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Paleobathymetric Study using Foraminifera Microfossil Analysis in the Wonocolo Formation, Tinawun Village Area, Malo District, Bojonegoro Regency, East Java

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ABSTRACT

Paleobathymetric study on the Wonocolo Formation in the Tinawun Village Area, Malo District, Bojonegoro Regency, East Java, using microfossil foraminifera analysis from rock samples in that area, aims to obtain information about the depositional environment of sedimentary rocks in the past. The Wonocolo Formation is a rock formation deposited during the Middle to Late Miocene, approximately 11 to 15 million years ago. The analysis of microfossil foraminifera involves the identification and counting of different foraminifera species from rock samples. The method used to determine paleobathymetry is the P/B ratio analysis with the maximum flooding surface (MFS) determined by the maximum abundance of planktonic foraminifera. For the P/B ratio analysis, the classification of planktonic and benthic foraminifera is determined based on their shell morphology. Based on the P/B ratio classification, the paleobathymetry of the Wonocolo Formation can be identified in two main bathymetric zones, namely the Neritic Bathymetric Zone (shallow marine environment) and the Oceanic Bathymetric Zone (deep-sea environment). The research indicates that paleobathymetry in the study area occurred during the Late Miocene (N16, N17, and N18) in an Outer Neritic environment with sea depths ranging from 100 to 200 meters.

Keywords: *Paleobathymetry; foraminifera; ratios.*

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ABSTRAK

Studi paleobatimetri pada Formasi Wonocolo daerah Desa Tinawun, Kecamatan Malo, Kabupaten Bojonegoro, Jawa Timur, menggunakan analisis mikrofosil foraminifera dari conto batuan di daerah tersebut, bertujuan untuk mendapatkan informasi tentang lingkungan pengendapan batuan sedimen pada masa lampau. Formasi Wonocolo merupakan formasi batuan yang diendapkan pada kala Miosen Tengah hingga Miosen Akhir, sekitar 11 – 15 juta tahun yang lalu. Analisis mikrofosil foraminifera melibatkan identifikasi dan penghitungan spesies foraminifera yang berbeda dari conto batuan. Metode yang digunakan untuk menentukan paleobatimetri adalah analisis rasio P/B dengan bidang maximum flooding surface (MFS) ditentukan dengan kelimpahan maksimum foraminifera planktonik. Untuk kebutuhan analisis rasio P/B, ditentukan klasifikasi foraminifera planktonik dan foraminifera bentonik berdasarkan morfologi cangkangnya. Berdasarkan klasifikasi rasio P/B, paleobatimetri Formasi Wonocolo dapat diidentifikasi dalam dua zona batimetri utama, yaitu Zona Batimetri Neritik (lingkungan laut dangkal) dan Zona Batimetri Oseanik (lingkungan laut dalam). Penelitian menunjukkan bahwa paleobatimetri di daerah penelitian terjadi selama kala Miosen Akhir (N16, N17, dan N18) dalam lingkungan Neritik Luar dengan kedalaman laut berkisar antara 100 – 200 meter.

Kata kunci: *Paleobatimetri; foraminifera; rasio.*

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INTRODUCTION

A study of paleobathymetry on the Wonocolo Formation in the Tinawun Village and surrounding areas, Malo District, Bojonegoro Regency, East Java (see Figure 1), involves the analysis of foraminifera microfossils in sediment cores from that region, aims to obtain information about the depositional environment of sedimentary rocks in the past [1]. The Wonocolo Formation is a sedimentary rock formation deposited during the Middle to Late Miocene, approximately 11 to 15 million years ago. Foraminifera analysis includes the identification and counting of different foraminifera species in rock samples. Different foraminifera species adapt to different water depths and environmental conditions, so by identifying existing species, scientists can infer the water depth and other environmental conditions present when the sediment was deposited. The results of the paleobathymetric study of the Wonocolo Formation in the Tinawun Village and surrounding areas can provide important information about the ancient marine environment in that region. This information can help understand how the environment has changed over time and how it may continue to change in the future. Additionally, this information can be useful for oil and gas exploration, as the presence of certain foraminifera species can indicate the presence of hydrocarbon deposits.

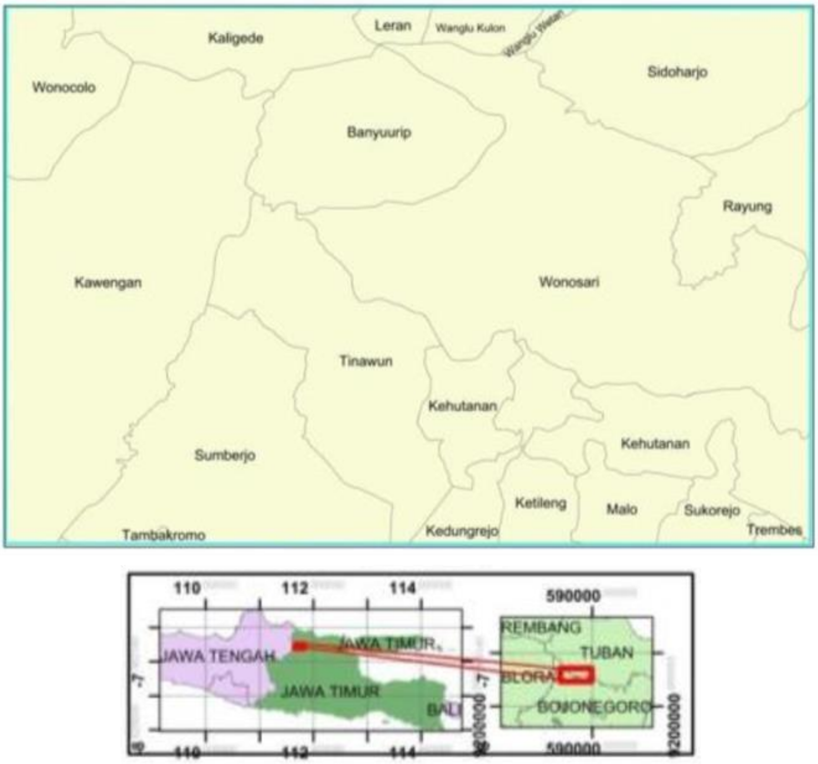

Figure 1. Map of the research location in Tinawun Village, Malo, Bojonegoro.

LITERATURE REVIEW

Foraminifera are single-celled organisms belonging to the phylum Protozoa, living in aquatic environments, primarily in the sea, although some species can be found in freshwater environments. Foraminifera are also used in biostratigraphy, which studies the distribution of fossil organisms in sedimentary rocks. Some examples of important planktonic foraminifera species in biostratigraphy studies are Globigerina, Globorotalia, and Orbulina. These species are often used to determine biostratigraphic zones during the Paleogene and Neogene eras in deep-sea environments. The most commonly used zonation method for planktonic foraminifera was developed by Blow [2]. This method is popular mainly because it divides the zones into N (Neogene) and P (Paleogene) zones with easily identifiable numbers. Moreover, this method also utilizes many evolutionary lineage stages, making it an effective tool for understanding the evolution and development of planktonic foraminifera. Paleobathymetry is the study of indications of underwater depth based on the presence of marine biota. Paleobathymetric studies are conducted by analyzing foraminiferal fossils, which are small single-celled organisms that live in the sea. The abundance and chemical composition of foraminiferal shells record various information that can be interpreted in relation to environmental changes based on paleobathymetric parameters [3]. By studying the distribution and abundance of different foraminifera species in each layer of sea sediment, scientists can infer the water depth and environmental conditions at the time the sediment was deposited. The method for determining paleobathymetry involves observing the population and distribution of foraminifera. The P/B ratio is a comparison between planktonic fossils and benthic fossils. This P/B ratio is one method to estimate the depth of the environmental deposition of sedimentary rocks.

METHOD

Paleobathymetric Analysis

The method used to determine paleobathymetry is the P/B ratio analysis, while the maximum flooding surface (MFS) is determined by the maximum abundance of planktonic foraminifera [4]. For the purposes of P/B ratio analysis, the classification of planktonic and benthic foraminifera is determined based on their shell morphology [5]. Afterward, the abundance data of individual foraminifera are normalized using the following equation [6]:

$$N = 2^n \times A$$

$$Nz = (m_a/m_b) \times N$$

where:

N : the number of individuals in the sample

n : the number of splits

A : the number of species in a section

Nz : the normalized number of individuals in the sample

m_a : the measured mass

m_b : the expected mass

The P/B ratio is the percentage of planktonic foraminifera abundance relative to the total foraminifera abundance (both planktonic and benthic). The calculation of the ratio of individual planktonic and benthic foraminifera is aimed at determining the depositional environment [7]. Changes in the P/B ratio at each interval can represent changes in paleobathymetry, and these changes may be caused by global climate and tectonic changes, as well as locally variable sedimentation rates [8]. Mathematically, the P/B ratio is as follows [9]:

$$\text{The P/B ratio} = P / (P+B) \times 100\%$$

where:

P : the number of planktonic individuals

B : the number of benthic individuals

The sedimentation rate decreases and becomes slower compared to older sediments over a certain period, indicating that the sedimentation rate does not significantly impact the P/B ratio [10].

RESULTS AND DISCUSSION

Based on petrographic analysis of the Wonocolo Formation, with the main lithology being Calcareous Sandstone, samples were taken at several points, namely LP 1 and LP 2.

Calcareous Sandstone at LP 1 location

At the LP 1 observation site, there is an appearance of yellowish Calcareous Sandstone. This rock has varying grain sizes, ranging from medium to coarse sand. The carbonate content is quite high. Based on planktonic foraminifera fossils (see Figure 2), Globigerina dutertrei, Globorotalia paralenguaensis, Orbulina universa, Globigerinoides immaturus, Globigerinoides trilobus were found, and their age was determined based on the appearance of these fossils (see Table 1), which is N16 (Late Miocene). As for the presence of benthic fossils (see Figure 3), such as Amphicoryna scalaris, Cibicidoides sp., Lenticulina sp., it indicates that the Calcareous Sandstone lithology at the research site was deposited in the Outer Neritic environment at a depth of 100 m – 200 m (see Table 2).

Calcareous Sandstone interbedded with Marl at LP 2 location

At the LP 2 observation site, there is a formation of Calcareous Sandstone alternating with Marl layers. This rock has a yellowish color and varying grain sizes, ranging from medium to coarse sand. The carbonate content is high. Based on the planktonic foraminifera fossils found (see Figure 4), Globorotalia miocenica, Globigerinoides trilobus, Pulleniatina primalis, Globigerinoides immaturus, Globorotalia multicamerata, Globorotalia plesiotumida, Hastigerina aequilateralis, the age at this location was determined (see Table 3), which is N17 and N18 (Late Miocene). Regarding the presence of benthic fossils (see Figure 5), Nodosaria sp., Cibicides sp., Planulina subtenuissima, Pulleniatina primalis, Cibicides lobatulus, it indicates that the LP 2 location was deposited in the Outer Neritic environment at a depth of 100 m – 200 m.

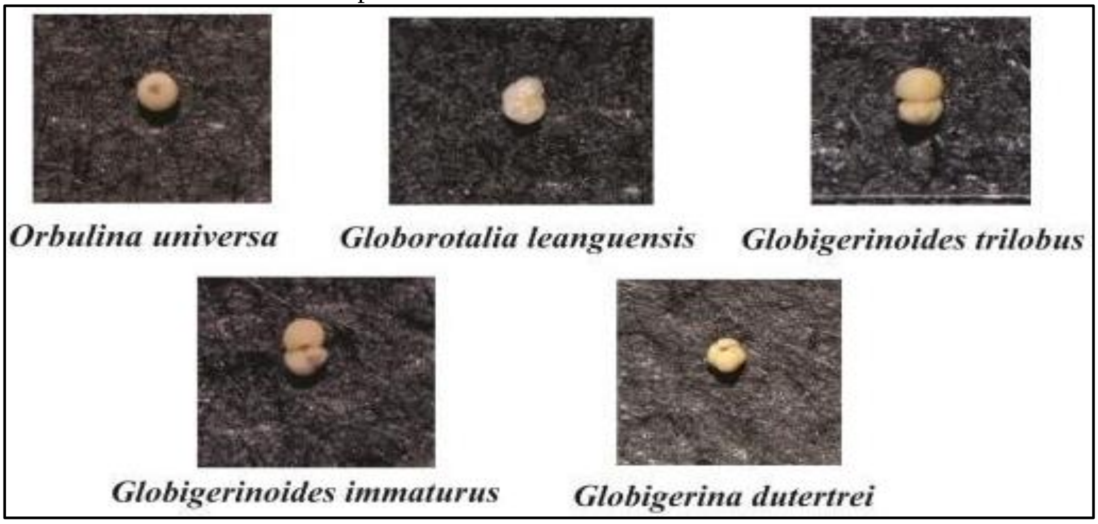

Figure 2. Appearance of Planktonic Foraminifera at LP 1.

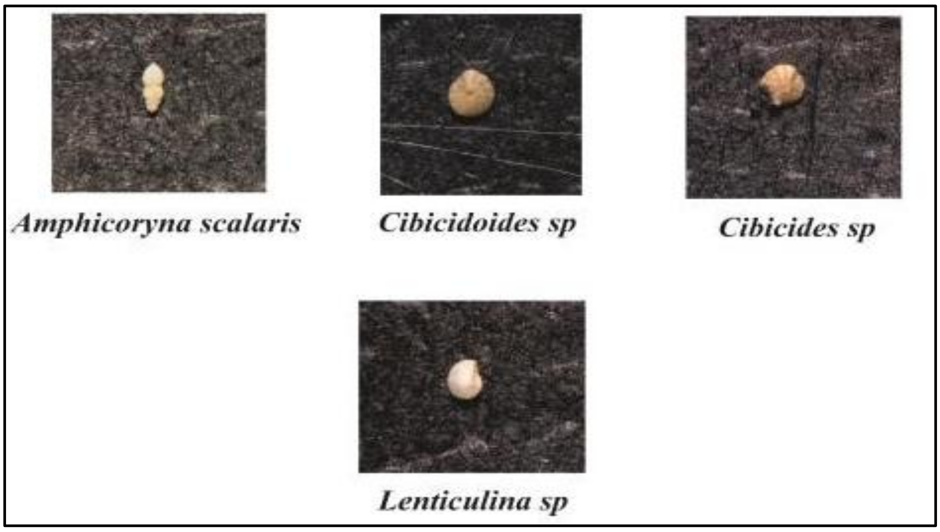

Figure 3. Appearance of Benthic Foraminifera at LP 1.

Table 1. Age range at the research site LP 1.

No.	Species	Miocene												Pliocene				Pleistocene	
		Early					Middle							Late					
		N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23
1	Globigerina dutertrei																				
2	Globorotalia paralenguaensis																				
3	Orbulina universa																				
4	Globigerinoides immaturus																				
5	Globigerinoides trilobus																				

Table 2. Range of deposition environments at the research site LP 1.

No.	Species	Paleobathymetry							
		Terrestrial	Transitional	Neritic			Bathyal		Abyssal
				Inner	Middle	Outer	Upper	Middle	Lower	
1	Cibicidoides sp.									
2	Lenticulina sp.									
3	Amphicoryna scalaris									

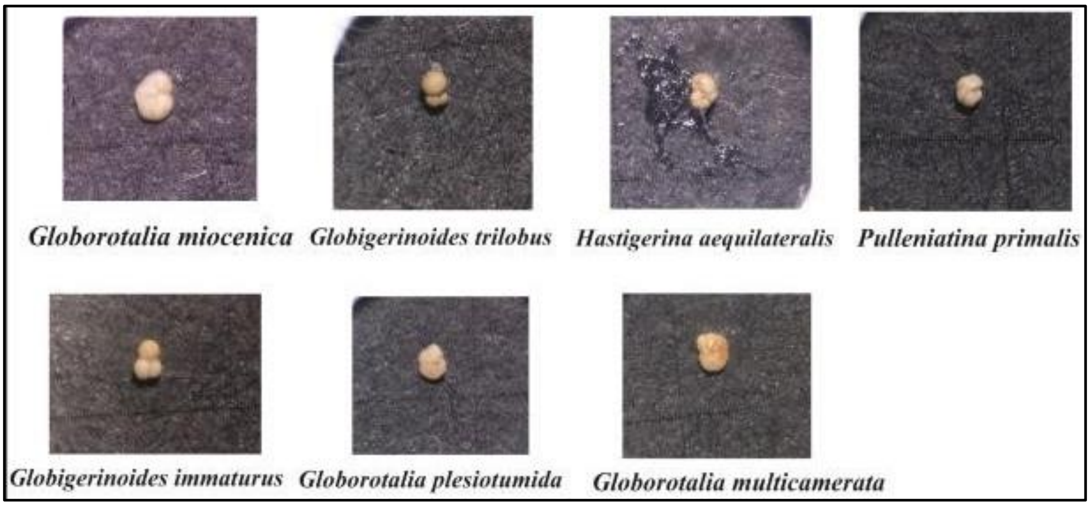

Figure 4. Appearance of Planktonic Foraminifera at LP 2.

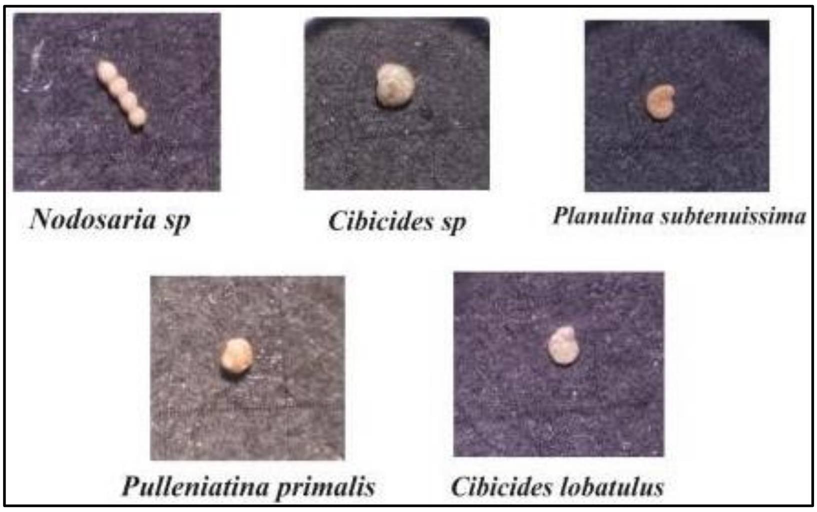

Figure 5. Appearance of Benthic Foraminifera at LP 2.

Table 3. Age range at the research site LP 2.

No.	Species	Miocene															Pliocene			Pleistocene	
		Early					Middle							Late							
		N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23
1	Globigerinoides immaturus																				
2	Globigerinoides trilobus																				
3	Globorotalia plesiotumida																				
4	Globorotalia miocenica																				
5	Pulleniatina primalis																				
6	Hastigerina aequilateralis																				
7	Globorotalia multicamerata																				

Paleobathymetric Analysis based on the P/B Ratio

The determination of the deposition environment begins with calculating the individual ratio of planktonic and benthic foraminifera, referring to the P/B ratio classification proposed by Murray (1976) and Boersma (1983) in the study by Valchev [11], as shown in Table 4. Table 4 indicates that the number of planktonic foraminifera individuals is greater than the number of benthic foraminifera individuals. This P/B ratio indicates that the research area during the Late Miocene was in a deep-sea environment with a depth falling within the Outer Neritic Zone. Based on the research by Sukardi and Budhistrisna [12], there is also evidence of tectonic activity during the Miocene to Pliocene period.

Table 4. Research area based on the ratio of planktonic and benthic foraminifera.

Sample	Number of Individual Planktonic Foraminifera	Number of Individual Benthic Foraminifera	P/B Ratio (%)	Environment
1	6	4	60	Outer Neritic
2	7	5	58,3	Outer Neritic

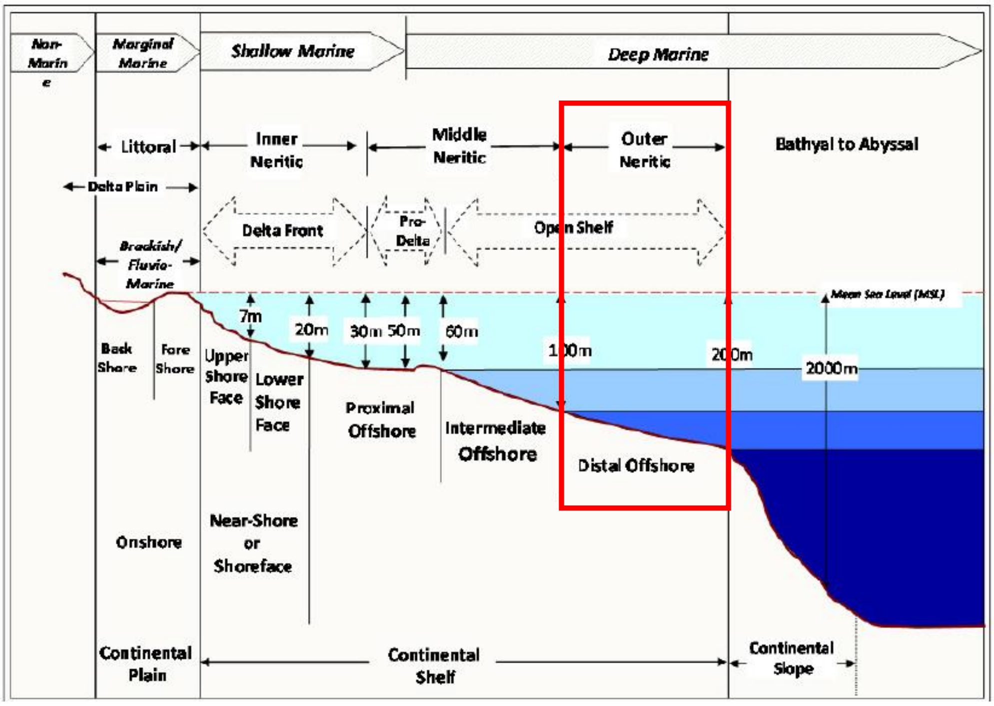

Figure 6. Marine environment at the research site, deep marine/outer neritic, with depth of 100 m – 200 m [13].

CONCLUSION

To obtain information about the depositional environment of sedimentary rocks in the past at the research area, a paleobathymetry analysis was carried out based on the P/B ratio of foraminifera microfossil. Based on the P/B ratio classification proposed by Murray (1976) and Boersma (1983) as presented in Valchev's study [11], the paleobathymetry of the Wonocolo Formation can be identified in two main bathymetric zones, namely the Neritic Bathymetric Zone (shallow marine environment) and the Oceanic Bathymetric Zone (deep-sea environment). The research indicates that paleobathymetry in the study area occurred during the Late Miocene (N16, N17, and N18), and in the Outer Neritic environment with sea depth ranging from 100 to 200 meters.

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