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RESEARCH ARTICLE

Biostratigraphic Interpretation of Lutut Beds, Kerek Formation, Based on Foraminifera Fossils

Anis Kurniasih [1,*], Ikhwannur Adha[2], Hasnan Lutfi Dalimunthe[1], Reddy Setyawan[1], Wahyu Budhi Khorniawan[1], Nurakhmi Qadaryati[1], Anita Galih Ringga Jayanti[1], Fadyaz Pugu Wijaya[1]

[1] *Department of Geological Engineering, Diponegoro University, Jl. Prof. H. Soedharto S.H. Tembalang Semarang Indonesia*

[2] *Department of Geological Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta, Jl. Padjajaran (Lingkar Utara), Condong Catur, Sleman, Yogyakarta, Indonesia*

* Corresponding author : anis.kurniasih@live.undip.ac.id
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Abstract

Lutut Beds are the sandstone beds exposed in the northwest margin of Kendeng Basin, which contain abundant metamorphic-quartz grains, frequent recycled sedimentary quartz, and reworked bioclasts. Lutut Beds are not shown on the regional geological map and are often neglected in determining the geological history of Kendeng Basin. However, they have significant roles because it was deposited on the basin edge, which may carry important keys. This study aims to discover the larger and smaller foraminifera fossils contained in the Lutut Beds. Outcrop samples were collected in Kali Lutut and its surrounding area, including Lutut Beds and its overlying layers. Larger foraminifera was identified within 3 of 11 thin sections, mostly of Order Rotaliida, which occur as reworked bioclasts. The smaller foraminifera was barely found in most samples except for the samples from the overlying layers of Lutut Beds. The study reveals that Lutut Beds were deposited during Early to Middle Miocene, marked by the occurrence of *Miogypsina* sp. and *Miogypsinoides* sp. and also contains reworked Eocene – Early Oligocene larger foraminifera such as *Nummulites* sp., *Discocyclina* sp., and *Dictyoconus* sp. Besides, the overlying layer of Lutut Beds is identified to be deposited in the Middle Miocene to Pliocene based on the occurence of smaller planktonic foraminifera, *Sphaeroidinella subdehiscens*. The bathymetric interpretation based on smaller benthic foraminifera showed that Lutut Beds were deposited in the upper-middle bathyal zone. We also believe that the larger benthic foraminifera fossils in Lutut Beds were transported along the slope from its original life position. Accordingly, it is considered as allochthonous fossils.

Keywords: foraminifera, Lutut Beds, reworked bioclasts

1. Introduction

Lutut Beds are the layer of sandstone exposed on the north-western edge of the Kendeng Basin. Its type locality, Kali Lutut, is located on the border of Kendal and Temanggung Regencies, Central Java. Van Bemmelen (1949) grouped Lutut Beds into members of the Merawu Formation from North Serayu, while Thaden et al., (1996) concluded that the Lutut Beds series is part of sedimentary rocks from the Kerek Formation of the Kendeng Basin.

Apart from its lithostratigraphic position, Lutut Beds is believed to be one of the most important sandstone layers due to its composition. Lutut Beds is unique because it contains abundant quartz fragment composition in sandstone and conglomerate layers and was deposited in the Miocene period, where the source rock of deposition was not known. The Lutut Beds has very distinctive sandstone units with coarse non-volcanic clasts dominantly composed of mixture of lithic fragments, polycrystalline quartz, and meta-sediments. Locally, limestone fragments and fossils are also presents in the conglomerate section (Lunt, 2013).

Smyth et al. (2008) considered Lutut Beds part of the Kendeng Basin, a quartz sandstone with mixed source rock consisting of metamorphic, volcanic, recycled sedimentary rocks and plutonic quartz. This rock unit also contains bioclastic lithic fragments from Eocene and Oligocene fossils. The potential source rock of the metamorphic-quartz grains in Lutut Beds is the Upper Cretaceous metamorphic series as exposed in the Karangsambung and Jiwo Hills. Based on the abundance of volcanic material and undulating Eocene and Oligocene fauna, the Lutut Beds are interpreted as the product of Miocene uplift and erosion of Lower Cenozoic and older bedrock in the Southern Arc mountains (Smyth et al., 2008).

In the previous study, Smyth et al. (2005) stated that Lutut Beds is interpreted to have been deposited at the southern boundary of the Kendeng Basin, and has experienced deformation and moved north due to reverse faults. Furthermore, they concluded that the Lutut Beds sandstone is the only quartz-rich sandstone in eastern Java with clear evidence of disturbance on older Cenozoic sedimentary rocks exposed on land. Adha and Sapiie (2019) classify the geological structure of the Kali Lutut area into normal faults, thrust faults, and strike-slip faults. Furthermore, they assume that these structures are the last deformation that occurred in the Kendeng Basin, which is thought to have occurred in the Pliocene - Pleistocene. These structures also caused the Lutut Beds sedimentary series to move from its original position to its present position.

The importance of the Lutut Beds in terms of sedimentation and development of Kendeng Basin is that it contains abundant re-working various rock fragments which reserves information about its source and tectonic cause. During Miocene, the northern Sundaland platform had been covered by the Miocene Limestone of Kujung Formation except for Karimunjawa, while the south had been covered with thick volcanic products

(Lunt, 2013). In result, it is not clear whether the potential source rocks were available for erosion during the Lutut Beds formation. Therefore, comprehend knowledge of Lutut Beds is necessary not only to resolve the depositional setting itself but also to answer related questions about the development of sedimentary basins in northern Java.

Based on the importance of Lutut Beds mentioned above, we analyzed the fossils, especially foraminifera fossils, to determine the deposition time and paleoenvironment of Lutut Beds. The results of this study are expected to increase knowledge about the process of Lutut Beds formation.

2. Methods

The main objective of this study was to analyze foraminifera fossils, including smaller and larger foraminifera, contained in rock samples that are representative of Lutut Beds. Analysis of larger foraminifera was performed by thin section description under a polarizing microscope of 11 rock samples. The sampling location is shown in Fig. 1. Identification of larger foraminifera following the catalog compiled by Renema et al. (2003) and BouDagher-Fadel, (2018). Age determination of larger foraminifera followed Tertiary Letter Stages by Vlerk (1955) and Lunt and Allan (2004).

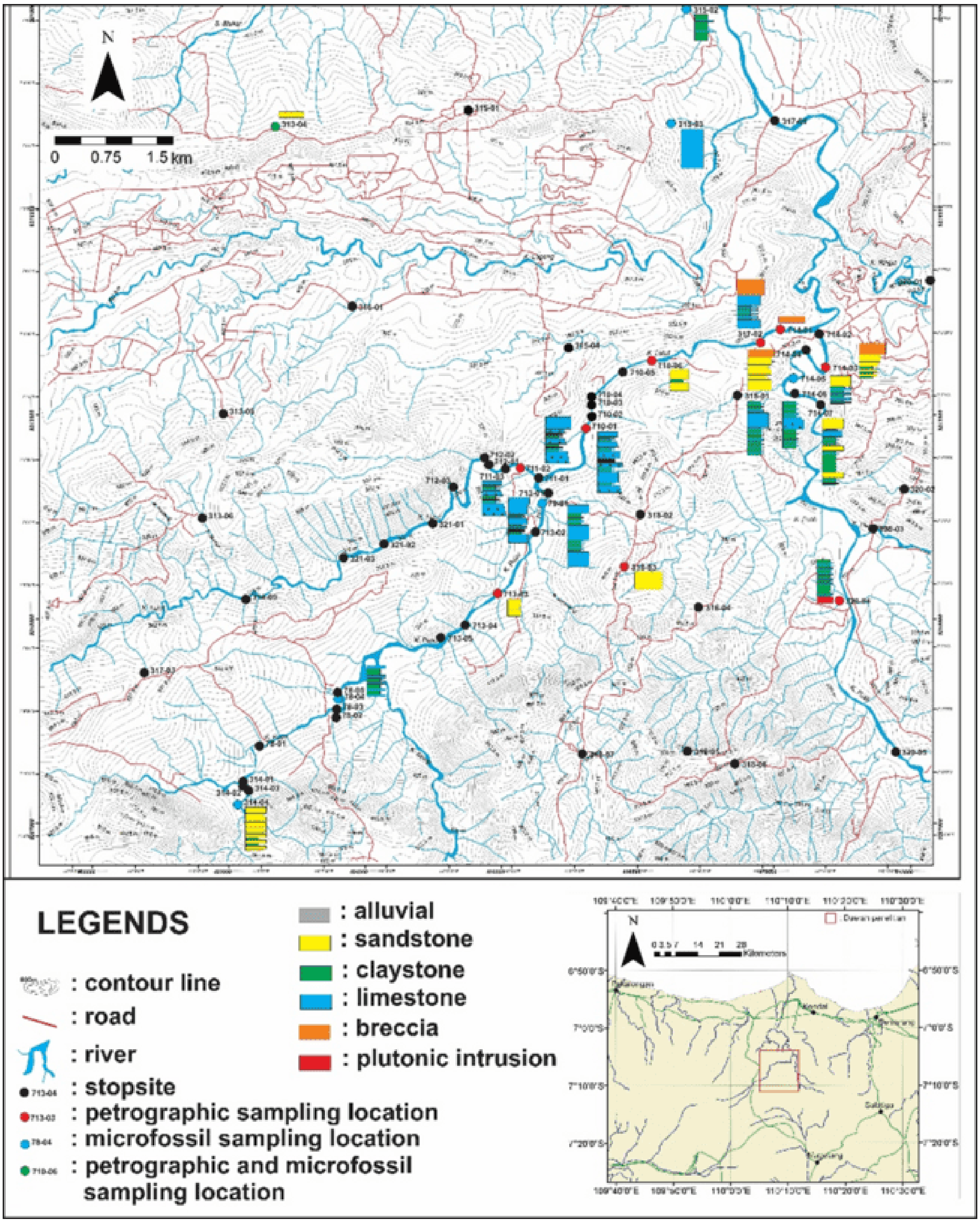

Fig. 1. Map of the study area showing sampling locations for petrographic and microfossil analysis.

Smaller foraminifera analysis was performed by grain sample description on nine rock samples, 4 of which were from Lutut Beds. The foraminifera analysis stage begins with preparation according to the procedure described by Armstrong and Brasier (2005), namely by immersing the crushed sample in a hydrogen peroxide (H_2O_2) solution for ± 24 hours. After 24 hours, the samples were washed thoroughly using running water on a 500 mesh sieve. The clean samples were dried in an oven (50 ℃) until dry. The samples were then flicked to separate foraminifera fossils grain from other sediment grains under an SZ61-type Olympus zoom stereo microscope. This process was carried out for each sample until all the fossils contained in the sample were finished. The fossils taken are then placed in a particular container, and the fossils are ready to be determined. The determination of foraminifera fossils refers to Postuma (1971), Morkhoven et al. (1986), and Loeblich and Tappan (1988). Determining the age of planktonic foraminifera refers to Postuma (1971), and determining the environment of benthic foraminifera follows Holbourn et al. (2013).

3. Results and Discussion

3.1 Lithostratigraphic Interpretation

Based on field investigations, we observe that, in general, the Lutut Beds consist of carbonaceous sandstone-claystone profiles that vertically exhibit fining upward succession (Fig. 2). The bottom of the succession is characterized by a conglomeratic sandstone lithology which has a grain-supported and poorly sorted texture, contains quartz, chert, basalt, larger foraminifera shells, and carbon fragments (Fig. 2) which does not show a particular orientation. Among all these fragments, the quartz fragment appears to be the most dominant and has a rounded grain shape. This observation is supported by petrographic observations, which show the same result (Fig. 4). We also observed distinct sedimentary structures such as convolute (Fig. 3), cross-bedding, slump, and load cast.

The middle part of the succession is characterized by alternating sandstone lithology with claystone (Fig. 3). We noticed the presence of rock fragments in the sandstone layers that were also found in the previous succession but with smaller grain sizes. In this section, the layer of claystone is thickening upward.

The lithology changes at the very top of the succession as the sandstone layer becomes thicker. The claystone layers become thin intercalations between the sandstone layers. Lithic fragments are still found in the sandstone layer, but the number is less.

Based on the lithological characteristics mentioned above, we interpret the Lutut Beds depositional environment to be in a deep marine environment, namely in the middle–distal facies of the submarine fan.

3.2 Smaller Foraminifera Analysis

The foraminifera analysis was carried out on nine samples taken at several locations (Fig. 1). Four represent Lutut Beds (714-05, 710-06, 78-04, 79-01). Among the four samples, one sample, taken from the observation station area 714-05, has fairly abundant planktonic foraminifera fossils, although most of them are fragile and break easily; and the very rare benthic foraminifera (Fig. 5). Samples from station 710-06 had very rare planktonic foraminifera and no benthic foraminifera. In samples from stations 79-01, only benthic foraminifera was found with low populations and diversity, while in samples 78-04, no foraminifera was found.

The foraminifera taxa found in samples 714-05 are *Sphaeroidinella subdehiscens*, *Orbulina universa*, *Globorotalia obesa*, *Globigerinoides immaturus*, *Globigerinoides trilobus*, and *Orbulina bilobata* (Table 1).

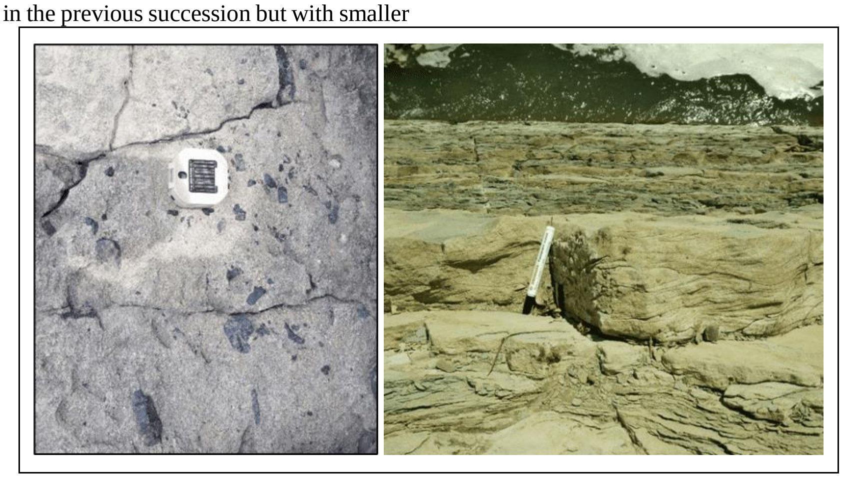

Fig. 2. The lower layer outcrop from Lutut Beds, shows fragments of various materials at observation stations 712-02 (left) and convolute sedimentary structures at the same observation station (right).

Fig. 3. An outcrop photo taken at station 713-04 shows a succession of fining upward claystones intercalated by sandstones.

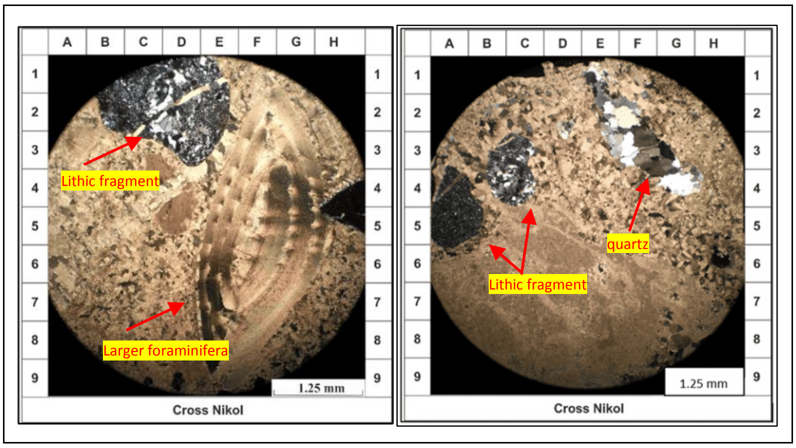

Fig. 4. The petrographic section of rock samples at stations 712-02 shows lithic fragments and larger foraminifera shells.

Based on the fossil assemblage, the relative age of the sample representing Lutut Beds is N13 – N18 (following the biozonation by Blow, 1969) or Middle Miocene to Pliocene. Sample 710-06 has a Pliocene age based on the presence of *Globorotalia plesiotumida*, *Globorotalia tumida*, *Globigerinoides immaturus*, *Orbulina bilobata*, *Globorotalia acostaensis*, and *Orbulina universa* (N18-N21; Blow, 1969). In the sample, there is also a collection of older foraminifera from the Middle Miocene age, which are suspected to be reworked fossils, namely *Globorotalia siakensis*, *Globigerinoides subquadratus*, and *Globigerina praebulloides*.

Based on the analysis of planktonic foraminifera fossils mentioned above, we agreed that the relative age of Lutut Beds rocks is Middle Miocene – Pliocene. This was obtained from the appearance of the diagnostic fossil *Sphaeroidinella subdehiscens* (N13 – N20 in biozonation by Blow, 1969). Thus the Lutut Beds biozonation based on planktonic foraminifera fossils found in the study area is the *Sphaeroidinella subdeshiscens* Zone.

The bathymetric analysis on the two samples (714-05 and 79-01) based on benthic foraminifera showed that Lutut Beds were deposited in the upper-middle bathyal (Table 2).

3.3 Larger Foraminifera Analysis

Analysis of larger foraminifera using thin sections was taken from 11 petrographic samples to determine the relative age and depositional environment. Of all the samples, we identified the presence of larger foraminifera in three samples, 710-01C, 710-06A, and 711-02A. At least seven genera were found in sample 710-01C, namely Miogypsina, Miogypsinoides, Lepidocyclina, Nummulites, Dictyoconus, Discocyclina, and Assilina (Fig. 6). According to Vlerk (1955) and Lunt and Allan (2004), Miogypsina and Miogypsinoides are Early Miocene diagnostic fossils, while Lepidocyclina is generally found in Early Oligocene to Late Miocene rocks. In addition, Nummulites were also found, known as diagnostic fossils for the Eocene – Early Oligocene, along with other Paleogene foraminifera such as Dictyoconus, Discocyclina, and Assilina. Therefore, we have found two distinct ages of the large foraminiferal assemblages, Eocene–Early Oligocene and Early Miocene (Table 3), and we agree that the Eocene–Early Oligocene fossil assemblages occurred as reworked fossils. Thus, the Lutut Beds sandstones are interpreted to have been deposited in the Early Miocene based on large foraminifera. Meanwhile, the petrographic analysis showed that these reworked fossils occurred as part of lithic bioclasts.

Similar results were also seen in the other two samples. Petrographic observations indicated the presence of Nummulites in sample 710-06A and large fragments of Nummulites, which partially recrystallized in sample 711-02A (Fig. 4, left). As stated in the previous samples, the Numulites in the last two samples also appeared as lithic fragments/bioclasts.

Based on these results, we assume that the biostratigraphic zonation of Lutut Beds based on larger foraminifera is Miogypsina – Miogypsinoides Zone.

Fig. 5. Planktonic foraminifera fossils in sample 714-05 (left) and benthic foraminifera in sample 79-01 (right).

Table 1. Relative age determination of the sample representing Lutut Beds indicating Middle Miocene - Late Miocene and Pliocene; the species in the yellow table are identified as reworked fossils.

		Planktonic Foraminifera Biozonation (Blow, 1969)																						
		Oligocene			Miocene														Pliocene				Pleistocene	
					Early					Middle							Late							
Sample Code	Planktonic Foraminifera	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23
714-05	*Sphaeroidinella subdehiscens*																							
	Orbulina universa																							
	Globorotalia obesa																							
	Globigerinoides immaturus																							
	Globigerinoides trilobus																							
	Orbulina bilobata																							
710-06	*Globorotalia tumida*																							
	Globorotalia siakensis																							
	Globigerinoides immaturus																							
	Orbulina bilobata																							
	Globigerinoides subquadratus																							
	Globorotalia acostaensis																							
	Globigerina praebulloides																							
	Orbulina universa																							

Table 2. Bathymetric determination based on benthic foraminifera in samples representing Lutut Beds which shows upper bathyal to middle and upper bathyal zone.

		Bathymetric Zone						
Sample Code	Benthic Foraminifera	Littoral	Inner Neritic	Outer Neritic	Upper Bathyal	Middle Bathyal	Lower Bathyal	Abyssal
714-05	*Cibicidoides barnetti*							
	Elphidium crispum							
	Bathysiphon sp.							
79-01	*Quinqueloculina sp.*							
	Cibicidoides barnetti							
	Cibicidoides pachiderma							
	Cibicidoides praemundulus							
	Bathysiphon sp.							

Table 3. Relative age determination based on the presence of larger foraminifera in the Lutut Beds samples. Sample 710-01C has two groups of larger foraminifera assemblage which respectively show Early Miocene and Eocene-Oligocene (reworked) ages. Reworked fossils from the Nummulites Genus were also found in samples 710-06A and 711-02A.

		Paleocene	Eocene			Oligocene					Miocene				
		Early	Early	Middle	Late	Early		Late			Early		Middle	Late	Pliocene
Sample Code	Larger Foraminifera Taxa	T.a1	T.a2	T.a3	T.b	T.c	T.d	Te.1	Te.2-3	Te.4	Te.5	T.f1	T.f2	T.f3	T.h
710-01C	Lepidocyclina														
	Miogypsina														
	Miogypsinoides														
	Assilina														
	Nummulites														
	Dictyoconus														
	Discocyclina														
710-06A	Nummulites														
711-02A	Lepidocyclina														
	Nummulites														

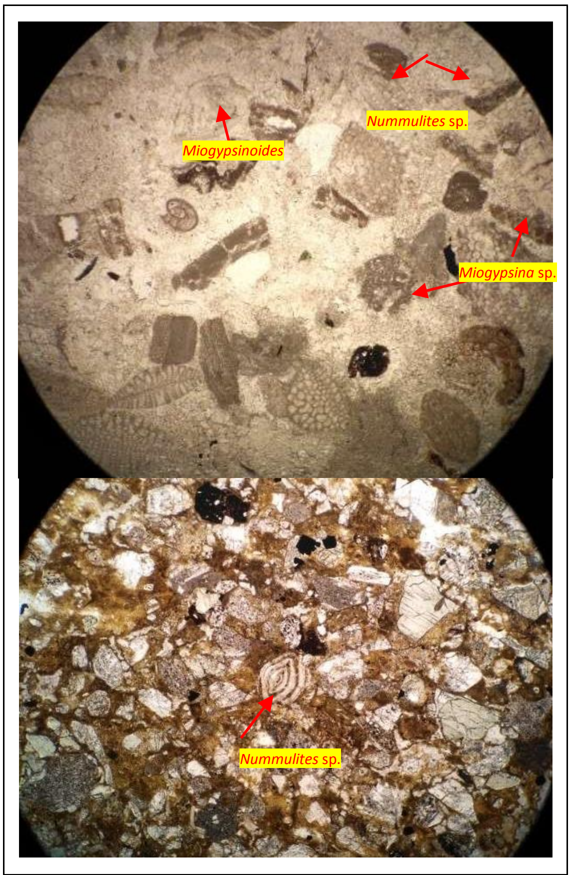

Fig. 6. Appearance of larger foraminifera fossil assemblages in 710-01C (left) and 710-06A (right) samples.

Meanwhile, we tried to analyze the depositional environment based on larger foraminifera, but several limitations prevented this from being carried out. Reworked fossils are not used for this purpose, so we only use Early Miocene fossil assemblages as indicators of depositional environment. Most larger foraminifera genera occupy a neritic environment near the reef ecosystem. Some genera are part of the reef ecosystem (Boudagher-Fadel, 2018). Hottinger (1983) notes that light penetration and water are the two most important parameters affecting the distribution of larger foraminifera, whereas temperature and salinity are factors that act only locally. Thus, we can use larger foraminifera as an indicator of depth. We noted the presence of Miogypsina-Miogypsinoides in sample 710-01C. We suspect these fossils appear to be allochtonous, meaning they cannot be used as indicators of paleoenvironments. Boudagher-Fadel (2018) and BouDagher-Fadel and Price (2013) mentioned that Miogypsina-Miogypsinoides were occurred only in shallow water marine limestones, associated with fossil algae. They believe that Miogypsinids such as Miogypsina cannot grow on flat surfaces, requiring them to attach to curved substrates such as macroalgae or seagrass. Therefore, if Miogypsina is to be fossilized as a living (autochtonous) assemblage, the macroalgae must be found in thin rock sections. However, we found no algae fossils in the samples during our observations. Thus, we assume that the foraminifera fossil grains were most likely transported from their habitat and preserved as dead assemblages (allochtonous or thanatocoenosis fossils). In addition, we observed in thin sections that Miogypsina-Miogypsinoides grains were preserved along with lithic grains from undulated sandstones, quartz, and bioclasts. This strengthens the argument that this larger foraminifera was transported and preserved together with other grains available at the bottom of the waters.

We believe the larger foraminifera fossils in the Lutut Beds were transported along the slope. Hohenegger and Yordanova (2001) concluded that larger foraminifera could be transported due to three factors, one of which was the steepness of the slope. On steep slopes (>30˚), the main possible transport mechanism is by gravity, and on flat slopes, transport is primarily driven by water movement. To support this assumption, we confirm the lithostratigraphic description. Sedimentary structures such as convolute, load cast, and slump, referred to as water-escape structures by Lowe (1975), are common in rocks deposited on steep slopes. These structures exhibit unconsolidated sediment displacement or movement in environments with steep slopes and fast sedimentation rates. This Interpretation is also consistent with the results of depth zone analysis based on smaller benthic foraminifera, which shows Lutut Beds were deposited in the upper to middle bathyal zones. This depth zone generally has a seabed morphology in the form of steep slopes.

4. Conclusion

We conclude that Lutut Beds sandstones were deposited in the Middle Miocene to Pliocene or N13 – N18 according to the planktonic foraminifera biozonation by Blow (1969) based on planktonic foraminifera fossils from sample 714-05. Meanwhile, based on the analysis of large foraminifera in sample 710-01C, we interpret that the Lutut Beds sandstone is Early Miocene age. This discrepancy is due to random sampling in the field without considering the stratigraphic position. Therefore, we assume that sample 714-05 is younger than sample 714-05 and both samples did not come from an identical stratigraphic position. We also found that Lutut Beds contain larger foraminifera from the Eocene – Early Oligocene fossil assemblages, such as Nummulites, Dictyoconus, Discocyclina, and Assilina which are present as lithic bioclasts.

Analysis of the depositional environment based on fossil characteristics and lithostratigraphic data, we conclude that Lutut Beds was deposited in a steep slope environment in the upper-middle bathyal zone.

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