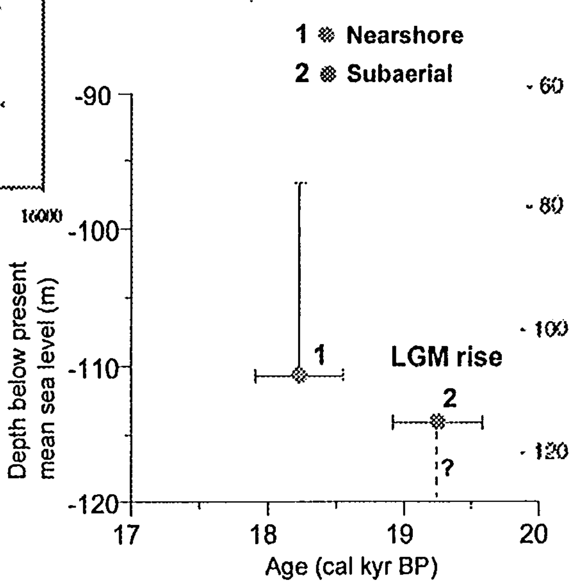
(A)

(modified from Stattegger et al., 1997)

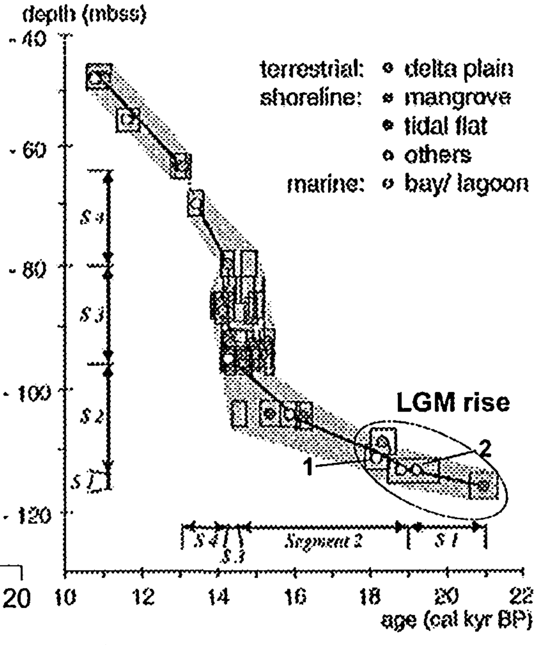




(B) Yokoyama et al., 2001



(C) This study



(D) Hanebuth et al., 2000

of coastal accretion occurred through the formation of mudflats down drift from the source area, where fine sediments formed extensive mudflats alongshore the low-energy areas, which acted as substrate for mangrove colonization. At times of abundant sediment supply, the shore advanced rapidly seaward through accumulation of marsh-capped mudflat deposits (Gagliano and McIntyre, 1968; Nguyen, 2000).

Thus, the study of the Holocene evolution of the Mekong River Delta (Nguyen et al., 2000) showed, that following the Holocene sea-level highstand (around 6, 000 – 5, 000 yr BP), the delta prograded through development of mangrove-marsh and beach ridges, as a result of sediment influx and longshore currents. A similar development of widespread mangrove forests was also reported in northern Australia (Woodroffe et al., 1985), Indonesia (Rimbaman, 1992), and Malaysia (Kamaludin, 1993).

Nguyen et al. (2000) placed the event of delta progradation (i.e. mangrove-marsh development) at the time interval of the Holocene sea-level highstand and at the beginning of the regression (around 5, 000 yr BP). It was also inferred by Nguyen et al. (2000) that as the sea-level regressed subsequently, mangrove development could have expanded several tens of kilometres to the South China Sea and the Gulf of Thailand.

It may thus be inferred that the mangrove-marsh formed in response to the Paleo-Sunda River Delta development (i.e. aggradation and progradation). Delta development occurred in response to a steady rate of sea-level rise from 14, 800 (+/- 500) years to 14, 400 (+/- 560) years at the time, one that allowed the mangrove-marsh to be maintained. Another inference may be drawn upon the nature of the northeast monsoon at the time, from the availability of sediment supply that maintained mangrove-marsh and delta development. The consistent supply of sediment that allowed mangrove marsh development, must have resulted due to an active northeast monsoon, which keep rivers at high flow rates with abundant sediment.

7.1.4.2. Gradual flooding of the Delta

Drowning of the mangrove marsh part of the delta, (post cal BP 14, 400 years, +/- 500 years) was marked by the transition from the arenaceous marsh faunal assemblage to calcareous faunal assemblages defining shallow marine environments. These shallow water environments included deltaic zones (Fig. 5 B), sub-tidal estuary (Fig. 9 B), coastal (Fig. 5 B), deltaic bay (Fig. 9 B), bay-lagoon (Fig. 5 B), and nearshore (Fig. 5 B) zones.

Thus, the flooding of the delta was gradual, marked by the deepening of the mangrove marsh zone, giving rise to shallow marine environments, from 14, 400 years (+/- 500 yr) to 13, 500 years (+/- 200 yr).

Complete flooding, leading to open Shelf conditions prevailed from post cal BP 13, 500 years.

7.2 The Sunda Shelf sea-level curve: comparison and revision

As mentioned in the previous sections, the only accurate sea-level indicator out of all the paleoenvironments identified, was the Mangrove Marsh. However the following problems associated with the ages obtained from the Mangrove Marsh Zone, for the specific time period, were as follows:

Sea-level points (i.e. AMS ^{14}C ages from various levels within the Mangrove Marsh zone) had calibrated age error bars spanning 1000 years (Fig. 13 B). Furthermore, some of the ages from higher levels in the Mangrove Marsh Zone were older than some of the ages from the lower levels in the Zone (Table 3 B, Fig. 13 B). Despite these problems, the advantage of these Mangrove Marsh Zone sea-level points over the ages obtained from nearshore paleo-zones was that the vertical error bar (error in depth/elevation with respect to the mean sea level at the time/age under discussion) was almost non-existent, due to the micro-tidal nature of the coastline (Table 4). The mangrove marsh environment thrives within a restricted tidal zone, which is usually half the size of the tidal range of the area (e.g. Scott and Medioli, 1978; Scott and Medioli, 1980; Hayward et al., 1999; also see section 3.1.1.) The study area (Sunda Shelf) is micro-tidal in nature with an average tidal range of 1.5 m (Wyrtki, 1961). Thus, the vertical error bar with respect to the mean sea level was negligible. Drawing a curve through the Mangrove Marsh sea-level points, however, was not justified due to the wide age error bars.

The concept of 'rapid flooding', in response to MeltWater Pulse 1A, as proposed by Hanebuth et al. (2000) is questionable. My study showed that the initiation of flooding of the delta led to the formation of shallow marine environments, such as bay-lagoon, estuarine, and near-shore settings. Complete flooding of the shelf, leading to open marine conditions, followed subsequently.

A large vertical error was associated with the date of cal BP 18, 230 years (+/- 300 years) obtained from the Nearshore Zone, whereas an unknown vertical error was associated with the date of cal BP 19, 250 years (+/- 330 years) obtained from the

Age (cal kyr. BP)	Depth (m)	Horizontal error (equal) (yr.)	Vertical error (+, -) (m)	Core
13.56	83.85	0.23	?, 0	18302
14.575	87.1	0.455	0, 0	18302
14.395	87.15	0.565	0, 0	18302
14.55	87.9	0.4725	0, 0	18302
14.69	91.61	0.53	0, 0	18300
14.93	93.06	0.585	0, 0	18300
14.7	93.23	0.54	0, 0	18300
14.88	95.04	0.56	0, 0	18300
14.86	95.15	0.555	0, 0	18300
14.69	95.28	0.53	0, 0	18300
14.76	95.31	0.53	0, 0	18300
12.9	107.87	0.2	25, 0	18298
18.23	110.71	0.32	14, 0	18305
19.25	114.11	0.335	0, ?	18305

Table 4. Sunda Shelf sea-level points used in Figure 19.

Subaerial Zone (Fig. 19, Table 4). These vertical errors of appropriate magnitude were not taken into account in the sea-level curve by Hanebuth et al. (2000) (Fig. 13 A). Thus, Hanebuth et al. (2000) proposed a low rate of sea-level rise during the termination of the LGM (Fig. 20 D); in fact they ignored the two age dates under discussion here, and did not quote a rate of sea-level rise for Termination 1, when the present study showed that there was an abrupt rise in sea-level during that time period; with a rise of at least 1.7 m per 100 years (Figs. 19, 20 C). Such an event was also documented by Yokoyama et al. (2001) from the Bonaparte Gulf of Australia (Fig. 20 B).

CHAPTER VIII

CONCLUSIONS

A combined technique using foraminifera, reflection seismics, sedimentology, and radiocarbon chronology allowed the Late Quaternary paleoenvironmental reconstruction of the Sunda Shelf, the largest Shelf area outside of the polar shelves.

The study provided evidence for the drowned delta system of the Paleo- Sunda Rivers through foraminiferal assemblages, seismic structures, and sedimentology. AMS radiocarbon chronology provided the timing for the evolution of the delta system, from subaerial exposure during the Late Quaternary lower sea levels, to flooding, due to post glacial sea-level rise. The published sea-level curve for the Shelf (Hanebuth et al., 2000) follows the general trend of the Barbados sea-level curve, the standard curve for the Late Quaternary (from Isotope Stage 2 to Stage 1). However, the present study provided a detailed evolution of the Shelf, and its response to Late Quaternay sea-level changes. The following points highlight the main findings of the study:

1. Based on a comparison of modern foraminiferal distributions along the coastline of the study area, and on the Shelf, with the foraminiferal assemblages in the sediment-cores, the following paleoenvironments were delineated (detailed in Table 2) :-

   Subaerial, Mangrove Marsh, Subtidal Estuary, Deltaic Estuary, Bay-Lagoon, Near-shore and Coastal – both bearing a distinct marine influence compared to the other zones, Shallow Marine, Shelf.

2. A shallow marine delta of the Paleo-Sunda River, of the Marine Isotope Stage 5 time interval was identified in the southwestern part of the study area (Fig. 14). It implicated the connection of the Indian Ocean with the Shelf, through the Borneo Strait, thus, an active southwest monsoon. A shoreline at an elevation of –50 m was inferred for the Stage 5 time period.

3. An estuarine delta of the North Paleo-Sunda River, of the Marine Isotope Stage 3 time interval was identified in the northeastern part of the study area (Fig. 16). It implied an active northeast monsoon.

4. The Last Glacial Maximum time interval (cal BP) was marked by subaerial exposure at cal BP 19, 000 years, at a depth of –115 m. The subaerial Sundaland may have been an area of sediment bypass by the Sunda Rivers. A near-shore environment dated at cal BP 18, 230 years, at –111 m, marked an abrupt rise in sea-level at the end of the LGM.

5. The absence of marginal marine environments during the time interval between the LGM and cal BP 14, 800 years (+/- 500 years) implied that the Shelf was subaerially exposed during this time interval, and may have been an area of sediment bypass for the paleo-drainage system.

6. Deglaciation, and the meltwater induced rise in sea-level (recognized as the event MWP 1A – e.g. Bard et al., 1996; Hanebuth et al., 2000) was marked by the development of a Mangrove Marsh in the central part of the study area, in the vicinity of Natuna Island (Fig. 18), from cal BP 14, 800 years (+/- 500 years) to cal BP 14, 400 years (+/- 560 years). Such a marginal marine environment implied a relatively steady rise in sea-level that allowed the Mangrove Marsh to be maintained, and an active monsoon, which provided sediment supply through riverine discharge. The paleo-shoreline was assumed to be the Mangrove Marsh Zone, thus, was inferred at an elevation from –95 m to –87 m.

7. Gradual flooding of the subaerial Sundaland advanced through shallow marine environments, from cal BP 14, 400 years (+/- 565 years) to cal BP 12, 900 years (+/- 200 years), until it reached the average water depth of the modern Shelf i.e. -50 m.

SYSTEMATIC TAXONOMY OF BENTHIC FORAMINIFERA

Genera are in accordance with Loeblich and Tappan (1964, 1987). Identifications were made from the following references: Matsunaga (1963), Wang et al. (1985a,b,c), Loeblich and Tappan (1994), Szarek (2001), Scott and Medioli (1980), Javaux (1999), Huang (2000), Scott et al. (2000). Original references and any name changes are indicated herein.

Order FORAMINIFERIDA Eichwald, 1830

Genus ***Ammomassilina*** Cushman, 1933a

Ammomassilina alveoliniformis (Millett), 1898

Plate 1, Figure 11

Massilina alveoliniformis MILLETT, 1898, p. 609, pl. 8, figs. 5-7.

Ammomassilina alveoliniformis (Millett). HAIG, 1988, p. 218, pl. 1, figs. 3-6. LOEBLICH and TAPPAN, 1994, p. 45, pl. 5, figs. 1-5, pl. 69, figs. 1, 2. SZAREK, 2001, p. 102, pl. 11, figs. 20-21.

Genus ***Ammonia*** Brünnich, 1772

Ammonia beccarii (Linné), 1758

Plate 2, Figure 5

Nautilus beccarii LINNÉ, 1758, p. 710.

Ammonia beccarii (Linné). BRÜNNICH, 1772, p. 232. VAN MARLE, 1991, p. 217, pl. 23, figs. 11-12. SZAREK, 2001, p. 148, pl. 26, figs. 13-15.

***Ammonia* sp.**

Genus ***Ammotium*** Loeblich and Tappan, 1953

Ammotium salsum (Cushman and Brönnimann), 1948a

Plate 1, Figure 3

Ammobaculites salsus CUSHMAN and BRÖNNIMANN, 1948a, p. 16, pl. 3, figs. 7-9.

Ammotium salsum (Cushman and Brönnimann). PARKER and ATHEARN, 1959, p. 340, pl. 50, figs. 6, 13. SCOTT et al., 1991, p. 384, pl. 1, figs. 11-13.

Genus ***Amphimorphina*** Loeblich and Tappan, 1987

Amphimorphina virgula (Brady), 1879a

Plate 1, Figures 14, 15

Sagrina virgula BRADY, 1879a, p. 275, pl. 8, figs, 19-21. BRADY, 1884, p. 583, pl. 76, figs. 4-7 (ZF 3361).

Amphimorphina virgula (Brady). HAIG, 1993, p. 171, pl. 7, figs. 13-18.

Genus ***Amphistegina*** d'Orbigny, 1826

Amphistegina lessoni d'Orbigny, 1826

Amphistegina lessoni d'ORBIGNY, 1826, p. 304, pl. 17, figs. 1-4. VAN MARLE, 1991, p. 80, pl. 21, figs. 7-8. LOEBLICH and TAPPAN, 1994, p. 156, pl. 340, figs. 1-9. JAVAUX, 1999, p. 312, pl. 1, fig. 10.

Genus *Anomalinoides* Brotzen, 1942

Anomalinoides **cf.** ***welleri*** (Plummer), 1926

Plate 2, Figures 1, 2

Truncatulina welleri PLUMMER, 1926, p. 143, pl. 9, fig. 6.

Anomalinoides welleri (Plummer). WANG et al., 1988, p. 178, pl. 32, figs. 12-13. 162, pl. 358, figs. 1-7. SZAREK, 2001, p. 145, pl. 24, figs. 8-10.

Genus *Asterorotalia* Hofker, 1951

Asterorotalia gaimardii (d'Orbigny), 1826

Rotalia (Turbinulina) gaimardii D'ORBIGNY, 1826, p. 275.

Asterorotalia gaimardii (d'Orbigny). VAN MARLE, 1991, p. 219, pl. 23, fig. 16; pl. 24, Figs. 1-3. LOEBLICH and TAPPAN, 1994, p. 166, pl. 372, figs. 1-7. SZAREK, 2001, p. 148, pl. 27, figs. 7-8.

Asterorotalia pulchella (d'Orbigny), 1839

Plate 2, Figure 17

Rotalina (*Calcarina*) *pulchella* D'ORBIGNY, 1839, p. 80.

Asterorotalia pulchella (d'Orbigny). HOFKER, 1951, p. 505, text figs. 343-344. HOFKER, 1968, p. 27, pl. 8, fig. 8-10, pl. 9, fig. 1-7. JONES, 1994, p. 114, pl. 115, fig. 8. SZAREK, 2001, p. 149, pl. 27, figs. 11-12.

Genus *Astrononion* Cushman & Edwards, 1937

***Astrononion* sp.**

Genus *Bigenerina* d'Orbigny, 1826

***Bigenerina* sp.**

Plate 1, Figure 10

Genus *Bolivina* d'Orbigny, 1839

Bolivina glutinata Egger, 1893

Plate 1, Figure 7

Bolivina glutinata EGGER, 1893, p. 297, pl. 8, figs. 57 – 62. LOEBLICH and TAPPAN, 1994, p. 111, pl. 213, figs. 1 – 8. SZAREK, 2001, p. 124.

Remark: This form may have been mistaken for *B. robusta* in previous works.

Bolivina macella Belford, 1966

Plate1, Figure 17

Brizalina macella BELFORD, 1966, p. 33, pl. 2, figs 7-10. VAN MARLE, 1991, p. 168, pl. 17, fig. 13. SZAREK, 2001, p. 124, pl. 16, fig. 12.

Bolivina sp.

Plate 1, Figure 16

Bolivina spathulata (Williamson), 1858

Textularia variabilis WILLIAMSON var. *spathulata* WILLIAMSON, 1858, p. 76, pl. 6, figs. 164-165.

Bolivina spathulata (Williamson). BARKER, 1960, p. 106, pl. 52, figs. 20-21. VAN MARLE, 1991, p. 163, pl. 16, figs. 15-16. SZAREK, 2001, p. 124, pl. 16, figs. 6-7.

Brizalina spathulata (Williamson). JONES, 1994, p. 57, pl. 52, figs 20-21.

Bolivina striatula Cushman, 1922b

Bolivina striatula CUSHMAN, 1922b, p. 27, pl. 3, fig. 10. JAVAUX, 1999, p. 318, pl. 1, fig. 22.

Bolivina subspinescens Cushman, 1922a

Bolivina subspinescens CUSHMAN, 1922a, p. 48, pl. 7, fig. 5. VAN MARLE, 1991, p. 164, pl. 16, figs. 12-14.

Bolivina vadescens Cushman, 1933b

Bolivina vadescens CUSHMAN, 1933b, p. 81, pl. 8, fig. 11. HOFKER, 1951, p. 52, text fig. 22.

Genus ***Bolivinellina*** Saidova, 1975

Bolivinellina translucens Phleger and Parker, 1951

Bolivina translucens PHLEGER and PARKER, 1951, p. 15, pl. 7, figs. 13, 14.

Bolivinellina translucens (Phleger and Parker). LOEBLICH and TAPPAN, 1987, pl. 547, figs. 6, 7. LOEBLICH and TAPPAN, 1994, p. 111, pl. 213, figs. 9-14.

Bulimina aculeata d'Orbigny, 1826

Bulimina aculeata D'ORBIGNY, 1826, p. 269. VAN MARLE, 1991, p. 84, pl. 5, figs. 3-5. JAVAUX, 1999, p. 321, pl. 2, fig. 6.

Bulimina marginata d'Orbigny, 1826

Bulimina marginata D'ORBIGNY, 1826, p. 269, pl. 12, figs. 10, 11. VAN MARLE, 1991, p. 87, pl. 5, figs. 9-10. LOEBLICH and TAPPAN, 1994, p. 124, pl. 242, figs. 1-4. JAVAUX, 1999, p. 321.

Genus ***Cancris*** de Montfort, 1808

***Cancris* sp.**

Genus ***Cassidulina*** d'Orbigny, 1826

Cassidulina laevigata d'Orbigny, 1826

Cassidulina laevigata D'ORBIGNY, 1826, p. 282, no. 1, pl. 15, figs. 4, 5.

Cassidulina teretis Tappan, 1951

Plate 2, Figure 11

Cassidulina teretis TAPPAN, 1951, p. 121, pl. 1, fig. 30.

Genus ***Cellanthus*** de Montfort, 1808

***Cellanthus* sp.**

Genus ***Cibicides*** de Montfort, 1808

Cibicides deprimus Phleger and Parker, 1951

Cibicides deprimus PHLEGER and PARKER, 1951, p. 29, pl. 15, figs. 16-17. SZAREK, 2001, p. 139.

Cibicides lobatulus (Walker and Jacob) in Kanmacher, 1798

Nautilus lobatulus WALKER and JACOB in KANMACHER, 1798, p. 642, pl. 14, fig. 36.

Cibicides lobatulus (Walker & Jacob). HADA, 1931, p. 141, text-fig. 95. VAN MARLE, 1991, p. 198, pl. 21, figs. 12-14. JONES, 1994, p. 97, pl. 92, fig. 10; pl. 93, figs. 1, 4-5; pl. 115, figs. 4-5. SZAREK, 2001, p. 139.

***Cibicides* sp.**

Genus ***Cibicidoides*** Thalmann, 1939

Cibicidoides mediocris (Finlay) 1940

Cibicides mediocris Finlay, 1940, p. 464, pl. 67, figs. 198-199.

Cibicidoides mediocris (Finlay). Van Marle, 1991, p. 134, pl. 12, figs. 8-10.

***Cibicidoides* sp.**

Genus ***Clavulina*** d'Orbigny, 1826

***Clavulina* sp.**

Plate 1, Figure 4

Genus ***Cyclogyra*** Wood, 1842

***Cyclogyra* sp.**

Genus ***Discorbinella*** Cushman & Martin, 1935

***Discorbinella* sp.**

Genus ***Discorbis*** Lamarck, 1804

***Discorbis* sp.**

Genus ***Elphidium*** de Montfort, 1808

Elphidium advenum (Cushman), 1922b

Plate 1, Figures 21 – 24

Polystomella advena CUSHMAN, 1922b, p. 56, pl. 9, figs. 11, 12.

Elphidium advenum (Cushman). CUSHMAN 1933c, p. 50, pl. 12, figs. 1-3. JAVAUX, 1999, p. 330, pl. 3, fig. 1. SZAREK, 2001, pl. 28, fig. 2.

Genus ***Epistominella*** Husezima and Maruhasi, 1944

Epistominella exigua (Brady), 1884

Pulvinulina exigua BRADY, 1884, p. 696, pl. 103, figs. 13, 14.

Epistominella exigua (Brady). PARKER, 1954, p. 533.

Epistominella pulchra (Cushman), 1933b

Plate 2, Figures. 3, 4

Pulvinulinella pulchra CUSHMAN, 1933b, p. 92, pl. 9, fig. 10.

Epistominella pulchra (Cushman). TODD, 1965, p. 31, pl. 10, figs. 3-4. VAN MARLE, 1991, p. 150, pl . 15, figs. 7-9. JAVAUX, 1999, p. 333, pl. 3, figs. 7-8.

***Epistominella* sp.**

Genus ***Eponides*** de Montfort, 1808

Eponides cribrorepandus (Asano and Uchio in Asano), 1951

Poroeponides cribrorepandus ASANO and UCHIO in Asano, 1951, p. 18, text-figs. 134-135.

Eponides cribrorepandus (Asano & Uchio). LOEBLICH and TAPPAN, 1987, p. 549, pl. 594, figs. 9-13. LOEBLICH and TAPPAN, 1994, p. 135, pl. 269, figs. 1-9. HAYWARD et al., 1999a, p. 138, pl. 9, figs. 37-38. SZAREK, 2001, p. 133, pl. 19, fig. 12.

Eponides repandus (Fichtel and Moll), 1798

Nautilus repandus FICHTEL and MOLL, 1798, p. 35, pl. 3, figs. a-d.

Eponides repandus (Fichtel and Moll). BARKER, 1960, p. 214, pl. 104, fig. 18.

***Eponides* sp.**

Genus ***Evolutononion*** N. W. Wang, 1964

Evolutononion shansiense N. W. Wang, 1964

Plate 2, Figures 20, 21

Evolutononion shansiense N.W. WANG, 1964, p. 58. LOEBLICH and TAPPAN, 1994, p. 157, pl. 342, figs. 13-14.

Genus ***Fissurina*** Reuss, 1850

***Fissurina* sp.**

Genus ***Fursenkoina*** Loeblich and Tappan, 1961

Fursenkoina fusiformis (Williamson), 1858

Bulimina pupoides D'ORBIGNY var. *fusiformis* WILLIAMSON, 1858, p. 64, pl. 5, figs. 129, 130.

Fursenkoina fusiformis (Williamson). GREGORY, 1970, p. 232.

Genus ***Globocassidulina*** Voloshinova, 1960

Globocassidulina subglobosa (Brady), 1881

Plate 2, Figure 12

Cassidulina subglobosa BRADY, 1881, p. 60; 1884, p. 430, pl. 54, fig. 17.

Globocassidulina subglobosa (Brady). LOEBLICH and TAPPAN, 1964, C738, fig. 604, 6a, b. VAN MARLE, 1991, p. 120, pl. 10, figs. 10-11. SZAREK, 2001, p. 125, pl. 16, figs. 16-17.

Genus ***Gyroidina*** d'Orbigny, 1826

Gyroidina **sp.**

Genus ***Hanzawaia*** Asano, 1944

Hanzawaia coronata (Heron-Allen and Earland), 1932

Discorbis coronata HERON-ALLEN and EARLAND 1932, p. 416, pl. 14, figs. 25-30.

Hanzawaia coronata (Heron-Allen and Earland). LOEBLICH and TAPPAN, 1994, p. 164, pl. 366, figs. 1-15.

Hanzawaia grossepunctata (Earland), 1934

Plate 2, Figure 6

Cibicides grossepunctatus EARLAND, 1934, p. 184, pl . 8, figs. 39-41.

Hanzawaia grossepunctata (Earland). LOEBLICH and TAPPAN, 1994, p. 164, pl. 364, figs. 9-13; pl. 365, figs. 1-13. SZAREK, 2001, p. 147, pl. 26, figs. 6-7.

Hanzawaia nipponica Asano, 1944

Plate 2, Figures 7, 8

Hanzawaia nipponica ASANO, 1944, p. 99, pl. 4, figs. 1-2. VAN MARLE, 1991, p. 137, pl. 12, figs. 5-7. HUANG, 2000, p. 261, pl. 26, figs. 7a-c, 8a-b.

Hanzawaia **sp.**

Genus ***Heterolepa*** Franzenau, 1884

Heterolepa praecincta (Karrer), 1868

Rotalia praecincta KARRER, 1868, p. 189, pl. 5, fig. 7.

Heterolepa praecincta LOEBLICH and TAPPAN, 1994, p. 163, pl. 360, figs. 1-10. SZAREK, 2001, p. 146, pl. 24, figs. 15-17.

Heterolepa subhaidingeri (Parr), 1950

Plate 2, Figure 23

Cibicides subhaidingeri PARR, 1950, p. 364, pl. 15, fig. 7.

Heterolepa subhaidingeri (Parr). TAPPAN and LOEBLICH, 1982, pl. 53, fig. 10. LOEBLICH and TAPPAN, 1994, p. 163, pl. 359, figs. 1-13. SZAREK, 2001, p. 146, pl. 24, figs. 15-17.

***Heterolepa* sp.**

***Hoeglundina elegans* (d'Orbigny), 1826**

Rotalia (Turbinulina) elegans D'ORBIGNY, 1826, p. 276.

Hoeglundina elegans (d'Orbigny). PHLEGER and PARKER, 1951, p. 22, pl. 12, fig. 1. VAN MARLE, 1991, p. 77, pl. 4, figs. 14-16. LOEBLICH and TAPPAN, 1994, p. 98, pl. 174, figs. 1-6. SZAREK, 2001, p. 123, pl. 16, figs. 3-5.

Genus ***Hopkinsinella*** Bermúdez and Fuenmayor, 1966

***Hopkinsinella glabra* (Millett), 1903**

Plate 1, Figure 13

Uvigerina auberiana D'ORBIGNY var. *glabra* MILLETT, 1903, p. 268, pl. 5, figs. 8-9.

Hopkinsinella glabra (Millett). BERMÚDEZ and FUENMAYOR, 1966, p. 508. LOEBLICH and TAPPAN, 1994, p. 118, pl. 232, figs. 1-11. SZAREK, 2001, p. 127.

Genus ***Hyalinea*** Hofker, 1951

***Hyalinea balthica* (Schröeter), 1783**

Nautilus balthicus SCHRÖETER, 1783, p. 20, pl. 1, fig. 2.

Hyalinea balthica (Schröeter). LEROY, 1964, p. F-44, pl. 9, figs. 34 – 36. VAN MARLE, 1991, p. 203, pl. 22, figs. 6, 7. SZAREK, 2001, p. 138, pl. 21, fig. 12.

Genus ***Lagena*** Walker & Jacob, 1798 (in Kanmacher)

***Lagena* sp.**

Genus ***Lenticulina*** Lamarck, 1804

Lenticulina orbicularis (d'Orbigny), 1826

Robulina orbicularis D'ORBIGNY, 1826, p. 288, pl. 15, figs. 8-9.

Lenticulina orbicularis (d'Orbigny). COUSTILLAS, 1983, pl. 23, figs. 1-2. VAN MARLE, 1991, p. 49.

Genus ***Miliammina*** Heron-Allen and Earland, 1930

Miliammina fusca (Brady), 1870

Quinqueloculina fusca BRADY, 1870, p. 286, pl. 11, figs. 2, 3.

Miliammina fusca (Brady). PHLEGER and WALTON, 1950, p. 280, pl. 1, figs. 19a, b. SCOTT et al., 1991, p. 386, pl. 1, fig. 14.

Genus ***Neoconorbina*** Hofker, 1951

Neoconorbina terquemi (Rzehak), 1888

Discorbina terquemi RZEHAK, 1888, p. 228.

Neoconorbina terquemi (Rzehak). HOFKER, 1951, p. 435, text figs. 298, 299. VAN MARLE, 1991, p. 147, pl. 14, figs. 15, 16. JAVAUX, 1999, p. 347, pl. 4, figs. 1-2.

***Neoconorbina* sp.**

Genus *Neoeponides* Reiss, 1960

Neoeponides praecinctus (Karrer), 1868

Rotalina praecincta KARRER, 1868, p. 189, pl. 5, fig. 7.

Neoeponides praecinctus JONES, 1994, p. 99, pl. 95, figs. 1-3.

***Neoeponides* sp.**

Neouvigerina ampullacea (Brady), 1884

Plate 1, Figure 19

Uvigerina asperula C_j_ek var. *ampullacea* BRADY, 1884, p. 579, pl. 75, figs. 10, 11.

Neouvigerina ampullacea (Brady). HOFKER, 1951, p. 208, text figs. 135-138.

Genus *Nonion* de Montfort, 1808

***Nonion* sp.**

Nonion subturgidum (Cushman), 1924

Plate 2, Figure 25

Nonionina subturgida CUSHMAN, 1924, p. 47, pl. 16, fig. 2.

Nonion subturgidum (Cushman). CUSHMAN, 1933c, p. 43, pl. 10, figs. 4-7. GRAHAM and MILITANTE, 1959, p. 72, pl. 11, fig. 3. LOEBLICH and TAPPAN, 1994, p. 158, pl. 343, figs. 1-9.

***Nonionella* sp.**

Nonionella turgida (Williamson), 1858

Plate 2, Figure 24

Rotalina turgida WILLIAMSON, 1858, p. 50, pl. 4, figs. 95-97.

Nonionella turgida (Williamson). BARKER, 1960, p. 224, pl. 109, figs. 17-19.

Genus ***Operculina*** d'Orbigny, 1826

***Operculina* sp.**

Genus ***Pararotalia*** Le Calvez, 1949

***Pararotalia* sp.**

Plate 2, Figures 15, 16, 22

Remarks: This form resembles *Pararotalia* sp.1 of Szarek, 2001, p. 147, pl. 26, figs. 9, 10, 12.

Genus ***Pseudorotalia*** Reiss and Merling, 1958

Pseudorotalia indopacifica (Thalmann), 1935

Rotalia indopacifica THALMANN, 1935, p. 605, pl. 73, fig. 1.

Pseudorotalia indopacifica (Thalmann). WHITTAKER and HODGKINSON, 1979, p. 80, pl. 6, figs 6a-8b; pl. 10, figs. 7-9. SZAREK, 2001, p. 149, pl. 27, figs. 4-6.

Pseudorotalia schroeteriana (Parker and Jones), 1862

Plate 2, Figures 18, 19

Rotalia schroeteriana PARKER and JONES, 1862, p. 213, pl. 13, figs. 7-9.

Pseudorotalia schroeteriana (Parker and Jones). REISS and MERLING, 1958, p. 13, pl. 1, fig. 15-17. HOFKER, 1968, p. 30, pl. 10, fig. 4-18.

Genus ***Pyrgo*** Defrance, 1824

***Pyrgo* sp.**

Genus ***Quinqueloculina*** d'Orbigny, 1826

Quinqueloculina agglutinans d'Orbigny, 1939

Plate 1, Figure 5

Quinqueloculina agglutinans D'ORBIGNY, 1939, p. 195, pl. 12, figs. 11-13. GRAHAM and MILITANTE, 1959, p. 41, pl. 4, fig. 10. JAVAUX, 1999, p. 358, pl. 4, figs. 24-25; plate 5, fig. 1.

Quinqueloculina auberiana d'Orbigny, 1839

Plate 2, Figure 9

Quinqueloculina auberiana D'ORBIGNY, 1839, p. 193, pl. 12, figs. 1-3. HEDLEY et al., 1967, p. 25, pl. 8, figs. 5A-C. JONES, 1994, p. 21, pl. 5, figs. 8-9. HAYWARD et al., 1999a, p. 100, pl. 4, figs. 13-14. SZAREK, 2001, p. 104, pl. 12, fig. 13.

Quinqueloculina pseudoreticulata Parr, 1941

Quinqueloculina pseudoreticulata PARR, 1941, p. 305. WHITTAKER and HODGKINSON, 1979, p. 28, pl. 2, fig. 9. VAN MARLE, 1991, p. 64, pl. 3, figs. 9-10. JONES, 1994, p. 25, pl. 9, figs. 2-3. JAVAUX, 1999, p. 362, pl. 5, fig. 19.

Quinqueloculina sulcata d'Orbigny in Fornasini, 1900

Quinqueloculina sulcata D'ORBIGNY, 1826, p. 301 (nom. nud.). FORNASINI, 1900, p. 364, text fig. 9. LOEBLICH and TAPPAN, 1994, p. 50, pl. 82, figs. 1-6.

***Quinqueloculina* sp.**

Plate 2, Figure 10

Genus ***Reussella*** Galloway, 1933

Reussella spinulosa (Reuss), 1850

Verneuilina spinulosa REUSS, 1850, p. 374, pl. 47, fig. 12.

Reussella spinulosa (Reuss). LOEBLICH and TAPPAN, 1987, pl. 575, figs. 9-12. HAYWARD et al., 1999a, p. 135, pl. 9, fig. 28. SZAREK, 2001, p. 131, pl. 18, figs. 18-19.

Genus ***Rosalina*** d'Orbigny, 1826

Rosalina columbiensis (Cushman), 1925

Plate 2, Figures 13, 14

Discorbis columbiensis CUSHMAN, 1925, p. 43, pl. 6, fig. 13.

Rosalina columbiensis (Cushman). SCOTT et al., 1980, p. 231, pl. 4, figs. 6, 7.

***Rosalina* sp.**

Genus ***Schlumbergerina*** Munier-Chalmas, 1882

Schlumbergerina alveoliniformis (Brady), 1879b

Miliolina alveoliniformis BRADY, 1879b, p. 54. BRADY, 1884, p. 181, pl. 8, figs. 15-20.

Schlumbergerina alveoliniformis (Brady). CUSHMAN, 1932, p. 29, pl. 8, fig. 1. GRAHAM and MILITANTE, 1959, p. 49, pl. 6, fig. 11. LOEBLICH and TAPPAN, 1994, p. 46, pl. 72, figs. 9-11.

Genus ***Seabrookia*** Brady, 1890

***Seabrookia* sp.**

Genus ***Sigmoilopsis*** Finlay, 1947

***Sigmoilopsis* sp.**

Genus ***Siphogenerina*** Schlumberger, in Milne-Edwards, 1882

Siphogenerina raphanus (Parker & Jones), 1865

Plate 1, Figure 20

Uvigerina (*Sagrina*) *raphanus* PARKER and JONES, 1865, p. 364, pl. 18, figs. 16-17.

Siphogenerina raphanus (Parker & Jones). CUSHMAN, 1926, p. 4, pl. 1, figs. 1-4 (not pl. 5, figs. 1, 2). HADA, 1931, p. 134, text-fig. 91. JONES, 1994, p. 87, pl. 75, figs. 21-22.

Genus ***Siphonina*** Reuss, 1850

Siphonina tubulosa Cushman, 1924

Siphonina tubulosa CUSHMAN, 1924, p. 40, pl. 13, figs. 1-2. VAN MARLE, 1991, p. 224, pl. 19, figs. 15-16. JONES, 1994, p. 100, pl. 96, figs. 5-7. LOEBLICH and TAPPAN, 1994, p. 144, pl. 299, figs. 1-10. 410, pl. 159, fig. 5. SZAREK, 2001, p. 136, pl. 20, fig. 11.

Genus ***Siphotextularia*** Finlay, 1939

Siphotextularia foliosa Zheng, 1988

Plate 1, Figure 2

Siphotextularia foliosa ZHENG, 1988, p. 126, pl. 38, figs. 1-2. LOEBLICH and

TAPPAN, 1994, p. 30, pl. 42, figs. 1-6. SZAREK, 2001, p. 96, pl. 9, figs. 17-18

Siphotextularia subplanoides Zheng, 1988

Siphotextularia subplanoides ZHENG, 1988, p. 130, pl. 38, fig. 5. SZAREK, 2001, p. 97, pl. 10, figs. 3-6.

Genus ***Siphouvigerina*** Parr, 1950

Siphouvigerina fimbriata (Sidebottom), 1918

Uvigerina porrecta Brady var. *fimbriata* SIDEBOTTOM, 1918, p. 147, pl. 5, fig. 23.

Siphouvigerina fimbriata (Sidebottom). PARR, 1950, p. 342, pl. 12, fig. 22. LOEBLICH and TAPPAN, 1994, p. 127, pl. 247, figs. 1-5.

Genus ***Spirillina*** Ehrenberg, 1843

***Spirillina* sp.**

Genus ***Spiroloculina*** d'Orbigny, 1826

***Spiroloculina* sp.**

Genus ***Spirotextularia*** Saidova, 1975

***Spirotextularia* sp.**

Genus ***Textularia*** Defrance, 1824

Textularia agglutinans d'Orbigny, 1839

Plate 1, Figure 1

Textularia agglutinans, D'ORBIGNY, 1839, p. 144, pl . 1, figs. 17, 18, 32, 34. LOEBLICH and TAPPAN, 1994, p. 27, pl . 33, figs. 8-12. JAVAUX, 1999, p. 376, pl. 7, fig. 14.

***Textularia* sp.**

Textularia fistula Cushman, 1911

Textularia agglutinans D'ORBIGNY var. *fistula* CUSHMAN, 1911, p. 10, text fig. 11.

Textularia fistula Cushman. ASANO, 1950, p. 4, figs. 17, 18.

Genus ***Trifarina*** Cushman, 1923

***Trifarina* sp.**

Genus ***Triloculina*** d'Orbigny, 1826

***Triloculina* sp.**

Triloculina tricarinata d'Orbigny, 1826

Triloculina tricarinata D'ORBIGNY, 1826, p. 299, pl. 7, fig. 94. VAN MARLE, 1991, p. 67, pl. 4, figs. 1-2. SZAREK, 2001, pl. 13, figs. 13-15

Genus ***Triloculinella*** Riccio, 1950

Triloculinella pseudooblonga (Zheng), 1980

Miliolinella pseudooblonga ZHENG, 1980, p. 158, 177, pl. 2, fig. 5.

Triloculinella pseudooblonga (Zheng). LOEBLICH and TAPPAN, 1994, p 57, pl. 88, figs. 7-18; pl. 97, figs. 10-12; pl. 98, figs. 1-3, 7-9.

***Triloculinella* sp.**

Genus ***Trochammina*** Parker and Jones, 1859

Trochammina inflata (Montagu), 1808

Plate 1, Figure 7

Nautilus inflata MONTAGU, 1808, p. 81, pl. 18, fig. 3.

Trochammina inflata (Montagu). PARKER and JONES, 1859, p. 347. SCOTT and MEDIOLI, 1980, p. 44, pl. 3, figs. 12-14; pl. 4, figs. 1-3. JAVAUX, 1999, p. 383, pl. 8, figs. 10-15.

Trochammina macrescens Brady, 1870

(forma ***polystoma***)

Plate 1, Figure 6

Trochammina inflata (Montagu) var. *macrescens* BRADY, 1870, p. 290, pl. 11, figs.5a-c.

Jadammina polystoma BARTENSTEIN and BRAND, 1938, p. 381, figs. 1a-c, 2a-l.

Trochammina macrescens Brady. PHLEGER and WALTON, 1950, p. 281, pl. 2, figs. 6,

7. SCOTT and MEDIOLI, 1980, p. 44, pl. 3, figs. 1-8.

Remark: This species includes two forms, forma *polystoma* (Plate 1, Fig. 2), the dominant form found in the Sunda Shelf samples, and forma *macrescens*. The difference in the two forms is in the presence or absence of supplementary apertures, which may be a response to salinity (Scott and Medioli, 1980). Although the supplementary apertures of forma *polystoma* are not visible in the SEM illustrated in Plate 1, they were observed under the microscope.

Genus ***Uvigerina*** d'Orbigny, 1826

Uvigerina* ex. gr. *auberiana d'Orbigny, 1839

Uvigerina auberiana D'ORBIGNY, 1839, p. 106, pl. 2, figs. 23-24. SZAREK, 2001, p. 130, pl. 18, figs. 11-12.

Uvigerina dirupta Todd, in Cushman and McCulloch, 1948

Uvigerina peregrina Cushman var. *dirupta* TODD in CUSHMAN and MCCULLOCH, 1948, p. 267, pl. 34, fig. 3. VAN MARLE, 1991, p. 104, pl. 7, figs. 16-17. LOEBLICH and TAPPAN, 1994, p. 128, pl. 250, figs. 7-10

Uvigerina schwageri Brady, 1884

Uvigerina schwageri BRADY, 1884, p. 575, pl. 74, figs. 8-10.

PLATE 1

Figure 1.	*Textularia agglutinans* d'Orbigny
Figure 2.	*Siphotextularia foliosa* Zheng
Figure 3.	*Ammotium salsum* (Cushman and Brönnimann)
Figure 4.	*Clavulina* sp.
Figure 5.	*Quinqueloculina agglutinans* d'Orbigny
Figure 6.	*Trochammina macrescens* f. *polystoma* Brady
Figure 7.	*Trochammina inflata* (Montagu)
Figure 8.	inner organic lining
Figure 9.	inner organic lining
Figure 10.	*Bigenerina* sp.
Figure 11.	*Ammomassilina alveoliniformis* (Millett)
Figure 12.	inner organic lining
Figure 13.	*Hopkinsinella glabra* (Millett)
Figure 14, 15.	*Amphimorphina virgula* (Brady)
Figure 16.	*Bolivina* sp.
Figure 17.	*Bolivina macella* Belford
Figure 18.	*Bolivina glutinata* Egger
Figure 19.	*Neouvigerina ampullacea* (Brady)
Figure 20.	*Siphogenerina raphanus* (Parker and Jones)
Figure 21, 22, 23, 24.	*Elphidium advenum* (Cushman). Fig. 21: apertural view; Figs. 22 – 24: side view.

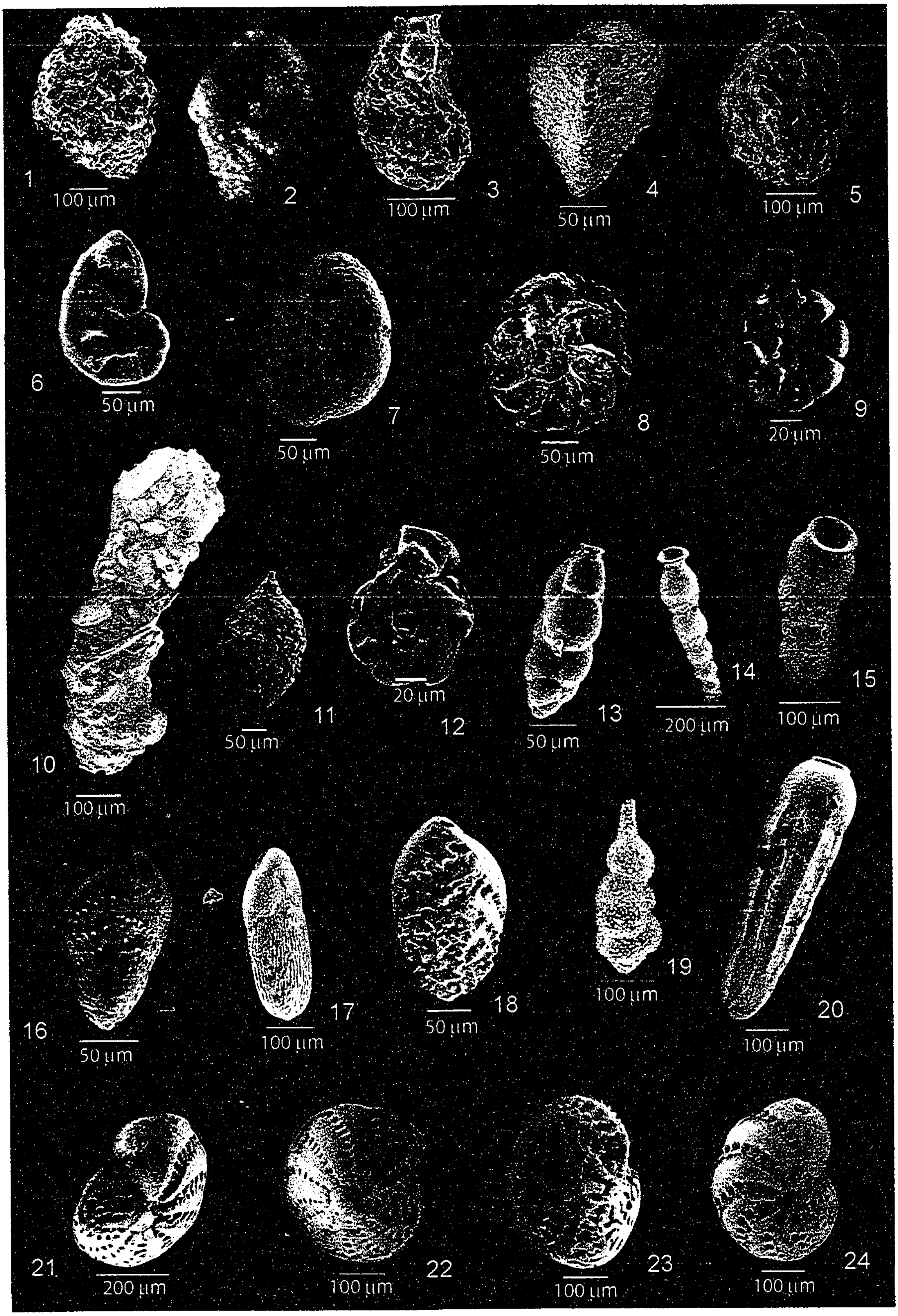
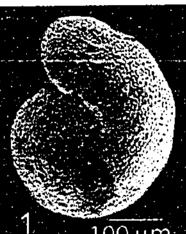
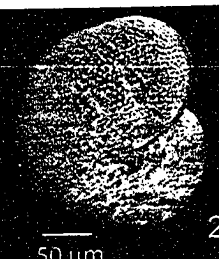

1
100 µm
2
100 µm
3
50 µm
4
100 µm
5
6
50 µm
7
50 µm
8
50 µm
9
20 µm
10
100 µm
11
50 µm
20 µm
12
13
50 µm
14
200 µm
15
100 µm
16
50 µm
17
100 µm
18
50 µm
19
100 µm
20
100 µm
21
200 µm
22
100 µm
23
100 µm
24
100 µm

PLATE 2

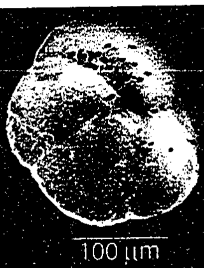
Figures 1, 2.	*Anomalinoides* cf. *welleri* (Plummer). Fig. 1: ventral view; Fig. 2: dorsal view.
Figures 3, 4.	*Epistominella pulchra* (Cushman). Fig. 3: ventral view; Fig. 4: dorsal view.
Figure 5.	*Ammonia beccarii* (Linné).
Figure 6.	*Hanzawaia grossepunctata* (Earland).
Figures 7, 8.	*Hanzawaia nipponica* Asano. Fig. 7: ventral view; Fig. 8: dorsal view.
Figure 9.	*Quinqueloculina auberiana* d'Orbigny.
Figure 10.	*Quinqueloculina* sp.
Figure 11.	*Cassidulina teretis* Tappan.
Figure 12.	*Globocassidulina subglobosa* (Brady).
Figure 13, 14.	*Rosalina columbiensis* (Cushman). Fig. 13: dorsal view; Fig. 14: ventral view.
Figure 15, 16, 22.	*Pararotalia* sp. Figs. 15, 22: dorsal view; Fig. 16: ventral view.
Figure 17.	*Asterorotalia pulchella* (d'Orbigny)
Figure 18, 19.	*Pseudorotalia schroteriana* (Parker and Jones).
Figure 20, 21.	*Evolutononion shansiense* N. W. Wang. Figs. 20, 21: side view.
Figure 23.	*Heterolepa subhaidengeri* (Parr).
Figure 24.	*Nonionella turgida* (Williamson).
Figure 25.	*Nonion subturgidum* (Cushman).


1

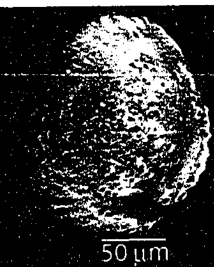
100 µm


2

50 µm


3

100 µm


4

50 µm


5

100 µm


6

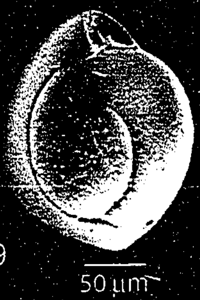
100 µm


7

100 µm


8

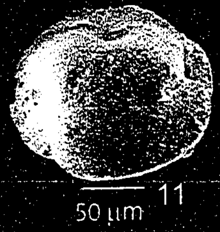
100 µm


9

50 µm


10

50 µm


11

50 µm


12

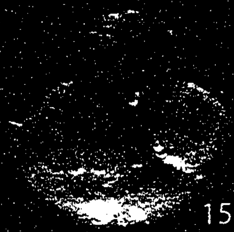
50 µm


13

100 µm


14

100 µm


15


16

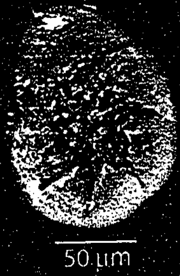

17

200 µm


18

200 µm

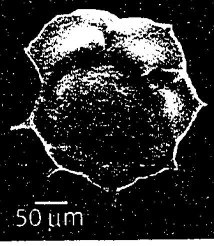

19


20

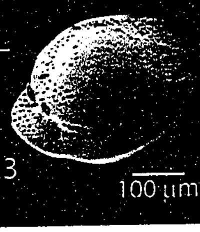
50 µm


21

50 µm


22

50 µm


23

100 µm


24

50 µm


25

100 µm

Appendix A. Data Tables

Station	Core	Coring Device	Latitude	Longitude	Water Depth	Recovery
SO-115-27	18274 -3	GC-10	4:36.313 N	109:34.818 E	117 m	755 cm
SO-115-29	18276 -2	GC-10	4:44.897 N	109:44.837 E	116 m	721 cm
SO-115-30	18277 -2	GC-10	4:56.355 N	109:56.298 E	133 m	490 cm
SO-115-33	18280 -2	GC-6	5:06.007 N	110:05.939 E	144 m	556 cm
SO-115-35	18282 -2	GC-9	5:14.687 N	110:14.605 E	151 m	634 cm
SO-115-51	18298 -2	VC-6	4:31.987 N	108:49.508 E	102 m	587 cm
SO-115-53	18300 -2	GC-11	4:21.778 N	108:39.215 E	91 m	885 cm
SO-115-54	18301 -2	VC-6	4:21.308 N	108:38.811 E	93 m	582 cm
SO-115-55	18302 -2	GC-11	4:09.585 N	108:34.535 E	83 m	598 cm
SO-115-58	18305 -2	VC-6	4:17.318 N	109:04.599 E	109 m	514 cm
SO-115-62	18309 -2	VC	3:27.959 N	108:41.174 E	83 m	597 cm
SO-115-63	18310 -2	VC-6	3:32.131 N	108:32.131 E	100 m	568 cm
SO-115-69	18316 -2	VC-6	2:29.263 N	107:27.522 E	71 m	597 cm
SO-115-73	18320 -2	VC-6	2:36.726 N	107:22.491 E	76 m	492 cm
SO-115-75	18322 -2	VC-6	2:18.405 N	107:37.881 E	70 m	493 cm
SO-115-76	18323 -2	VC-6	2:47.030 N	107:53.200 E	92 m	540 cm

Appendix A, Table 1. Sunda Shelf sediment core locations. GC = Gravity Core, VC = Vibra Core.

Appendix A, Table 2. Percentage abundance of foraminifera in Vibracore 18316-2.

Core 18316-Depth (cm)	10	20	30	40	50	60	70	80	130	140	150	160	170	180	190	230	240	250	310	320	330	350	360	370	420	430	450	510	540	560	580	590
No. of benthic indiv. (counts/10 cc)		3	7		40	6	1	33	2					2	310	259	273	595	1	2		23			116	9, 536	8. 800	19, 008	33, 664	230, 400	2, 536	
No. of benthic species		3	5		13	6	1	14	1					1	49	31	35	54	1	1		6			19	34	23	34	45	31	44	
No. of planktonic indiv. (counts/10 cc)			3		8	4		3							55	32	39	156							3	256	3	192	1, 472	8, 704	136	
BENTHIC SPECIES (%)																																
Ammomassilina alveoliniformis			p		p			p							4	2	4	5				P				1		1	6	2	1	
Ammonia beccarii					p	p		p	p					p	15	51	53	23				p			3	23	22	16	23	17	18	
Ammonia sp.			p		p			p							3			1							8	3			p	1	5	
Ammotium salsum																		p	p													
Amphimorphina virgula																	p	p													p	
Amphistegina lessoni																									2			p				
Anomelinoides welleri															2		1	1											p		2	
Asterorotalia gaimardii																															1	
A. pulchella					p											3		p							18	10	16	8	2	3	1	
Astrononion sp.																	1									p			p	4	p	
Bigenerina sp.		p			p										p											p		p	1	2	1	
Bolivina glutinata						p		p							15	12	8	8				p			1	24	35	27	13	17	18	
B.macella															1	p	p	p				p				p	3	2	p			
B. spathulata																p	p	2										p				
B. striatula																1						p				p					p	
B subspinescens															1		1	2								p			3	3	3	
B. sp.					p		p	p							p	1	2	2							9	p		p	p		p	
Bulimina aculeata															1			p											p			
B. marginata								p							2	p	1	1										1			1	
Cancris sp.															p	1		p				p			3		1			p	p	
Cassidulina laevigata								p								p	p	1										1	p		p	
C. teretis																	p	p											p		1	
Cibicides deprimus								p							p		1	p												1	p	
C. lobatulus																									9							
C.wuellerstorfi																									1							
Cibicides sp.															2		1	1										2	1	1		
Cibicidoides mediocris								p							4	1	2	2							4	3	3	2	1	7	3	
Cibicidoides sp.															1			p											p			
Clavulina sp.															4		1	1								p						
Discorbinella sp.																p		1														
Elphidium advenum					p			p							3	1	1	2							3	3	p		p	p	1	
Epistominella exigua															2	p	1	2										1	p	p	p	
E. pulchra															5		4	4								p			4	2	4	
Eponides cribrorepandus																													p		2	
Eponides sp.																									1	1			1	4	2	
Evolutononion shansiense															2		2	2								p			2			
Fissurina sp.															1	2	1	2							3	1	1	1	2	1	2	

Core 18316-Depth (cm)	10	20	30	40	50	60	70	80	130	140	150	160	170	180	190	230	240	250	310	320	330	350	360	370	420	430	450	510	540	560	580	590
BENTHIC SPECIES (%) (cont.)																																
Fursenkoina fusiformis																		1														
Globocassidulina subglobosa															p	1		1														
Hanzawaia grossepunctata															1	p		p									p	7	2	3	3	
H. nipponica								p							3		p	2							2	4	5	3	7	7	9	
Hanzawaia spp.																											1	4				
Heterolepa praecincta																										2			p	p		
H. subhaidingeri					p	p		p							4	2	2	3							1	2	5	8	11	10	9	
Hopkinsinella glabra															p	7	2	1				p				1						
Hyalenia balthica																1		p													p	
Lagena sp.															1	p		1									1		p	1	1	
Lenticulina sp.																		p													p	
Neoeponides praecinctus			p			p									1										1			1			1	
Nonion subturgidum																	p									1			1			
Nonion sp.															p		p	2								1		2	6	1	3	
Nonionella sp.																1	1	p									p	p		p	p	
Operculina sp.					p	p									1	1		1										1				
Pararotalia sp.																5									3	1	p	1				
Pseudorotalia schroeteriana																									30	12	1	3	p	5	p	
P. sp.																															p	
Planulina sp.								p							p			p										1	p	p		
Pyrgo sp.																									1							
Quinqueloculina agglutinans					p			p							p		p	1														
Q. auberiana			p		P			p							4	3	1	4														
Q. sulcata																										p			1		p	
Q. spp.		p	p		p			p							2		1	5								1			p	2	p	
Reusella sp.															5	1	1	2								1	1	1	p	p	p	
Rosalina columbiensis															5		2	6										1	7		p	
Seabrookia sp.															p			p														
Siphonina tubulosa																													1			
Spiroloculina sp.					p										p	1		1														
Textularia agglutinans					p										1	p										2	1	4	2	6	1	
Textularia spp.															1		2	1													3	
Trifarina sp.															p			p											p			
Triloculina tricarinata		p				p									1	p		p														
Triloculinella sp.																		1														
Uvigerina sp.															p													p				

Appendix A, Table 2 (continued).

Depth in Core 18302-2 (cm)	50	70	100	150	200	270	300	330	360	400	420	430	450	460	480	490	500	510	520	530	540	550	560	580	590
No. of benthic indiv./10 cc	8608	4672	5760	1744	1244	14176	13554	29056	3024	3246	85	43	69	8	48	349	6			12					6
No. of benthic species	45	42	47	35	34	42	29	43	39	14	14	6	4	4	5	5	2			6					4
No. of planktonic indiv./10cc	1632	464	1749	224	64	224	102	1216	112	114	2									11					10
Benthic Species (%)																									
Ammobaculites sp.	1							1																	
Ammomassilina alveoliniformis	1			1			1																		
Ammonia sp.			3																						
Ammonia beccarii	8	19	16	23	24	23	13	20	27	17	2									p					p
Ammotium salsum				1								23	13												
Amphimorphina virgula	4	5	2	4	3	1		1	2																
Anomalinoides welleri			4																						
Arenoparrella mexicana												2			4	1									
Asterorotalia pulchella	1	4	3	7	14	17	24	19	22	23	3														
Astrononion sp.	2	1																							
Bigenerina sp.			p			1																			
Bolivina glutinata	5	9	13	12	11	8	4	9	3	9	3									P					p
B. spp.	6	9	4	3	3	6	7	7	6	6	2														
Bulimina aculeata	2	2	2			1																			
Bulimina marginata	4	1	3	1	1	1			1																
Bulimina sp.				2	1																				
Cancris sp.	1		1				1				1														
Cassidulina laevigata	1	1	p	1																					
C. teretis			p																						
Cibicides deprimus			p																						
Cibicides lobatulus	1																								
Cibicides mediocris	1	2	1																						
Cibicides sp.	1	1	p							1															
Cyclogyra sp.	1		p																						
Discorbis sp.	1		1																						
Edentostomina cultrata	1	1																							
Elphidium advenum	3	2	p	1	1	2	2	1	1	2										p					
Epistominella pulchra	1	1	p			1																			
Eponides sp.			p																						
Evolutononion shansiense			9	5	1	2		1	1																
Fissurina sp.	2		1	1	1		1	1	1																
Fursenkoina fusiformis	1	1	p					1																	
Hanzawaia nipponica	5	4	10	16	13	14	18	10	15	30	2														
H. spp.	4	4		1		1		2	2																
Heterolepa subhaidingeri	2	3	1	3	2	1		2	2	1										p					
Hopkinsinella glabra			1																						
Hyalinea balthica	1	1																							
Lagena sp.	2	1	1	1	1			1	1																
Lenticulina sp.				1																					
Miliammina fusca											1														
Neoconorbina terquemi			p																						
Neoeponides praecinctus																									
Neouvigerina ampullacea	1		p																						
Nodosaria sp.																									
Nonion spp.	2	1	1	2	1				1																
Nonion subturgidum			1		1			1	1																
Nonionella sp.	1	1			1		1			4															

Appendix A, Table 3. Percentage abundance of foraminifera in Gravity core 18302-2.

Depth in Core 18302-2 (cm)	50	70	100	150	200	270	300	330	360	400	420	430	450	460	480	490	500	510	520	530	540	550	560	580	590
Nonionella turgida	1		1	1																					
Operculina sp.	1	1	p	4	5	4	8	8	7																
Pararotalia sp.				1		1	1		1	3															
Planorbulina sp.		2			1																				
Pseudorotalia schroeteriana	1	1			1																				
Pyrgo sp.							1																		
Quinqueloculina agglutinans	1	1			1	1	1																		
Q. auberiana	15	7	5																						
Q. pseudoreticulosa			p																						
Q. spp.			2	1	4	4	12	6		1	1									p					p
Reussella spinulosa	5	3	p	2	1	1		1	1																
Rosalina columbiensis	1		1																						
Schlumbergeriana alveoliniformis			p																						
Seabrookia sp.			1																						
Siphogenerina raphanus						1			1																
Siphotextularia subplanoides			1																						
Siphouvigerina fimbriata			p																						
Spirillina sp.							1																		
Spiroloculina sp.		1	1																						
Textularia sp.	1	3	1	2	2	4	1	1	1																
Triloculina spp.	3	3		1	4	4	1	5	1																
Triloculinella sp.			1																						
Trochammina inflata											48	49	54	p	2	4									
T. macrescens f. *polystoma*											33	10	7	p	87	84	p								
Uvigerina auberiana					1				1																
Uvigerina sp.				1	1	1	1	1	1	1	1														
? sp		1		1				1																	
linings	1									1		16	26	p	6	12	p								

Appendix A, Table 3 (continued).

Core 18300-2 Depth (cm)	30	58.5	90	130	160	190	232	260	290	320	410	440	470	500	530	560	590	620	650	680	710	800	820	860
No. of Benthic Indiv (counts/10cc)	18, 368	87	65	126	168	99	359	121	67	55	22		143	18			1			4		1		1
No. of benthic species	29	9	3	3	5	5	2	3	8	2	1		4	5			1			3		1		1
Total calcareous benthic spp. (%)	95	24	1	1	2	3			8				2											
No. of planktonic indiv. (counts/10cc)	10688	4				3	2						3				2			1				
Benthic Species (%)																								
Ammomassilina alveoliniformis	1																							
Ammonia beccarii	8	5			1								1							p				
Ammotium salsum		1																						
Arenoparrella mexicana					1			2	1															
Asterorotalia pulchella	1																							
Bolivina glutinata	16	6			1									p										
B. spp.	7	1				1			1				1											
Bulimina aculeata	1																							
Bulimina marginata	4																							
Cassidulina sp.	6																							
Cibicides sp.	3																							
Elphidium advenum	1																			p				
Epistominella sp.	4																							
Fissurina sp.	1																							
Globocassidulina subglobosa	1																							
Hanzawaia nipponica	6	2							2					p			p							
H. sp.	4																							
Heterolepa praecincta	4																							
Lenticulina sp.	1																							
Neoeponides praecinctus	1																							
Nonion sp.						1			1															
Operculina sp.	2	1							1															
Pseudorotalia schroeteriana	1																							
Quinqueloculina spp.	13	9	1	1		1			3					p						p				
?Reophax sp.	1																							
Reussella spinulosa	1																							
Spiroloculina sp.	1																							
Textularia sp.	3																							
Trifarina sp.	1																							
Triloculina sp.	2																							
Trochammina inflata		54	51	14	23	38	22	25	34	36			3	p										
Trochammina macrescens f. *polystoma*		21	48	85	75	59	77	73	55	64	100		95	P										
Uvigerina spp.	5																							
Other																								
Bivalves (counts/10cc)	576																							

Appendix A, Table 4. Percentage abundance of foraminifera in Gravity core 18300-2.

CORE 18301-2 Depth (cm)	250	290	330	390	460	560
No. of benthic indiv. (counts/10 cc)	274	1	3	4	1	19
No. of benthic species	31	1	2	2	1	3
No. of planktonic indiv. (counts/10 cc	67					
BENTHIC SPECIES (%)						
Ammonia beccarii	39					p
Ammonia sp.	1					
Amphimorphina virgula	p					
Anomalinoides welleri	1					
Asterorotalia pulchella	8					
Bolivina glutinata	7					
B. macella	1					
B. spp.	1					
B. striatula	1					
Bulimina marginata	4					
Cassidulina laevigata	3					
Cibicides lobatulus	p					
C. sp.	2					
Cibicidoides mediocris	p					
Elphidium advenum	2					
Epistominella pulchra	1					
Eponides repandus	p					
Fissurina sp.	3					
Fursenkoina fusiformis	p					
Hanzawaia nipponica	7					
Haplophragmoides sp.				p		
Heterolepa subhaidingeri	1					
Lagena sp.	p					
Neouvigerina ampullacea	2					
Nonion subturgidum	1					
N. sp.	p					
Nonionella turgida	1					
N. sp.	p					
Pararotalia sp.	9					
Quinqueloculina sp.	1					
Rosalina columbiensis	p					
Rosalina sp.	p					
Schlumbergerina alveoliniformis	1					
Textularia agglutinans	p					
Trochammina inflata		p	p	p		p
T. macrescens f. *poystoma*			p		p	p

Appendix A, Table 5. Percentage abundance of foraminifera in Vibracore 18301-2.

Depth in Core 18310-2 (cm)	119	151	195	231	260	494	567
Number of benthic indiv./10 cc	8408	113		2			
Number of benthic species	47	15					
Number of planktonic indiv./10 cc	2168	46					
BENTHIC SPECIES (%)							
Ammomassilinia alveoliniformis	5						
Ammonia sp.	3	8					
Ammonia-Pararotalia intergradation	8	10					
Ammonia beccarii	3						
Amphistegina lessoni	p						
Asterorotalia pulchella	4	9					
Astronion sp.	3						
Bigenerina sp.	p						
Bolivina glutinata	9	10		p			
B. glutinata (var.)	2	4					
B. macella	1						
B. subspinescens	1						
Bulimina aculeata	p						
B. marginata	4	17		p			
Cancris sp.	1						
Cassidulina sp.	4						
Cibicides sp.	1						
Clavulina sp.	p						
Cyclogyra sp.	1						
Elphidium advenum	2	2					
Eponides sp.							
Fissurina sp.	1	2					
Globocassidulina subglobosa	1						
Gyroidina sp.	1						
Hanzawaia nipponica		11					
H. sp.	2						
Heterolepa praecincta		9					
H. subhaidingeri	8	1					
Hyalinea balthica	1						
Lagena sp.	1						
Lenticulina sp.	p						
Neouvigerina ampullacea	4	4					
Nodosaria sp.	p						
Nonionella sp.	1						
Pararotalia sp.	1	3					
Pseudorotalia indopacifica	1	3					
Pseudorotalia schroeteriana	2	5					
Q. agglutinans	1						
Q. auberiana	9	2					
Q. pseudoreticulosa	1						
Quinqueloculina sp.	3						
Reussella spinulosa	1						
Siphogenerina raphanus	p						
Spiroloculina spp.	3						
Textularia agglutinans	1						
Textularia spp.	3						
Triloculina spp.	3						
Trochammina inflata ?		1					
lining		1					

Appendix A, Table 6. Percentage abundance of foraminifera in Vibracore 18310-2.

SS-Core18298-2 Depth (cm)	150	230	260	440	450	470	480	490	500	510	520	530	540	550	560	570	580	587
No. of benthic indiv./10 cc	12, 832	7744	9824	5176	9920	798	106	405	26	306	334	190	6	5		222	109	
No. of benthic species	33	31	40	34	45	49	31	30	7	38	16	27	3	2		28	25	
No. of planktonic indiv./10 cc	1152	704	448	440	1760	75	3	37	p	36	48	4		1			18	
Benthic Species (%)																		
Ammobaculites sp.						p	1	1										
Ammomassilina alveoliniformis	2	1	p		p	1	1	1		1	p	1				1		
Ammonia beccarii	25	12	13	9	25	16	15	22		19	20	48				27	17	
Ammotium salsum					1	1	8	10		2	5	1		p		1	4	
Amphistegina lessoni				p		p				p						1	1	
Arenoparrella mexicana					p	p	1	1		1	2							
Asterorotalia pulchella	6	10	13	26	14	29		16	P		7	1					1	
Astrononion sp.	p		p			p	3	1		4	1	2				1	1	
Bigenerina sp.			p			1												
Bolivina sp.	2		2		1	p	2	1		4	1	1	p			2		
B. glutinata	26	17	9	3	9	6	15	3		15	4	4				6	7	
B. glutinata (var.)	2	3	1	1	p	1		p		1								
B. macella	4	2	2	2	p	1	1			1		1				3		
B. striatula			p		1		1	p		2		6						
B. subspinescens		1																
Bulimina aculeata	1	2		p			3			p								
B. marginata	1	p	2	1	3	2	3	5		7	2	2				4	2	
B. sp.												1						
Cancris sp.	1			1	p	1												
Cassidulina laevigata			2		1	2	1			2		1				1		
C. teretis	p		1		3		5	1		4								
C. sp.		1		p	p					p						1	1	
Cellanthus sp.					p													
C. wuellerstorfi																		
C. spp.			p		2	1												
Cibicidoides mediocris				1	3	2				p	1					3		
Discorbinella sp.						p	1			1	1							
Elphidium advenum	1	3	5	5	3	5	1	3		2	6	1				10	4	
Epistominella pulchra	1	1	1	1	2	1						1				2		
Epistominella sp.					p	p	1			1		1				4		
Eponides sp.	p		1														1	
Fissurina sp.	3	1			p	1				2		3				1	1	
Fursenkoina fusiformis	p		p		1	p	2											
Glabratella sp.								1										
Globocassidulina subglobosa					p	p	4			2	p						1	
Gyroidina sp.		p		p		p	1			1								
Hanzawaia nipponica	3	10	15	15	10	7	7	1		6	4	3				8	15	
H. sp.										p							4	
?H. sp.	4	4	3															
? *Helenina anderseni*								1		1								
Heterolepa sp.	3	4	3	5	2	3				1	1					1		
Hyalinea balthica	p		1		1													
Lagena sp.	1		1		1	1		p		1		1						
Lenticulina sp.								p										
Miliammina fusca								1										
Neoconorbina sp.						p												
Neoeponides praecinctus		1				p			p									
Neouvigerina ampullacea					2	p										2		
Nonion sp.	1	p	p	1	1	1		p		1								
N. turgida						p												
Nonionella sp.	1	2	1								p						1	
Nonionellina sp.							1									1		
Operculina ammonoides	p		p	p	1	p	2	1	p	1		1				1	3	
Pararotalia sp.	p	2	1	2	2	3	2	17	P	6	20	2				16	11	
Pseudorotalia indopacifica		6		5		1	1	2	p		13						1	
P. schroeteriana		3	1	8	1	8	1	7	p	1	7	3				2	4	
Quinqueloculina spp.	10	9	11	6	5	p	13	2		3	4	12	p	p		4	19	
Reussella spinulosa	1	p	1	p	1	p		1		2	1							
Reussella sp.					2	1												
Rosalina sp.	1				1		1			p								
Spirillina sp.					p													
Spiroloculina sp.		p	1	p	p	p						1					1	
Textularia agglutinans		3	1	5	1	p												
Textularia sp.	1	1	3	p		1	1			1						1	1	
Triloculina sp.	1	p	2	1			1											
Trochammina inflata												1						
T. macrescens											p							
Uvigerina sp.	1	p	1	1			2	3		4	1	2						
lining				p	p		2	1		1	p	3	p				2	
Others (counts/10 cc)																		
Bivalve	1760	512	160	104	64	7												
Bivalve (articulate)	128	256	32	24	192	1												
Coral fragment/barnacle	0	0		32														
Insect remain	32				192		6	9	p		46	16		8	4		7	
Ostracods	928	128		160	64	7												
Pteropod fragments		64	160	72		3		1			2			1			3	
Scaphopods		128																

Appendix A, Table 7. Percentage abundance of foraminifera in Vibracore 18298-2.

CORE 18305 Depth (cm)	124	183	216	339	401
No. of benthic indiv. (counts/10cc)	19, 328	1, 744	21	15	2
No. of benthic species	41	37	3	9	1
No. of planktonic indiv. (counts/10cc)	8, 960	1, 032	11	11	2
BENTHIC SPECIES (%)					
Ammomassilina alveoliniformis	3	3			
Ammonia beccarii	15	17			
Ammonia sp.			P	p	
Ammotium salsum		p			
Amphimorphina virgula		1			
Anomalinoides welleri	3	5			
Asterorotalia gaimardii	1	2			
A. pulchella				p	
Bolivina glutinata	23	27			
B. subspinescens		1			
B. spp.	p			p	
B. striatula					
Bulimina aculeata	1	1			
B. marginata	4	4			
Cancris sp.	p	1			
Cassidulina laevigata	3	6			
C. teretis		1			
Cibicides deprimus		1			
Cibicides lobatulus		1			
Cibicides sp.		1			
Cibicidoides mediocris		1			
Cibicidoides sp.	p	1			
Clavulina sp.	1				
Elphidium advenum	p	1			
Epistominella pulchra	2	1			
Epistominella sp.		1			
Eponides sp.		1			
Fissurina sp.	1	1			
Fursenkoina fusiformis	p				
Globocassidulina subglobosa	2				
Hanzawaia grossepunctata	1				
H. nipponica	1				
Heterolepa praecincta		1			
H. subhaidingeri	3	4		p	
Hyalinea balthica	1	2			
Lagena sp.	1				
Lenticulina sp.	1				
Miliolids	1				
Neouvigerina ampullacea	1	5			
Nonion subturgidum	1	1			
Nonion sp.	2	2			
Nonionella sp.		1			
Pararotalia sp.				p	
Pseudorotalia indopacifica			P	p	
P. schroeteriana		1		p	
Quinqueloculina auberiana	7	2			
Q. sulcata ?	3				
Q. spp.	3	2	p	p	
Reussella spinulosa	p	1			
Rosalina columbiensis	6	3			
Seabrookia sp.	2				
Spiroloculina sp.	p				
Textularia agglutinans	1				
T. fistula	p				
T. sp.		1			
Triloculina sp.	p				
Triloculinella pseudooblonga	p			p	

Appendix A, Table 8. Percentage abundance of foraminifera in Vibracore 18305-2.

Core18274-3 Depth (cm)	20	30	40	50	60	70	89	100	110	120	130	140	150	180	690	700	710	720	730	740	750
No.of benthic individuals (counts/10cc)	14	1					62	3						1					2		
No. of benthic species	9	1					18	3						1					2		
No. of planktonic spp. (counts/10 cc)	56	1					133														
Benthic Species (%)																					
Ammonia beccarii	7						5														
Bolivina glutinata	7						16														
B. macella							10														
B . spp.							8														
?Buccella frigida							2														
Bulimina marginata							6														
Cassidulina sp.	7						2														
Cibicides wuellerstorfi	7						13														
C. sp.	7																				
Eponides sp.							2														
Gyroidina sp.																					
Hanzawaia nipponica	7																				
Hanzawaia sp. (replaced)							2														
Heterolepa subhaidingeri	21						13														
H. sp. (var.)	7																				
Pararotalia sp. (replaced)	29						10														
Quinqueloculina sp.							3														
Reussella sp.							2														
Triloculina sp. (replaced)							2														
Uvigerina sp.							5														
linings		1					2														
Others (counts/10 cc)																					
Bivalve	1																				
Bivalve (articulate)	1						62														
Insect remain		3					11	7	3			6		4	2	4			6	17	2
Ostracod	1																				
Pteropod fragments	7						4														
Scaphopods	1																				

Appendix A, Table 9. Percentage abundance of foraminifera in Gravity core 18274-3; samples barren between 189 – 680 cm.

Core 18277-2 Depth (cm)	41	61	81	101	121	141	161	181	201	221	281	301	321	341	401	441	481
No. of benthic indiv. (counts/10 cc)	256, 000	67, 840	1384	4176	434	1360	988	710	1032	466	235	29	300	493	1384	400	2328
No. of benthic species	61	58	59	38	16	16	32	17	15	17	18	10	13	14	21	18	17
No. of planktonic indiv. (counts/10 cc)	317, 952	97, 536	2000	216	30	16	264	18	5		4		4	3		12	32
BENTHIC SPECIES (%)																	
Ammomassilina alveoliniformis	1	2	3	p													1
Ammonia beccarii	8	4	5	5	8	12	23	18	25	24	15	p	10	52.5	6	5	12.03
A. spp.	1	2	1	2	3	1	2	7	1	0	5	0	8	0	1	0	1
Ammotium salsum			1	17	36	29	24	8	12	13	4	p	5	1	10	3	8
Amphistegina lessoni	1				p												
Anomalinoides welleri	2	2	2	p			p										
Asterorotalia pulchella		1	1	36	18	18	7	13	16	23	6	p	22	6	11	13	21
Astrononion sp.	p																
Bolivina glutinata	14	20	20	2	3		5	p	p					2		1	
B. macella			p	1					p						1		
B. striatula	1		p		1	1	1	p	2	p				7.03	1	1	p
B. subspinescens	1	p	3	p													
B. vadescens	5	3	1	2			3	p		p			1				
B. spp.		2	1		1			1						1			
Bolivinellina transluscens							7										
Bulimina aculeata	4	2	1														
B. marginata	2	5	4	p			2	p			p		p				
Cancris sp.				p		p	1										
Cassidulina laevigata	6	5	3		1	p	p										
C. teretis	1	1	1														
Cibicides deprimus	p	1	1														
C. sp.	2	2	2														
Cibicidoides mediocris	1		p	p			1										
Cibicidoides sp.			1	p													
Clavulina sp.	1	1	2														
Cyclogyra sp.		p															
Discorbis sp.			2														
Elphidium advenum	p	p	1	4	2	3	p	7	1	1		p	1	5	2	4	1
Epistominella exigua	1	1	1	p													
E. pulchra	1	p	5	p			1			p							
Eponides repandus	1						p										
E. sp.	5	3	2	p													
Evolutononion shansiensis	1	2	1				p										
Fissurina sp.	2	1	1	1		p		1			1		1				p
Fursenkoina fusiformis				p						p					p		
Globocassidulina subglobosa	12	6	8	1			1									1	
?Gyroidina sp.		1	1														
Hanzawaia coronata	2	2		p													
H. grossepunctata	p	p	1														
H. nipponica	1	1	1	15	7	4	8	9	21	2		p	2		2	3	p
H. sp.	2							1			1		2				
Heterolepa praecincta							1										
H. subhaidingeri	1	p	2				p				p						
Hoeglundina elegans	p	p															
Hopkinsinella glabra				p		p	p							2	p	3	
Hyalinea balthica	1	2	p														
Lagena sp.	p	1	1						p								
Lenticulina orbiculare		p															
L. sp.	p	1	1				p										
? Miliammina fusca			p														
Neoconorbina terquemi	p	p	1	p													
Neoeponides sp.		1	1														
Neouvigerina ampullacea	2	5	6	p			1	1	p	p						2	
Nonion subturgidum	p	p	1	2			p	16	1	1	2				p	2	
Nonion sp.	2	2	4				p			p			p				
Nonionella turgida	1	p	1	1	3	5	p	2	5	11	22	P	7	13	5	45	2
N. sp.	1	p	1				p					p			p		
Pararotalia sp.	p	1	1	24	11	22	5	13	14	18	1	p	11	1	31	8	23
Pararotalia-Ammonia intergradation				1	5	2	1		1	p				1			4
Pseudorotalia schroeteriana					1								p				
Quinqueloculina agglutinans	p									p	p				p		
Q. auberiana	1	2	1	3						4	35	p	26	10.3	27		24
Q. spp.	2	3	2	1	1	2			p		2	p			p	6	
Reussella spinulosa	1		p				1										
Rosalina sp.		p															
Schlumbergerina alveoliniformis	1																
Seabrookia sp.	1	p	1														
Sigmoilopsis sp.															p		
Siphonina tubulosa		p															
Siphotextularia subplanoides	1	2	1														
Siphouvigerina fimbriata	p	p															
Spiroloculina sp.	p	1									1				p		1
Spirotextularia sp.	1																
Textularia agglutinans																2	
T. fistula	p	p	1													1	
T. sp.	p	1	p	p													
Trifarina sp.			1														
Triloculina tricarinata	p			p							p		p		1		p
Triloculinella sp.	2	1	1											p	p		
Uvigerina dirupta	1	1	p	p													p
U. schwageri							p										
U. sp.		1									p		p				
lining			p														
Others (counts/ 10 cc)																	
Ostracods				392				3			8	3	66				
Ostracods (articulate)				16							7		2				

Appendix A, Table 10. Percentage abundance of foraminifera in Gravity core 18277-2.

SS-Core18282-2 Depth (cm)	33	52	132	262	401	564
No. of benthic indiv./10cc	26. 112	11, 296	5288	3808	1292	1285
No. of benthic species	43	41	27	14	16	26
No. of planktonic indiv./10cc	34, 496	8832	152	192	8	4
BENTHIC SPECIES (%)						
Ammomassilina alveoliniformis	1		2			1
Ammonia beccarii	6	18	17	19	29	26
Ammonia sp.	2	1	p			
Ammotium salsum		2	9	10	5	3
Amphimorphina virgula	1					p
Amphistegina lessoni	p					
Asterorotalia pulchella		15	8	21	6	5
Astrononion sp.		2				
Bolivina glutinata	14	9	5	9	10	20
B. glutinata (var.)	7	2	2	4	1	3
B. macella	2					
B.subspinescens	4	1				
B . sp.	1	3	p		1	2
Bulimina aculeata	p	2	p		1	
B. marginata	1	2				
B. sp.	1	1	1		1	
Cancris sp.		1	1	4	1	1
Cassidulina laevigata	12	7	p			
C. sp.		1				
Cibicides sp.		1				
Cibicidoides mediocris	1					
Clavulina sp.		p				
Cyclogyra sp.	1					
Elphidium advenum		1	2	2	1	p
Epistominella pulchra	3					
Eponides sp.	1	1				
Fissurina sp.	1	1	p	1	1	1
Fursenkoina fusiformis		p	1			p
Globocassidulina subglobosa	4	1				
Hanzawaia coronata		p				
H. nipponica	7	7	9	10	6	13
H. sp.	1		1			
Heterolepa praecincta	2					
H. subhaidingeri	p					
Hopkinsinella glabra				3	2	6
Hyalinea balthica		1				
Lagena sp.	1	1				
Lenticulina sp.	2					
?*Miliammina fusca*		p				
Neouvigerna ampullacea	4	1	1	1		2
Nodosaria sp.		p				
Nonion subturgidum		p		2	1	
Nonion sp.	p		6		1	2
Nonionella turgida	p	2	1	2	15	4
Operculina sp.	p		p			
Pararotalia sp.	p	2	27	6	2	p
Pseudorotalia schroeteriana		p				
Quinqueloculina agglutinans	1					1
Q. auberiana	5	8	6	1	14	7
Q . spp.	3	2	4			3
Reussella spinulosa	1	1	p			
Rosalina columbiensis	4					
Rosalina sp.		p				
Siphogenerina raphanus	1					p
Spiroloculina sp.	3	p				p
Textularia sp.	1					
Triloculina tricarinata						1
Triloculina sp. (replaced)	1	1	1			
Triloculinella sp.	1	4				p
Uvigerina dirupta	1					
OTHERS (/10 cc)						
Bivalves	128	256	192			20
Bivalves (articulate)		64	16			11
Ostracods	256	576	208			65
Ostracods (articulate)	128	160	24			6

Appendix A, Table 11. Percentage abundance of foraminifera in Gravity core 18282-2.

Depth in Core 18276-2 (cm)	70	150	220	300	380	460	540	615
No. of benthic indiv. (counts/10 cc)	2							
No. of benthic species	1							
No. of planktonic indiv. (counts/10 cc)	2							3
BENTHIC SPECIES								
Heterolepa praecincta	p							

Appendix A, Table 12. Foraminiferal abundance in Core 18276-2.

Depth in Core 18309-2 (cm)	339	420	450	480
No. of benthic indiv. (counts/10 cc)	2			
No. of benthic species	2			
No. of planktonic indiv. (counts/10 cc)				
BENTHIC SPECIES				
Pseudorotalia indopacifica	p			
Trochammina macrescens f. *polystoma*	p			
OTHERS (counts/10 cc)				
Insect remains	242			

Appendix A, Table 13. Foraminiferal abundance in Core 18309-2.

Depth in Core 18320-2 (cm)	150	250	450
No. of individuals (counts/10 cc)			

Appendix A, Table 14. Foraminiferal abundance in Core 18320-2.

Depth in Core 18322-2 (cm)	260	360	470
No. of individuals (counts/10 cc)			2
BENTHIC SPECIES			
Asterorotalia pulchella			p
Pseudorotalia schroeteriana			p

Appendix A, Table 15. Foraminiferal abundance in Core 18322-2.

Depth in Core 18323-2 (cm)	30	61	90	97	226	372	417	477
No. of benthic individuals (counts/10 cc)	7	1						
No. of benthic species	1							
BENTHIC SPECIES								
Trochammina macrescens f. *polystoma*	P	p						
OTHERS (/10 cc)								
Insect remains	224	5	60					

Appendix A, Table 16. Foraminiferal abundance in Core 18323-2.

Appendix B. Description of the Parasound System onboard the *Sonne*

The PARASOUND system of ATLAS-Elektronik GmbH comprised the following components:-

- a hull-mounted transducer
- a model DESO 25 recording unit
- an analog facsimile recorder
- several control and monitoring units
- the PARADIGMA system for the digitization of the PARASOUND signals (sampling rate of 40 kHz) and coupling to a PC control system
- a colour monitor and a colour printer for data output
- a 9-track magnetic recorder for data storage, and
- a printer for data logging at 2 minute intervals

The system implemented the following functions:-

- transmission of acoustic signals which propagate as compressional waves through the water column and the subbottom to be reflected at interfaces with significant impedance contrasts.
- high resolution of approximately the uppermost 100 m of the subbottom
- acquisition of high resolution seismic profiles

Acoustic and operational characteristics comprised the following:-

- source signal within the frequency range of 2.5 to 5.5 kHz using the parametric effect whereby the constructive interference of two highly directional signals of similar frequencies (upper frequency: 18 kHz, lower frequency: 20.5 to 23.5 kHz) produces a low difference frequency
- angle of the radiation cone: 4°
- area irradiated: 7 % of the water depth
- depth of penetration: up to 150 m depending on the bottom characteristics
- profiling speed of the ship: 4 knots (when the air gun system is deployed simultaneously) to 12 knots.

Appendix C. Modern distribution of foraminifera on the Sunda Shelf and its coastal areas – tables and description.

MODERN ENVIRONMENT	DOMINANT FAUNA (entirely benthic)
Inter-tidal banks (mangrove swamp, alluvium - Lupar Estuary, East Malaysia)	Indigenous:- *Ammonia beccarii, A. japonica, Arenoparrella mexicana, Elphidium advenum, Haplophragmoides canariensis, Quinqueloculina seminulum, Trochammina inflata* Transported:- *Haplophragmoides subglobosum, Hauerina ornatissima, Massilina inequalis, Miliolinella subrotunda, Quinqueloculina* spp., *Sigmoilina* sp., *Triloculina* spp., *Amphistegina* spp., *Bolivina abbreviata, Cibicide* spp., *Baggina indica, Discopulvinulina advena, Discorbis candeianus, Cymbaloporetta squamosa, Elphidium reticulosum, Fissurina marginata, Oolina globosa, Loxostomum limbatum, Lagena* sp., *Nonion* spp., *Astrononion gallowayi, Ammonia parkinsoniana, Asterorotalia pulchella*, Pararotalia ozawai, *Pseudorotalia gaimardii, P. schroeteriana*, *Rotalia murrayi*

Appendix C, Table 1. Foraminiferal distribution in the Lupar Estuary, East Malaysia (Dhillon, 1968a).

MODERN ENVIRONMENT	DOMINANT FAUNA (entirely benthic)
Inter-tidal banks (mangrove swamp, alluvium - Labuk Estuary, East Malaysia)	Indigenous:- *Ammobaculites exiguus, A. dilatatus, Ammotium salsum*, *Gobbetia* spp. (=*Trochammina macrescens* f. *polystoma*), *Haplophragmoides* spp., *Miliammina* spp., *Arenoparrella* spp., *Trochammina* spp., *Tiphotrocha comprimata, Elphidium advenum, Ammonia beccarii, Ammonia japonica* Transported:- *Ammonia parkinsonia, Asterorotalia* spp., *Elphidium craticulatum, E. reticulosum, Nonion pacificum*

Appendix C, Table 2. Foraminiferal distribution in the Labuk Estuary, East Malaysia (Dhillon, 1968a).

MODERN ENVIRONMENT	DOMINANT FAUNA (entirely benthic)
Mangrove swamp (Belawan, Sumatra)	*Arenoparrella mexicana, Haplophragmoides wilberti, Haplophragmium salsum, Miliammina pariaensis, Trochammina laevigata*

Appendix C, Table 3. Foraminiferal distribution in the mangrove swamp of Belawan, Sumatra (Biswas, 1976).

MODERN ENVIRONMENTS	FAUNA (Benthic)
Tidal inlet (Brunei River - high organic content)	*Trochammina* cf. *lobata* assemblage:- *T.* cf. *lobata*, *T. laevigata, T. hadai, T. inflata, Miliammina fusca, Siphotrochammina lobata, Remaneica* cf. *helgolandica, Arenoparrella mexicana, Lituola salsa, Haplophragmoides wilberti, Ammotium salsum, Ammoscalaria pseudospiralis, Ammobaculites exiguus*
Inner Bay, Tidal inlets, River mouths of Limbang and Trusan Rivers	*Ammobaculites exiguus*, *A.* sp., *Haplophragmoides* sp., *Trochammina* cf. *lobata*
Seaward part of Inner Bay (strong marine influence)	Indigenous forms:- *Asterorotalia pulchella* assemblage:-*Asterorotalia pulchella, Pseudorotalia schroteriana, Ammonia annectens, A. annectens* var. *concinna, Elphidium koeboeense, Nonion japonicum, Ammobaculites exiguus, Ammobaculites* sp., *Cellathus craticulatus, Ozawaia tongaensis, Ammonia beccarii, Ammonia rolshauseni* Swept-in forms:- *Operculina* sp., *Peneroplis* sp, *Calcarina spengleri, Triloculina* sp., *Quinqueloculina* sp., *Dentostomina agglutinans*

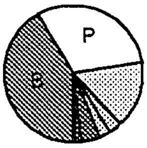
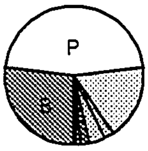
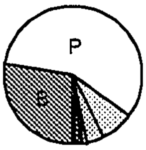
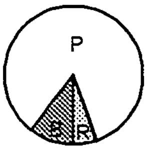
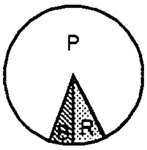
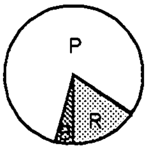
Appendix C, Table 4. Foraminiferal distribution in the Inner Brunei Bay (Ho, 1971).

MODERN ENVIRONMENT	DOMINANT FAUNA
Puerto Galera Bay:- Basin, land-locked on one end, tidally influcenced, coral reefs fringe the coast, eel grass and mangroves abound.	*Elphidium advena, E. craticulatum, E. crispum* *Heterostegina suborbicularis, Operculina complanata, O. ammonoides, Ammonia beccarii (var.), Amphistegina* spp., *Calcarina spengleri, Cibicides sp., Textularia* spp., *Pseudomassilina australis var. reticulata, Hauerina ornatissima, Quinqueloculina bicarinata, Q. crassa, Q.* spp., *Schlumbergerina alveoliniformis, Triloculina affinis, T.* spp, *Dendritina antillarum, Marginopora vertebralis, Peneroplis discoideus, P.* sp, *Sorites marginalis, Alveolinella quoii, Reusella spinulosa*
Balateros Region:- Open body of water, fringing reefs along coast, eel grass.	*Elphidium* spp., *Nonion japonicum, N. subturgidum, N.* spp., *Operculina* spp., *Heterostegina* sp., *Bolivina abbreviata, (B. spp), Loxostomum limbatum, Reussella spinulosa, Siphogenerina raphanus, Virgulina schriberiana, Conorbella patelliformis, Discopulvinulina advena, (Discorbis), Rosalina globularis, R. terquemi, Ammonia* spp.*(R. calcar), Amphistegina radiata (A.* spp.*), Calcarina spengleri, Cymbaloporetta bradyi,* *Cibicides* sp., *Planorbulina* sp., *Rhizammina algaeformis, Textularia* spp., *Hauerina diversa, Massilina, Miliolinella circularis, Pseudomassilina australis, Q. bicarinata, Q. crassa, Q.* spp., *Schlumbergerina alveoliniformis, Spiroloculina communis, S.* sp., *Triloculina tricarinata, T.* spp., *Planispirinella exigua, Vertebralina striata, Dendritina antillarum, Marginopora vertebralis, Peneroplis* spp.
Varadero Bay:- Broad indentation, **river input**, eel grasses along sandy beaches, fringing coral reefs.	*Amphistegina* spp., *Dendritina antillarum, Elphidium advenum, E. craticulatum, E. crispum,* ***Haplophragmoides canariensis***, *Miliolinella circularis, Nonion japonicum, Nonionella* sp., *Operculina ammonoides, O. complanata, Peneroplis* spp., *Pseudomassilna australis, Q. spp., Rhizammina algaeformis, Rosalina* spp., *Rotalia japonica, R. ozawai, Textularia* spp., *Triloculina affinis, T. oblonga,* ***Trochammina nana***
Markoe Cove:- Strong wave action, coarse sediment, no protecting reef.	Poor biota.
Sabang Cove:- Deep, wider mouth, protective fringing reef, finer grained sediment.	*Elphidium craticulatum, E. advena, E. crispum, E. reticulosum, Heterostegina suborbicularis, Operculina* spp., *Rosalina terquemi, Ammonia beccarii, Rotalia calcar, R. japonica, R. ozawai, Rotalia* sp., *Valvulineria* sp., *Amphistegina* spp., *Calcarina spengleri, Cibicides* sp., *Textularia foliacea, Flintina bradyana, Pseudomassilina australia var. reticulata, Quinqueloculina agglutinans, Q. bicarinata, Q. bidentata, Q. crassa, Troloculina affinis, Dendritina antillarum, Marginopora vertibralis, Peneroplis* sp, *Sorites marginalis.*

Appendix C, Table 5. Foraminiferal distribution from Northern Mindoro, Philippines (Graham and Militante, 1959).

MODERN ENVIRONMENT <u>Offshore Borneo</u>:-	DOMINANT FAUNA
Mid – shelf (20 – 60 m) Sunda Shelf, SCS	Alveolinidae, Soritidae, Nummulitidae, Heterosteginidae, Amphisteginidae, Elphidiidae, *Ammonia beccarii*, *Ammonia* sp., *Clavulina pacifica*, *Cellanthus craticulatus*, *Quinqueloculina pseudoreticulata*, *Quinqueloculina seminulum*, *Reusella simplex*, *Textularia* spp., *Discorbinella* sp., *Alveolinella* sp., *Spiroloculina* spp., *Triloculina* sp., *Pseudorotalia schroteriana*, *Cibicides praecinctus*, *Loxostomum* sp., *Eponides berthelotianus*, *Cancris indicus*, *Bigenerina nodosaria*, *Siphouvigerina ampullacea* Planktonics appear at 54 m water depth.
Deep Shelf (60 – 120 m) Sunda Shelf, SCS	*Cibicides praecinctus*, *Cancris indicus*, *Spiroloculina communis*, *Bigenerina nodosaria*, *Bolivina schwagerina*, *Siphouvigerina* spp., *Cibicides margaritiferus*, *Loxostomum* sp., *Spiroplectammina carinata*.
Very Deep Shelf (120 – 200 m) Sunda Shelf, SCS	Nodosariidae, Bolivinitidae, Uvigerinidae, Cibicididae, Ceratobuliminidae, Osangularidae

Appendix C, Table 6. Foraminiferal distribution from the Shelf zones offshore Borneo (Biswas, 1976).

MODERN ENVIRONMENTS OF THE SUNDA SHELF	FAUNAL ASSOCIATION	
Inner neritic zone (60 - 100 m)	*Heterolepa* aff. *dutemplei* - *Asterorotalia gaimardii*	
Outer neritic zone (100 - 200 m)	*Bulimina marginata* - *Neouvigerina proboscidea*	
Bathyal zone I (200 - 400 m)	*Siphotextularia foliosa* - *Bulimina mexicana*	
Bathyal zone II (400 - 800 m)	*Uvigerina auberiana* - *Ehrenbergina undulata*	
Bathyal zone III (800 - 1, 400 m)	*Nuttallides rugosus* - *Uvigerina peregrina*	
Bathyal zone IV (1, 400 - 1, 975 m)	*Astrononion novozealandicum* - *Eggerella bradyi*	

Appendix C, Table 7A. Foraminiferal and associated meiofaunal distribution on the Sunda Shelf (Szarek, 2001).

Legend:-

▨ benthos(B) ░ gastropoda ░ pteropoda ▩ ostracoda
☐ plankton(P) ░ bivalvia ▩ bryozoa ░ radiolaria(R)

Appendix C, 7B. Foraminiferal distribution along a northeast – southwest transect of the Sunda Shelf (Szarek, 2001).

In a study of box-core and surface samples collected along the same NE - SW transect across the Sunda Shelf as the one from which the sediment cores for this study were collected (SONNE – 115 cruise), Szarek (2001) related two associations to the neritic zone and four to the bathyal zone of the Sunda Shelf.

The inner neritic zone (60 - 109 m) was dominated by Rotaliids and Miliolids. The dominant fauna was *Heterolepa* aff. *dutemplei*. Subordinate fauna included *Ammomassilina alveoliniformis, Textularia* cf. *lythostrota, Quinqueloculina seminulum, Asterorotalia gaimardii, Elphidium advenum, Islandiella japonica, Hanzawaia grossepunctata,Cibicidoides* ex gr. *pachyderma, Ammonia beccarii, Discorbinella* sp., *Discorbia candeiana, Bigenerina* sp., *Reussella spinulosa, Cancris auriculus, Fijinonion fijiense, Helenina anderseni, Paracibicides endomica.*

In the outer neritic zone occupying the outer shelf (109-166 m), both *Heterolepa* aff. *dutemplei* and *Ammomassilina alveoliniformis* co-dominated. Subordinate fauna included *Asterorotalia gaimardii, Bulimina marginata, Neouvigerina proboscidea, Epistominella pulchra, Textularia bocki, Hanzawaia grossepunctata, Quinqueloculina seminulum, Ammonia beccarii, Textularia* cf. *lythostrota*

The uppermost bathyal zone (226 – 404 m), occurring on the uppermost continental slope, comprised a mixed, shallow and deep-water fauna. The fauna was generally dominated by Buliminida, Lagenida, and Rotaliida. The dominant species, *Asterorotalia pulchella*, was considered transported from shallower waters. Subordinate fauna included *Pararotalia* sp., *Bulimina marginata, Uvigerina* ex. gr. *auberiana, Siphotextularia foliosa, Bulimina mexicana, Siphogenerina striatula, Bolivina subaenariensis* var. *mexicana.*

The Upper Bathyal Zone (482 – 790 m), located on the upper continental slope, was characterised by a high proportion of Buliminida, Lituolida, and Trochamminida. The dominant fauna was *Uvigerina* ex. gr. *auberiana.* Subordinate fauna included *Bolivina robusta, Lagenammina difflugiformis, Ehrenbergina undulata, Eggerella bradyi, Paratrochammina challengeri, Reophax* spp., *Hormosina* sp., *Hormosinella* sp., *Ammobaculites* sp., *Reophanus* sp., *Recurvoides* sp., *Bulimina aculeata, Bulimina affinis, Fontbotia wuellerstorfi, Parrelloides bradyi*

In the Middle Bathyal Zone (978 – 1404 m), on the mid continental slope the dominant fauna was *Nuttallides rugosus, Uvigerina peregrina, Lagenammina difflugiformis, Uvigerina* ex gr. *auberiana.* Subordinate fauna included *Paratrochammina challengeri, Saccammina sphaerica, Parrelloides bradyi, Eggerella bradyi, Cassidulina carinata, Nodosinum gaussicum, Trochammina nana, Adercotryma glomeratum, Coronatoplanulina okinawaensis, Laticarinina pauperata.*

The Lower Bathyal Zone (1852 – 1974 m) represents the lower continental slope. This zone was represented by two sites only. The benthic fauna was similar to that of the preceding zone, however, the species diversity decreased. The dominant fauna was *Saccammina sphaerica*. Subordinate fauna included *Astrononion novozealandicum, Eggerella bradyi, Cibicidoides pachyderma, Hormosinella guttifera, Glomospira gordialis, Isbekistania charoides, Oridorsalis umbonatus, Melonis affinis, Eratidus recurvus.*

REFERENCES CITED

Asano, K., 1944. *Hanzawaia*, a new genus of Foraminifera from the Pliocene of Japan. Journal of the Geological Society of Japan, 51: 97-99.

Asano, K., 1951. Illustrated Catalogue of Japanese Tertiary Smaller Foraminifera, Part 14, *Rotaliidae*. Tokyo, Hosokawa Printing Company: 1-21.

Bard, E., Hamelin, B., Arnold, M., Montaggioni, L., Cabioch, G., Gaure, G., and Rougerie F., 1996. Deglacial sea-level record from Tahiti corals and the timing of global meltwater discharge. Nature, 382: 241-244.

Barker, R.W., 1960. Taxonomic notes on the species figured by H.B. Brady in his report on the foaminifera dredged by H.M.S. Challenger during the years 1873-1876. Society of Economical Petrology and Mineralogy, Special Publication 29, 238 p.

Bartenstein, H., and Brand, E., 1938. Die Foraminiferan-Fauna des Jade-Gebietes 1. *Jadammina polystoma* n.g., n.sp. aus dem Jade-Gebietes (For). Senckenbergiana, 20(5): 381-385.

Belford, D.J., 1966. Miocene and Pliocene smaller foraminifera from Papua and New Guinea. Australia Bureau of Mineral Resources, Geology and Geophysics Bulletin, 79, 306 p.

Bermúdez and Fuenmayor, 1966. Consideraciones sobre los sedimentos del Mioceno medio al Reciente de las costas central y oriental de Venezuela. Segunda parte. Los foraminiferos bentónicos. Boletín de Geología, Venezuela, 7: 413-611.

Biswas, B., 1973. Quaternary changes in sea level in the South China Sea. Geological Society of Malaysia, Bulletin 6: 229-256.

Biswas, B., 1976. Bathymetry of Holocene foraminifera and Quaternary sea-level changes on the Sunda Shelf. Journal of Foraminiferal Research, 6(2): 107-133.

Brady, H.B., 1870. With an analysis and descriptions of the Foraminifera (Part II). In: Brady, G.S., Robertson, D. The Ostracoda and Foraminifera of tidal rivers. Annals and Magazine of Natural History, 4(6): 273-309.

Brady, H.B., 1879a. Notes on some of the reticularian Rhizopoda of the "Challenger" Expedition. Part I. On new or little known arenaceous types. Quarterly Journal of Microscopical Science, new ser. 19: 20-63.

Brady, H.B., 1879b. Notes on some reticularian Rhizopoda of the Challenger Expedition. Part 2. Additions to the knowledge of porcellanous and hyaline types. Quarterly Journal of Microscopical Science, new ser. 19: 261-299.

Brady, H.B., 1881. Notes on some of the reticularian *Rhizopoda* of the Challenger Expedition. Part III. Quarterly Journal of Microscopical Science, London, 21: 31-71.

Brady, H.B., 1884. Report on the foraminifera dredged by H.M.S. Challenger, during the years 1873-1876. In: Reports of the Scientific Results of the Voyage of the H.M.S Challenger, Zoology, London, 9, 814 p.

Brady, H.B., 1890. Note on a new type of foraminifera of the family Chilostomellidae. Journal of the Royal Microscopical Society, London: 567-571.

Broecker, W.S., Andree, M., Klas, M., Bonani, G., Wolfli, W., and Oeschger, H., 1988. New evidence from the South China Sea for an abrupt termination of the last glacial period. Nature, 333: 156-158.

Brotzen, 1942. Brotzen, F., 1936. Foraminiferen aus dem schwedischen untersten Senon von Eriksdal in Schonen. Arsbok Sveriges Geologiska Undersökning, 30(3): 1-206.

Brünnich, M.T., 1772. M.T. Brunnich Zoologiae fundamenta. Grunde i Dyeloeren, Hafniae et Lipsiae, 253 p.

Camoin, G.F., Ebren, Ph., Eisenhauer, A., Bard, E., Faure, G., 2001. A 300 000-yr coral reef record of sea level changes, Mururoa atoll (Tuamotu archipelago, French Polynesia). Palaeogeography, Palaeoclimatology, Palaeoecology, 175: 325-341.

Chivas, A.R., Garcia, A., Kaars, S. V. D., Couapel, M.J.J., Holt, S., Reeves, J.M., Wheeler, D.J., Switzer, A.D., Murray-Wallace, C.V., Banerjee, D., Price, D.M., Wang, S.X., Pearson G., Edgar, N.T., Beaufort, L., De Deckker, P., Lawson, E., Cecil, C. B., 2001. Sea-level and environmental changes since the last interglacial in the Gulf of Carpentaria, Australia: an overview. Quaternary International, 83 – 85: 19-46.

Collins, E., 1996. Marsh-estuarine benthic foraminiferal distributions and Holocene sea-level reconstructions along the South Carolina coastline. Unpublished Ph.D Thesis, Dalhousie University.

Coustillas, F., 1983. Les facies recents de la plate-forme orientale de Kalimantan (Indonesie) et leur contenu micropaleontologique (Foraminiferes benthiques). Thesis Univ. Bordeaux, 3rd cycle, d' enseignement superieur no, 1920. Vol. I: Texte, p. 1-170. Vol. II: Planches, photographiques, index des especes, chartes de repartition specifique.

Cushman, J.A., 1911. A monograph of the foraminifera of the North Pacific Ocean. Part. 2. *Textulariidae*. Bulletin of the United States National Museum 71(2), 108 p., 156 text figs.

Cushman, J.A., 1922a. The foraminifera of the Atlantic Ocean, Part 3. Textulariidae. Bulletin of the United States National Museum, 104 (3), 143 p., 26 pl.

Cushman, J.A., 1922b. Shallow-water foraminifera of the Tortugas Region. Publications of the Carnegie Institution of Washington, no. 311, Department of Marine Biology 17:1-85, pl. 1-14.

Cushman, J.A., 1923. The foraminifera of the Atlantic Ocean. Part 4. Lagenidae. Bulletin of the United States National Museum. 104 (4), 228 p., 42 pl.

Cushman, J.A., 1924. Samoan foraminifera. Publications of the Carnegie Institution of Washington, no. 342, Department of Marine Biology Papers, 21: 1-75, pl. 1-25.

Cushman, J.A., 1925. Recent foraminifera from British Columbia. Contributions from the Cushman Laboratory for Foraminiferal Research, 1: 38-47.

Cushman, J.A., 1926. Foraminifera of the genera *Siphogenerina* and *Pavonina*. Proceedings of theUnited States National Museum, 67 (25):1-24.

Cushman, J.A., 1933a. The foraminifera of the tropical Pacific collections of the "Albatross," 1899-1900, Pt. 2. Lagenidae to Alveolinellidae. Bulletin of the United States National Museum, 161: i-vi, 1-79.

Cushman, J.A., 1933b. Some new Recent foraminifera from the tropical Pacific. Contributions from the Cushman Laboratory for Foraminiferal Research, 9: 77-95.

Cushman, J.A., 1933c. Some new foraminiferal genera. Contributions from the Cushman Laboratory for Foraminiferal Research, 9: 32-38.

Cushman, J.A., and Bronnimann, P., 1948. Some new genera and species of foraminifera from the brackish waters of Trinidad. Contributions from the Cushman Laboratory for Foraminiferal Research, 24: 15-22.

Cushman, J.A. and Edwards, P.G., 1937. *Astrononion* a new genus of the foraminifera, and its species. Contributions from the Cushman Laboratory for Foraminiferal Research, 13: 29-36.

Cushman, J.A. and Martin, L.T., 1935. A new genus of foraminifera, *Discorbinella*, from Monterey Bay, California. Contributions from the Cushman Laboratory for Foraminiferal Research, 11: 89-90.

Cushman, J.A., and McCulloch, I., 1948. The species of *Bulimina* and related genera in the collections of the Allan Hancock Foundation. Allan Hancock Pacific Expeditions, 6(5): 211-294.

Debenay, J.P., Duleba, W., Bonetti, C., De Melo E Souza, S.H., and Eichler, B.B., 2001. *Pararotalia cananeiaensis* n. sp.: indicator of marine influence and water circulation in Brazilian coastal and paralic environments. Journal of Foraminiferal Research, 31(2): 152-163.

Defrance, J.L.M., 1824. Dictionnaire des Sciences Naturelles, vol. 32, moll-morf. Strasbourg, F.G. Levrault, 567 p.

Dhillon, D.S., 1968. Notes on the foraminiferal sediments from the Lupar and Labuk estuaries, east Malaysia. In: Collenette, P., Goh, J., (Eds.), Geological Papers (Bulletin 9), Geological Survey Borneo Region, Malaysia, Kuching, Sarawak, 56-73.

Dickerson, R.E., 1941. Molengraaff River: A drowned Pleistocene stream and other Asian evidences bearing upon the lowering of sea level during the ice age. Univ. of Pennsylvania bicentennial conf. Univ. of Penn., Philadelphia, 13-30.

d'Orbigny, A., 1826. Tableau méthodique de la classe des Céphalopodes. Annales des Sciences Naturelles, 7, 245-314.

d'Orbigny, A., 1839. Foraminifères. In: R. de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, (2): 1-224. A. Bertrand, Paris.

Earland, A., 1934. Foraminifera. Part III. The Falklands sector of the Antarctic (excluding South Georgia). Discovery Reports, 10, 1-208.

Egger, J.G., 1893. Foraminiferen aus Meeresgrundproben, gelohtet von 1874 bis 1876 von S. M. Sch. Gazelle. *Abhandlungen der Bayerischen Akademie der Wissenschaften, München*, 18(2): 193-458.

Ehrenberg, C.G., 1843. Verbreitung und Einfluss des Mikroskopischen Lebens in Süd- und Nord-Amerika. Physikalische Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, 1841(1): 291-446.

Eichwald, C.E. von, 1830. Zoological specialis. Vol. 2. Vilnae. D.E. Eichwaldus, 323 p.

Esat, T.M., McCulloch, M.T., Chappell, J., Pillans, B., and Omura, A., 1999. Rapid fluctuations in sea level recorded at Huon Peninsula during the penultimate deglaciation. Science, 283: 197-201.

Evans, C.D.R., Brett, C.P., James, J.W.C., and Holmes, R., 1995. Shallow seismic reflection profiles from the waters of east and southeast Asia – an interpretation manual and atlas. BGS Technical Report WC/94/60, Keyworth, Nottingham.

Fairbanks, R.G. 1989. A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. Nature, 342: 637-642.

Fichtel, L., von and Moll, J. P. C., 1798 and 1803 (reprint). Testacea microscopica, aliaque minuta ex generibus *Argonauta et Nautilus*, ad naturam picta et descripta (Microscopische und andere klein Schalthiere aus den geschlechtern Argonaute und Schiffer). Camesina, Vienna, 124 p.

Finlay, H.J., 1939. New Zealand foraminifera: Key species in stratigraphy – No. 1. Transactions of the Royal Society of New Zealand, 68: 504-543.

Finlay, H.J., 1940. New Zealand Foraminifera: Key species in stratigraphy – No. 4. Trans. Royal Soc. N.Z., 69(4): 448-472.

Finlay, H.J., 1947. New Zealand foraminifera: Key species in stratigraphy – No. 5. New Zealand Journal of Science and Technology 28: 259-292.

Fornasini, C., 1900. Intorno ad alcuni esemplari di foraminiferi Adriatici. Memorie della R. Accademie della Scienze dell'Istituto di Bologna, Scienze Naturali, ser 5 8(1899 – 1900): 357-402.

Franzenau, A., 1884. *Heterolepa* egy uj genus a Foraminiferák rendjében. Természetrajzi Füzetek, Budapest, 8, p. 181-184; 214-217.

Gagliano, S.M., and McIntire, W.G., 1968. Reports on the Mekong River Delta. Coastal Studies Institute, Louisiana State University, Technical Report No. 57. Baton Rouge, 143 p.

Galloway, J.J., 1933. A Manual of Foraminifera. Bloomington, Principia Press, xii + 483 p.

Graham, J.J., and Militante, P.J., 1959. Recent Foraminifera from the Puerto Galeraarea, northern Mindoro, Philippines. Stanford Univ Publications, Stanford, Geological Sciences, 6(2), 170 p.

Gregory, M.R., 1970. Distribution of benthic foraminifera in Halifax Harbour, Nova Scotia, Canada: Ph.D. Thesis, Dept. of Geology, Dalhousie University, Halifax, Nova Scotia [unpublished manuscript].

Gregory, M.R., 1973. Benthonic foraminifera from a mangrove swamp, Whangaparapara, Great Barrier Island. Tane, 19: 193-204.

Gupta, A., Rahman, A., Poh-P, W., and Pitts, H., 1987. The old alluvium of Singapore and the extinct drainage system to the South China Sea. Earth surface processes and landforms, 12: 259-275.

Hada, Y., 1931. Report of the biological survey of Mutsu Bay. 19, Notes on the Recent Foraminifera from Mutsu Bay. Science Reports of the Tôhoku Imperial University, ser. 4, Biology, 6(1): 45-148.

Haig, D., 1988. Miliolid foraminifera from inner neritic sand and mud facies of the Papuan Lagoon, New Guinea. Journal of Foraminiferal Research, 18(3): 203-236.

Haig, D., 1993. Buliminid foraminifera from inner neritic sand and mud facies of the Papuan Lagoon, New Guinea. Journal of Foraminiferal Research, 23(3): 162-179.

Hanebuth, T. 2000. Sea-Level Changes on the Sunda Shelf during the last 50,000 years. Ph.D. thesis, Univ. Kiel. 104 p.

Hanebuth, T., Schimanski, A., and Stattegger, K., (submitted) a. Late Pleistocene forced regression deposits on the Sunda Shelf (SE Asia). ?Marine Geology.

Hanebuth, T., and Stattegger, K., submitted. The stratigraphic evolution of the Sunda Shelf during the past fifty thousand years. In: Sidi, F. H., Nummedal, D., Posamentier, H. W., Darman, H., and Imbert, P., (eds.). Deltas of Southeast Asia and vicinity: Sedimentology, Stratigraphy, and Petroleum Geology. Society of Economic Paleontologists and Mineralogists, Special Publication.

Hanebuth, T., Stattegger, K., and Grootes P., 2000. Rapid flooding of the Sunda Shelf: A Late-Glacial Sea-Level Record. Science, 288, 1033-1035.

Hanebuth, T., Stattegger, K., and Saito, Y., (submitted) b. The stratigraphic architecture of the central Sunda Shelf (SE Asia) recorded by shallow-seismic surveying. Geo-Marine Letters.

Hayward, B.W., Grenfell, H.R., Reid, C.M., and Hayward, K.A., 1999a. Recent New Zealand shallow-water benthic foraminifera: Taxonomy, Ecologic Distribution, Biogeography, and use in paleoenvironmental assessment. Institute of Geological & Nuclear Sciences Ltd., Monograph 21, Lr. Hutt, New Zealand. 258 p.

Hayward, B.W., Grenfell, H.R., and Scott, D.B., 1999b. Tidal range of marsh foraminifera for determining former sea-level heights in New Zealand. New Zealand Journal of Geology and Geophysics, 42: 395-413.

Hedley, R. H., Hurdle, C.M., and Burdett, I. D. J., 1967. The marine fauna of New Zealand: Intertidal foraminifera of the *Corallina officinalis* Zone. Memoirs New Zealand Oceanographic Institute, 38: 1-86.

Heron-Allen, E., and Earland, A, 1930. *Miliammina*, a new siliceous genus. Journal of the Royal Microscopic Society of London, 50: 38-45.

Heron-Allen, E., and Earland, A, 1932. Foraminifera Part 1. The ice free area of the Falkland Islands and adjacent seas. Discovery Reports 4: 291-460.

Hesp, P. A., Hung, C.C., Hilton, M., Ming, C.L., and Turner, I.M., 1998. A first tentative Holocene sea-level curve for Singapore. Journal of Coastal Research, 14(1): 308-314.

Ho, K.F., 1971. Distribution of Recent Benthonic foraminifera in the inner Brunei Bay. Brunei Museum Journal, 2: 124-137.

Hoekstra, P., 1993a. Humid tropical zone deltas, their potential and limitations for development: examples from Java, Indonesia. In: Kay, R. (Ed.), Deltas of the World. American Society of Civil Engineers, 85-98.

Hoekstra, p., 1993b. Late Holocene development of a tide-induced elongate delta, the Solo Delta, East Java. Sedimentary Geology, 83: 211-233.

Hofker, J., 1951. The foraminifera of the Siboga expedition. Part 3, Siboga-Expeditie, Monographie IVa, E. J. Brill, Leiden, 1-513.

Hofker, J., 1968. Foraminifera from the Bay of Jakarta, Java. Bijdragen tot de Dierkunde Afl.37, 11-59.

Hofker, J., 1978. The foraminifera collected in 1929 and 1930 in the eastern part of the Indonesian Archipelago. Zoologische Verhandelingen no. 161, The Hague, 69 p.

Huang G., 2000. Holocene record of storms in sediments of the Pearl River Estuary and vicinity. Ph.D. thesis, Univ. of Hong Kong, 353 p.

Huang, T.-Y., 1964. '*Rotalia*' group from the Upper Cenozoic of Taiwan. Micropaleontology, New York, 10 (1): 49-62, pls. 1-3.

Husezima, R., and Maruhasi, M., 1944. A new genus and thirten new species of foraminifera from the core-sample of Kasiwazaki oil-field, Nigata-ken. Journal of Sigenkagaku Kenkyusyo, 1: 391-400.

Javaux, E.J.J.M., 1999. Benthic foraminifera from the Modern sediments of Bermuda: Implications for Holocene sea-level studies. Ph.D. thesis, Dalhousie Univ., N.S., 625 pp.

Jian, Z., Huang, B., Kuhnt, W., and Lin, H-L., 2001. Late Quaternary upwelling intensity and East Asian monsoon forcing in the South China Sea. Quaternary Research, 55(3): 363-370.

Jones, R. W., 1994. The Challenger Foraminifera. Oxford Univ. Press, 149 p.

Kamaludin B.H., 1993. The changing mangrove shorelines in Kuala Kurau, Peninsular Malaysia. Sedimentary Geology, 83: 187-197.

Kanmacher, F., 1798. Adam's Essays on the Microscope; the Second Edition, with Considerable Additions and Improvements. Dillon and Keating, London, 712 p.

Karrer, F., 1868. Die Miocene Foraminiferenfauna von Kostej im Banat. Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften Wien, Mathematisch-Naturwissenschaftliche Klasse 58(1): 121-193.

Kennett, J., 1982. Marine Geology. Prentice-Hall, Inc., New Jersey.

Kienast, M., Steinke, S., Stattegger, K., and Calvert, S.E., 2001. Synchronous tropical South China Sea SST change and Greenland warming during deglaciation. Science, 291: 2132-2134.

Lamarck, J.B., 1804. Suite des mémoires sur les fossiles des environs de Paris. Annales Muséum National d'Histoire Naturelle, 5, 179-188; 237-245; 349-357.

Le Calvez, Y., 1949. Révision des foraminifères Lutétiens du Bassin de Paris. II. Rotaliidae et familles affines. Mémoires du Service de la Carte Géologique Détaillée de la France, 1-54.

LeRoy, L.W., 1964. Smaller Foraminifera from the late Tertiary of southern Okinawa. Professional Papers U.S. Geological Survey 454-F:i – iv, F1 – F58.

Linné, C., 1758. Systema naturae, 10th ed., vol. 1. G. Engelmann, Leipzig. 824 p.

Loeblich, A.R., and Tappan, H., 1953. Studies of Arctic Foraminifera. Smithsonian miscellaneous collections, 21(7), 150 p.

Loeblich, A.R., and Tappan, H., 1961. Suprageneric classification of the Rhizopodea. Journal of Paleontology, 35: 245-330.

Loeblich, A.R., and Tappan, H., 1964. Sarcodina, chiefly "Thecamoebians" and Foraminiferida. In: R.C. Moore (ed.). Treatise of Invertebrate Paleontology, Protista 2, part C. Geological Society of America and University of Kansas Press, Lawrence. 2 vols, 900 p.

Loeblich, A. R., and Tappan, H., 1987. Foraminiferal Genera and their Classification. New York: Van Nostrand Reinhold Company, 2 vols., 1182 p.

Loeblich, A. R., and Tappan, H., 1994. Foraminifera of the Sahul Shelf and Timor Sea. Cushman Found. Foram. Res. Sp. Pub. 31, 661 p.

Martinez, J. I., De Deckker, P., and Chivas, A. R., 1997. New estimates for salinity changes in the Western Pacific Warm Pool during the Last Glacial Maximum: oxygen-isotope evidence. Marine Micropaleontology, 32: 311-340.

Matsunaga, T., 1963. Benthonic smaller foraminifera from the oil fields of Northern Japan. The science reports of the Tohoku University, Sendai, Second series (Geology), 35(2): 67-209.

McGregor, H., and Gagan, M., (retrieved 2001, Nov.11). Mid-Holocene to present coral records of climate variability in the Western Pacific Warm Pool. http://wwwrses.anu.edu.au/enproc/AQUADATA/AQUA/meetings/Bowlerfest/McGregor.html

Michie, M.G., 1987. Distribution of foraminifera in a macrotidal tropical estuary: Port Darwin, Northern Territory of Australia. Australian Journal of Marine and Freshwater Research, 38: 249-259.

Millett, F.W., 1898. Report on the Recent foraminifera of the Malay Archipelago collected by Mr. A. Durrand, F.R.M.S., Part III. Journal of the Royal Microscopical Society, 1898: 607-614.

Millett, F.W., 1903. Report on the Recent foraminifera of the Malay Archipelago collected by Mr. A. Durrand, F.R.M.S., Part XIV. Journal of the Royal Microscopical Society 1903: 253-275.

Milliman, J.D., 1999. Fluvial fluxes to the sea: Importance of South Asian Rivers. In: Saito, Y., Ikehara, K., and Katayama, H. (eds.), Land-Sea link in Asia. Prof. Kenneth O. Emery Commemorative International Workshop. Proceedings of an international workshop on sediment transport and storge in coastal sea-ocean system, STA (JISTEC) & Geological Survey of Japan, Tsukuba, Japan: 259-262.

Milne-Edwards, A., 1882. Rapport sur les travaux de la Commission chargée d'étudier la faune sous-marine dans les grandes profondeurs de la Méditerranée et de l'Océan Atlantique. Archives des Missions Scientifiques et Littéraires, Paris, 3(9):1-59.

Molengraaff, G.A.F., 1921. On the relation between the Pleistocene Glacial Period and the origin of the Sunda Sea (Java- and South China Sea), and its influence on the distribution of coral reefs and on the land and freshwater fauna (Geological Part). Proceedings: Royal Academy of Amsterdam, 23(1): 395-428.

Montague, G., 1808. Testacea Britannica, or Natural History of British Shells, marine, land and fresh-water, including the most minute. Supplement. S. Woolmer, Exeter, 183 p.

Montfort de, P.D. 1808. Conchyliologie systématique et classification méthodique des coquilles 1: F. de Schoell, Paris, 409 p.

Munier-Chalmas, E., 1882. [La structure des Triloculines et des Quinqueloculines]. Bulletin de la Société Géologique de France (1881 – 1882) sér. 3, 10: 424 – 425.

Murray, J.W., 1991. Ecology and paleoecology of benthic foraminifera. Longman Scientific and Technical, London, 397 p.

Nguyen, V.L., Ta, T.K.O., and Tateishi, M., 2000. Late Holocene depositional environments and coastal evolution of the Mekong River Delta, Southern Vietnam. Journal of Asian Earth Sciences, 18: 427-439.

Parker, F.L., 1954. Distribution of the foraminifera in the northeastern Gulf of Mexico: Bulletin of the Harvard Museum of Comparative Zoology, v. 111, 453-588.

Parker F.L., and Athearn, W.D., 1959. Ecology of marsh foraminifera in Poponesset Bay, Massachusetts. Journal of Paleontology, 33(2): 333-343.

Parker, W.K., and Jones, T.R., 1859. On the nomenclature of the foraminifera, Part 2: on species enumerated by Walker and Montague. Annals and magazine of natural history, series 2, 4: 333-351.

Parker, W.K., and Jones , T.R., 1862. In: Carpenter, W.B., Parker, W.K., and Jones , T.R., Introduction to the Study of the Foraminifera. Ray Soc. Publs., 319 p.

Parker, W.K. & Jones, T.R., 1865. On some Foraminifera from the North Atlantic and Arctic Oceans, including Davis Straits and Baffin's Bay. Philosophical Transactions of the Royal Society of London, 155, 325-441.

Parr, W.J., 1941. A new genus, *Planulinoides*, and some species of foraminifera from South Australia. Mining and Geological Journal, 2, 1-305.

Parr, W.J., 1950. Foraminifera, Reports B.A.N.Z. Antarctic Research Expedition 1929-1931, Ser. B (Zoology, Botany) 5(6): 232-392.

Pelejero, C., Kienast, M., Wang, L., and Grimalt, J.O., 1999. The flooding of Sundaland during the last deglaciation: imprints in hemipelagic sediments from the southern South China Sea. Earth and Planetary Science Letters, 171: 661-671.

Phleger, F.B, and Parker, F.L., 1951. Ecology of Foraminifera, northwest Gulf of Mexico. Part II. Foraminifera species. Geological Society of America, Memoirs, 46, 1-64, pl. 1-20.

Phleger, F.B., and Walton, W.R., 1950. Ecology of marsh and bay foraminifera, Barnstable Mass. American Journal of Science, 248, 274-294.

Plummer, H. J., 1926. Foraminifera of the Midway Formation in Texas. University of Texas Bulletin, 2644, 1-198.

Polski, W., 1959. Foraminiferal biofacies off the North Asiatic coast. Journal of Paleontology, 33(4): 569-587.

Reiss, Z., 1960. Structure of so-called *Eponides* and some other rotaliiform foraminifera. Bulletin of the Geological Survey of Israel, 29: 1-28.

Reiss. Z., and Merling, P., 1958. Israel Geol. Survey Bull, 21, 13 p., pl. 1, fig. 15-17.

Reuss, A.E., 1850. Neue foraminiferen aus den Schichten des österreichischen Tertiärbeckens. *Denkschriften der Kaiserlichen Akademie der Wissenschaften, Wien, Mathematisch-Naturwissenschaftliche Classe*,1, 365-390.

Riccio, J.F., 1950. *Triloculinella*, a new genus of foraminifera. Contributions from the Cushman Foundation for Foraminiferal Research, 1, 90 p.

Rimbaman, I., 1992. The role of sea-level changes on the coastal environment of northrn West Java (case study of Eretan, Losarang and Indramayu). Journal of Southeast Asian Earth Sciences, 7(1): 71-77.

Rzehak, A., 1888. Die Foraminiferen der Nummuliten-schichten des Waschberges und Michelsberges bei Stockerau in Nieder-Österreich. Verhandlungen der Geologischen Bundesanstalt 1888: 226-229.

Saidova, Kh. M., 1975. Bentosnye Foraminifery Tikhogo Okeana {Benthonic foraminifera of the Pacific Ocean}, 3 vol. Moscow: Institut Okeanologii P. P. Shirshova, Akademiya Nauk SSSR, 875 p.

Sarnthein, M., and Wang, P., 1999. Response of West Pacific Marginal Seas to Global Climate Change. Marine Geology, 156: 1-307.

Schröder, C.J., Scott, D.B., and Medioli, F.S., 1987. Can smaller benthic foraminifera be ignored in paleoenvironmental analyses? Journal of Foraminiferal Research, 17(2): 101-105.

Schröeter, J.S., 1783. Einleitung in die Conchylien-kenntniss nach Linné. J.J. Gebauer, Halle, 1, 860 p.

Scott, D.B., Collins, E.S., Duggan, J., Asioli, A., Saito, T., and Hasegawa, S., 1996. Pacific Rim marsh foraminiferal distributions: implications for sea-level studies. Journal of Coastal Research, 12: 850-861.

Scott, D.B. and Hermelin, J.O.R., 1993. A device for precision splitting of micropaleontological samples in liquid suspension. Journal of Paleontology, 67(1): 151-154.

Scott, D.B. and Medioli, F.S., 1980. Quantitative studies of marsh foraminiferal distributions in Nova Scotia: Implications for sea level studies. Cushman Found. Foraminiferal Res. Spec. Publ. 17, 58 p.

Scott, D.B., Medioli, F.S., and Schafer, C.T., 2001. Monitering in coastal environments using Foraminifera and Thecamoebian indicators. Cambridge Univ. Press, 180 p.

Scott. D.B., Mudie, P.J., and Bradshaw, J.S., 1976. Benthonic foraminifera of three southern Californian lagoons: ecology and Recent stratigraphy. Journal of foraminiferal research, 6(1): 59-75.

Scott, D.B., Piper, D.J.W., and Panagos, A.G., 1979. Recent salt marsh and intertidal mudflat Foraminifera from the western coast of Greece: Rivista Italiana de Paleontologia, 85(1): 243-266.

Scott, D.B., Schafer, C.T., and Medioli, F.S., 1980. Eastern Canadian estuarine foraminifera: a framework for comparison. Journal of Foraminiferal Research, 10: 205-234.

Scott, D.B., Schnack, E.J., Ferero, L., Espinosa, M., and Barbosa, C.F., 1990. Recent marsh foraminifera from the east coast of South America: Comparison to the northern hemisphere. In: Hemleben, C., Kaminski, M.A., Kuhnt, W., Scott, D.B.

(Eds.), Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera (NATO/ASI Ser. C, 327). Kluwer, Dordrecht, 717-737.

Scott, D.B., Suter, J.R., and Kosters, E.C., 1991. Marsh foraminifera and arcellaceans of the lower Mississippi Delta: Controls on spatial distributions. Micropaleontology, 37(4): 373-392.

Scott, D.B., Takayanagi, Y., Hasegawa, S., and Saito, T., 2000. Illustration and taxonomic reevaluation of Neogene foraminifera described from Japan. Palaeontologica Electronica, 3(2), 41 p.

Sidebottom, H., 1918. Report on the Recent foraminifera dredged off the east coast of Australia, H.M.S. "Dart", Station 19 (May 14, 1895), lat. 29° 22' S., long. 153° 51' E., 465 fathoms. Pteropod ooze. Journal of the Royal Microscopical Society 1918: 121-152.

Simmons, M, D.. Bidgood, M.D., Brenac, P., Crevello, P.d., Lambiase, J.J., and Morley, C.K., 1999. Microfossil assemblages as proxies for precise palaeoenvironmental determination – an example from Miocene sediments of northwest Borneo. In: Jones, R.W., and Simmons, M.D. (eds.) Biostratigraphy in Production and Development Geology. Geological Society, London, Special Publications, 152: 219-241.

Stanley, D.J., and Warne, A.G., 1994. Worldwide initiation of Holocene marine deltas by deceleration of sea-level rise. Science, 265: 228-231.

Stattegger, K., Kuhnt, W., Wong, H.K., Bühring, C., Haft, C., Hanebuth, T., Kawamura, H., Kienast, M., Lorenc, S., Lotz, B., Lüdmann, T., Lurati, M., Mühlhan, N., Paulsen, A.-M., Paulsen, J., Pracht, J., Putar-Robers, A., Hung, N.Q., Richter, A., Salomon, B., Schimanski, A., Steinke, S., Szarek, R., Nhan, N.V., Weinelt, M., Winguth, C. 1997. Sequence stratigraphy, late Pleistocene-Holocene sea-level fluctuations and high resolution record of the post-Pleistocene transgression on the Sunda Shelf. Ber.- Reports, Geol.-Paläont. Inst., Univ. Kiel, Kiel. 86, 211 p.

Steinke, S., Kienast, M., and Hanebuth, T. J. J., submitted. The importance of sea-level variation and shelf palaeo-morphology in governing shelf margin and slope sedimentation: Examples from the southern South China Sea during the last deglaciation. Marine Geology.

Steinke, S., Kienast, M., Pflaumann, U., Weinelt, M., and Stattegger, K., 2001. A high-resolution sea-surface temperature record from the tropical South China Sea (16,500 – 3000 yr B.P.). Quaternary Research, 55: 352-362.

Stuiver, M. and Reimer, P.J., 1993. Radiocarbon calibration program. Radiocarbon, 35: 215-230.

Szarek, R., 2001. Biodiversity and biogeography of recent benthic foraminiferal assemblages in the south-western South China Sea (Sunda Shelf). Ph.D. Thesis, Christian-Albrechts-Universität zu Kiel, 273 p. Retrieved from http://e-diss.uni-kiel.de/diss_537/d537.pdf on February 4, 2002

Ta, T.K.O., Nguyen, V.L., Tateishi, M., Kobayashi, I., and Saito, Y., 2001. Sedimentary facies, diatom and foraminifer assemblages in a late Pleistocene – Holocene incised-valley sequence from the Mekong River Delta, Bentre Province, Southern Vietnam: the BT2 core. Journal of Asian Earth Sciences, 20(1): 83-94.

Tappan, H., 1951. Foraminifera from the Arctic slope of Alaska, General Introduction and Part I, Triassic Foraminifera: US Geolocical Survey , Professional Paper 236-A, p. 1-20, pl. 1-5, 2 text-figs.

Tappan, H. and Loeblich, Jr., A.R., 1982. Granuloreticulosa, in: S. P. Parker (Ed.), Synopsis and Classification of Living Organisms, vol. 1, New York. McGraw-Hill Company, 527-552.

Thalmann, H.E., 1935. Mitteilungen über Foraminiferen, Part 2., *Rotalia indopacifica*, nom. nov. im indo-pazifischen Verbreitungsgebiet. *loc. cit.* 28 (2): 605-606.

Thalmann, H.E., 1939. Bibliography and index to new genera, species and varieties of foraminifera for the year 1936. Journal of Paleontology, 13(4): 425-465.

Tjia, H. D., 1970. Quaternary shorelines of the Sunda Land, Southeast Asia. Geologie en Mijnbouw, 49(2): 135-144.

Tjia, H.D., 1980. The Sunda Shelf, Southeast Asia. Zeitschrift für Geomorphologie N. F., 24(4): 405-427.

Tjia, H. D., and Fujii, S., 1992. Late Quaternary shorelines in Peninsula Malaysia. In: Tjia, H.D., and Abdullah, S.M.S. (Eds.), The coastal zone of Peninsula Malaysia. Bangi: Penerbit Universiti Kebangsaan Malaysia, 28-41.

Todd, R., 1965. The foraminifera of the tropical Pacific Collections of the "*Albatross*", 1894-1900, Part IV, Rotaliform families and planktonic families. *Bulletin of the United States National Museum*, 161, 1-139.

Todd, R., and Bronnimann, P., 1957. Recent foraminifera and thecamoebina from the eastern Gulf of Paria. Cushman Foundation for Foraminiferal Research Spec. Publ. No. 3, 43 p.

Ujiié, H., and Rifardi, D., 1993. Some Benthic Foraminifer from the Ôura River Estuary and its Environs, Okinawa. Bulletin of the College of Science, University of the Ryukyus, 56, 121-143.

Van Marle, L.J., 1991. Eastern Indonesian Late Cenozoic smaller benthic foraminifera. Verhandelingen der Koninklijke Nederlandse Akademie der Wetenschappen, Afd. Natuurkunde, eerste Reeks, Deel 34, 328 p.

Voloshinova, N.A., 1960. Uspekhi mikropaleontologii v dele izucheniya vnutrennego stroeniya foraminifer {Progress in micropaleontology in the work of studying the inner structure of Foraminifera}, in Trudy Pervogo Seminara po Mikrofaune. Leningrad: Vsesoyuznyy Neftyanoy Nauchno-issledovatel'skii Geologo-razvedochnyy Institut (VNIGRI), 48-87.

Waller, H.O., 1960. Foraminiferal biofacies off the South China coast. Journal of Paleontology, 34(6): 1164-1182.

Wang, Nie-Wen, 1964. Discovery of *Evolutononion shanxiense* (Foraminifera) and its stratigraphic, paleogeographic significance. Abstract, in Zhong Guo Hai Yang Hu Zhao Xue Hui 1963 Nian Xue Shu Nian Hui Lun Wen Zhai Yao Hui Bian. Ke Xue Chu Ban She, 58 p.

Wang, P., Min, Q., Bian Y., 1985a. On marine-continental transitional faunas in Cenozoic Deposits of East China. In: Wang, P., (Ed.), Marine Micropaleontology of China, China Ocean Press, Beijing, 15-33.

Wang, P., Min, Q. and Bian, Y., 1985b. Foraminiferal biofacies in the northern continental shelf of the South China Sea. In: Wang, P., (Ed.), Marine Micropaleontology of China, China Ocean Press, Beijing, 151-175.

Wang, P., Min, Q. and Bian, Y., and Hua, D., 1985c. Characteristics of foraminiferal and ostracod thanatocoenoses from some Chinese estuaries and their geological significance. In: (Ed.) P. Wang, Marine Micropaleontology of China, China Ocean Press, Beijing, 229-242.

Wang, P., Zhang, J., Zhao, Q., Min, Q., Bian, Y., Zheng, L., Cheng, X. & Chen, R., 1988. Foraminifera and Ostracoda in bottom sediments of the East China Sea, 438 p.

Wang, L., Sarnthein, M., Erlenkeuser, H., Grimalt, J., Grootes, P., Heilig, S., Ivanova, E., Kienast, M., Pelejero, C., and Pflaumann, U., 1999. East Asian monsoon climate during the Late Pleistocene: high-resolution sediment records from the South China Sea. Marine Geology, 156: 245-284.

Wang, L., and Wang, P., 1990. Late Quaternary paleoceanography of the South China Sea: Glacial-interglacial contrasts in an enclosed basin. Paleoceanography, 5: 77-90.

Wang, P., Wang, L., Bian, Y., Jian, Z., 1995. Quaternary paleoceanography of the South China Sea: Surface circulation and carbonate cycles. Marine Geology, 127: 145-165.

Wang, P., Zhang, J., and Gao, J., 1985d. A close-up view of lowered sea-level microfauna from the East China and Huanghai Seas in the Late Pleistocene. In: Wang, P., (Ed.), Marine Micropaleontology of China, China Ocean Press, Beijing, 256-264.

Wang, P., Zhang, J., and Min, Q., 1985e. Distribution of Foraminifera in surface sediments of the East China Sea. In: Wang, P., (Ed.), Marine Micropaleontology of China, China Ocean Press, Beijing, 34-69.

Whittaker, J.E., and Hodgkinson, R.L., 1979. Foraminifera of the Togopi Formation, eastern Sabah, Malaysia. Bulletin of the British Musuem of Natural History (Geology), 31(1): 1-120.

Williamson, W.C., 1858. On recent foraminifera of Great Britain. Ray Society London, 107 p.

Wood, S.V., 1842. A catalogue of shells from the Crag: Annals and Magazine of Natural history, 1(9): 455-462.

Woodroffe, C.D., 2000. Deltaic and estuarine environments and their Late Quaternary dynamics on the Sunda and Sahul Shelves. Journal of Asian Earth Sciences, 18: 393-413.

Woodroffe, C.D., Thom, B.G., and Chappell, J., 1985. Development of widespread mangrove swamps in mid-Holocene times in northern Australia. Nature, 317: 711-713.

Wyrtki, K., 1961. Physical Oceanography of the Southeast Asian Waters. Scientific results of marine investigations of the South China Sea and the Gulf of Thailand, 1959-1961: Naga Report Vol. 2. University of California, La Jolla, 195 p.

Yan, X.-H., Ho, C.R., Zheng, Q., and Klemas, V., 1992. Temperature and size variabilities of the western Pacific warm pool. Science, 258: 1643-1645.

Yokoyama, Y., De Deckker, P., Lambeck, K., Johnston, P., Fifield, L.K., 2001. Sea-level at the Last Glacial Maximum: evidence from northwestern Australia to constrain ice volumes for oxygen isotope stage 2. Palaeogeography, Palaeoclimatology, Palaeoecology, 165: 281-297.

Yokoyama, Y., Lambeck, K., De Deckker, P., Johnston, P., and Fifield, K., 2000. Timing of the Last Glacial Maximum from observed sea-level minima. Nature, 406: 713-716.

Zheng, S-Y., 1980. The Recent foraminifer of the Zhongsha Islands, Guangdong Province, China. II. Studia Marina Sinica 16: 143-182.

Zheng, S.-Y., 1988. The agglutinated and porcelaneous foraminifera of the East China Sea. China Ocean Press, Beijing, 337 p.