FORAMINIFERAL DISTRIBUTION AS INDICATOR OF SEDIMENT PROVENANCE IN SEGARA ANAKAN LAGOON, SOUTHERN JAVA

By:

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ABSTRACT

Sediment samples from a borehole (BH-5) drilled in the Segara Anakan Lagoon in southern coast of Central Java have been used to investigate the biostratigraphy of the sediments. This study derives sediment provenance using planktonic and benthic foraminiferal assemblages in lagoonal sediments. A quantitative approach shows that two different biofacies can be distinguished in the sediment sequences: firstly, a succession dominated by Ammonia beccarii (Linne) and secondly, a succession dominated by Uvigerina bassensis Parr. These successions are used to compare depth intervals of the core and the sources of the sediment samples. The results show that there are two different sediment sources supplied the sediments to the lagoon. Sediments of depth interval I (0 - 704 cm) are derived from the Jampang, Nusakambangan and Kalipucang Formations in the northwest of the lagoon transported by the Citanduy River. In contrast, sediments from depth intervals II (704 - 1825 cm) and III (1825 - 3000 cm) are derived from the Halang Formation transported by the Cibeureum River entering the lagoon from the north.

SARI

Percontoh sedimen dari sebuah Sumur Bor (BH-05) yang diambil di Laguna Segara Anakan, pantai selatan Jawa Tengah, telah digunakan untuk studi biostratigrafi. Studi ini dilakukan berdasarkan analisa kandungan foraminifera planktik dan bentik yang dikorelasikan dengan studi provenan. Hasil analisa kuantitatif menunjukkan adanya dua biofasies yang dapat membedakan lapisan sedimen yaitu: pertama, suatu lapisan yang didominasi oleh *Ammonia beccarii* (Linne) dan lapisan kedua yang didominasi oleh *Uvigerina bassensis* Parr. Kedua lapisan ini digunakan untuk membedakan lapisan kedalaman sepanjang sumur bor dan sumber sedimen. Hasilnya menunjukkan bahwa ada dua sumber sedimen yang berbeda sebagai pemasok laguna. Sedimen dari interval kedalaman I (0 – 704 cm) berasal dari Formasi Jampang, Nusakambangan dan Kalipucang yang terletak di barat laut laguna dan terbawa oleh Sungai Citanduy. Sedangkan sedimen dari interval kedalaman II (704 -1825 cm) dan III (1825 – 3000 cm) berasal dari Formasi Halang yang ditranspor oleh Sungai Cibeureum dan masuk dari sebelah utara laguna.

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INTRODUCTION

Segara Anakan Lagoon is located in the southern coast of Central Java (108° 47' 16" E - 07° 38' 21" S and 108° 52' 16" E - 07° 42' 43" S). The lagoon is separated from the Indian Ocean by a barrier-island called the Nusakambangan Island. It is connected to the ocean by two inlets in the southeast and southwest of the lagoon. The barrier island blocks sediment transport into the ocean and acts as a dam to the sediment supplies from the catchment area. This makes the lagoon as a unique environment, which is characterized by small islands inside the lagoon. There are a lot of tributaries in this area, one of the biggest tributary is Citanduy River Basin, as mentioned by Setyawan (2002) that at present, Segara Anakan Lagoon is a part of the Citanduy River Basin, therefore any changes in the Citanduy River morphology will influence the Segara Anakan area. For example, at the peak of the Last Glaciation, 18,000 B.P., the present Segara Anakan Lagoon area was part of the Citanduy River drainage system and it was located in a subaerial environment.

Sedimentation rate is very high in the lagoon (0.1 cm/year, Sarmili, *et al.*; 2000). It is also corresponding with the result of pollen analysis which shows that approximately 8000 years of the depth interval 670 – 720 cm in borehole BH-5 studied (Desiana, personal communication, 2001). The capacity of Segara Anakan Lagoon to take up sediments is rapidly decreasing due to sedimentation from the Citanduy River and other tributaries to the lagoon. The lagoon is becoming more and more shallow to the point of being transformed into land. As a consequence, mangrove swamps expand and tidal channels develop. The sediments of the lagoon are increasingly alluvial and swamp sediments consist of a mix of clay, silt and organic materials (Rahardjo, 1982). This transformation forms a considerably economic problem for the people in the region as they depend on the lagoon for making a living.

The high rates of sedimentation have influenced the distribution of the biota, including microfauna such as foraminifera. Foraminifera are typical components of marine sediments. In the lagoon, they are usually abundant as autochthonous and allochthonous specimens. Consequently, the analysis of foraminiferal remains associated with the Quaternary deposits is one of the most useful methods to interpret the paleoenvironmental conditions of the lagoon.

The objective of this study is to analyze the occurrence of reworked foraminiferal fossils in the lagoon and its relationship with sediment provenance. This is done by comparing the foraminiferal distribution in the lagoon's sediments with the foraminiferal assemblage characteristics of the sediment formations surrounding the lagoon. These formations are the Jampang, Nusakambangan, Kalipucang and the Halang Formations. The age of these formations ranges from Miocene to Pleistocene.

Based on sediment textures, sediment structures and grain size distribution, we have also compared the sediment type along the borehole with the sediment types in the surrounding formations, and those found in four other cores previously studied by Sarmili, *et al.* (2000).

METHODS

A 30-meters borehole (BH-5) from four meters water depth was drilled in the eastern part of the Segara Anakan Lagoon (108^0 51' 41" – 07^0 41' 45"). This is carried out by Marine Geological Institute of Indonesia in 1999. The unconsolidated samples are dominated by mud, silt and clay (Fig. 1).

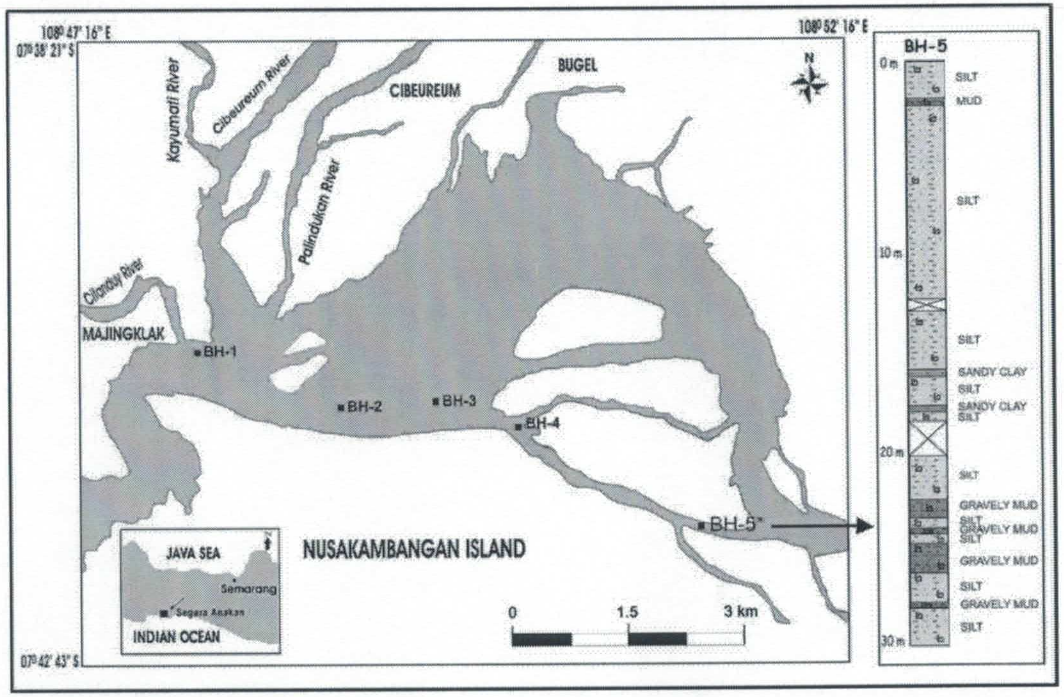

Fig. 1 Map of the research area and site of core sampling (*) with sediment section of core BH-5 (Modified after Sarmili, *et al.*; 2000).

The 62 subsamples were selected at 50 cm intervals from this borehole for a foraminiferal study. Additional samples were collected where lithological changes occurred. The samples were sieved using three different sizes of sieves: 250 µm, 100 µm, and 60µm. About 200 specimens of foraminifera were picked from the fraction larger than 100µm. The determination of geological age of each sediment sequence or depth interval was done by identifying each foraminiferal species using previous studies of planktic and benthic foraminifera (Phleger and Parker, 1951; Matsunaga, 1963; Saito, 1963; Barker, 1960; Postuma, 1971; Bolli and Saunders, 1985; Loeblich Jr. and Tappan, 1988; Van Marle, 1991; Albani and Yassini, 1993; Yassini and Jones, 1995).

Quantitative and semi-quantitative analysis is used to explain the foraminiferal distribution. The numbers of foraminifera per 1 gram dry weights were calculated and the results were given in percent.

From this analysis, the distribution pattern of foraminifera along the core was determined. These data are then used to calculate the diversity index by using the q-basic computer program (Bakus, 1990). The diversity index is used to explain the variety of the species composition in each subsample. Based on the similarity of species from each subsamples, the percentages of foraminiferal contents per 1 gram dry weights are also used in cluster analysis for grouping benthic foraminifera. The result is presented in a dendogram and then it is correlated with secondary data from previous researchs, such as data from four other cores sampled in the lagoon (Sarmili, *et al.*; 2000). This comparison includes studies of regional stratigraphy (Simandjuntak and Surono, 1992), distribution of planktic foraminifera from the Halang Formation (Kadar, 1986), grain size analysis (Oktaviani, 2001; Salinita, 2001), the current pattern of this area (Sarmili, *et al.*; 2000) and age estimation by pollen analysis (Desiana, personal communication, 2001). The result represents the correlation between the foraminiferal distribution and sediment provenances.

RESULTS

Vertical distribution of foraminifera throughout core BH-5 shows 13 genera and 50 species of planktic foraminifera, and 52 genera and 117 species of benthic foraminifera. According to the result from the semi-quantitative analysis (Table 1), the distribution of benthic foraminifera at the top of the core is different from that at the base. The sediment in the study area can be divided into three major sequences.

- Sequence of depth interval I (0 – 704 cm). Both planktic and benthic foraminifera are very rare in this part, which is dominated by *Spiroloculina* sp.3. Besides, there are also some pathological specimens and reworked fossils. The diversity indices in this layer vary between 0.69 and 1.61 (medium).
- The benthic foraminiferal fauna of depth interval II (704 – 1825 cm) is dominated by *Ammonia beccarii*, which is associated with Elphidiidae and Miliolid. The planktic foraminiferal fauna is dominated by *Orbulina universa,* which is present together with *Globigerina praebulloides*. The diversity indices for this part are between 1.1 and 3.58 (medium – high).
- Depth interval III (1825 – 3000 cm), benthic foraminifera is dominated by *Uvigerina bassensis,* which is associated with *Uvigerina peregrina* var. *dirupta*, *Bolivina* cf. *B. robusta*, *Bulimina marginata* and *Hyalinea balthica*. The planktic foraminifera is characterized by the occurrences of several species having high abundances such as *Globigerina*

Table 1. Distribution of benthic foraminifera in core BH-5, Segara Anakan Lagoon

Genera of Foraminifera

LEGEND:
X = < 0.1
O = 0.1 - 1
V = > 1

Core interval (cm)	Ammomassilina	Ammonia	Amphistegina	Bolivina	Bolivinita	Brizalina	Bulimina	Calcarina	Cassidulina	Chrysalidinella	Cibicides	Cribrononion	Elphidium	Eponides	Fissurina	Guttulina	Gyroidina	Houglundina	Hyalinea	Laevidentalina	Lagena	Lagenodosaria	Lamarckina	Laticarinina	Lenticulina	Marginulina	Miliolina	Miliolinella	Nodosaria	Nonion	Nonionella	Oolina	Operculina	Osangularia	Parafrondicularia	Planularia	Planulina	Pleurostomella	Poroeponides	Procerolagena	Pseudoglandulina	Pyrulina	Quinqueloculina	Robulus	Rosalina	Siphouvigerina	Spirillina	Spiroloculina	Stilostomella	Streblus	Uvigerina	Valvulineria
Total Species	1	1	1	7	1	1	5	1	1	1	2	1	7	2	7	1	5	1	3	1	5	1	1	1	2	1	1	2	4	2	1	3	1	1	1	2	2	4	1	1	1	1	5	4	1	1	1	6	4	1	4	1
15-19																																																				
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115-119																																																				
150-154																																																				
215-219													O																																		O	V				
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315-319													V																																							
350-354																																																				
415-419																																																				
450-454																																																				
515-519																																																V				
553-557																																																				
602-606																																																				
650-654													O																																			O				
704-708		V											O						O											O																						
750-754		V		O									X	X					X											X							X															
803-807		V					O																																													
850-854		V		O		X					X		O						X		X							X		O								X		X	X		X					O				
906-910		V		O				X					O				X		X									X	X	O	X		X										X				X	X		X		
950-954		V		O																								O		X													O					O				
1003-1007		V		O									X															X		X													X					X				
1050-1054		V		O				X			X		X				X											X		O													X					X				
1115-1119		V		O				O																		X		X		O																		X				
1150-1154		V		O				X					O					X												X													X					X				
1205-1209		V		X				X					X					X	X									X		X													X		X			X				
1225-1229		V		X				X				X	O															X		X													X		X			O				
1303-1307		V	X	X								X	O						X									X		O																		X				
1350-1354		V		O				X					O														X			O																		O				
1400-1404		V		X				X					O																	X													X	X	X			X				
1450-1454		V		O				X					V										X							X																						
1500-1504		V											V	O																																		X				
1550-1554		V		O				X					O				X											X		X															X			X				
1605-1609		V		O									V		X													X		O									O						X							
1650-1654		X			X						X		O						X																								X									
1706-1710		X									X		V																	X													O					O				
1750-1754		X		X			X	X					O															X		X													X									
1804-1808		X					X					X	O	X																X													X									X
1825-1829	X	X		O	X	X	O						X	X		X	X		O		X	X		X		X					X	X					X	X						X	X				X		O	X
2027-2031		X		O		X	X			X			X	X	X		X		X		X								X	X	X					X	X	X						X		X					O	X
2050-2054		X		O	X	X	O	X			X		X	X			X	X	O		X								X		X							X													O	
2075-2079		X		O	X	X	X						X	X					O		X									X	X					X		O	X				X	X					X		O	X
2103-2107		X		O		X	O		X				X	X	X				O												X					X	X	X					X	X		X			X		O	
2150-2154		X		O		X	O						X	X					O												X					X		X						X	X						O	
2205-2209		X		O	X		O								X				O											X	X						X	O						X							O	
2250-2254				O			O								X				X											X								X				X		X							O	
2300-2304		X		O		X	X		X										O		X										X					X	X	X						X							O	
2350-2354		X		O			X						X				X		O		X									X	X					X		X						X							O	
2416-2420		X		O			O												O																			O						X				X	X		O	
2450-2454		X		O			O				X		X	X					O																	X		X													O	
2502-2506		X		O	X	X	X												O						X	X		X								X								X							O	
2525-2529		X		O			X							X			X		O		X								X								X							X							O	
2550-2554		X		O	X		X		X		X			X	X		X		O		X				X						X					X	X	X			X			X							O	X
2575-2579	X	X		O	X		X				X			X	X		X		X		X				X				X			X				X	X	X						X	X				X	X	O	X
2603-2607		X		O			O				X			X					O											X						X		X						X							O	
2650-2654		X		O			X	X	X		X			X			X		O						X				X			X						X													O	X
2706-2710		X		O	X	X	X		X		X			X	X		X		O		X					X								X				O						X							O	
2750-2754				O	X		X		X		X			O			X		O															X	X	X		X						X	X						O	X
2779-2783				O	X		X		X					O	X		X		O		X				X											X	X	X						X					X		O	
2821-2825				V	X	X	X		O		O			X			X		O		X															X								X		X		X	X	X	O	
2850-2854		X		O	X	X	X		X		X			X			X		O		X								X							X		X						X							O	X
2910-2914	X	X		O			X		X		X			O			X		O	X					X				X			X				X	X	X						X	X				X		O	
2950-2954		X		O	X	X	X		X		X			X	X		X		O		X				X											X	X	X					X	X							O	

praebulloides, Globigerinoides ruber, Globorotalia mayeri, and some species of genus *Pulleniatina*. The diversity indices for this layer are between 3.17 – 4.36 (high).

In general, the assemblages of planktic foraminifera are higher than those of benthic forms. Planktic foraminifera is dominated by *Globigerina praebulloides*, which is associated with *Globorotalia mayeri* and genera *Pulleniatina*. The assemblages of benthic foraminifera show lower number, especially Subordo Rotaliina which is found to be the dominant species in all depth intervals throughout the borehole.

Based on cluster analysis of the benthic foraminiferal percentage per 1 gram of dry weight from 62 subsamples, two biofacies can be recognized: firstly, biofacies I is dominated by *Ammonia beccarii* (Linne) in depth interval II and secondly, biofacies II is dominated by *Uvigerina bassensis* Parr in depth interval III (Fig. 2). The assemblage dominated by *Ammonia beccarii* is found in 44 subsamples, from depth interval II to depth interval III. The percentage of this species decreases in depth interval III. The percentage per 1 gram of dry weight in depth interval II is between 1.77 – 6.69 %, but in depth interval III it was 0.005 – 0.04 %. In contrast, the *Uvigerina bassensis* dominated assemblage is only found in depth interval III. The percentage of this assemblage in 25 subsamples is between 0.06 – 0.34 %.

Sediment samples of BH-5 in Segara Anakan Lagoon can be divided into three depth intervals based on the pattern of *in situ* foraminiferal distribution:

- Depth interval III (3000 - 1825 cm) indicates a Late Pleistocene to Holocene age (N22 - N23), according to Blow (1969, in Postuma, 1971), with marker fossil of *Globigerina calida calida*. Inferred from the abundances of *Uvigerina bassensis, Bolivina albatrossi*, and also *Ammonia beccarii*, these samples reflect a middle neritic to inner neritic zone of a shallow-water sedimentary system.
- Depth interval II (1825 - 704 cm) has the same age as depth interval III and the same marker fossil of *Globigerina calida calida*. The sediment reflects an inner neritic to marsh habitat zone and typical of a sedimentary lagoon system according to the abundance of *Ammonia beccarii*, that is typical for a marginal marine environment, especially marsh and lagoon environment (Phleger, 1960; Yassini and Jones, 1993; Samir and El-Din, 2001).
- Depth interval I (704 - 0 cm) is characterized by sediments of recent age, typical of a marsh habitat zone and indicative of a fluvial sedimentary system. This is supported by the macroscopic sediment description from BH-5, which shows that this interval is dominated by mud from fluvial sediment which is not lithified yet. There are no *in situ* fossil, neither planktic nor benthic foraminifera.

DISCUSSION

Based on the comparison of the foraminiferal distributions in the eastern part of the lagoon (BH-5) with those of previous studies by Simandjuntak and Surono (1992) in the north of the study area, and Kadar (1986) in South Central Java, it can be estimated that there are two different sediment sources from which the sediments in BH-5 were supplied. According to the geological map of this area (Simandjuntak and Surono, 1992), it can be seen that there are two large estuarine areas in the north of the lagoon, the estuaries of the Citanduy and Cibeureum Rivers.

- Sediments in depth interval I are derived from the Jampang, Nusakambangan and Kalipucang Formations, which have been

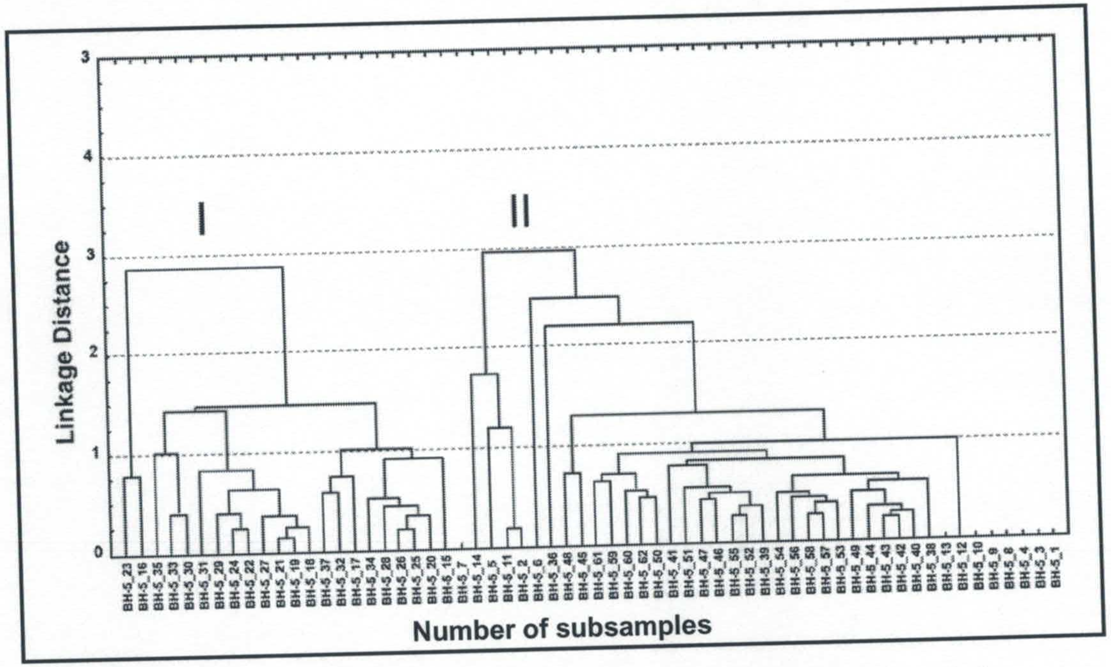

Fig. 2 Dendogram from Q-mode cluster analysis which points out two different biofacies : dominated by *Ammonia beccarii* (Linne) and *Uvigerina bassensis* Parr respectively.

transported by the Citanduy River. This can be seen from the very low abundance of foraminifera in this interval. This fact suggests that the river which transported this sediment passed a sediment formation with low or no foraminiferal content. This is true for the Citanduy River, which flows in a fault zone and crosses a volcanic sediment area. Although a section of this river system crosses the Halang Formation, which has abundant foraminifera, the sediment supplies by this river are dominated by breccia, tuff, sandstone, and also reef limestone, which contain less of foraminifera (Jampang, Nusakambangan and Kalipucang Formations). Besides, the Citanduy River is a meandering river with a low slope. It is likely that most of the sediment has been deposited along a meander. However only small amounts of sediment and foraminifera from these formations have deposited in the lagoon.

- In contrast, in depth intervals II and III, the sediments were derived from the Halang Formation, which were transported by the Cibeureum River. This conclusion is based on the biostratigraphic correlation, where reworked fossils of planktic foraminifera in interval II and III are compared with planktic foraminifera in the Halang Formation (Kadar, 1986). The distribution patterns of the foraminifera in these two depth intervals suggest that these intervals have the same age from Middle Miocene (N14) to Late Miocene (N18), according to Blow (1969, in Postuma, 1971). The depositional environment is from outer neritic to upper bathyal water depths. The Halang Formation is dominated by clay and this is in accordance with the composition of the sediment sections in intervals II and III, which consist of muds comprising clay and silt. This shows that there are facies changes from clay to silt because of transportation. The Cibeureum River flows along the Halang Formation. In the upstream the river flow is straight and braided, and has an extreme slope. This makes it possible for the sediment to be carried to the estuary and to be deposited there.

The comparison of five sediment cores from the Segara Anakan Lagoon is based on foraminiferal distribution. This comparison shows that there are two different sedimentary systems (Fig. 3) of the same geological age. Core BH-5 is dominated by a fluvial sedimentary system (0 - 704 cm) and by a lagoon - shallow water sedimentary system (704 – 3000 cm). The other four cores have the same sedimentary system, but they are appeared different at depths of the cores.

The foraminiferal distribution in the Segara Anakan Lagoon is also influenced by the current pattern. The current mostly moves from the west to the east of the lagoon and the velocity is getting slow in the east. This can be seen from the differences among core BH-5 and the other four cores from a previous study (Sarmili, *et al.*; 2000), which are located west of BH-5. In cores BH-1, 2, 3 and 4, the abundances of foraminifera are not as high as in BH-5. This is due to the current pattern in the study area where is slower in the eastern part of the lagoon, including BH-5. Those slower currents occurred in the past at this site are also reflected by the finer grain sizes in the sediments of BH-5 compared to the other cores (Sarmili, *et al.*; 2000; Oktaviani, 2001; Salinita, 2001).

CONCLUSIONS

The analysis of a borehole in the eastern part of the Segara Anakan Lagoon shows that recent sedimentation is considerably higher than average sedimentation during the past 30,000 years. The core section in interval I (0-704 cm) is dominated by fluvial sediment, which is

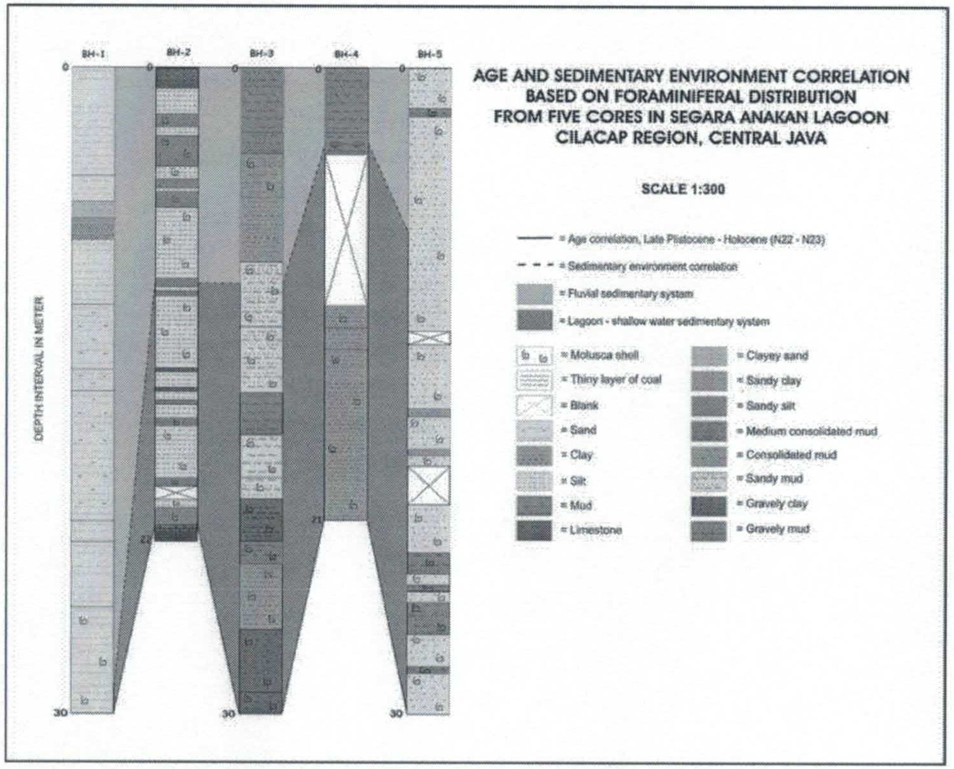

Fig. 3 Age and sedimentary environment correlation based on foraminiferal distribution from five cores in the srudied area. It shows two different sedimentary systems: fluvial and lagoon - shallow water sedimentary system.

different from the lower interval of the core. The latter is dominated by lagoon – shallow water sediment.

This clearly raises the question, why the current Citanduy River gives such a high sediment supply to the Segara Anakan Lagoon approximately in the last 8,000 years B.P. According to Sarmili, *et al.* (2000), the average sedimentation rates in this area over the past 30,000 years B.P. were considerably lower. This may suggest that human activities since 30,000 years B.P. have increased along the Citanduy River, resulting in enhanced erosion. Human activities can be traced by findings of numerous vertebrate and *Homo erectus* fossils in East Java, which are considered to have populated the area since the Pleistocene (Darman and Sidi, 2000).

Fig. 3 shows the age and sedimentary environment correlation based on foraminiferal distribution from five cores in the studied area. It shows two different sedimentary systems: fluvial and lagoon – shallow water sedimentary systems. Obviously, the development in recent times has not been compensated for by efforts to conserve the natural environment along the river. Erosion has increased causing sediment supply from this river dominates recent sediments in the Segara Anakan Lagoon.

This study points out the need of future studies in which should focus on the sustainable management of the environment during further development of the Citanduy area, including land, water and mangrove forests.

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REFERENCES

Albani, A.D. and I.Yassini, , 1993, *Taxonomy and Distribution of The Family Elphidiidae (Foraminiferida) From Shallow Australian Waters.* The University of New South Wales, Sydney.

Bakus, G.J., 1990, *Quantitative Ecology and Marine Biology.* Department of Biologycal Sciences, University of Southern California, Los Angeles. A.A. Balkema, Rotterdam.

Barker, R.W., 1960, Taxonomic *Notes, Soxy of Economic Paleontologist and Mineralogist.* Special Publication no. 9, Tulsa, Oklahoma, U.S.A.

Bolli, H.M., and J.B. Saunders, 1985. Oligocene to Holocene Low Latitude Planktic Foraminifera. In: H.M. Bolli, J.B. Saunders and K. Perch-Nielsen (Editors). *Plankton Stratigraphy.* Vol. I. Cambridge University Press, p. 155-328

Darman, H., and F.H. Sidi, 2000. *An Outline of The Geology of Indonesia.* Indonesian Association of Geologysts.

Kadar, D., 1986, *Neogene Planktonic Foraminiferal Biostratigraphy of The South Central Java Area, Indonesia.* Special Publication no. 5. Geological Research and Development Centre, Directorate General of Geology and Mineral Resources, Ministry of Mines and Energy, Republic Indonesia.

Loeblich Jr., A.R. and H. Tappan, 1988,

Foraminiferal Genera and Their Classification. Van Nostrand Reinhold. New York.

Matsunaga, T., 1963, *Benthonic Smaller Foraminifera from The Oil Fields of Northern Japan.* Second Series (Geology) vol. 35, no. 2. The Sciences Report of The Tohoku University, Sendai, Japan.

Oktaviani, P., 2001, *Studi Lingkungan Pengendapan dan Iklim Purba di Perairan Segara Anakan, Kabupaten Cilacap, Provinsi Jawa Tengah.* Jurusan Teknik Geologi, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Padjadjaran, Bandung. (Unpublished S1 Thesis)

Phleger, F.B. and F.L. Parker, 1951. *Ecology of Foraminifera Northwest Gulf of Mexico, Part II Foraminifera Species.* The Geological Society of America, Memoir 46, Waverly Press, Inc. New York.

Phleger, F.B., 1960, *Ecology and Distribution of Recent Foraminifera.* The John Hopkins Press, Baltimore.

Postuma, J.A., 1971, *Manual of Planktonic Foraminifera.* Elsevier, Amsterdam.

Rahardjo, W., 1982, Geological Features of the Cilacap Region. *Proceedings of The Workshop on Coastal Resources Management in The Cilacap Region.* The Indonesian Institute of Sciences and The United Nations University Jakarta, p23 – 26.

Saito, T., 1963, *Miocene Planktonic from Honshu, Japan.* Second Series (Geology) vol. 35, no.2. The Sciences Report of The Tohoku University, Sendai, Japan.

Salinita, S., 2001, *Perubahan Garis Pantai Berdasarkan Analisa Besar Butir di Perairan Segara Anakan, Kabupaten Cilacap, Provinsi Jawa Tengah.* Jurusan Teknik Geologi, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Padjadjaran, Bandung. (Unpublished S1 Thesis)

Samir, A.M., and A.B. El-Din, 2001, Benthic Foraminiferal Assemblages and Morphological Abnormalities as Pollution Proxies in Two Egyptian Bays. *Marine Microplaeontology 41*, p193-227.

Sarmili, L., L. Arifin, M. Karmini,, D.A.S. Ranawijaya, A. Wahib, and Suprijadi., 2000, *Penelitian Proses Sedimentasi Perairan Segara Anakan, Jawa Tengah.* Departemen Pertambangan dan Energi, Direktorat Jenderal Geologi Kelautan, Bandung. (Unpublished report).

Setyawan, W.B., 2002, Development of Segara Anakan: A Preliminary Study. *Proceeding of Indonesian Association of Geologists Vol II, The 31st Annual Convention*, p. 672 – 679.

Simandjuntak, T.O. and Surono, 1992, *Peta Geologi Lembar Pangandaran Skala 1: 100.000.* Departemen Pertambangan dan Energi, Direktorat Jenderal Geologi dan Sumberdaya Mineral, Pusat Penelitian dan Pengembangan Geologi, Bandung.

Van Marle, L.J., 1991, *Eastern Indonesian, Late Cenozoic Smaller Benthic Foraminifera.* Geomarine Centre Institute of Earth Sciences, Vrije Universiteit, Amsterdam.

Yassini, I. and B.G., Jones, 1995. *Foraminiferida and Ostracoda from Eustuarine and Shelf Environments on the Southeastern Coast of Australia.* University Press, Wollongong.