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Foraminifera Biostratigraphy and Paleobathymetry of the Ombilin Formation in the Sumpur Kudus Area, Sijunjung Regency, West Sumatra, Indonesia

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Abstract

The Ombilin Formation in the Sumpur Kudus area, Sijunjung Regency, West Sumatra, is known for its abundance of foraminiferal fossils. However, studies on the relative age of the rock layers, particularly regarding paleobathymetry, still require more in-depth research. This study aims to determine the relative age and bathymetric environment of the Ombilin Formation. The research method used is foraminiferal microfossil analysis, which includes identifying planktonic and benthic foraminifera from rock samples in the study area. The data used consist of five carbonate rock samples. The results of the study indicate that the relative age of the Ombilin Formation in the Sumpur Kudus area, Sijunjung Regency, West Sumatra, based on planktonic foraminifera analysis, is Early Miocene (N5), and its bathymetric environment, based on benthic foraminifera analysis, is in the neritic margin to mid-neritic zone (11–175 fathoms). Thus, the results of this study not only confirm previous findings but also strengthen evidence regarding the relative age and depositional characteristics of the Ombilin Formation, in both regional and local contexts, thereby providing supporting data to understand the geological history and evolution of sedimentation in the Ombilin Basin.

1. Introduction

The Ombilin Basin is one of the basins in West Sumatra that formed as a result of extensional tectonic activity from the Late Eocene through the Oligocene, and subsequently underwent deformation during the Neogene compression phase due to the interaction between the Indo-Australian and Eurasian plates [1]. Regionally, the stratigraphic sequence consists of Pre-Tertiary basement rocks overlain by the Brani Formation, Sangkarewang Formation, Sawahlunto Formation, Sawahtambang Formation, Ombilin Formation, and, finally, the Quaternary deposits of the Ranau Formation. The Ombilin Formation is a Miocene-aged unit dominated by sandstone, mudstone, and shale with interbeds of carbonate limestone, deposited in shallow marine to marginal marine environments[2]. The sedimentary facies of the Ombilin Formation indicate that deposition occurred in a shallow- to marginal-marine system influenced by sea-level changes and tectonic activity during the Miocene [3]. The evolution of deposition in the Ombilin Basin shows a shift in environment from a lacustrine system to a fluvial and shallow-marine environment in response to tectonic and eustatic changes [4]. This study focuses on outcrops of the Ombilin Formation in the Sumpur Kudus area, Sijunjung Regency, West Sumatra, which contain abundant foraminifera fossils that can be used to determine the relative age of the rocks and reconstruct the depositional environment through micropaleontological analysis [5]. Foraminifera are a group of microfossils that can provide information about their age and the environment in which they were deposited [6]. Planktonic and benthic foraminifera provide information about the age, paleobathymetry, and evolution of the depositional environment of a sedimentary basin [7]. Fossil foraminifera are used as parameters based on their characteristics and adaptations to specific environmental conditions; therefore, the assemblage of fossil foraminifera in each rock sample is important and is considered capable of providing a general picture of the depositional environment of sedimentary rocks [8]. Biostratigraphic analysis using microfossils, including foraminifera and nannoplankton, is an effective method for determining the relative age of rocks and correlating stratigraphic units in the Ombilin Basin with higher resolution [9]. The determination of relative age relies on the smallest stratigraphic overlap of index species, using the globally established First Appearance Datum (FAD) and Last Appearance Datum (LAD) as chronological constraints. [10]. Meanwhile, paleobathymetric interpretation is based

on the distribution of benthic foraminifera assemblages using a classification of marine environmental depths that has been developed and refined in previous studies [11], [12]. This study focuses on the outcrop interval of the Ombilin Formation in the Sumpur Kudus area, Sijunjung Regency, West Sumatra. The study interval consists of carbonate sandstone and carbonate shale containing planktonic and benthic foraminifera fossils. The presence of foraminifera assemblages in this interval offers good potential for determining relative age and reconstructing paleobathymetric conditions during deposition. Micropaleontological studies of the Ombilin Formation have been conducted at several locations in the Ombilin Basin and have yielded interpretations of varying depositional environments, ranging from the Transitional-Marginal Neritic zone to the Transitional-Outer Neritic zone [13][14]. However, research on the biostratigraphy and bathymetric environment of the Ombilin Formation in the Sumpur Kudus area has not yet been comprehensively studied. Therefore, this study aims to determine the relative age of the rocks and the paleobathymetry of the Ombilin Formation in the study area. The results of this study are expected to enrich our understanding of the stratigraphic and paleobathymetric characteristics of the Ombilin Formation and serve as comparative data for similar studies in the Ombilin Basin.

2. Methodology

This study employs an integrated approach involving field and laboratory activities, including geological observations, sampling, petrographic analysis, and micropaleontological analysis [15]. Petrographic analysis was conducted only on sandstone samples, whereas for shale, on-site testing was performed using a 5–10% HCl solution. Carbonate rocks containing calcite react with dilute HCl solution, producing CO_2 bubbles, which can be used as a method for identifying carbonate rocks[16]. A total of five representative samples were collected from the Ombilin Formation Sandstone Unit (Tmo; RL2 and RL4) and the Ombilin Formation Claystone Unit (Tmo; RL1, RL3, and RL4). Standard micropaleontological preparation methods were employed to process samples collected from four study locations. A total of 312 foraminiferal specimens were identified, comprising 161 planktonic and 151 benthic specimens recovered from sandstone and mudstone lithologies. The preparation process involved mechanical disaggregation of the rock samples, followed by immersion in a hydrogen peroxide (H_2O_2) solution at a 2:3 ratio for 20–24 hours to promote matrix breakdown and facilitate the extraction of foraminiferal specimens. [17]. The processed residue was subsequently cleaned, dried, and separated using a series of 20-, 50-, 100-, and 200-mesh sieves to obtain the 63–500 µm fraction required for micropaleontological analysis.

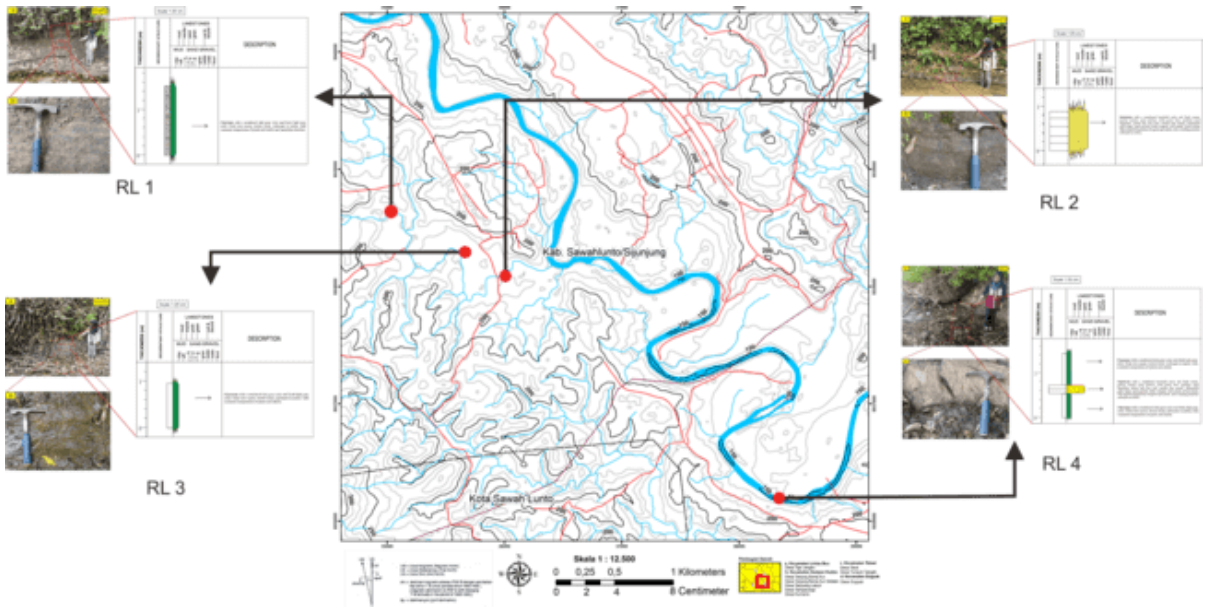

Figure 1. Results of Field Observations of the Ombilin Formation in the Study Area: (A) RL1 claystone outcrop; (B) RL2 sandstone outcrop with bedding structure; (C) RL3 claystone outcrop with lamination structure; (D) RL4 outcrop of interbedded sandstone and claystone.

Foraminiferal tests were hand-picked with the aid of a binocular microscope prior to taxonomic identification. Specimen abundance was evaluated according to the classification system used by the Geological Engineering Program at Sriwijaya University, consisting of Rare (1–5 specimens), Common (6–10 specimens), and Abundant (≥11 specimens)[18]. Biostratigraphic age assessment based on planktonic foraminifera utilizes globally calibrated bioevents, represented by the First Appearance Datum (FAD) and Last Appearance Datum (LAD) of stratigraphically important taxa. These calibration points are integrated with updated geological timescales to improve the reliability and accuracy of relative age determinations[19]. Reconstruction of the depositional environment relied on the bathymetric preferences of benthic foraminiferal assemblages. Only taxa classified as common or abundant were prioritized in the interpretation to minimize the influence of sporadically occurring rare species[20]. A comprehensive interpretation of relative age and depositional environment is achieved by integrating qualitative assessments of foraminiferal assemblage composition with quantitative abundance data, thereby improving the reliability of paleoenvironmental and biostratigraphic interpretations[21].

3. Results and discussions

Field mapping within the study area revealed four outcrop exposures consisting of sandstone and mudstone lithologies. Based on these exposures, five representative rock samples were obtained for paleontological examination. The locations of the sampling sites and the corresponding analyzed samples are illustrated in Figure 1.

3.1. Ombilin Formation (Tmo) Sandstone Unit on RL2

At RL 2, a sandstone outcrop with the following characteristics was found. The Ombilin Formation sandstone exhibits a brownish weathered color and a fresh grayish-brown color in its macroscopic appearance. Grain size: fine sand; matrix: silt; cement: sub-rounded clay; well-sorted; closed-pack; moderately compact; carbonate in nature; with a mineral composition of quartz and calcite. A plan view of Singakapan and a stratigraphic cross-section of the RL2 sandstone unit of the Ombilin Formation are shown in (Figure 2).

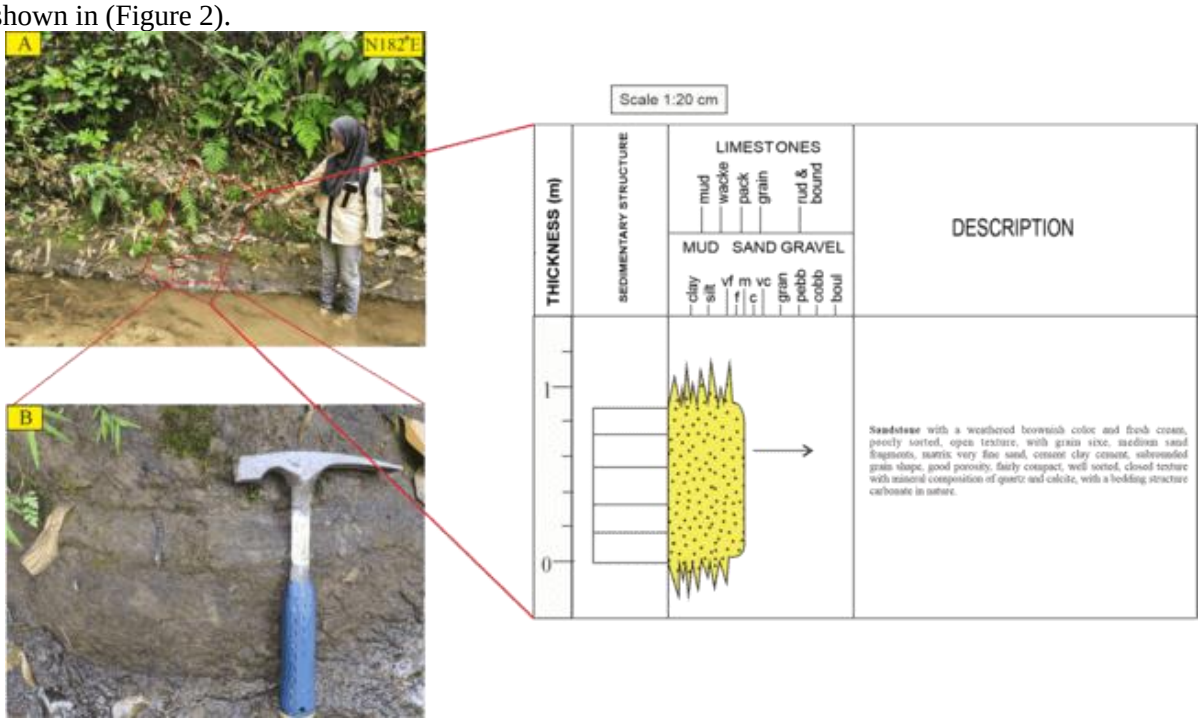

Figure 2. Stratigraphic Cross-Sections of the Far-Distance and Near-Distance Outcrops of Sanstone/RL 2 (UTM 703074; 9938187), Ombilin Formation

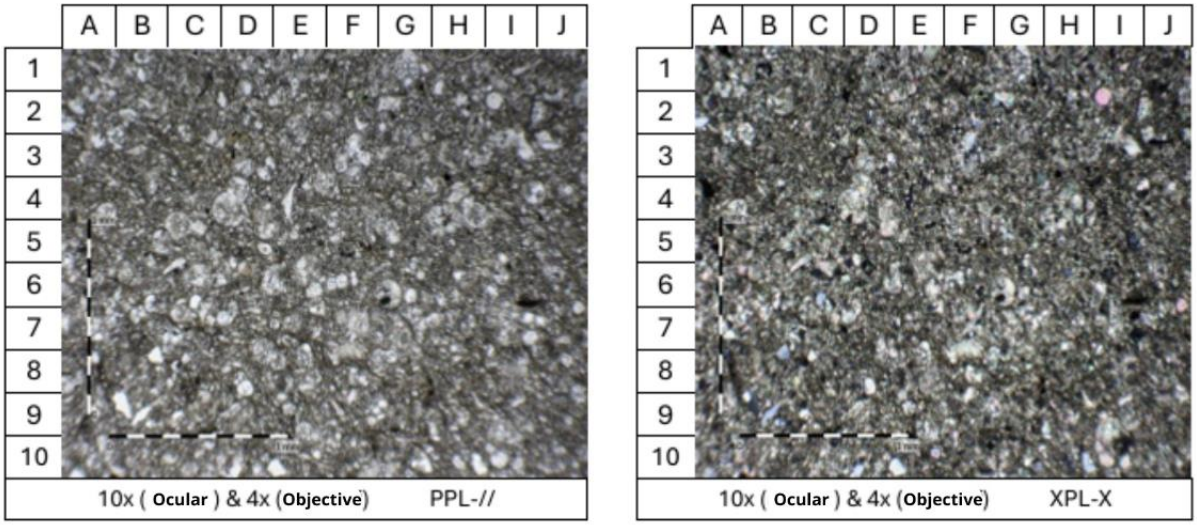

Figure 4. Thin Section of Sandstone/RL 2 (UTM 703074; 9938187), Ombilin Formation

Next, a microscopic analysis was conducted on thin sections to determine their mineral composition (Figure 4). Thin sections of siliciclastic sedimentary rock at 40× magnification showed brown color (PPL) and bluish-brown interference color (XPL), with grain sizes ranging from 0.05 to 0.26 mm (coarse silt–medium sand), matrix 0.02–0.01 mm (fine silt–medium silt), and cement <0.01 mm; grain shape subrounded–subangular; high sphericity; closed-grain fabric (grain-supported fabric); well-sorted, contact types concave contact (C5) and point contact (G6), moldic porosity type, consisting of skeletal grains and quartz, a micrite and clay matrix, and sparite and clay cement with chlorite as a secondary mineral. The rock was named using the Mount classification[22] , with a mineral composition of 34% Allocheme, 13% Sand, and 41% micrite. After normalization and plotting, the designation Sandy Micrite was assigned.

The micropaleontological investigation of sample RL2 recognized five distinct planktonic foraminiferal taxa, as follows: *Globigerinoides primordius* (12 specimens) (A), *Globigerinoides altiaperturus* (12 specimens) (B), *Globigerinoides subquadratus* (3 specimens) (C), *Orbulina universa* (2 specimens) (D), and *Globigerinoides quadrilobatus* (7 specimens) (E). *Globigerinoides primordius* and *Globigerinoides altiaperturus* are classified as abundant, *Globigerinoides quadrilobatus* as common, while the other taxa are classified as rare. Thus, the foraminiferal association in this sample is dominated by taxa with moderate to abundant abundance, indicating that the fossil population obtained is representative and not merely an isolated occurrence, as shown in Figure 5.

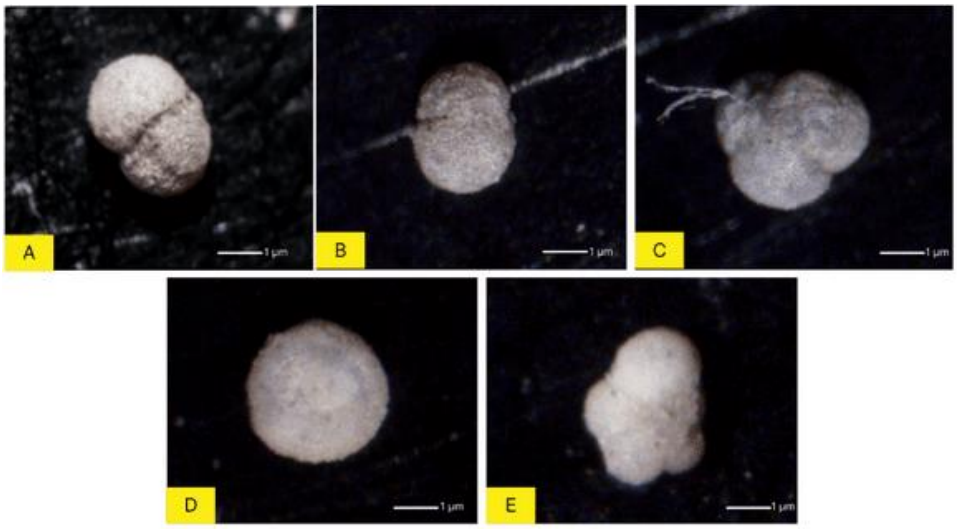

Figure 5. Planktonic Foraminifera Fossils from Sandstone/RL 2 (UTM 703074; 9938187), Ombilin Formation

Table 1 Taxonomy of Planktonic Foraminifera from the Sandstone/RL 2 Member of the Ombilin Formation

Sample / Formation	: RL 2 / Tmo	Rock Type	: Sedimentary Rock
Location	: Kumanis Village	Age Range	: Early Miocene
Rock Name	: Sandy Micrite		

Age ->	Oligocene		Miocene										
	Late		Early					Middle					
	e.1-4		e.5					f.1		F.2		f.3	
Planktonic Foraminifera (Blow, 1969)	N2 P21	N3 P22	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14
Globigerinoides primordius (A)			———	———									
Globigerinoides altiaperturus (A)				———	———	———	———	———	———	———	———		
Globigerinoides subquadratus (R)				———	———	———	———	———	———	———	———	———	
Orbulina universa (R)								———	———	———	———	———	———
Globigerinoides quadrilobatus (C)			———	———	———	———	———	———	———	———	———	———	———

Biostratigraphic evaluation of the planktonic foraminiferal assemblage indicates an Early Miocene age, equivalent to the N5 biozone. This interpretation is supported by the integrated stratigraphic overlap of all identified taxa, whose collective occurrence provides a more reliable chronological framework than reliance on a single diagnostic species. The corresponding stratigraphic relationships are presented in Table 1.

Five benthic foraminiferal taxa were identified from the analyzed samples (Figure 6), including *Spirolina acicularis* (1 specimen), *Streblus gaimardii* (9 specimens), *Amphistegina quoyii* (11 specimens), *Tubinella funalis* (4 specimens), and *Tubinella inornata* (8 specimens). Quantitative assessment based on the established abundance categories indicates that the assemblage is primarily composed of taxa assigned to the common and abundant classes, with the dominant species shown in Figure 6.

Bathymetric preferences of the identified benthic foraminifera were evaluated to infer the depositional setting. Comparison of the minimum and maximum depth ranges for the five taxa suggests sediment accumulation within the neritic margin to middle neritic environment, equivalent to water depths of about 11–60 fathoms. The occurrence of *Streblus gaimardii* also provides evidence for a broader bathymetric distribution reaching the inner-middle neritic zone, as shown in Table 2.

Figure 6. Benthic Foraminifera Fossils from Sandstone/RL 2 (UTM 703074; 9938187), Ombilin Formation

Table 2. Benthic Foraminifera Fauna of the Sandstone/RL 2 Formation, Ombilin Formation

Sample / Formation	: RL 2/Tmo	Rock Type	: Sedimentary Rock
Location	: Kumanis Village	Bathymetric Environment	: Inner Neritic – Middle Neritic
Rock Name	: Sandstone		

Bathymetric Environment, feet depth ->	Transitional	Neritic			Bathyal		Abyssal
		Inner	Middle	Outer	Upper	Lower	
Benthic Foraminifera (Barker, 1960)	0	20	100	200	500	2000	4000
Spirolina acicularis (R) 11 fathoms	*						
Streblus gaimardii (A) 28 fathoms		*					
Amphistegina quoyii (A) 16- 25 fathoms		*	*				
Tubinela funalis (C) 20-60 fathoms			*	*			
Tubinela inornata (R) 20-60 fathoms			*	*			

3.2 Ombilin Formation (Tmo) Clay Unit at RL 1 and RL 3

At RL 1, with UTM coordinates 704079; 9938208, an outcrop of claystone with the following characteristics was found. The Ombilin Formation claystone exhibits a dark gray weathered color and a light gray fresh color in its macroscopic appearance. It consists of clay grains, is compact in texture, carbonate in nature, and composed of quartz and calcite. No petrographic analysis was conducted on the claystone to determine its calcite content or carbonate composition; however, a test using HCl solution was performed during field observations. An aerial view of Singakapan and a stratigraphic cross-section of the RL1 claystone unit of the Ombilin Formation are shown in Figure 7.

The micropaleontological investigation of sample RL1 recognized five distinct planktonic foraminiferal taxa, as follows: *Globigerinoides quadrilobatus* (8 specimens) (A), *Globigerinoides primordius* (12 specimens) (B), *Globigerinoides pseudomiocenica* (3 specimens) (C), *Globigerapsis mexicana* (2 specimens) (D), and *Globorotalia obesa* (7 specimens) (E). *Globigerinoides primordius* falls into the "abundant" category, *Globigerinoides quadrilobatus* falls into the "common" category, while the other taxa are classified as "rare." Thus, the foraminiferal association in this sample is dominated by taxa with moderate to abundant abundance, indicating that the fossil population obtained is representative and not merely an isolated occurrence, as shown in Figure 8.

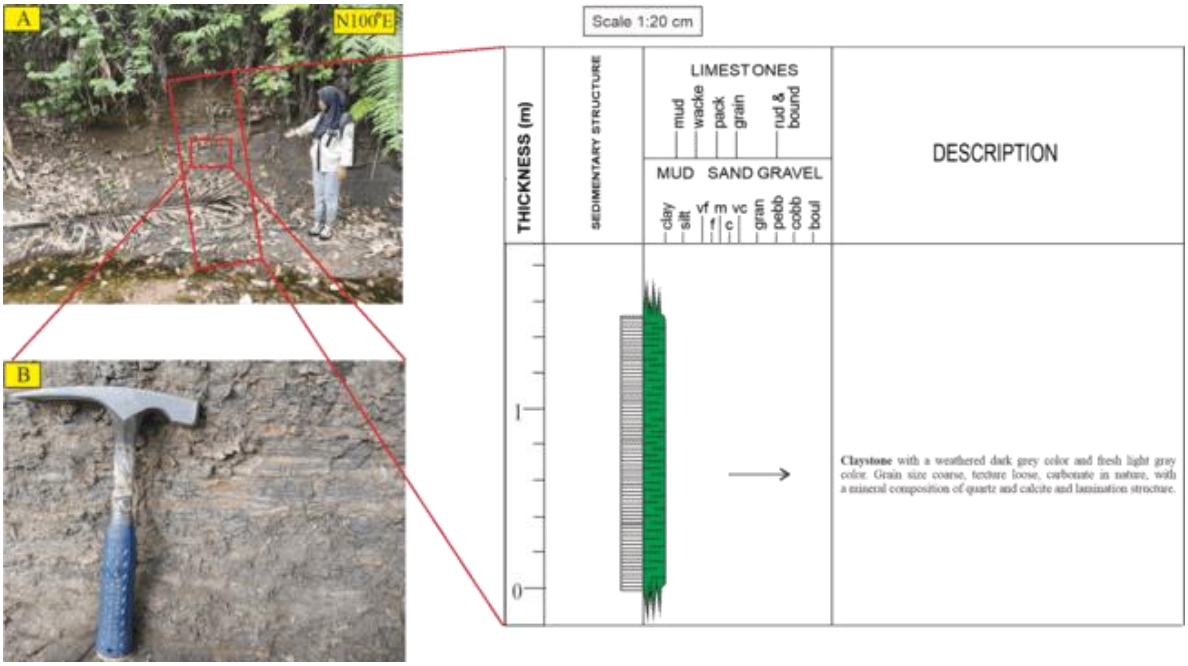

Figure 7. Stratigraphic Cross-Sections of the Long-Distance and Short-Distance Outcrops of Claystone/RL 1 (UTM 704079; 9938208), Ombilin Formation

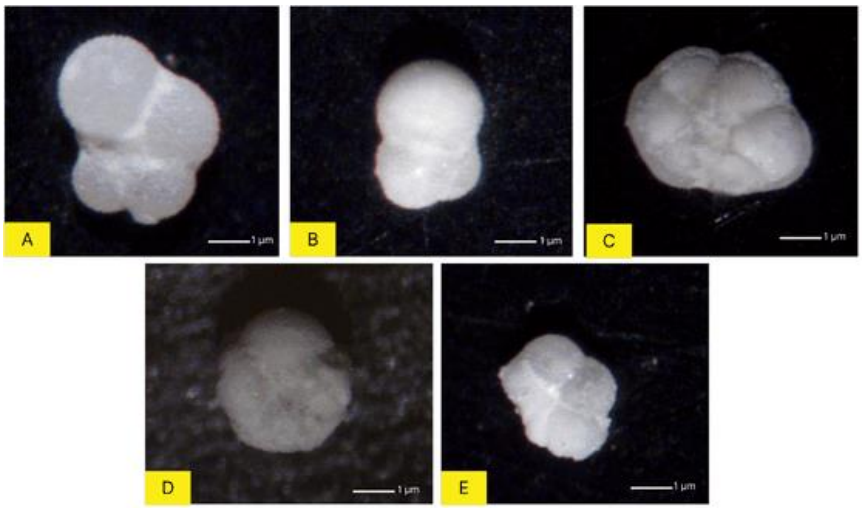

Figure 8. Planktonic Foraminifera Fossils from Claystone/RL 1 (UTM 704079; 9938208), Ombilin Formation

Biostratigraphic evaluation of the planktonic foraminiferal assemblage indicates an Early Miocene age, equivalent to the N5 biozone. This interpretation is supported by the integrated stratigraphic overlap of all identified taxa, whose collective occurrence provides a more reliable chronological framework than reliance on a single diagnostic species. The corresponding stratigraphic relationships are presented in Table 3.

Five benthic foraminiferal taxa were identified from the analyzed samples (Figure 9), including *Streblus gaimardii* (11 specimens) (A), *Tubinella inornata* (12 specimens) (B), *Amphistegina quoyii* (7 specimens) (C), *Technitella legumen* (3 specimens) (D), and *Spirolina acicularis* (1 specimen) (E). (Based on abundance classification, this association is dominated by taxa in the moderate to abundant categories, particularly *Tubinella inornata*, as shown in Figure 9.)

Table 3. Taxonomy of Planktonic Foraminifera from the Claystone /RL 1 Member of the Ombilin Formation

Sample / Formation	: RL 1 / Tmo	Rock Type	: Sedimentary Rock
Location	: Limo Koto Village	Age Range	: Early Miocene
Rock Name	: Claystone		

Age ->	Oligocene		Miocene										
	Late		Early					Middle					
	e.1-4		e.5					f.1		F.2		f.3	
Planktonic Foraminifera (Blow, 1969)	N2 P21	N3 P22	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14
Globigerinoides quadrilobatus (C)													
Globigerinoides primordius (C)													
Globigerinoides pseudomiocenica (A)													
Globigerapsis mexicana (R)													
Globorotalia obesa (R)													

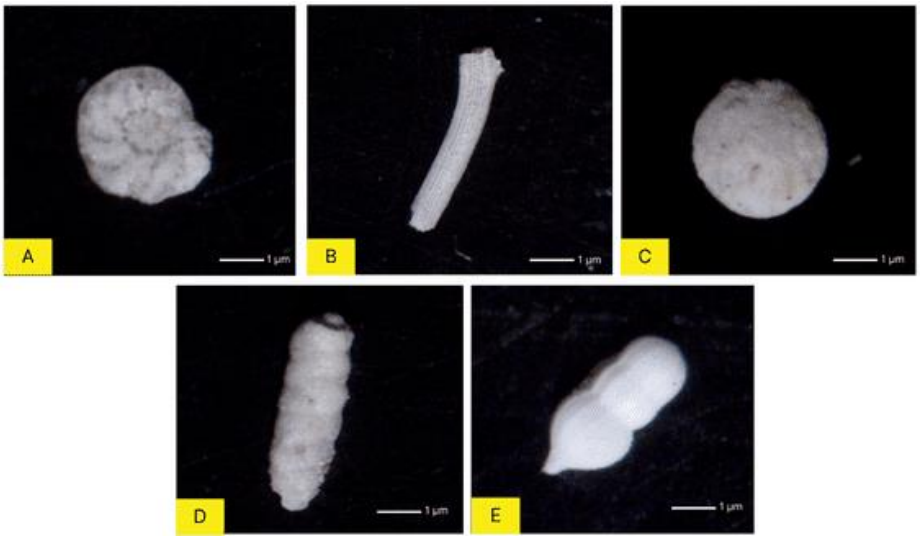

Figure 9. Benthic Foraminifera Fossils from Claystone/RL 1 (UTM 703074; 9938187), Ombilin Formation

Bathymetric preferences of the identified benthic foraminifera were evaluated to infer the depositional setting. Comparison of the minimum and maximum depth ranges for the five taxa suggests sediment accumulation within the neritic margin to middle neritic environment, equivalent to water depths of about 11–120 fathoms. The occurrence of *Streblus gaimardii* also provides evidence for a broader bathymetric distribution reaching the upper inner-middle neritic, as shown in Table 4.

In addition to RL 1, an analysis was conducted on the outcrop of RL 3 claystone located at UTM coordinates 703091; 9938767, which has the following characteristics. The Ombilin Formation claystone exhibits a dark gray weathered color and a light gray fresh color in its macroscopic appearance. It consists of clay grains, is compact in texture, is carbonate in nature, and contains quartz and calcite. No petrographic analysis was conducted on the claystone to determine its calcite content or carbonate composition; however, a test using HCl solution was performed during the field observation. An aerial view of Singakapan and a stratigraphic cross-section of the RL 3 claystone unit of the Ombilin Formation are shown in Figure 10.

Table 4. Benthic Foraminifera Fauna of the Claystone /RL 1 Member of the Ombilin Formation

Sample / Formation	: RL 1/Tmo	Rock Type	: Sedimentary Rock
Location	: Limo Koto Village	Bathymetric Environment	: Inner Neritic – Middle Neritic
Rock Name	: Claystone		

Bathymetric Environment, feet depth ->	Transitional	Neritic			Bathyal		Abyssal
		Inner	Middle	Outer	Upper	Lower	
Benthic Foraminifera (Barker, 1960)	0	20	100	200	500	2000	4000
Streblus gaimardii (A) 28 fathoms		*					
Tubinela inornata (A) 20-60 fathoms		*	*				
Amphistegina quoyii (C) 16- 25 fathoms		*	*				
Technitella legumen (C) 120 fathoms				*			
Spirolina acicularis (R) 11 fathoms	*						

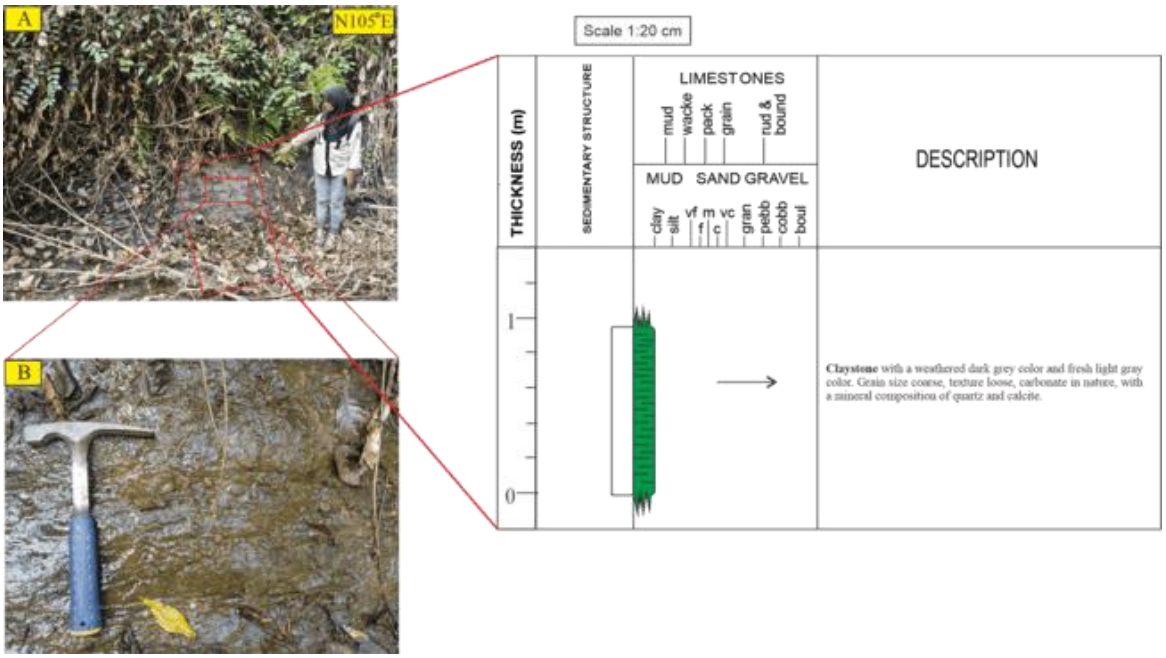

Figure 10. Stratigraphic Cross-Sections of the Long-Distance and Short-Distance Outcrops of Claystone/RL 3 (UTM 703091; 9938767), Ombilin Formation

The micropaleontological investigation of sample RL3 recognized five distinct planktonic foraminiferal taxa, as follows: *Globigerinoides quadrilobatus* (8 specimens) (A), *Globigerinoides primordius* (12 specimens) (B), *Globigerinoides trilobus* (7 specimens) (C), *Globorotalia pseudomicenica* (2 specimens) (D), and *Globorotalia mayeri* (3 specimens) (E*). Globigerinoides primordius* is classified as abundant, *Globigerinoides quadrilobatus* and *Globigerinoides trilobus* as common, while the other taxa are classified as rare. Thus, the foraminifera association in this sample is dominated by taxa with moderate to abundant abundance, indicating that the fossil population obtained is representative and not merely an isolated occurrence, as shown in Figure 11.

This foraminifera association is interpreted as Early Miocene in age, corresponding to the N5 planktonic foraminifera biostratigraphic zone, based on the stratigraphic overlap of the taxa that were successfully identified. This interpretation is based on the co-occurrence of taxa characteristic of the Early Miocene and does not rely solely on a single marker species, as shown in Table 5.

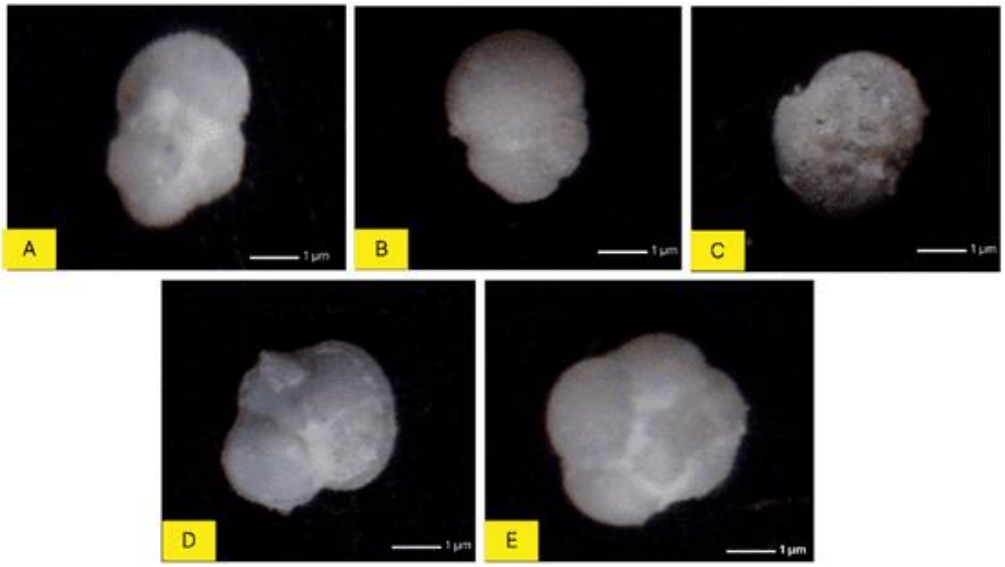

Figure 11. Fossils of Planktonic Foraminifera from Claystone /RL 1 (UTM 703091; 9938767), Ombilin Formation

Table 5. Taxa Foraminifera Planktonik Claystone/RL 3 Ombilin Formation

Sample / Formation	: RL 3 / Tmo	Rock Type	: Sedimentary Rock
Location	: Kumanis Village	Age Range	: Early Miocene
Rock Name	: Claystone		

Age ->	Oligocene		Miocene										
	Late		Early					Middle					
	e.1-4		e.5					f.1		F.2		f.3	
Planktonic Foraminifera (Blow, 1969)	N2 P21	N3 P22	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14
Globigerinoides quadrilobatus (C)													
Globigerinoides primordius (C)													
Globigerinoides trilobus (A)													
Globorotalia pseudomicenica (R)													
Globorotalia mayeri (R)													

Five benthic foraminiferal taxa were identified from the analyzed samples (Figure 12), including: *Tubinella inornata* (7 specimens) (A), *Streblus gaimardii* (12 specimens) (B*), Amphistegina quoyii* (11 specimens) (C), *Tubinella funalis* (8 specimens) (D), and *Eponides umbonatus* (1 specimen) (E). (Based on abundance classification, this association is dominated by taxa in the moderate to abundant categories, particularly *Streblus gaimardii*, as shown in Figure 12).

Bathymetric preferences of the identified benthic foraminifera were evaluated to infer the depositional setting. Comparison of the minimum and maximum depth ranges for the five taxa suggests sediment accumulation within the neritic margin to middle neritic environment, equivalent to water depths of about 16-175 fathoms. The occurrence of *Streblus gaimardii* also provides evidence for a broader bathymetric distribution reaching the inner-middle neritic zone, as shown in Table 6.

Figure 12. Benthic Foraminifera Fossils from Siltstone/RL 1 (UTM 703074; 9938187), Ombilin Formation

Table 6. Benthic Foraminifera Fauna of the Claystone /RL 3 Formation, Ombilin Formation

Sample / Formation	: RL 3/Tmo	Rock Type	: Sedimentary Rock
Location	: Kumanis Village	Bathymetric Environment	: Inner Neritic – Middle Neritic
Rock Name	: Claystone		

Bathymetric Environment, feet depth ->	Transitional	Neritic			Bathyal		Abyssal
		Inner	Middle	Outer	Upper	Lower	
Benthic Foraminifera (Barker, 1960)	0	20	100	200	500	2000	4000
Tubinela inornata (C) 20-60 fathoms		*	*				
Streblus gaimardii (A) 28 fathoms		*					
Amphistegina quoyii (A) 16- 25 fathoms		* *					
Tubinela funalis (C) 20-60 fathoms		*	*				
Eponides umbonatus (R) 175 fathoms				*			

3.3 Contact between the sandstone and shale of the Ombilin Formation at RL4

At RL 4, with coordinates UTM 706004; 9537073, an outcrop was found where sandstone and claystone come into contact. An analysis was then conducted on both rocks, which exhibited the following characteristics. The Ombilin Formation sandstone exhibits a weathered brownish color and a fresh grayish-brown color in macroscopic appearance. Grain size: fine sand; matrix: silt; cement: sub-rounded clay; well-sorted; closed-pack; moderately compact; carbonate-rich; with a mineral composition of quartz and calcite. The Ombilin Formation claystone, when viewed macroscopically, has a dark gray weathered color and a light gray fresh color. Grain size: clay; compactness: compact; carbonate in nature; with a mineral composition of quartz and calcite. An image of the RL 4 outcrop is shown in Figure 13.

Next, microscopic analysis was performed on thin sections to determine their mineral composition (Figure 14). Thin sections of siliciclastic sedimentary rock at 40× magnification, showing a grayish-brown color (PPL) and a brownish-pink interference color (XPL), grain sizes ranging from 0.04 to 0.34 mm (coarse silt–medium sand), a matrix of 0.03–0.01 mm (fine silt–medium silt), and cement <0.01 mm; grain shape: subrounded to rounded; high sphericity; open fabric (matrix-supported fabric); moderately sorted, contact types: floating contact (F5), point contact (B7), intergranular porosity type, consisting of skeletal grains, quartz, orthoclase, plagioclase, and lithic clay, a matrix of microquartz and micrite, and cement consisting of calcite and clay. The rock was named using the Mount classification[22]. With a mineral composition of 4% allocheme, 23% sand, and 31% micrite, after normalization and plotting, the rock was classified as Sandy Micrite.

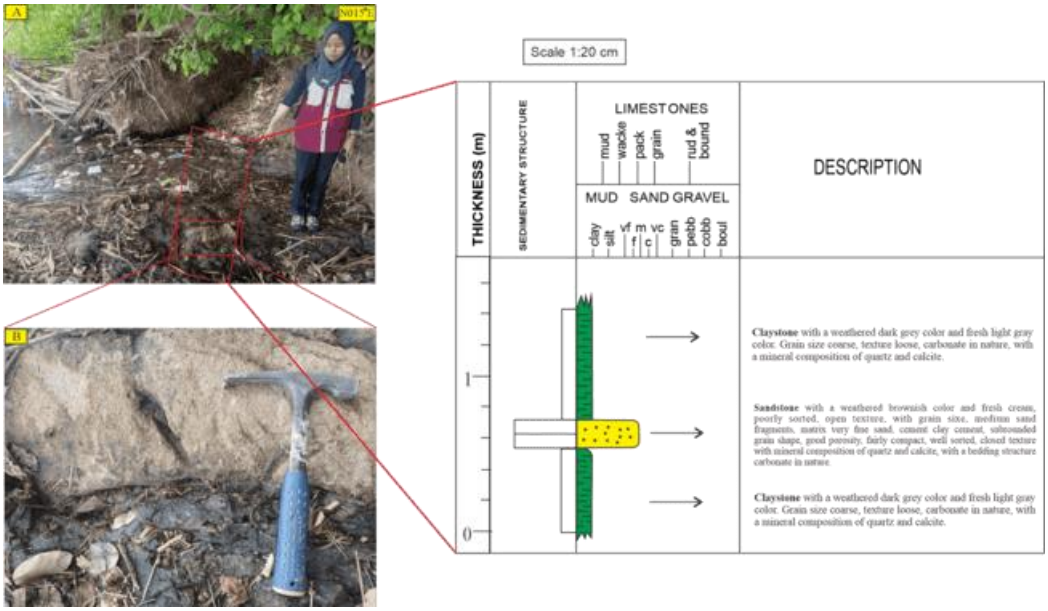

Figure 13. Stratigraphic Cross-Section of Long-Range and Short-Range Outcrops of Sandstone and Shale Layers/RL 4 (UTM 706004; 9537073), Ombilin Formation (Tmo)

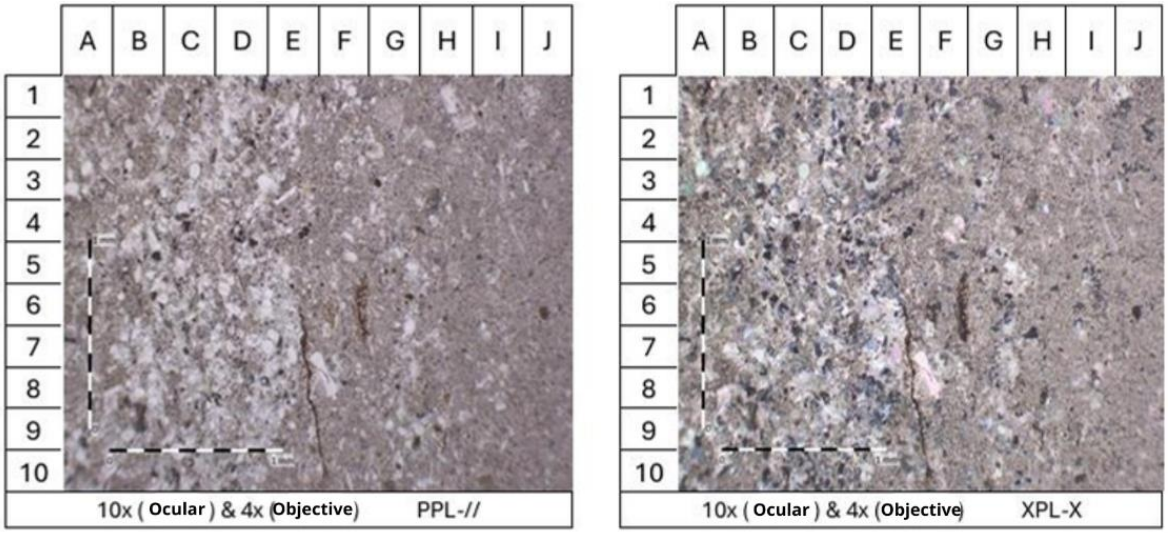

Figure 14. Thin Section of Sandstone/RL 4 (UTM 706004; 9537073), Ombilin Formation (Tmo)

The micropaleontological investigation of sample Sandstone RL4 recognized five distinct planktonic foraminiferal taxa, as follows: *Globigerinoides primordius* (13 specimens) (A), *Globorotalia siakensis* (1 specimen) (B), *Globigerioides altiapertusus* (3 specimens) (C), *Globigerinoides quadrilobatus* (2 specimens) (D), and *Globorotalia pseudomiocenica* (8 specimens) (E). *Globigerinoides primordius* is classified as abundant, *Globorotalia pseudomiocenica* as common, while the other taxa are classified as rare. Thus, the foraminiferal association in this sample is dominated by taxa with moderate to abundant abundance, indicating that the fossil population obtained is representative and not merely an isolated occurrence, as shown in Figure 15.

Biostratigraphic evaluation of the planktonic foraminiferal assemblage indicates an Early Miocene age, equivalent to the N5 biozone. This interpretation is supported by the integrated stratigraphic overlap of all identified taxa, whose collective occurrence provides a more reliable chronological framework than reliance on a single diagnostic species. The corresponding stratigraphic relationships are presented in Table 7.

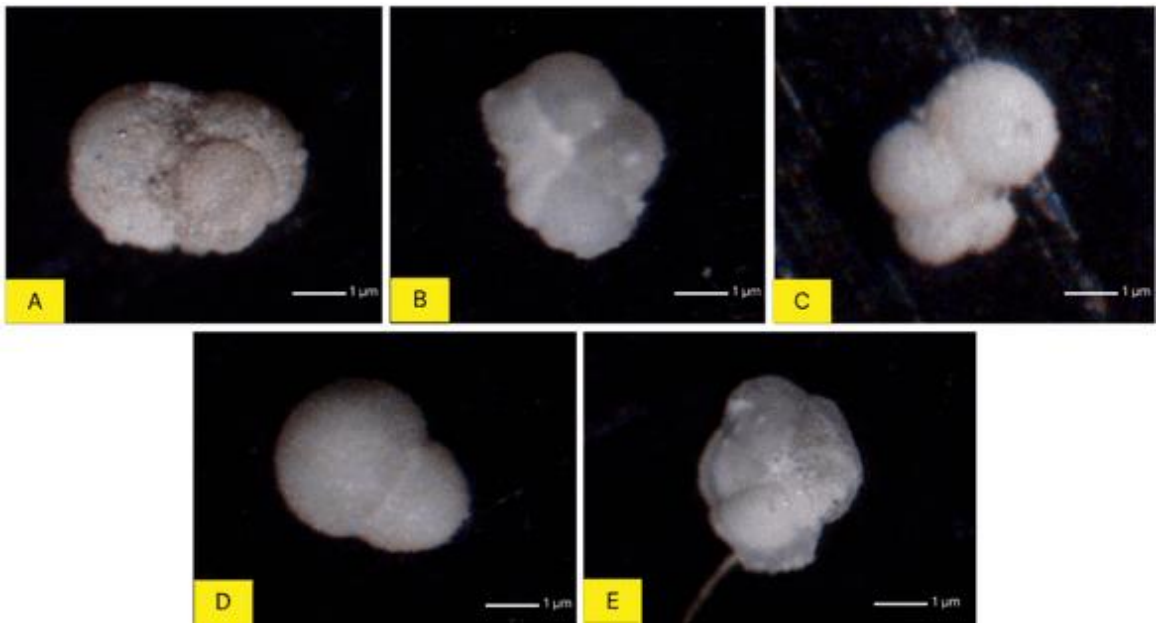

Figure 15. Planktonic Foraminifera Fossils from Sandstone/RL 4 (UTM 706004; 9537073), Ombilin Formation

Table 7. Taxonomy of Planktonic Foraminifera from the Sandstone/RL 4 Member of the Ombilin Formation

Sample / Formation	: RL 4 / Tmo	Rock Type	: Sedimentary Rock
Location	: Tanjung Bonai Aur Village	Age Range	: Early Miocene
Rock Name	: Sandy Micrite		

Planktonic Foraminifera (Blow, 1969)	Age ->	Oligocene	Miocene											
		Late	Early						Middle					
		e.1-4	e.5						f.1		F.2		f.3	
		N2 P21	N3 P22	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14
Globigerinoides primordius (A)														
Globorotalia siakensis (R)														
Globigerinoides altiapertusus (A)														
Globigerinoides quadrilobatus (A)														
Globorotalia pseudomiocenica (C)														

Five benthic foraminiferal taxa were identified from the analyzed samples (Figure 16), including: *Eponides umbonatus* (2 specimens) (A), *Streblus gaimardii* (13 specimens) (B), *Tubinella funalis* (6 specimens) (C), *Tubinella inornata* (8 specimens) (D), and *Peneroplis carinatus* (2 specimens) (E). (Based on abundance classification, this association is dominated by taxa in the moderate to abundant categories, particularly *Streblus gaimardii*, as shown in Figure 16).

Bathymetric preferences of the identified benthic foraminifera were evaluated to infer the depositional setting. Comparison of the minimum and maximum depth ranges for the five taxa suggests sediment accumulation within the neritic margin to middle neritic environment, equivalent to water depths of about 11-175 fathoms. The occurrence of *Streblus gaimardii* also provides evidence for a broader bathymetric distribution reaching the inner-middle neritic zone, as shown in Table 8.

Figure 16. Benthic Foraminifera Fossils from Sandstone/RL 4 (UTM 706004; 9537073), Ombilin Formation

Table 8. Benthic Foraminifera Fauna of the Sandstone/RL 4 Ombilin Formation

Sample / Formation	: RL 4/Tmo	Rock Type	: Sedimentary Rock
Location	:Tanjung Bonai Aur Village	Bathymetric Environment	: Inner Neritic – Middle Neritic
Rock Name	: Sandy Micrite		

Bathymetric Environment, feet depth ->	Transitional	Neritic			Bathyal		Abyssal
		Inner	Middle	Outer	Upper	Lower	
Benthic Foraminifera (Barker, 1960)	0	20	100	200	500	2000	4000
Eponides umbonatus (R) 175 fathoms				*			
Streblus gaimardii(A) 28 fathoms		*					
Tubinela funalis (C) 20-60 fathoms		*	*				
Tubinela inornata (R) 20-60 fathoms		*	*				
Peneroplis carinatus (R) 11 fathoms	*						

The micropaleontological investigation of sample Claystone RL4 recognized five distinct planktonic foraminiferal taxa, as follows: *Globigerinoides subquadratus* (8 specimens) (A), *Globigerinoides primordius* (11 specimens) (B), *Globigerinoides quadrilobatus* (7 specimens) (C), *Globorotalia plesiotumida* (2 specimens) (D), and *Globigerinoides trilobus* (1 specimen) (E). *Globigerinoides primordius* is classified as abundant, *Globigerinoides quadrilobatus* and *Globigerinoides subquadratus* as common, while the other taxa are classified as rare. Thus, the foraminiferal association in this sample is dominated by taxa with moderate to abundant abundance, indicating that the fossil population obtained is representative and not merely an isolated occurrence, as shown in Figure 17.

Biostratigraphic evaluation of the planktonic foraminiferal assemblage indicates an Early Miocene age, equivalent to the N5 biozone. This interpretation is supported by the integrated stratigraphic overlap of all identified taxa, whose collective occurrence provides a more reliable chronological framework than reliance on a single diagnostic species. The corresponding stratigraphic relationships are presented in Table 9.

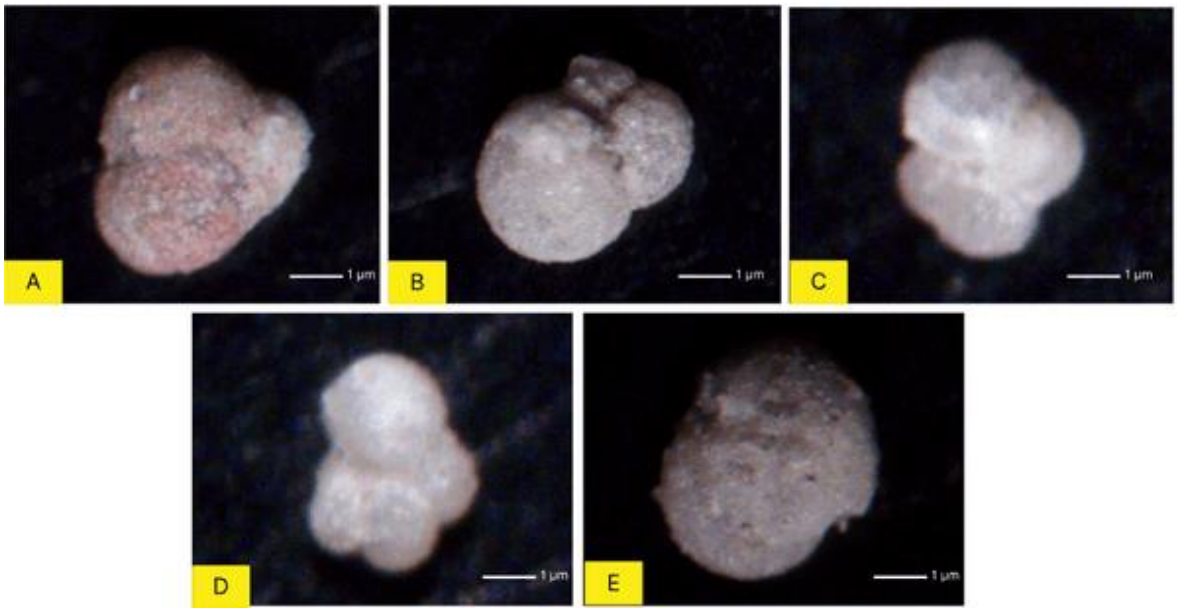

Figure 17. Planktonic Foraminifera Fossils from Claystone /RL 4 (UTM 706004; 9537073), Ombilin Formation

Table 9. Taxonomy of Planktonic Foraminifera from the Claystone /RL 4 Member of the Ombilin Formation

Sample / Formation	: RL 4 / Tmo	Rock Type	: Sedimentary Rock
Location	: Tanjung Bonai Aur Village	Age Range	: Early Miocene
Rock Name	: Claystone		

Age ->	Oligocene		Miocene										
	Late		Early					Middle					
	e.1-4		e.5					f.1		F.2		f.3	
Planktonic Foraminifera (Blow, 1969)	N2 P21	N3 P22	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14
Globigerinoides subquadratus (C)													
Globigerinoides primordius (A)													
Globigerinoides quadrilobatus (C)													
Globorotalia plesiotumida (R)													
Globigerinoides trilobus (R)													

Five benthic foraminiferal taxa were identified from the analyzed samples (Figure 18), including *Tubinella funalis* (8 specimens) (A), *Quinqueloculina venusta* (3 specimens) (B), *Streblus gaimardii* (14 specimens) (C), *Tubinella inornata* (2 specimens) (D), and *Amphistegina quoyii* (1 specimen) (E). (Based on abundance classification, this association is dominated by taxa in the moderate to abundant categories, particularly *Streblus gaimardii*, as shown in Figure 18).

Bathymetric preferences of the identified benthic foraminifera were evaluated to infer the depositional setting. Comparison of the minimum and maximum depth ranges for the five taxa suggests sediment accumulation within the neritic margin to middle neritic environment, equivalent to water depths of about 15–60 fathoms. The occurrence of *Streblus gaimardii* also provides evidence for a broader bathymetric distribution reaching the upper inner-middle neritic zone, as shown in Table 10.

Figure 18. Benthic Foraminifera Fossils from Claystone/RL 1 (UTM 703074; 9938187), Ombilin Formation

Table 10. Taxa of Benthic Foraminifera from the Siltstone/RL 4 Member of the Ombilin Formation

Sample / Formation	: RL 4/Tmo	Rock Type	: Sedimentary Rock
Location	: Tanjung Bonai Aur Village	Bathymetric Environment	: Inner Neritic – Middle Neritic
Rock Name	: Limestone	Analyzed by	: Febi Annisa

Bathymetric Environment, feet depth ->	Transitional	Neritic			Bathyal		Abyssal
		Inner	Middle	Outer	Upper	Lower	
Benthic Foraminifera (Barker, 1960)	0	20	100	200	500	2000	4000
Tubinela funalis (C) 20-60 fathoms		*	*				
Quinqueloculina venusta (R) 15-20 fathoms		*	*				
Streblus gaimardii (A) 28 fathoms			*				
Tubinela inornata (R) 20-60 fathoms			*	*			
Amphistegina quoyii (R) 16- 25 fathoms		*	*				

The results of this study are consistent with various previous studies indicating that the Ombilin Formation generally dates to the Early Miocene (N5)[14]. Furthermore, the interpretation of the depositional environment obtained in this study is also consistent with previous research concluding that the Ombilin Formation was deposited in a Marginal to Mid-neritic environment [13],[14]. This consistency between the results of this study and previous studies indicates the reliability of biostratigraphic and paleobathymetric data for the Ombilin Formation. Thus, the results of this study not only confirm previous findings but also strengthen the evidence regarding the relative age and depositional environment characteristics of the Ombilin Formation, both in regional and local contexts, thereby providing supporting data for understanding the geological history and sedimentary evolution of the Ombilin Basin. The results of this study are consistent with various previous studies, indicating that the Ombilin Formation is generally Early Miocene (N5) in age. Furthermore, the interpretation of the depositional environment obtained in this study is also consistent with previous research concluding that the Ombilin Formation was deposited in a marginal to mid-neritic environment. The consistency between the results of this study and previous studies indicates the reliability of the biostratigraphic and paleobathymetric data for the Ombilin Formation.

4. Conclusion

Based on the results of micropaleontological analysis integrated with stratigraphic data and field observations, it can be concluded that the Ombilin Formation in the study area is of Early Miocene (N5) age based on the analysis of planktonic foraminifera fossil associations. Furthermore, analysis of benthic foraminifera indicates that the Ombilin Formation was deposited in a marginal to mid-neritic marine environment at depths ranging from approximately 11–175 fathoms, reflecting shallow- to intermediate-depth marine conditions during sedimentation. Stratigraphically, the Ombilin Formation consists of carbonate-rich sandstone and mudstone lithologies, which support the abundance and preservation of foraminifera fossils that form the basis for biostratigraphic and paleobathymetric interpretations.

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