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Research Article

Biostratigraphy and Paleobathimetry Microfossil Foraminifera in the Sentolo Formation on the Jambon Line, Bantul Regency, Special Region of Yogyakarta Province

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ABSTRACT
Foraminifera microfossils can be used to determine the age of rocks and the depositional environment of an area. The research location is part of Sentolo Formation. Our stratigraphic data located on the Jambon section, Bantul Regency, Special Region of Yogyakarta Province. The appearance of the research area is in the form of well-exposed and ideal cliffs and the lithology of the formation has the potential for rock content rich in foraminifera microfossils. This is the reason for the microfossil analysis of planktic and benthic foraminifera in the study area. The purpose of this study is to determine the age and depositional environment. The research method was carried out by measuring the stratigraphic sections, sampling, and doing paleontological analysis based on planktic and benthic foraminifera. The results showed that the biostratigraphy can be divided into *Globigerina venezuelana* Zone (N18) & the *Globorotalia plesiotumida* Zone (N19), as well as the paleobathimetry, belongs to upper - lower bathyal.

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INTRODUCTION
Foraminifera is unicellular organisms from the phylum Protozoa with pseudopods (pseudopodia). The Sentolo Formation is one of the formations in Bantul Regency with rock constituents in the form of agglomerates and marl at the bottom and gradually turning into limestone. The rocks are layered and abundant in planktic and benthic foraminifera microfossils (Rahardjo et al. 1995).

In non-taxonomic classification (based on habitat) foraminifera can be divided into two, there are planktonic foraminifera and benthic foraminifera. Planktic foraminifera lives on the surface of sea waters while benthic foraminifera live on the suitable substrate. Planktic foraminifera can be used for dating while benthic foraminifera fossils can be used to determine biofacies of the ancient depositional environment.

The Jambon route is in Jambon, Argosari Village, Sedayu District, Bantul Regency, Yogyakarta Special Region Province. This line is the upper part

of the Sentolo Formation. The path appearance is in the form of well-exposed cliffs and is ideal for microfossil analysis for planktonic and benthic foraminifera. This encourages the author to research because from the foraminifera microfossil analysis, the abundance of foraminifera can be seen as well as determining the age and depositional environment in the Jambon Line.

MATERIALS AND METHODS

Materials

The sampling location is in Jambon, Argosari Village, Sedayu District, Bantul Regency, Yogyakarta Special Region Province. The samples were prepared and analysed at the Palaeontology Laboratory, Department of Geological Engineering, Faculty of Engineering, Universitas Gadjah Mada. The tools used in the field are geological hammers, tape meters, markers, and chest boards while the materials used are HCl, zip lock, labels, and stationery. The tools used in the laboratory are plastic bottles, porcelain pounder, filter/mesh (sizes 991, 850, 351, 175 millimetres), heater (oven) while the materials used are a solution of soapy water, blue methyl solution, and watered.

Methods

This research was carried out in several stages, such as the creation of stratigraphic columns, collection, and grouping of rock samples, rock sample preparation, identification, and analysis of foraminifera.

Making Stratigraphic Columns

The stratigraphy on the Jambon Line has measured a scale of 1:10 in 2 dimensions on the stratigraphic column form. Retrieval of stratigraphic measurement data using the Jacob Staff method generates data stratigraphic measurements ± 10.8 meters thick. Written information about the sedimentary structure, rock composition, rock characteristics including colour, strike/dip of layer, and thickness of the rock (Figure 6).

Rock Sampling and Grouping

Sediment sampling uses a continuous sampling technique. Each sediment sample to be taken is dripped with 0.1 M HCl solution to determine the presence of carbonate content in the rock. If it is bubbly, 1 kg of rock is taken. Rock samples were taken as much as 1 chunk per meter of the total thickness of the rock. Each sample taken is then stored in a separate zip lock and described the sample code and sample location and date of the collection so that it can be systematically arranged.

Rock Sample Preparation

The sample preparation process serves to separate the microfossils that are in the sediment from other materials that cover the microfossils. The fresh samples were crushed and weighed about ± 500 grams, then the samples were

cleaned with a detergent solution for 15 minutes. After that, the samples were washed using a mesh filter under running water to remove the sludge. After cleaning, the samples were dried in the sun until the samples were dry. The filter that has been used is then immersed in a blue methyl solution so that it can be seen if there is mixing of fossils in the next sample. The dry sample obtained and ready for observation weighs about ± 100 g.

Identification and Analysis of Foraminifera Data

Foraminifera samples were placed on foraminiferal slides for identification using a binocular microscope and a maximum of 300 individuals were taken in each sample (Hallock et al. 2003). The identification of benthic foraminifera used references from Barker (1960), Jones (1994), Holbourn et al. (2013) as well as for determining the depth range of their habitat for each bathymetric zone. Identification of planktic foraminifera using references Postuma (1971) and Bolli et al. (1985) as well as for determining age. From the identification of fossils, the data obtained are recorded in the fossil list table and distribution chart. The identification results were used for biostratigraphy and paleobathimetry analysis.

RESULTS AND DISCUSSION

The Jambon route is part of the Sentolo Formation which has quite good outcrops. The measured stratigraphic thickness of the Jambon Line is 10.8 m which is composed of 3 rock facies, that are tuffa-calcareous sandstone, calcareous siltstone, and grainstone (Figure 1). From the measured stratigraphy, 10 samples of rocks were systematically taken from the old layer (bottom) to the younger layer (top). The name of the sample refers to the research location which is in Jambon (JBN). The distribution and abundance of planktic and benthic foraminifera species can be seen in Figure 2 and Figure 5.

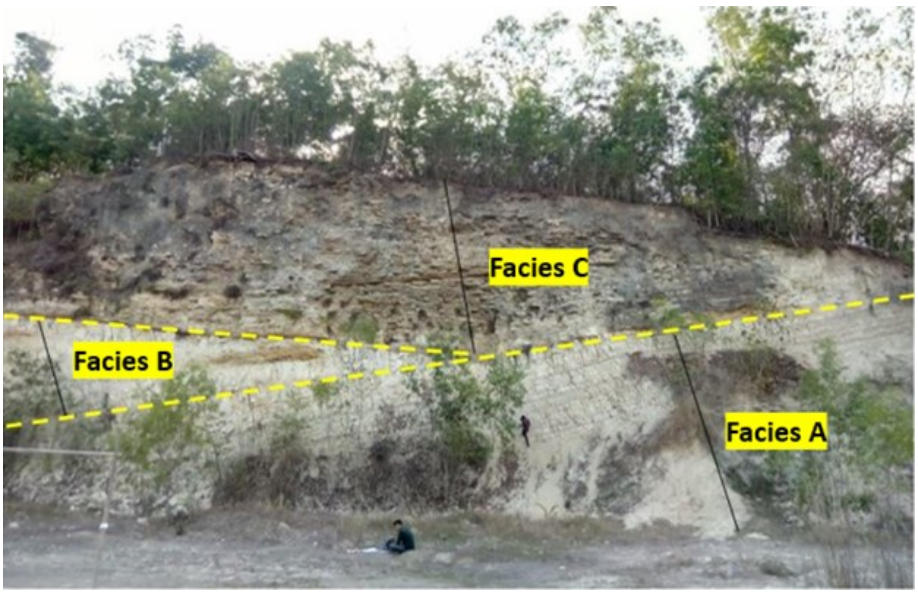

Figure 1. Outcrops of tuffa-calcareous sandstone, calcareous siltstone, and grainstone in the Jambon area. There are three facies, that are Facies A (tuffa-calcareous sandstone), Facies B (calcareous siltstone), and Facies C (grainstone).

Planktic Foraminifera Biostratigraphy (Age Determination)

Facies	Fossil Type	PLANKTONIC FORAMINIFERA															Abundance	Foraminifera Biodatum	Foraminifera Biozonation		Age
	Species	*Globigerina praebulloides*	***Globogerina venezuelana***	*Globigerinoides altiaperturus*	*Globigerinoides obliquus*	*Globigerinoides primordius*	*Globigerinoides quadrilobatus*	*Globigerinoides sacculifer*	*Globigerinoides trilobus immaturus*	*Globoquadrina altispira*	***Globorotalia plesiotumida***	*Globorotalia siakensis*	*Globorotalia tumida tumida*	*Orbulina bilobata*	*Orbulina universa*	*Sphaerodinellopsis seminulina seminulina*			This Study (2020)	Blow (1969)	
	Samples	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15					
Grainstone	JBN 010	-	-	4	-	-	5	-	2	7	39	-	-	-	29	-	86				
	JBN 009	-	-	5	-	-	3	-	-	23	30	-	-	-	41	8	110				
	JBN 008	-	-	4	-	1	3	2	2	19	20	-	1	1	39	5	97		*Globorotalia plesiotumida*	N19	Late Miocen - Early Pliocene
	JBN 007	-	-	19	-	4	10	2	-	32	51	-	3	-	73	3	197				
	JBN 006	2	-	-	2	5	26	-	1	63	25	-	-	5	53	-	182				
Calcareous Siltstone	JBN 005	-	-	26	8	8	2	4	2	49	72	-	3	5	98	9	286				
	JBN 004	1	3	30	-	14	4	13	1	37	78	-	-	3	89	15	288	*Globogerina venezuelana*	*Globogerina venezuelana*	N18	
Tuffa-calcareous Sandstone	JBN 003	-	-	7	1	9	15	9	-	57	75	-	9	1	87	6	276				
	JBN 002	-	2	-	4	-	41	15	-	39	68	1	10	10	87	-	277				
	JBN 001	-	5	4	18	2	14	-	3	47	62	1	16	15	100	-	287				

Figure 2. Distribution chart and biozonation Jambon line from planktic foraminifera.

The biostratigraphy reconstruction in the study area was carried out using the planktic foraminifera zoning method. The number of planktic foraminifera found in all samples was 2086 individuals. From the total sample, 15 species of planktic foraminifera were identified (Figure 2). In general, the Sentolo Formation in the study area can be divided into 2 zones, the *Globigerina venezuelana* Zone (N18) and the *Globorotalia plesiotumida* Zone (N19).

Globigerina venezuelana (N18) was used as bio datum to delimit the end of zone N18 and the beginning of zone N19. The initial (lower) boundary datum in this zone was not found but the final (upper) boundary datum was found in the JBN 004 sample, which is the end of the emergence of *Globigerina venezuelana*. From measured stratigraphic data, this zone has a thickness of about 4 meters. This sample also found some reworked fossils. The reworked fossils found in the form of species were *Globigerina praebulloides*, *Globigerinoides altiaperturus*, *Globigerinoides primordius*, *Globigerinoides altiaperturus*, and *Globorotalia siakensis*. *Globigerina venezuelana* is thought to have experienced a severe extinction caused by unsuitable environmental conditions. It is marked with no emergence of this species in samples JBN 005 to JBN 010. The morphological appearance of *Globigerina venezuelana* can be seen in Figure 3.

Figure 3. *Globigerina venezuelana*: (a) Dorsal, (b) Ventral, (c) Peripheral. (1 mm line scale).

Globorotalia plesiotumida (N19) was used as bio datum aged N19. The baseline (lower) and final boundary (upper) datum of this species was not found because this species appeared continuously from samples JBN 001 to JBN 010. From measured stratigraphic data, this zone has a thickness of about 6.8 meters. This sample also found some reworked fossils. The reworked fossils found in the form of species were *Globigerina praebulloides*, *Globigerinoides altiaperturus*, *Globigerinoides primordius*, and *Globigerinoides altiaperturus*. The morphological appearance of *Globorotalia plesiotumida* can be seen in Figure 4.

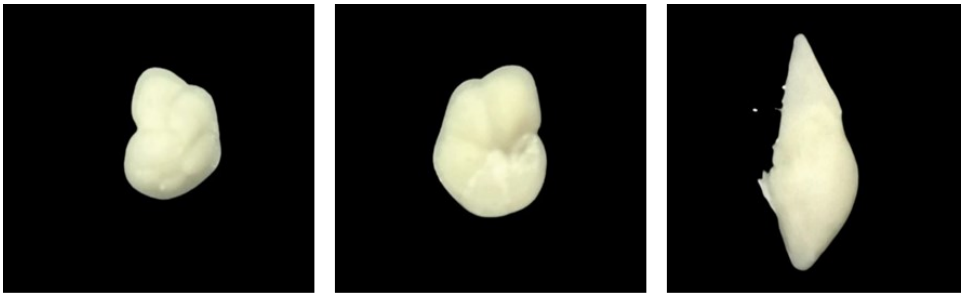

Figure 4. *Globorotalia plesiotumida*: (a) Dorsal, (b) Ventral, (c) Peripheral. (1 mm line scale).

The depositional environment of the study area was obtained based on the content of benthic foraminifera in the sample. The number of benthic foraminifera found in all samples was 197 individuals. From the total sample, 20 species of benthic foraminifera were identified (Figure 5). For the classification of the depositional environment, P / B ratio is used (Murray 1976 & Boersma 1983 in Valchev 2003). Also, a species analysis of benthic foraminifera was carried out using an overlapping method of bathymetry on the fossil forms (Figure 5). The P/B ratio of benthic foraminifera in Jambon line is shown in Table 1.

Biofacies Foraminifera Benthic (Determination of the Precipitation Environment)

Facies	Fossil Type	BENTHIC FORAMINIFERA																				Abundance	Paleobathimetry						
	Species	*Bolivinita quadrilatera*	*Bricalina subspinescens*	*Cibicides kuelleribergi*	*Cibicidoides wuellerstrofi*	*Dentalina filiformis*	*Elphidium crispum*	*Fissurina bradi*	*Logena sulcata*	*Lenticulina convergens*	*Marsipella cylindrica*	*Melonis affinis*	*Melonis pompiloides*	*Nodosaria sp.*	*Praeoglobulimina pupoides*	*Procerolagena gracilima*	*Pyrgo murrina*	*Rectuvigerina multicostata*	*Sphaeroidina bulloides*	*Stilostomella paleocenica*	*Uvigerina hispida*		Transition	Inner Neritic	Middle Neritic	Outer Neritic	Upper Bathyal	Lower Bathyal	Abyssal
	Samples	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20								
Grainstone	JBN 010	-	-	3	-	-	7	-	-	-	-	-	-	2	-	9	-	-	-	-	-	21						●	
	JBN 009	-	-	3	-	-	-	-	-	-	2	-	1	-	-	7	-	-	-	-	-	13						●	
	JBN 008	-	-	2	3	-	1	-	-	2	-	-	1	-	-	7	-	-	-	-	-	16						●	
	JBN 007	-	-	4	-	-	1	5	-	5	1	-	-	-	-	7	2	-	-	-	-	25						●	
	JBN 006	-	-	9	1	-	-	-	-	3	1	-	3	-	-	14	4	-	-	-	1	36						●	
Calcareous Siltstone	JBN 005	4	-	-	1	-	-	-	-	-	1	-	1	-	-	3	2	-	-	1	1	14						●	
	JBN 004	-	-	1	1	-	-	-	-	-	-	-	2	1	-	-	2	1	2	-	2	12					●		
Tuffa-calcareous Sandstone	JBN 003	-	3	-	1	1	-	-	-	-	1	1	5	2	1	2	1	-	1	2	3	24						●	
	JBN 002	-	-	-	6	-	-	2	1	-	-	-	-	-	-	-	3	3	-	8	-	23					●		
	JBN 001	-	-	-	2	-	-	-	-	-	-	1	2	-	-	5	1	-	1	-	1	13						●	

Figure 5. Distribution chart and paleobathimetry of Jambon Line benthic foraminifera species.

Table 1. P/B Ratio of Benthic Foraminifera in Jambon Line.

Samples	Number of Individual Foraminifera			P/B Ratio	
	Planktic	Benthic	Total	Percentage	Information
JBN 010	86	21	107	80.37	Upper bathyal
JBN 009	110	13	123	89.43	Upper bathyal
JBN 008	97	16	113	85.84	Upper bathyal
JBN 007	197	25	222	88.74	Upper bathyal
JBN 006	182	36	218	83.49	Upper bathyal
JBN 005	286	14	300	95.33	Lower bathyal
JBN 004	288	12	300	96.00	Lower bathyal
JBN 003	276	24	300	92.00	Lower bathyal
JBN 002	277	23	300	92.33	Lower bathyal
JBN 001	287	13	300	95.67	Lower bathyal

The results of the analysis of this benthic foraminifera species have the same depositional environment results as the P / B ratio, which is in bathyal. Based on the P / B ratio, it is found that rock samples JBN 001 - JBN 005 show the lower bathyal environment, and JBN 006 - JBN 010 shows the upper bathyal environment. Benthic foraminifera analysis with the overlap method shows that the JBN 001 sample is in the lower bathyal, JBN 002 is in the upper bathyal, JBN 003 is in the lower bathyal, JBN 004 is in the upper bathyal, and JBN 005 - JBN 010 is in the lower bathyal. This difference indicates sea-level fluctuation in the research path.

Cibicidoides wuellerstrofi is a species that reflects the deep-sea environment with active currents (Singh & Rai 2011). The JBN 004 sample contains the species *Nodosaria* sp. as an indicator of the shallow environment that is present along with the species *Cibicidoides wuellerstrofi* (Figure 5). The JBN 002 sample also containing the *Fissurina bradii* species which was present along with the *Cibicidoides wuellerstrofi* species. This indicates a downslope. This condition is supported by the older sample, JBN 003 (tuffa-calcareous sandstone) which has a grain size that is coarser than the sample JBN 004 (calcareous siltstone). The grain size that smooths upwards to the JBN 005 sample characterizes the energy that was initially high then weakened. Shallow benthonic foraminifera can be transferred to the deep ocean when energy is high.

CONCLUSION

Based on the planktic foraminifera assemblage, the stratigraphic range of the Jambon line in the study area appeared as the Late Miocene to the Early Pliocene, which is between N18 - N19. The research area was divided into 2 zones, the *Globigerina venezuelana* zone (N18) and the *Globorotalia plesiotumida* zone (N19). The depositional environment of the Sentolo Formation based on the content of benthic foraminifera shows that the research area is in the Bathyal Zone (200 - 2000 m) which changes from lower to upper bathyal.

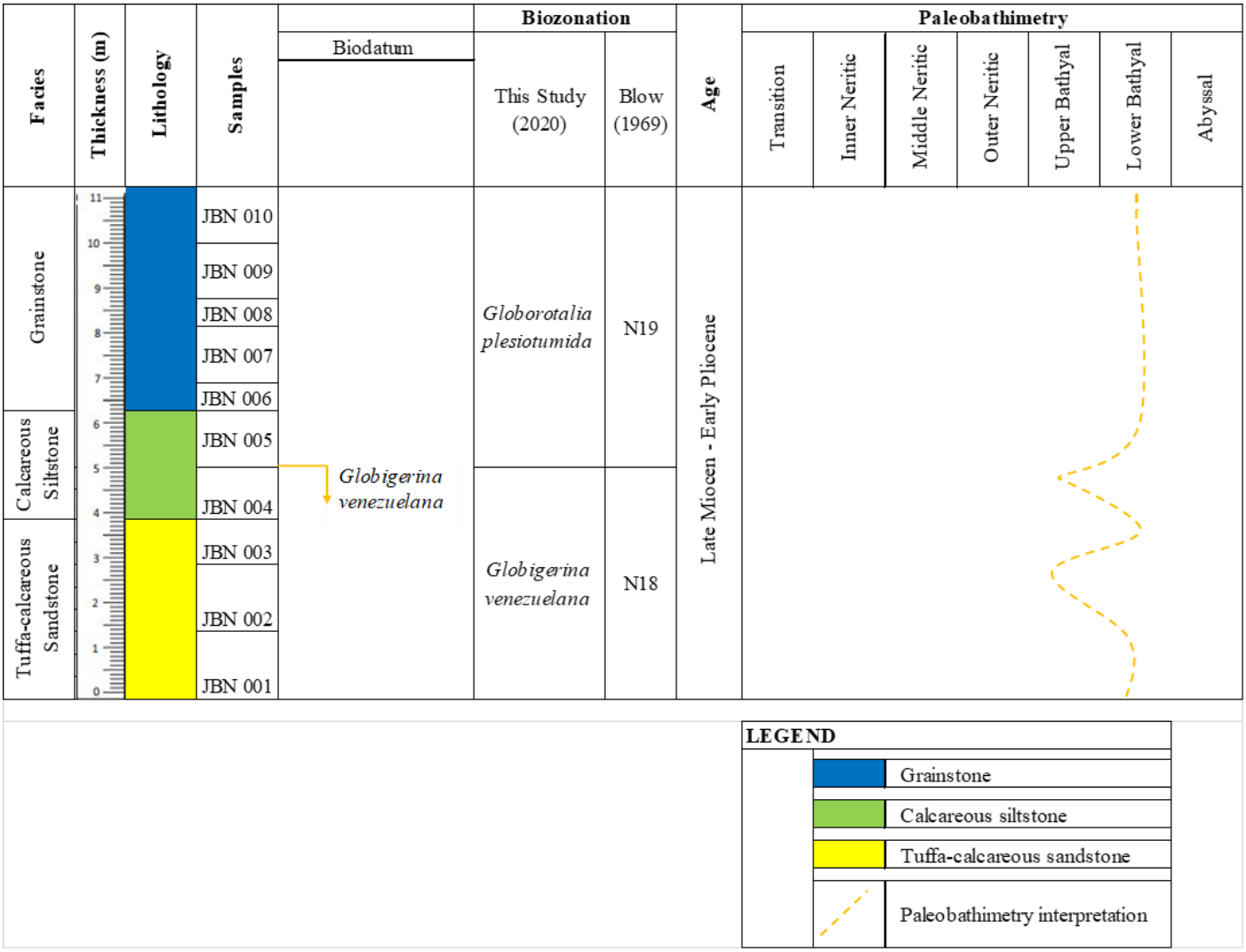

Figure 6. Stratigraphic column, biostratigraphy zones, and paleobathimetry of Jambon line.

AUTHORS CONTRIBUTION

C.F.R. collected and analysed the data and wrote the manuscript, D.S.Y and D.H.B. designed the research and supervised all the process.

ACKNOWLEDGMENTS

Thank you to the team which helped us in the completion of this study especially the palaeontology laboratory assistant.

CONFLICT OF INTEREST

There is no conflict of interest regarding the research or the research funding.

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Valchev, B., 2003. On the potential of small benthic foraminifera as paleoecological indicators: recent advances. *Annual University of Mining and Geology "St. Ivan Rilski",* 46(1), pp.189-194.

Erratum

Due to a technical error with the typing of one word in the previous title, this manuscript has changed its title to be "Biostratigraphy and Paleobathimetry Microfossil Foraminifera in the Sentolo Formation on the Jambon Line, Bantul Regency, Special Region of Yogyakarta Province".

The editorial team of Journal of Tropical Biodiversity and Biotechnology would like to apologize for the inconvenience caused by this oversight.