PALEOENVIRONMENTAL RECONSTRUCTION FROM BENTHIC FORAMINIFERAL ASSEMBLAGES OF EARLY HOLOCENE, SHALLOW MARINE DEPOSITS IN GOMBONG, CENTRAL JAVA

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ABSTRACT

A 30m-long sediment core covering the Holocene period was taken from the area of Gombong in the southern part of Central Java. The sediments were deposited in a shallow marine to lagoonal environment that was confirmed by the dominance of Ammonia beccarii along the core intervals. In addition, the species Quinqueloculina poeyana, Miliolinella lakemacquariensis, and Miliolinella subrotunda were also found in the sediments that are typical of normal shallow marine conditions.

The decrease and increase in the abundance of these species throughout the core is an expression of sea level change in the area, which results the environmental changes. Low sea level is expressed by the dominance of Ammonia beccarii, and the low abundances or absence of the other three species. In contrast, high sea level stands are reflected by the presence of all four species. The high sea level would imply favorable conditions for benthic foraminifera because it would result in normal shallow marine conditions in the area.

Finally, from this benthic assemblages study, it can be assumed that the environmental transformation from the originally shallow marine environment into land was occurred at level 5.5m depths of the sediment core, when all benthic foraminifera were terminated, including Ammonia beccarii. These new results from the shallow marine deposits in the Gombong area are a new contribution to the understanding of paleoenvironmental change in the region, which in turn is important for understanding sea level change as well as climate change in the region.

Keywords: Benthic foraminifera; Holocene; paleoenvironmental changes; sea level changes; southcoast of Central Java

SARI

Sebuah percontoh sedimen bor sepanjang 30m yang berumur Holosen diambil dari daerah Gombong, bagian selatan Jawa Tengah. Percontoh sedimen diendapkan pada lingkungan laut dangkal – laguna, berdasarkan kelimpahan foraminifera bentik Ammonia beccarii di sepanjang sedimen bor. Selain itu ditemukan juga spesies-spesies Quinqueloculina poeyana, Miliolinella lakemacquariensis, dan Miliolinella subrotunda, yang merupakan penciri lingkungan laut dangkal dengan kondisi normal.

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Penurunan dan kenaikan dari kelimpahan masing-masing spesies foraminifera bentik di atas, dapat mencerminkan perubahan permukaan air laut daerah studi, yang menghasilkan terjadinya perubahan lingkungan. Penurunan muka air laut dapat dicirikan dengan hadirnya Ammonia beccarii yang sangat dominan, sementara spesies lainnya cenderung berkurang bahkan hampir tidak ada. Sebaliknya ketika muka air laut naik, maka keempat spesies foraminifera tersebut cenderung hadir dengan jumlah yang seimbang satu sama lainnya. Kenaikan muka air laut akan menghasilkan lingkungan laut normal yang merupakan kondisi ideal bagi foraminifera.

Akhirnya, dari kajian perubahan kelimpahan foraminifera bentik ini, dapat diperkirakan bahwa pada level kedalaman bor 5,5m, terjadi perubahan lingkungan dari lingkungan laut dangkal-laguna menjadi daratan, yang ditandai dengan musnahnya semua jenis foraminifera bentik, termasuk Ammonia beccarii. HAsil kajian ini merupakan kontribusi baru untuk mempelajari perubahan lingkungan pada lokasi penelitian, terutama penting untuk lebih mengerti mengenai perubahan muka air laut dan perubahan iklim.

Keywords: Benthic foraminifera; Holocene; paleoenvironmental changes; sea level changes; southcoast of Central Java

Introduction

During the last four decades, foraminifera have been considered to be the most useful tool to reconstruct marine environmental changes, in both modern and ancient water bodies (Boltovskoy & Wright, 1976; Murray, 1991b; Hald and Steinsund, 1992; Reinhardt et al, 1994; Thomas et al., 2003; and Valchev, 2003). Benthic foraminifera are both sensitive to and able to adapt to environmental changes, each benthic foraminiferal taxa requires different environmental conditions in order to live. This is demonstrated by the following examples:

The estuarine to tidal zone is characterized by *Elphidium, Quinqueloculina,* and *Ammonia*; the coral zone is dominated by *Peneroplis* and *Amphistegina*; and the deltaic zone is characterized by *Bolivina, Nonionella,* and *Brizalina* (Rositasari, 1989). The presence of agglutinated foraminifera is related to hyposaline environments, and high energy levels in the water (Valchev, 2003). Large populations of miliolids (*Quinqueloculina, Triloculina*) and *Ammonia* characterize normal marine to lagoonal environments with a salinity ranging from 32 to 65‰ (Reinhard et al., 1994). From this range, we assume for this paper that in shallow marine conditions, the salinity is close to 32‰ and *Ammonia* and *Quinqueloculina* abundances are equal. In contrast, the salinity will be close to 65‰ when the environment is a lagoon, and then *Ammonia* is dominant.

Some taxa are known to be cosmopolitan species, able to tolerate environmental changes, and hence survive within unstable areas; certain species are more cosmopolitan than others. These species get the benefit of more nutrition in unstable conditions, due to the termination of other species, which couldn't tolerate the variable environment. One of the cosmopolitan species is *Ammonia*, with a distribution from brackish water to innershelf, it can live in contaminated areas, anaerobic conditions, and throughout a great range of salinity and temperature (Boltovskoy & Wright, 1976; Murray, 1991a; Sharifi et al., 1991; Alve, 1995; and Thomas et al., 2003).

In this paper, we investigate benthic foraminiferal assemblages in order to infer the palaenvironmental changes that occurred in the Gombong area at the south coast of Java. The area is an understudied region with regard to our understanding of palaenvironmental change and the effects of sealevel changes in the area. We present an inexpensive approach to research that is applicable to the wider region.

Regional setting

Southern Gombong, is a coastal area of Central Java, through which 8 rivers flow; the Telomoyo, Kali Abang, Kali Ketik, Kali Turus, Kali Banda, Kali Coek, Kali Karang Anyar and Kali Kemit Rivers (Fig. 1). The estuaries of these 8 rivers join at one spot in the Gombong area. For that reason, accompanied by high rainfall that exceeds both the capacity of the rivers and the rate of evaporation, there is a flooding problem in the Gombong area during the wet season. Gombong people also suffer drought in the dry season, and cannot rely on groundwater since the geological characteristics of the area's sediment layers impede water release. Moreover, there is connate water found in some areas of the Gombong aquifer, which has caused the aquifer to become brackish (Rachmat et al., 2002). This connate water is ancient saline water that is trapped in the sediment. A sediment core taken from Gombong as part of a previous study (Soebowo et al. 2002) contains ostracod fossils which indicate shallow water conditions, and also shows high abundance of the benthic foraminifera *Ammonia beccarii,* reflective of an estuarine deposition.

Methods

The sediment core was sampled by the Research Centre for Geotechnology- LIPI, Bandung in 2002 from southern Gombong,

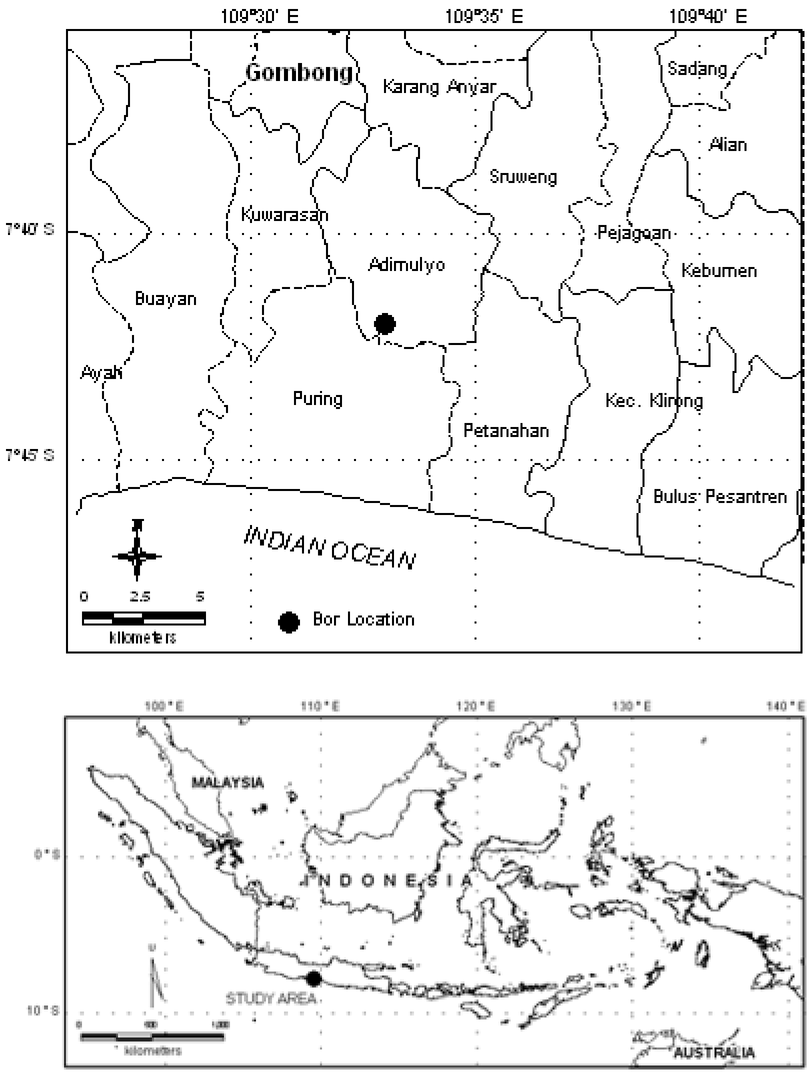

Figure 1. Study area

East Java (109^{0}33’ E, 07^{0}42’ S). The length of the sediment core is 30 m and the present study was done based on fifteen samples taken at 1m-intervals, between the depths of 5 and 20 metres. The study excluded the material above and below this depth because the uppermost five meters of the core are composed of soil, and the sediments below 20m are loose sands which indicate beach deposits with no foraminifera. The washed residue (larger than 63μ) of fifteen sub-samples was then used for the foraminiferal study. The 300 specimens of foraminifera were picked under a binocular microscope. They were then identified, and interpreted with reference to Barker (1960), Phleger, (1960), Albani & Yassini (1993), and Yassini and Jones (1995).

Results

Lithologically, the base of the sediment core is composed of clay-rich sand. According to the results of the grain size analysis, this sand was deposited in both beach and fluvial environments (Fig.2). Above the section of 20 m, the sediments consist of fine shells in clay sediments, followed by greenish gray clay deposits containing larger shells, together with ostracods, indicative of a shallow marine to estuarine environment.

Benthic foraminifera were found abundantly (more than 300 specimens) throughout the sediment core and were accompanied by ostracods and mollusca (Table 1), with the exception of the interval of the uppermost 5.5m, which only contained 2 specimens of *Ammonia beccarii.* There are 9 species of benthic foraminifera identified

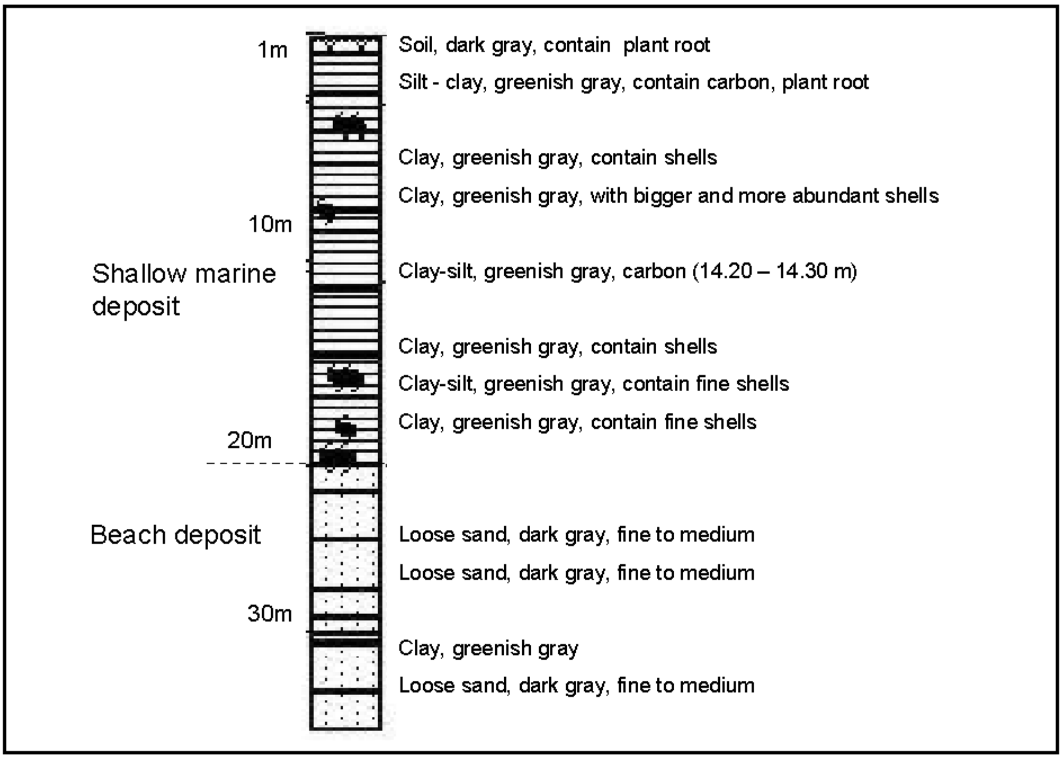

Figure 2. Bore sediment description (Soebowo, wt.al. 2004)

Table 1. Semi-quantitative analysis of the microfaunal composition in the Gombong sediment core (After Soebowo, et.al., 2004)

No.	No. interval	Foraminifera	Ostracods	Mollusca
1	5.4-5.5m	+	-	-
2	6.7-6.8m	+++	++	-
3	7.55-7.6m	>>>>	++	-
4	8.7-8.8m	>>>>	++	-
5	9.6-9.7m	>>>>	++	-
6	10.4-10.5m	>>>>	+++	-
7	11.3-11.4m	>>>>	++	-
8	12.5-12.6m	>>>>	+	>>>>
9	13.6-13.65	+++	+	>>>>
10	14.4-14.45	>>>>	+	>>>>
11	15.4-15.5m	>>>>	-	>>>>
12	16.7-16.8m	>>>>	-	>>>>
13	17.5-17.6m	>>>>	-	>>>>
14	18.7-18.8m	+++	+	>>>>
15	19.5-19.6m	+++	+	-

- = 0
\+ = < 5
++ = common (5 - 50)
+++ = abundant (50 - 300)
>>>> = very abundant (> 300)

from the sediment core, which is dominated by *Ammonia beccarii* (Table 2). This species is found in all sub-samples and the highest number of the species (92.66% in average) is found at intervals between 6.7m and 11.4m.

The core sediment of Gombong could be divided into 3 zones, based on the distribution of foraminifera:

1. Zone 1 (interval below 19.6m); characterized by the occurrence of 4 foraminiferal species: *Ammonia beccarii* as the most dominant species (can reach up to 91% abundance), associated with *Cibrononion simplex, Quinqueloculina poeyana,* and *Textularia* sp.
2. Zone 2 (interval between 18.8m and 12.5m); consists of *Ammonia beccarii* as the dominant species (with an average percentage abundance of 59.26%), *Quinqueloculina poeyana, Miliolinella lakemacquariensis, Miliolina subrotunda, C. simplex,* and *Textularia* sp.2.
3. Zone 3 (interval up from 11.4m), is almost exclusively dominated by *Ammonia beccarii,* with an average abundance of 92.66%. Also present are *Quinqueloculina poeyana, Miliolinella lakemacquariensis, Miliolina subrotunda, C. simplex,* and *Elphidium striatopunctatum.*

Table 2. Percentage (%) of benthic foraminifera in the Gombong sediment core per 300 specimen

Location	**Gombong**														
no.interval samples	5.4-5.5m	6.7-6.8m	7.55-7.6m	8.7-8.8m	9.6-9.7m	10.4-10.5m	11.3-11.4m	12.5-12.6m	13.6-13.65	14.4-14.45	15.4-15.5m	16.7-16.8m	17.5-17.6m	18.7-18.8m	19.5-19.6m
Ammonia beccarii Linne	100	98.33	98.33	91.00	89.67	89.33	89.33	57.67	62.65	80.79	52.00	56.00	62.00	68.67	91.00
Cribrononion simplex (Cushman, 1933)	0.00	0.33	1.00	1.33	2.67	2.67	0.67	0.33	0.00	0.00	0.67	0.00	1.67	4.33	5.00
Elphidium depressulum Cushman	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.67	0.33	0.33	0.00	0.00
Elphidium striatopunctatum (Fichtel & Moll)	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miliolinella lakemacquariensis sp.nov.	0.00	1.33	0.00	3.33	4.00	2.33	3.00	4.00	1.20	0.99	6.67	0.33	5.00	5.67	0.00
Miliolinella subrotunda (Montagu, 1803)	0.00	0.00	0.00	1.00	1.33	2.33	2.67	3.33	0.00	0.00	5.00	2.67	3.33	0.33	0.00
Quinqueloculina poeyana d'Orbigny	0.00	0.00	0.67	3.33	2.33	3.33	3.33	34.33	36.14	18.21	35.00	40.67	27.67	21.00	3.67
Textularia sp.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
Textularia sp.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Some specimens, mostly *Quinqueloculina,* were found to be brown to black in color, particularly at the bottom part of the core, in the samples taken from 17.5-17.6m, 18.7-18.8m, and 19.5-19.6m.

Discussion

The sediments from the Gombong area are characterized by nine species of benthic foraminifera, and dominated by *Ammonia beccarii,* the typical species for coastal lagoons, and open estuaries; it mostly inhabits shallow water to near shelf environments (Boltovskoy & Wright, 1976; Murray, 1991b; Yassini & Jones, 1995; and Debenay, et. al., 1998). The fact that *Ammonia beccarii* is associated with *Quinqueloculina* and *Milliolinella,* suggests that the Gombong area was in the past a lagoonal environment with normal salinity conditions, and warm temperatures (Murray, 1991b). Normal salinity conditions range from 30-40‰ (Boltovskoy & Wright, 1976), and warm temperatures are temperatures of more than 22^0C (Murray, 1991). According to Reinhardt et al. (1994) the domination of *Ammonia,* associated with miliolids (*Quinqueloculina, triloculina, Miliolinella*), suggests an environmental zone transitional between lagoonal and normal marine conditions. According to Debenay, et. al. (1998), *Ammonia beccarii* is common in marine environments with salinities greater than 33%. Since *Ammonia* and *Quinqueloculina* are species that live freely at the bottom, this further suggests a low energy environment. Reinhard et al. (1994) noted that *Ammonia* (*parkinsoniana*) is a quiet water foraminiferal fauna. In contrast, high-energy environments are represented by sessile fauna (Murray, 1991a; Murray, 1991b). The shallow marine conditions were also confirmed by the absence of planktonic foraminifera, a group that need a thick water column in which to float. The presence of connate water at several locations in the study area also confirms that the Gombong used to be a marine environment.

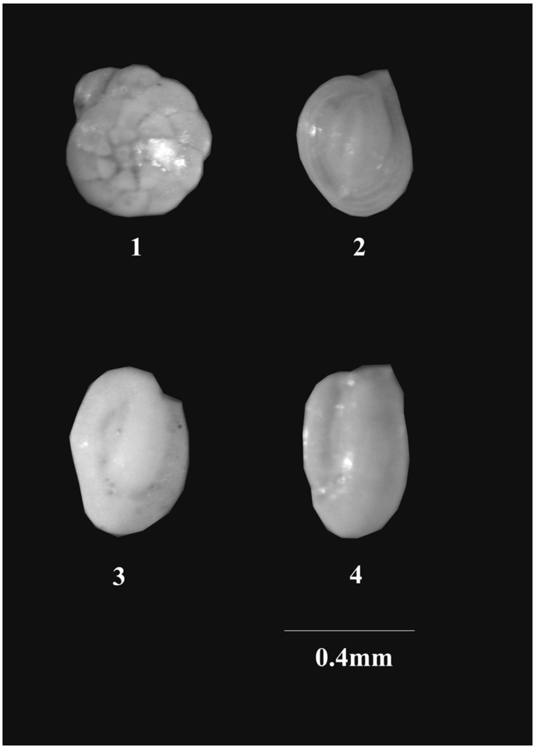

Figure 3.The four most abundant species of benthic foraminifera in the sediment core (1. *Ammonia beccarii*; 2. *Quinqueloculina poeyana*; 3. *Miliolinella lakemacquariensis*; 4. *Miliolinella subrotunda*)

In the past, as a shallow marine environment, the area of the current Gombong city was influenced by both the land and sea. This influenced the distribution and composition of benthic foraminifera. The Gombong sediment is dominated by *Ammonia beccarii,* accompanied by *Quinqueloculina poeyana, Miliolinella lakemacquariensis,* and *Miliolinella subrotunda* (Fig.3). These four most abundant species show different distribution in different sections of the sediment core (Fig.4). Based on the changes observed in the abundance of the four

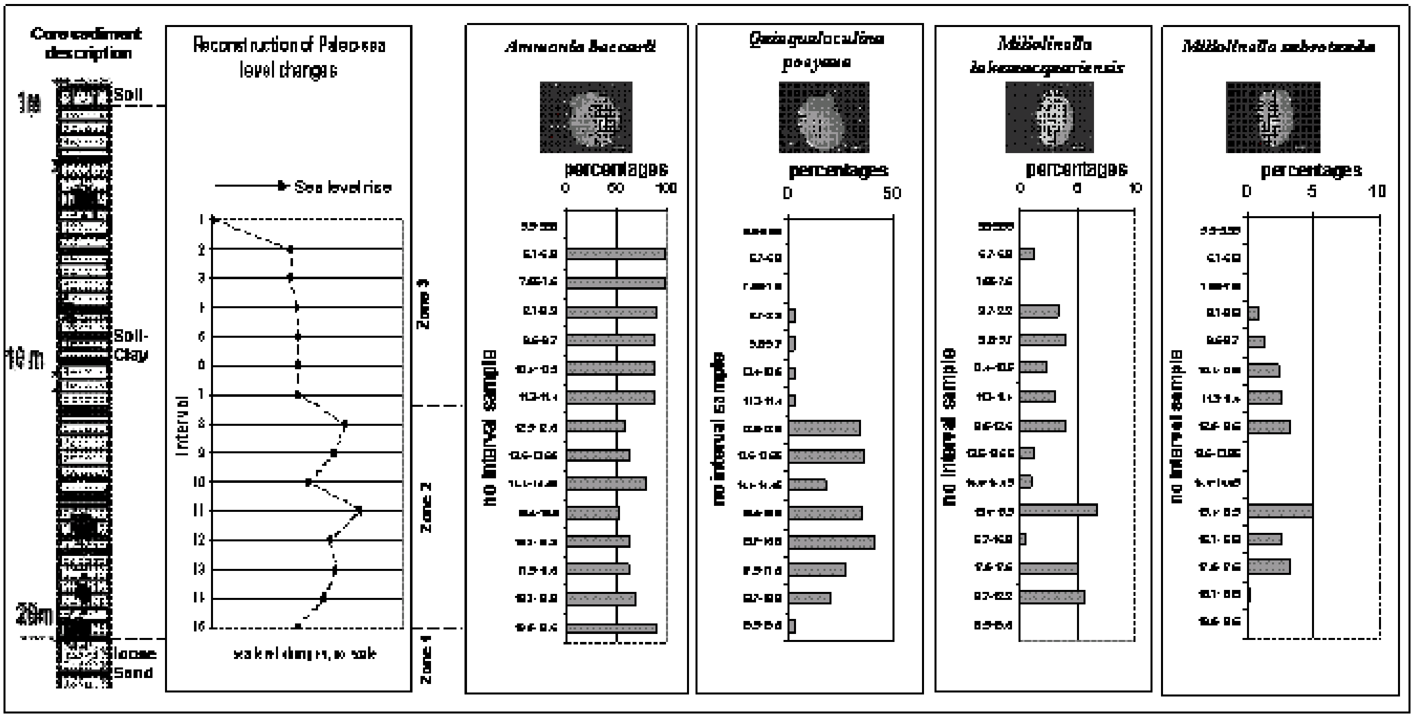

Figure 4.Distribution of the 4 most abundant species of benthic foraminifera in the Gombong sediment core (1. *Ammonia beccarii*; 2. *Quinqueloculina poeyana*; 3. *Miliolinella lakemacquariensis*; 4. *Miliolinella subrotunda*)

dominant species, it was inferred that there were three periods of environmental changes:

In the interval below 19.6m, *Ammonia beccarii* was the dominant species, while *Quinqueloculina poeyana*, *Miliolinella lakemacquariensis,* and *Miliolinella subrotunda* were rare, or even were absent. This suggests that the influence of the ocean on the area was weak. As the sediments in the core section below 20m were composed of sand indicative of beach sedimentation, we infer that this interval reflects rather low sea level, low salinity and abnormal water circulation that caused changes in some environmental parameters, such as temperature and oxygen supply. These environmental conditions are also confirmed by the brown colour of the tests of some foraminifera, which is indicative of a decline in oxygen level, and the presence of bacterial activity (Seiglie, 1973; Boltovskoy & Wright, 1976). Such an environment the Miliolids type could not tolerate, only species that have a high ability to adapt to environmental stress survived. *Ammonia beccarii* is one of those opportunistic species, able to adapt to changing situations. Therefore, the species dominates the environment, mainly because of the low degree or even absence of competition from other species.

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In interval 18.8m to 12.5m, the benthic foraminifera were more diverse. This suggests that in this interval the environmental factors were more suitable for benthic foraminifera. As the sea level rose, the sea's influence increased; the consequences of which were better water circulation, more normal marine salinity levels, higher temperature, and higher oxygen concentration. The numbers of *Ammonia beccarii* decreased while the numbers of *Quinqueloculina poeyana, Miliolinella lakemacquariensis,* and *Miliolinella subrotunda* increased. The competition between the foraminifera caused lower numbers of *Ammonia beccarii*. The relative abundance of *Ammonia beccarii* varies noticeably throughout this interval.

In the upper interval, from 11.4 to 5.5m, once again the environment changed. *Ammonia beccarii* dominated almost exclusively while *Quinqueloculina poeyana* and *Miliolinella lakemacquariensis* decreased significantly in abundance. At this interval, the influence from the ocean decreased abruptly while the influence from the land increased. This was strongly related to the transformation of the sea environment into land. From this interval onwards, the environmental conditions were not suitable for most foraminifera. From a shallow marine area, Gombong was turned into an unstable area, which is a transition zone between water and land. At this level, as the only survivor, *Ammonia beccarii* thrived, and in fact appeared to be better suited to the conditions of this interval than it was to those of previous intervals, as shown by the better preservation of their tests here compared with the intervals described above (Fig. 5). Finally, when the estuary became land, *Ammonia beccarii* was also terminated; in the sample taken from 5.4-5.5 m, only two specimens of *Ammonia beccarii* and no other microfauna could be found.

Conclusions

The assemblages of benthic foraminifera suggest that Gombong was once generally a typical shallow marine to lagoonal environment. This was confirmed by the presence of *Ammonia beccarii* and *Quinqueloculina*. As a shallow water environment, Gombong was influenced by land and sea, and results of the core analysis suggested 3 mayor paleoenvironmental changes in the area. This environmental change was related to sea level changes, and was illustrated by the changes in both the abundance and dominance of benthic foraminiferal species.

In this paper we have presented an inexpensive research methodology and demonstrated its applicability in reconstructions of paleoenvironmental change in the region. This method can be adapted by other researchers in the country and applied to other coastal areas of Indonesia. This economic aspect of the research is important, given that Indonesia today is a developing country facing many challenges with regard to future development.

The study area of this paper is a part of the Sunda Shelf Margin. It has been shown that the latter strongly influenced the regional climate during the Last Glacial Maximum (Hanebuth, et.al., 2003). However, regional data on past sea level change is very limited

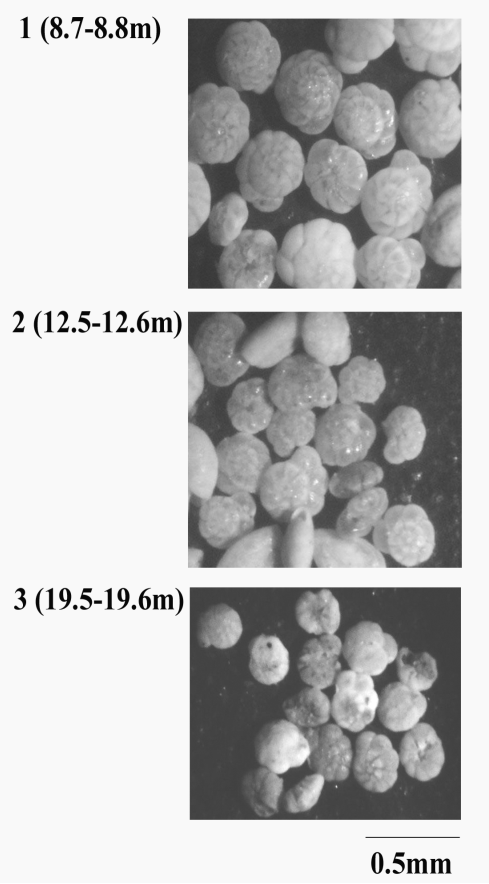

Figure 5.Levels of preservation of *Ammonia beccarii* at different depths in the core (8.7-8.8m; 12.5-12.6m; 19.5-19.6m). The figure shows that the degree of preservation differs throughout the core section. Three images were taken from sample intervals, 8.7-8.8 m (image 1), 12.5-12.6 m (image 2) and 19.5-19.6 m (image 3). In the uppermost sample of the three samples shown in the images, the foraminifera are of bigger size than further downcore, and the tests show a whiter colour, compared to samples shown in the second and third images. Also, in the latter two images, there is evidence of broken tests reflecting poorer preservation compared to the first image.

for the region, in particular from the south coast of Java. Past sea level change can be reconstructed from well-dated studies of paleoenvironmental change. However, so far, the only paleoenvironmental reconstructions for the south coast of Java were done in the area of Cilacap city and the nearby Segara Anakan Lagoon (Sarmili, et. al., 1998). Clearly, we need a wider spatial coverage when looking at environmental changes related to sea level changes in the region, and we need to include in the investigations adjacent coastal areas of the southcoast of Java. Clearly, our study of the shallow marine deposits in the Gombong area is a new contribution to the understanding of paleoenvironmental change in the region.

Complemented by sound dating of the records, our results will allow in future studies the reconstruction of the sea level changes that occurred in the area. Such reconstructions will also contribute new knowledge for predicting and managing the occurrence of connate water in the area, which causes a significant problem for the local people of the area. With such knowledge in hand, predictions of natural environmental change will be less uncertain for the area. Only with such improved predictions will it be possible to respond to climate variability and change. This may be in the form of beneficial adaptation strategies which hope to ensure ongoing social economic and environmental wellbeing in the region.

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