Paleoenvironment and Paleoecology Based on Recent Benthic Foraminifera in Cikadal Beach, Ciletuh Geopark, West Java, Indonesia

Reisha Navelie, Hany Nabila, Lia Jurnaliah, Winantris, and Mega Rosana

***Abstract*—three recent sediment cores (P2S2, P1S1, and P3S1) about 38.5 cm – 47.5 cm length collected from mangrove and coastal area in Cikadal Beach, Sukabumi, West Java, Indonesia. Cikadal Beach is in the same area of Ciletuh Geopark, commonly be the main geological object study in Indonesia. The purpose of this study is to determine paleoenvironment and paleoecology based on recent benthic foraminifers. The methodology is using cluster analysis; the results are two dendrograms that explain sample association and species association. Sample association divided into 5 biofacies, which are the depositional environment of Biofacies A Transitional – Middle Shelf, Biofacies B Transitional – Middle Shelf, Biofacies C Transitional – Middle Shelf, Biofacies D Transitional – Inner Shelf, and Biofacies E Transitional – Middle Shelf. Whereas, species association divided into 2 dominant species, which are *Ammonia spp* and *Operculina ammonoides* from 17 determined recent benthic foraminifers. From this result, the conclusions are the occurrence of environmental changes during the deposition process takes place based on the results of the correlation of the three cores. Based on low index diversity of research area, the existence of ecological changes simultaneously with environmental changes.**

***Index Terms*—Benthic foraminifers, cluster analysis, paleoecology, paleoenvironment.**

I. Introduction

Benthic foraminifera forms a large part of the biomass of the marine benthic community (Heip *et al*. 2001) and are important proxies for paleoenvironmental studies owing to their abundance, sensitivity to environmental changes and extensive fossilization potential. Foraminifera can be used as one of indicator for the depositional environment because its morphology is flexible and can be changed by the ambient environmental conditions. For example, in foraminifera, the development of spines and the arrangement of chambers are controlled genetically, but pore size and density, the length of spines, and shell height are influenced by the ambient environment (Tsuchiya *et al*. 2008, 2009) [1]. Benthic foraminifers are common used for Biostratigraphycal for Geological used. The benthic foraminifers are reliable indicators of paleoecological condition changes (Gebhardt, 1999; Drinia *et al*., 2007; Holcová and Zágoršek, 2008; Hohenegger *et al*., 2009; Zágoršek *et al*., 2009; Gupa *et al*., 2013). Classification for paleoenvironment are continental, marginal-marine and marine (Boggs, 2006). Marine environment divides into two parts; neritic and oceanic. Neritic is consist of neritic (litoral): inner shelf, middle shelf, and outer shelf. Oceanic is consist of Bathyal (upper bathyal, middle bathyal, and lower bathyal), abyssal and hadal (Berggren in Haq & Boersma, 1998) [2].

Core sampling collected from Cikadal Beach, Sukabumi, and West Java along the coastal area and mangrove (Fig. 1). There are 3 core samples that are P1S1 in coordinate 7°11’22.49”S and 106°26’46.65”T, P3S1 in coordinate 7°11’22.65”S and 106°26’41.71”T, and P2S2 in coordinate 7°11’27.70”S and 106°26’41.82”T. All over the world, the coastal areas are most intensely affected by changes caused by anthropogenic influence (Eichler *et al*. 2012) and some of these changes directly influence the benthic communities and, among them, the foraminifera assemblages (e.g. Alve 1995; Cearreta *et al*. 2000).

Fig. 1. Location of study from Google earth.

Cikadal beach is in Ciletuh region which is “Laboratory of Nature Geology” West Java. Based on the characteristic of morphology in the field, Ciletuh area that includes Beas Mountain group, Badak Mountain group, and its surrounding can be divided into 3 original form, which are structural morphology original form, fluvial morphology original form, and marine morphology original form. Stratigraphically, Ciletuh area can be divided into 2 geologic time scale which are Pre-tertiary rocks and Tertiary rocks. (Sukamto, 1975), 1 of 3 places in Java Island exposed the oldest group of rocks in Java Island. (Pre-Tertiary - Pre-Middle Eocene). This area is known as a complex geological phenomena [3]. The pre-tertiary group consists of melange rock which mixture of metamorphic rock, basalt, ultra basalt and Citireum Formation. The tertiary group consists of Ciletuh Formation, Bayah Formation, and Jampang Formation. The youngest is recent alluvium deposited.

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In this paper, the biofacies are discussed to fulfill the purpose of this study which is paleoenvironment. Sedimentary facies is a group of lithology and organic characteristic that inseparable and can be distinguished from facies surrounding (Gressly, 1838). In biofacies determination, the samples commonly divided based on the present of biota in each sample, then the biofacies are determined and can be utilized in determining the change of marine environment in the study area. Paleoecology interpretation is done using the Diversity Index by Shannon-Weaver (1949) [4].

II. Method

The present study is based on the examination and investigation of about 11 samples collected from 3 cores (Fig. 2) were prepared in a paleontological laboratory. Each core (P3S1, P2S1, and P1S1) has different depth (Fig. 3). P3S1 is 47 cm in depth and divided into 4 samples, taken per 10 cm. P2S2 is 38.5 cm and divided into 3 samples, taken per 10 cm. P1S1 is 44 cm in depth and divided into 4 samples, taken per 10 cm. The washing of recent samples using detergent to remove the remnants of sand grains attached to the foraminifera. The samples were washed several times through a sieve of125 µm, by using gently flowing water, dried in an oven at 50 ˚C. Micropaleontological analysis using a binocular microscope, then each sample is seen the percentage of each sediment and foraminifera. The sample in picking depleted as much as 1 gram of the total dry sample. Literature using are Loeblich, A.R Jr, & Tappan, H (1994). R. Wright Barker (1960), and Jean-Pierce Debenay (2012).

The following data were calculated for paleoenvironment interpretation by using the computer software SPSS to determine the spread of biofacies (sample analysis) and the association of each species (species analysis). The degree of similarity between all pairs of samples in a study area can be calculated and these similarity values are then arranged together in a hierarchical order until clusters of similar samples are lumped together. Presence/absence data or quantitative measures of species abundance have been used to calculate the measures of similarity. (Kaesler, 1966; Mello & Buzas, 1968; Howarth & Murray, 1969; Gevirtz, Park & Friedman, 1971; Brooks, 1973; Johnson & Albani, 1973). Paleoecology interpretation based on recent foraminifera is using index diversity by Shannon-Weaver, 1990. Index diversity explains a relationship the assemblages of species in community. Diversity consists of 2 components, which are:

Amount of species total

Similarity (how the abundance of data spread in between those species)

$$H' = -\sum(Pi \log Pi)$$

where:

Pi = ni/N

$\sum$ = Total

ni = total of individu

N = total of ni

Range of H':

Low: H' < 1, 0

Medium: 1, 0 < H' < 3, 0

High: H' > 3, 0

The abundance of small benthonic foraminifera was then analyzed using SPSS 20.0 to obtain sample associations (biofacies) and species associations. For depositional environment using classification marine environment from Tipsword *et al*, 1996 in Pringgoprawiro and Kapid, 2000) (Fig. 4).

Fig. 2. Collected samples view from Google earth.

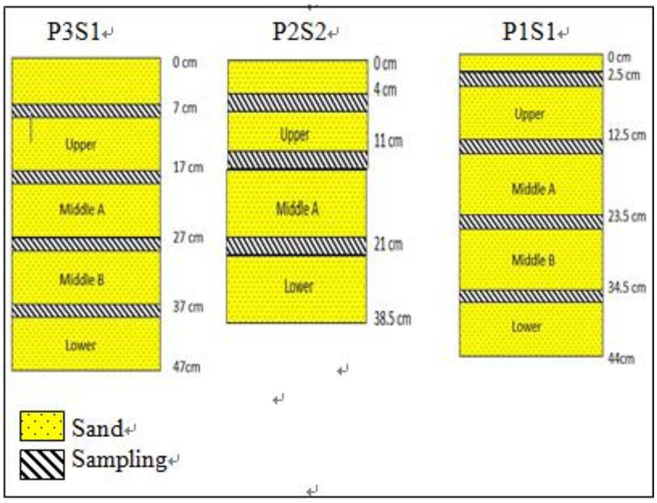

Fig. 3. Disseverance of each 3 cores collected from Ciletuh area.

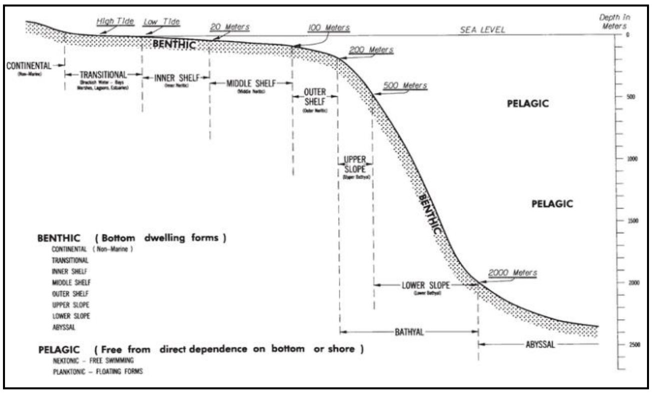

Fig. 4. Classification of benthonic marine environment based on the compilation of that by (Tipsword, *et al.* 1996 and Ingle, 1980).

III. Results

The results of 11 samples collected showed 9 samples containing benthic foraminifers and 2 samples (bottom P3S1 and bottom P1S1) no benthic foraminifers. Determination of 17 benthic foraminifer's species consisting data as follows (Table I):

TABLE I: 17 BENTHIC FORAMINIFERS IN RESEARCH AREA

Species	Individuals
Ammonia spp	100
Streblus spp	16
Pararotalia nipponica	5
Palmarinella palmerae	1
Planulinoides retia	1
Eponides repandus	2
Elphidium crispum	16
Haplophragmoides pussilus	1
Cribrostomoides spiculotestus	1
Eponides bradyi	2
Discolpuvinulina bertheloti	1
Operculina ammonoides	10
Cibicides subhaidingeri	3
Heterolepa subhaidingeri	2
Cibrostomoides jeffreysii	24
Cibides robertsianus	2
Elphidium bartletti	16

A. Sample Association

Based on variable dendrogam (Fig. 5) and calculation of each biofacies percentage, obtained data as follows (Table II):

TABLE II: 5 BIOFACIES IN RESEARCH AREA

	Samples	Species Abundant > 5%	Environment
Biofacies A	Middle P3S1 A	Ammonia spp (Linnaeuss, 1758), Operculina ammonoides (Gronovius, 1781) , Elphidium bartletti (Cushman, 1933) (Cushman, 1933), Cibrostomoides jeffreysii (Williamson, 1858)	Transitional – Middle Shelf
Bio-facies B	Middle P3S1 B	Ammonia spp (Linnaeuss, 1758), Cibrostomoides jeffreysii (Williamson, 1858)	Transitional – Middle Shelf
Bio-facies C	Top P3S1	Ammonia spp (Linnaeuss, 1758), Elphidium bartletti (Cushman, 1933) (Cushman, 1933), Cibrostomoides jeffreysii (Williamson, 1858)	Transitional – Middle Shelf
Bio-facies D	Middle P2S2 Bottom P2S2	Ammonia spp (Linnaeuss, 1758), Streblus spp (Linnaeuss, 1758), Elphidium crispum, Operculina ammonoides (Gronovius, 1781) , Eponides bradyi (Brady, 1884), Cibicides subhaidingerii (Parr, 1950)	Transitional – Inner Shelf
Bio-facies E	Top P2S2 Top P1S1 Middle P1S1 A Middle P1S1 B	Ammonia spp (Linnaeuss, 1758), Streblus spp (Linnaeuss, 1758), Pararotalia nipponica (Asano, 1936) , Palmerinella palmerae (Bermudez, 1934) , Eponides repandus (Ficthel & Molli, 1798) .	Transitional – Middle Shelf

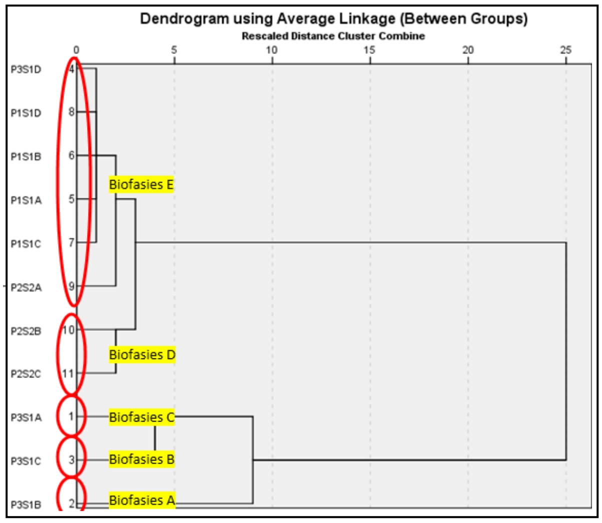

Fig. 5. Dendrogram variables from SPSS to determine biofacies in each sample.

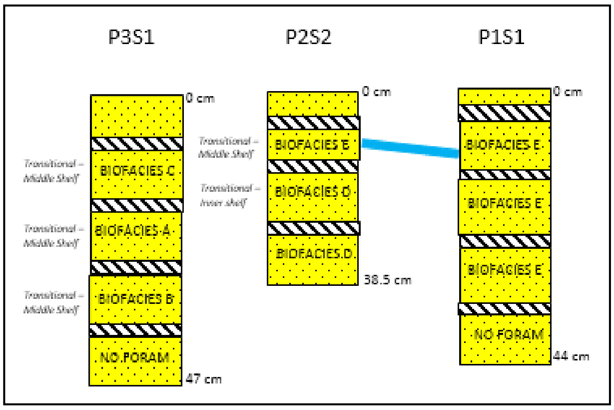

Fig. 6. Correlation between 3 cores based on Biofacies in each cores.

In species association (Fig. 7), there are 2 dominant species of all species in 3 core samples which are *Ammonia spp* association and *Operculina ammonoides* association. *Ammonia spp* association is consisting of *Ammonia spp, Streblus spp, Elphidium crispum, Cibrostomoides jeffreysii,* and *Elphidium bartletti*. *Operculina ammonoides* association is consisting of *Pararotalia nipponica, Palmarinella palmerae, Planulinoides retia, Eponides repandus, Haplophragmoides pussilus, Cibrostomoides spiculotest, Eponides bradyi, Discolpuvinulina bertheloti, Operculina* *ammonoides*, *Cibicides subhaidingeri*, *Heterolepa subhaidingeri*, and *Cibicides robertsianus* as in [5]-[7].

Ammonia spp, categorized as infaunal, the composition of test is calcareous, the substrate is muddy sand, salinity of this species is marine hypersaline, commonly live in brackish, hypersaline lagoons, and inner shelf at warm temperate-tropical (0-30^{o}C). While *Operculina ammonoides* is epifaunal, the substrate is muddy carbonate sediment, the salinity is marine-slightly hypersaline, live in inner shelf and lagoons at warm temperature.

The calculation of index diversity of each biofacies are; Biofacies A -0.45, Biofacies B -0.318, Biofacies C -0.459, Biofacies D -0.898, Biofacies E -0.801.

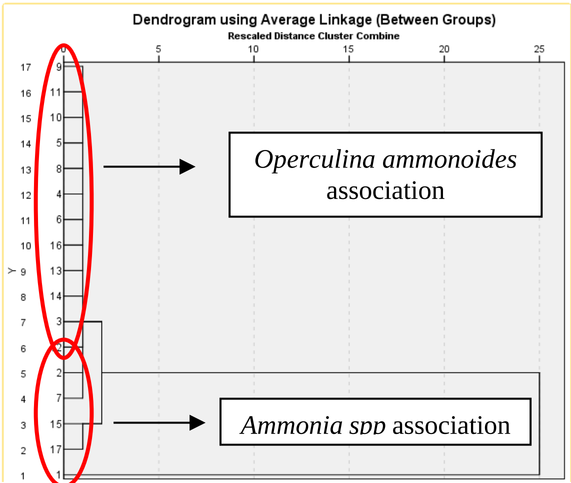

Fig. 7. Dendrogram cases from SPSS to determine species association in each samples.

Fig. 8. (*a*) *Ammonia spp* and (*b*) *Operculina ammonoides*.

IV. Discussions

Correlation between cores (Fig. 6) can only be done between P2S2 cores with P1S1 based on their biofacies. However, interesting in the determination of environmental changes based on these benthic foraminifers, there is a significant difference between each core based on the collection of its benthic foraminifera [8]. The location of the sampling at P3S1 and P1S1 is at 1 m elevation and the point of the location is nearby (coastal), in contrast to P2S2 sampling which is at 3 m elevation and the point of the location which is much different from the other two sampling (mangrove). From old to young, P3S1 has the same deposition environment, ie transitional to middle shelf. P1S1 also has the same deposition environment as P3S1, the underlying difference being the different biofacies components. The diversity index obtained from all biofacies is low, it can be deduced that the low productivity of benthic foraminifers results in high ecological pressures (Shannon-Weaver, 1990). The characteristic species in P3S1 is *Cibrostomoides jeffreysii* (Fig. 9a) whereas in P1S1 is *Pararotalia nipponica* (Fig. 9b). *Cibrostomoides jeffreysii* lives on a shelf to bathyal environment and in cold temperatures, while *Pararotalia nipponica* lives on the inner shelf and in warm temperature. Even though the deposition environment is the same, there is a high ecological control in this area.The correlation formed between P2S2 and P1S1 underlies the biofacies equations therein. P2S2 from old to young changes the environment from the inner shelf to the middle shelf. This happens because of differences in biofacies in P2S2. The presence of *Palmerinella palmerae* (Fig. 9c) on Top P2S2 is living on the outer shelf - upper slope shows the environmental changes in the deposition process of P2S2 deepening.

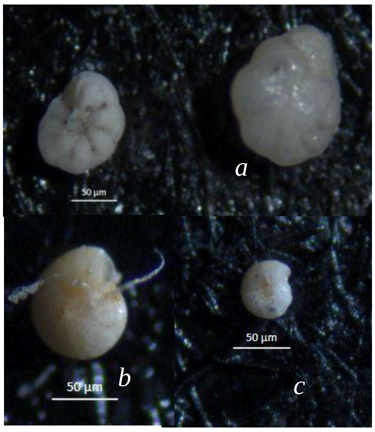

Fig. 9. (*a*) *Cibrostomoides jeffreysii*, (*b*) *Pararotalia nipponica*, and (c) *Palmerinella palmarae*

P3S1

No	Depth (cm)	Biofacies	Bathimetric Zone	Percentage of Abundance of 2 Dominant Species of Recent Benthic Foraminifers	
				Ammonia spp	*Operculina ammonoides*
1	9	C	Transitional - middle shelf	18%	10%
2	19	A	Transitional - middle shelf	39%	30%
3	29	B	Transitional - middle shelf	27%	0%
4	39	BARREN		0%	0%

P1S1

No	Depth (cm)	Biofacies	Bathimetric Zone	Percentage of Abundance of 2 Dominant Species of Recent Benthic Foraminifers	
				Ammonia spp	*Operculina ammonoides*
1	4.5	E	Transitional - middle shelf	2%	10%
2	14.5	E	Transitional - middle shelf	1%	
3	25.5	E	Transitional - middle shelf	2%	
4	36.5	BARREN			

P2S2

No	Depth (cm)	Biofacies	Bathimetric Zone	Percentage of Abundance of 2 Dominant Species of Recent Benthic Foraminifers	
				Ammonia spp	*Operculina ammonoides*
1	6	E	Transitional - middle shelf	4%	
2	13	D	Inner shelf	5%	10%
3	23	D	Inner shelf	2%	40%

Fig. 10. Analysis of species association.

Based on species association (Fig. 10), the abundance of *Ammonia spp* (Fig. 8a) in P3S1 shows a fluctuating state seen from the percentage of abundance of 2 dominant species of recent benthic foraminifers. In P3S1 (top-bottom), the abundance of *Ammonia spp* on the top shows a percentage of 18% then increased to 39%, but decreased to 27% and showed no presence of *Ammonia spp* at the bottom. The abundance of *Operculina ammonoides* (Fig. 8b) in P3S1 has a similar pattern to the abundance of *Ammonia spp*, that is 10% at the top and increases downward to 30%, then does not indicate the presence of *Operculina ammonoides* at the bottom.

In P1S1, the presence of *Ammonia spp* dropped just about 1-2% both at the top and bottom. The presence of *Operculina ammonides* in this sample also not as much as P3S1, only the top section showed the presence of this species about 10% and does not indicate the presence of *Operculina ammonoides* at the bottom section.

The abundance of *Ammonia spp* in P2S2 show the small and fluctuation percentages: 4%-5%-2%, while the presence of *Operculina ammonoides* increased along with the increasing of depth. The top of P2S2 does not show the presence of this species, then increase to 10% and the bottom section have 40% of *Operculina ammonoides* percentages.

V. Conclusions

Environmental changes occurs in all three cores according to the biofacies analysis and species analysis. P3S1 has the highest dominance of *Ammonia spp* among other cores, indicating the dominance of the settling environment is the Transitional - Inner Shelf. However, in P1S1, the percentage of *Ammonia spp* is small, so that the P1S1 deposition environment can be interpreted deeper than P3S1.

The presence of high ecological controls in both of these samples showed differences in the deposition environment, although both samples were taken at close proximity. At a lower elevation, P2S2 has the same precipitation environment as P3S1, this is because P2S2 has the same sediment source as P3S1 supported by the same percentage data of *Ammonia spp* and *Operculina ammonoides*.

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