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RESEARCH ARTICLE

Relative Age and Depositional Environment of The Limestone Unit of Karangsambung Formation in Jatibungkus Hill, Kebumen Geopark, Indonesia

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Abstract

The Jatibungkus Hill is an isolated karst hill and is one of the olistolith fragments in the Karangsambung Formation deposited as olistostrome deposits. This formation formed above the Luk-Ulo Mélange Complex, one of the geological heritage sites in the Kebumen Geopark. The presence of limestone as a fragment in the olistostrome deposits requires further investigation because its formation history is related to regional geological history. This study aims to determine the relative age and depositional environment of limestone in Jatibungkus Hill based on microfossil analysis through petrographic observations. Of the 39 rock samples obtained during field data collection, 15 rock samples were selected for petrographic analysis. The petrographic analysis is divided into two parts, namely descriptive methods and point counting as the basis for classifying carbonate rocks. Based on the classification results, reef facies analysis was conducted using facies zonation and standard microfacies (SMF) to obtain an overview of the limestone depositional environment. In addition, the types of large foraminifera fossils and algae were also used as a basis for determining the relative age. The lithology found in the research area consist of packstone, rudstone, grainstone, and crystalline limestone. The limestone depositional environment is located in SMF 4, SMF 5, and SMF 6 which are included into FZ 4 (Slope) on a restricted carbonate platform. This facies zone influenced by currents and waves between the storm base wave and the normal base wave. The petrographic analysis showing the domination of large bioclastic grain indicating that the deposition were under a high energy. The influence of waves is also reflected in the mixture of bioclass and lithoclast grains or high-density terrigenous clastics that are observed in most of the samples. This facies contains more quartz clastics and bioclast grains than carbonate mud as consistently observed in the identified samples.The association of large benthic foraminifera fossils and algae indicates that the limestone was formed in Zone Ta1 (Late Paleocene) characterized by the presence of *Discocyclina* sp., *Ranikothalia* sp., *Nummulites* sp., *Miscelanea* sp., *Distichoplax biserialis*, and *Parachaetes* sp. It can be seen that the deposition of the limestone olistolith occured after the initial subduction event which produced the mélange complex in Early Cretaceous.

Keywords: limestone, Karangsambung Formation, olistostrome, petrography, Kebumen Geopark

1. Introduction

The Kebumen Geopark is a geological heritage site within the Karangsambung-Karangbolong National Geopark (GNKK) area. The diverse rock outcrops provide evidence of subduction and collision between Sundaland and the East Java Microcontinent during the Early Cretaceous to Paleocene (Hall, 2012). The Luk-Ulo Mélange Complex is evidence of this subduction product, composed of a mixture of rocks from oceanic and continental plates. Overlying this formation are Paleogene sedimentary layers, namely the Karangsambung Formation and the Totogan Formation. The presence of distinctive fragments or boulders (olistoliths) in random layers is caused by gravity-driven sedimentation in an active tectonic basin (Asikin, 1974). These boulders and fragments consist of foraminiferal limestone and conglomerate, ranging in size from a few meters to hundreds of meters in length.

The complex geological history makes Karangsambung-Karangbolong an interesting location for geological research, so that quite a lot of research has been done in this area. Most of the previous research focused on the characteristics and petrogenesis of Luk-Ulo metamorphic complex, including that conducted by Sucipta (2006), Harsolumakso et al. (2016), Pratama et al. (2017), Nurhayati (2018), and Isyqi and Anshori (2021). These studies took metamorphic rocks in the Luk Ulo mélange group as the main object for interpreting the tectonic history of the Karangsambung complex. Other researchs focusing on tectonic evolution are Isyqi et al. (2019), Anshori et al. (2019), and Nugroho et al. (2021) which uses a seried of granitoid rocks as basis for reconstructing the tectonic origin of the exotic blocks. Along with the designation of Karangsambung-Karangbolong as a national geopark, research in the field of geodiversity in this area has also begun to be carried out, including by Fadlin et al. (2020), Anshori et al. (2021), and Anshori et al. (2023).

According to Hall (2012), the Jatibungkus Hill is an olistolith fragment within the Karangsambung Formation formed by gravity landslides. This process produces a mixed sedimentary rock characterized by oceanic and continental plates. The Jatibungkus Hill consists of coral limestone that have undergone karstification and formed several karst caves within them, including Langse Cave, Silodong Cave, and Sikempul Cave. These caves are located relatively close to each other and have several distinctive ornaments inside the caves, including stalactites, stalagmites, and several other ornaments (Wardhani et al., 2020).

Despite of the Jatingkus Hill's uniqueness, the age and depositional setting of this limestone olistolith remains ambiguous. Asikin (1974) stated in his research that the Karangsambung Formation was deposited during Middle to Late Eocene. Another research mentioned that the Karangsambung Formation is the result of olistolostromic deposits of Middle-Late Eocene to Oligo-Miocene age (Harsolumakso & Noeradi, 1996). Research in Karangsambung-Karangbolong has been conducted more on mélange and ophiolite groups, while research on the olistolith section the Karangsambung Formation and its relationship to regional geological history is still limited. Questions regarding the presence of limestone as fragments in olistostrome deposits require further investigation.

Based on this background, this study was conducted to determine the relative age of the Jatibungkus limestone olistolith based on the occurence of larger foraminiferal fossils and to estimate its depositional environment. Both of these factors are important for supporting a thorough and comprehensive understanding of the geological history of Karangsambung. Analysis of mineral composition and fossils in limestone through thin section observations can assist in the interpretation of facies and formation environments as has been done by Adhari and Hidayat (2023), and Khorniawan et al. (2024). The abundance of larger benthic foraminifera fossils in limestone is also reliable as a basis for determining the relative age of rocks (Djunaedi and Taufiq, 2010; Nisa et al., 2023).

2. Materials and methods

Fieldwork resulted in 39 rock samples representing the entire research area (Fig.1). Of these 39 samples, 15 were selected that met laboratory testing criteria and were representative for use in petrographic analysis. These fifteen samples were selected based on their macroscopic characteristics, which are consedered to represent each variation of the limestone group. Thin sections were prepared at Obsidian Geo Laboratory Services, Bandung, Indonesia.

Petrographic analysis is divided into two parts: descriptive and point counting methods. The descriptive method is descriptive observation using an Olympus polarizing microscope at the Mineral Resources Laboratory, Diponegoro University. Observations and descriptions of thin section characteristics include composition, texture, and rock structure. From 15 thin sections, each sample was divided into three fields of view. The microscope objective lens used in this analysis used 4x magnification due to the grain size of the foraminifera fossils being large enough to allow observation of the entire morphology in one filed of view. However, in several observations of smaller fossil minferal grains, ore detailed observations were also carried out using 10x magnification. Rock components were quantitatively calculated using point counting analysis using ImageFocusAlpha software. In practice, each sample contains a minimum of 300 points or approximately 100 points in each field of view to achieve ideal and representative criteria. The grid spacing in point counting is set at 1 mm each based on consideration of the grain size of larger foraminifera fossils and mineral grains. The frequency of identified mineral grains and fossils is calculated from how many points are visually included in the mineral and fossil grains. This frequency is expressed in percentage (relative abundance) calculated based on the following formula:

$$P(\%) = \frac{Sn}{T} \times 100 \qquad (1)$$

Where:

P(%)= relative abundance of each grain

Sn= the number of points counted on a specific grain

T= total number of measured points

Based on the petrographic analysis and point counting results, carbonate rocks were classified using the classifications by Dunham (1962) and Embry & Klovan (1971). Based on these classifications, reef facies analysis was performed using facies zonation and Standard Microfacies (SMF) by Wilson (1975). The carbonate facies zone applied in this study refers to the type of restricted carbonate platform (rimmed platform setting). The Standard Microfacies (SMF) analysis is based on the type of carbonate grains, paleontological data, micrite abundance, carbonate fabrication, and carbonate rock classification that has been carried out previously. These data were then used to reconstruct the carbonate depositional environment in the study area. Identification of large benthic foraminifera fossils in this study uses references by Boudaugher-Fadel (2018). Algae identification uses references from Lunt & Allan (2004). The relative age of carbonate rocks is obtained from the abundance of large foraminiferal fossils based on the letter stage classification of Vlerk & Umbgrove (1927) with modifications by Lunt & Allan (2004) who added several types of algae that characterize certain ages. Determination of the relative age of rocks is limited to the content of large foraminiferal fossils and algae in thin sections.

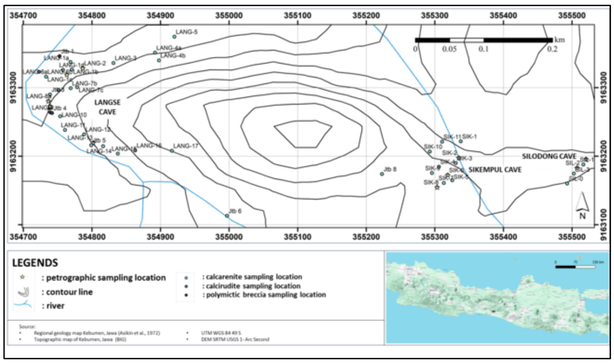

Fig. 1. Map of sampling locations

3. Results and Discussions

3.1 Limestone Microfacies Analysis

A total of 15 limestone samples in the Jatibungkus Hill Complex were subjected to petrographic analysis using descriptive and quantitative methods (point counting). Composition identification was divided into allochem, orthochem, cement, and voids (pores). Then, the percentage of allochem and orthochem was normalized to be classified into the Dunham (1962) and Embry & Klovan (1971) classifications. The detailed relative abundace of each sample are given in the Table 1.

3.1.1 Packstone

Packstone can be found in LANG-1C and SIK-8. The microscopic appearance that can be observed is the occurence of large bioclast allochem accompanied by the presence of carbonate mud (Fig. 2a). In some samples, minerals are found present as clastic grains (Fig. 2a) and some others as diagenetic products. Contacts between grains in each sample tend to float and touched (point), as can be seen in Fig. 2b. Some mineral formations resulting from diagenesis appear to adapt to the shape of the bioclasts they replace.

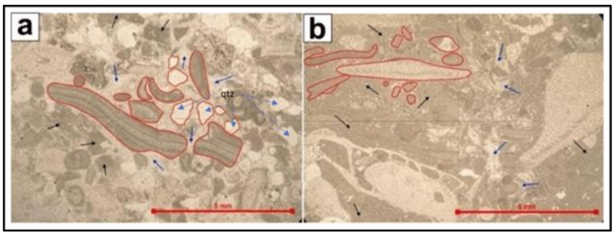

Fig. 2. Parallel nicol view in samples LANG-1C (a) and SIK-8 (b), it appears that the allochem has floating and point contacts, tends to float on carbonate cement (black arrows) and the cavities between grains are filled by cement (dark blue arrows).

3.1.2 Rudstone

Rudstone is represented by samples JTB-5, JTB-5+, LANG-8A, LANG-8B, and LANG-13, which are located close to each other. The microscopic appearance that can be observed is the appearance of dominantly large allochem containing bioclasts reaching more than 10%. The largest allochem dimension in this rock reaches 15 mm (Fig. 3d). The carbonate mud is limited and filled the space between the bioclasts. These samples share a common texture, containing >10% allochem with a size of >2 mm, thus classifying them as rudstone. In general, the allochem content present in the five samples consists of large foraminifera, algae, ooids, other bioclasts, and quartz clastic.

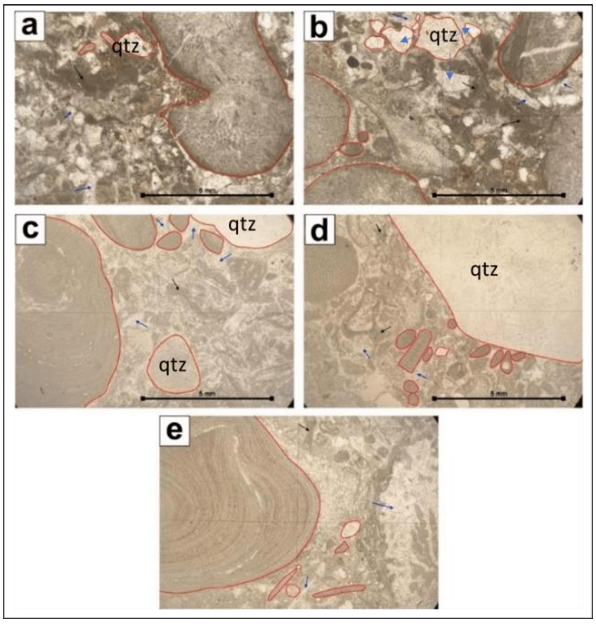

Fig. 3. Parallel nicol views in sections (a) JTB-5, (b) JTB-5+, (c) LANG-8A, (d) LANG-8B, (e) LANG-13 show that the allochem has floating and point contacts, tending to float on carbonate cement (dark blue arrows). In images (a) and (b) carbonate mud can still be seen with clotted distribution in certain fabrications (black arrows).

3.1.3 Grainstone

The lithological distribution of grainstone was found in SIK-2, SIK-6, and SIL-2, characterized by microscopic grain-supported and matrix-free fabrication. The allochem content in each rock reaches >90% (Fig. 4). Point counting analysis shows that the allochem composition in the three samples reaches >90%, thus identifying them as grainstone.

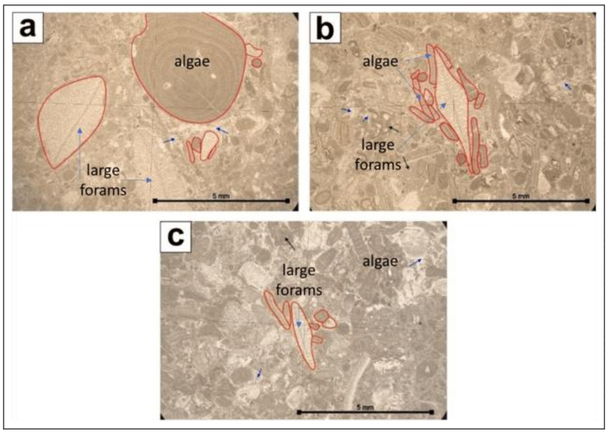

Fig. 4. Parallel nicol views in sections (a) SIK-2, (b) SIK-6, (c) SIL-2 showing grain-supported fabrication with point to concavo-convex contact types. As seen in the image, the composition is dominated by allochem measuring <5 mm. The black arrow indicates the matrix and the dark blue arrow indicates the cement.

3.1.4 Crystalline Limestone

This lithology can be found in JTB-3, JTB-4, JTB-6, JTB-8, and LANG-2. The formation process of this lithology is greatly influenced by diagenesis and karstification processes after the rock is exposed to the surface. On megascopic view, this appearance is difficult to distinguish and identify. In microscopic appearance, most to all depositional structures can no longer be observed (Fig. 5). However, some sections still show relict structures from the original depositional texture (Fig. 5c). The size of allochem grains that can still be identified ranges from <2 mm to >5 mm. The largest identified allochem has a size of 6 mm. Based on the unobservable depositional texture, the description of this rock is consedered as crystalline limestone.

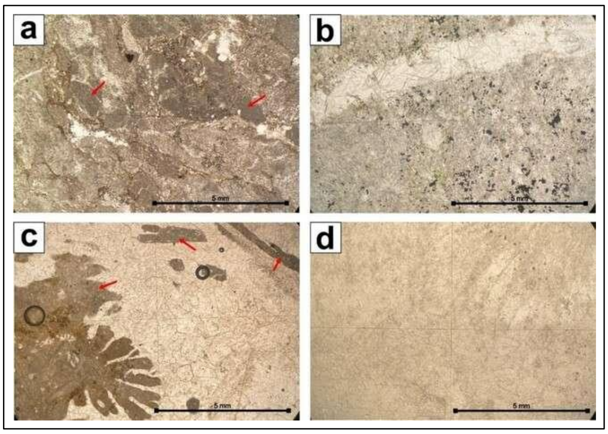

Fig. 5. Variation in the appearance of rock textures petrographically from (a) JTB-3, (b) JTB-4, (c) JTB-6, (d) LANG-2. The image above is a parallel nicol view. Micrite can be observed in (a) and (c) marked with red arrows.

The facies and environmental analysis of carbonate rocks in this study used data from petrographic analysis. Of the 15 thin-section samples, 10 were selected, not belonging to the crystalline limestone type, with well-preserved depositional textures.

Table 1. The relative composition and special features of each sample.

Sample Code	Relative Composition (%)				Special Features	Identification based on Dunham (1962) and Embry & Klovan (1971)
	Allochem	Orthochem	Cement	Pore		
JTB-3	3	51	45	1	The sample has undergone diagenesis and neomorphism processes.	Crystalline
JTB-4	0	0	91	9	The sample has undergone diagenesis and neomorphism processes.	Crystalline
JTB-5	56.72	23.66	18.82	0.54	The allochem consist of foraminifera, algae, quartz, ooid, pisoid	Rudstone
JTB-5+	71.51	4.03	24.19	0.27	The allochem consist of foraminifera, algae, quartz, ooid, pisoid	Rudstone
JTB-6	29	22	49	0	The sample has undergone diagenesis and neomorphism processes.	Crystalline
JTB-8	0	0	100	0	The sample has undergone diagenesis and neomorphism processes.	Crystalline
LANG-1C	53.23	5.65	41.13	0	Quartz clastics are very dominant among algal and foraminiferal bioclasts	Packstone
LANG-2	0	34	66	0	The sample has undergone diagenesis and neomorphism processes.	Crystalline
LANG-8A	46.77	13.44	39.78	0	Large quartz clasts are frequent among the bioclasts of foraminifera and algae.	Rudstone
LANG-8B	70.16	8.87	20.97	0	Large quartz clasts are frequent among the bioclasts of foraminifera, algae, and mollusc.	Rudstone
LANG-13	62.9	5.11	31.99	0	Large bioclast of foraminifera and algae are frequent	Rudstone
SIK-2	70.97	1.34	26.08	1.61	The allochem dominantly consist of foraminifera and algae; sparit fills the gaps between grains	Grainstone
SIK-6	83.33	6.08	8.99	0.55	The allochem dominantly consist of foraminifera and algae	Grainstone
SIK-8	44.35	30.38	24.46	0.81	The allochem consist of foraminifera, algae, molluscs, ooid, peloid; no quartz grains found	Packstone
SIL-2	73.12	1.08	25.27	0.54	The allochem consist of foraminifera, algae, molluscs, ooid, peloid	Grainstone

Based on the allochem and orthochem compositions in the rocks, the limestones of the Jatibungkus Hill are generally composed of bioclastic and clastic materials with a small amount of micrite. Bioclastic materials include algae, foraminifera, corals, and various shallow marine organisms. The type of algae that can be found mostly in all sections is the lithophylloid algae, namely Distichoplax biserialis, followed by geniculate coralline algae and Solenoporacean algae. Coralline algae are the main sediment producers in carbonate formation environments. Miliolides can be found in several rock samples, which characterizes the association of organisms that live in shallow and clear marine environments. Large foraminifera of the Nummulites type and red algae thrive well in the oligophotic zone (lower mesophotic) with sufficient light intensity but located slightly deeper.

From these conditions, it can be seen that reef development in the study area is caused by collapse and debris flow mechanisms, resulting in a mixture of organisms from the photic zone. This statement is supported by the presence of quartz clastic grains commonly found in several rock samples. The exposure developing in the study area can likely be categorized as a rimmed shelf. Under rimmed platform conditions, the highest carbonate production intensity occurs on the outer and middle exposures, referred to as the subtidal carbonate factory (James, 1984). The standard microfacies and facies zones identified in this study are as follows:

a. SMF 4 (Microbreccia Bioclastic-Lithoclastic Packstone)

Thin sections that can be categorized into this microfacies are samples JTB-5, JTB-5+, LANG-1C, LANG-8A, LANG-8B, and LANG-13. Based on its texture, this type of microfacies is characterized by a massive or gradational structure with a medium to coarse bioclastic texture, poor sorting, and angular-subrounded roundness. The main constituent of this microfacies is characterized by reworked grains, composed of mixed fragments of both cemented bioclasts and lithoclasts, commonly found quartz or chert fragments, and other carbonate fragments. The carbonate mud content in this microfacies is not dominant due to the high abundance of allochem grains. The petrographic evidence on this can be seen at Fig. 3 which shows the abundance of quartz grains.

b. SMF 5 (Bioclastic Grainstone-Packstone Floatstone)

The rock sample that can be categorized into this microfacies is sample SIK-8. The main composition of the rock consists of bioclasts from organism's characteristic of the reef top and reef flank, commonly found filling fine sediment in the pore cavities. In this rock (SIK-8, Fig. 2b), the foraminifera species identified are Discocyclina sp., Ranikothalia sp., and Miscellanea sp. The genus Nummulites is generally deposited in environments with strong sedimentary energy (Rahmawati, 2012). It can be interpreted that SMF 5 shows a carbonate rock formation environment caused by quite high sedimentary energy. The high sedimentary energy causes the breakdown of reef-origin material to be transported and deposited on the reef slope. This facies is located on the front of the reef slope or reef flank.

c. SMF 6 (Reef Rudstone)

Rock sections categorized as this microfacies include samples SIK-2, SIK-6, and SIL-2. These rock fossils are dominated by algae, followed by large foraminifera. In general, this microfacies indicates a depositional process that occurred at the front of a reef slope that progressed seaward. This microfacies is characterized by the presence of large bioclasts (Fig. 4) as markers of the reef top and reef flank, and the absence of carbonate mud in the rocks. The high bioclast content in the rocks is influenced by high depositional energy, as it was formed by debris flow mechanisms resulting from erosion of the reef top and reef flank (Shima, 2014). The presence of the genus Discocyclina indicates that the carbonate formation environment was influenced by varying hydrodynamic energy (Rahmawati, 2012).

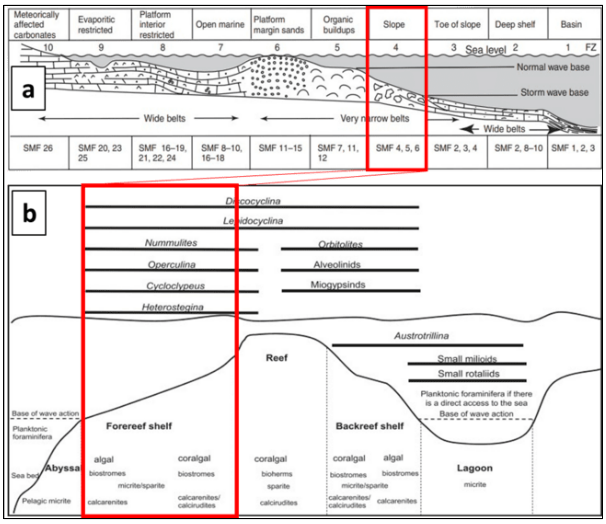

Fig. 6. (a) The study area is included in the FZ 4 (slope) according to the facies zone and SMF model on a restricted carbonate platform by Wilson (1994), shown by the red box; (b) Distribution of large benthic foraminifera on the Tethys carbonate exposure in general (Boudaugher-Fadel, 2018). The study area is located in the red box.

Based on the identification of Standard Microfacies (SMF) above, the association of Facies Zone (FZ) 4 is obtained, namely slope which is located on a restricted carbonate platform (rimmed platform setting) (Figure 6a). This facies is equivalent to a fore slope or fore reef according to the limestone depositional environment by James (1984). Wilson (1975) described this area as a facies characterized by fine to coarse grained rocks accompanied by breccia and exotic blocks, deposited on the edge of the shelf towards the sea to the end of the shelf (<200 meters) with a slope of 5-90°, possibly there is a collapse of carbonate rocks previously originating from FZ 5 (the shelf edge reef). FZ 4 is still influenced by currents and waves because it is located between the storm base wave and the normal base wave. This can be seen by the dominantly large size of bioclastic grain (SIK-2, SIK-6, and SIL-2) showing that the deposition of the grains were under a high energy. The influence of waves is also reflected in the mixture of bioclass and lithoclast grains or high-density terrigenous clastics that are deposited within this rock, as can be seen in samples JTB-5, JTB-5+, LANG-1C, LANG-8A, LANG-8B, and LANG-13 (Fig. 3). Therefore, this facies contains more quartz clastics and bioclast grains than carbonate mud as consistently observed in the identified samples. The change in rock component type, initially dominated by quartz clastics, then by foraminifera, and then by algae, is interpreted as an environmental change trend that moves closer to the reef core, but remains on the slope of a carbonate shelf (Fig. 6b).

3.1 2. Relative Age Analysis

The determination of the age of the rocks in this study uses the age range association of large benthic foraminifera fossils and algae based on the Tertiary Letter Stages classification by Lunt & Allan (2004). The description of the index fossils found in the limestone in the Jatipakang Hill Complex is as follows.

a. *Discocyclina* sp.

Discocyclina belongs to the Orthophragminidae family (Fig. 7a), that lived in shallow marine environments from the Paleocene to the Late Eocene (Özcan et al., 2022).

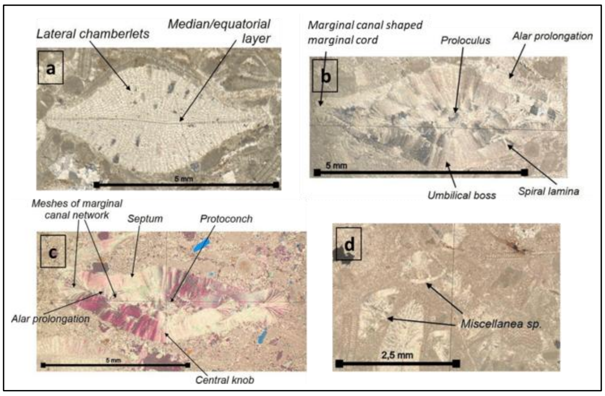

Fig. 7. (a) Axial section morphology of Discocyclina (parallel section, not cutting the embryonic chamber); (b) Axial section morphology of Nummulites in a thin section of limestone sample SIL-2; (c) Axial section morphology of *Ranikothalia* sp. in a thin section of sample LANG-13; (d) Appearance of *Miscellanea* sp. in a thin section (crossed nicol appearance) of limestone sample SIK-8.

b. *Nummulites* sp.

Nummulites belong to the order Rotaliida, a large family of Nummulitoidea (Fig. 7b) that lived in the Late Paleocene in shallow marine environments.

c. *Ranikothalia* sp.

Ranikothalia Caudri, 1944, also known as *Nummulites nuttali* Davies, 1927, is a species of the Nummulitidae family that is a marker of Late Paleocene age (Fig. 7c).

d. *Miscellanea* sp.

Miscellanea Pfender, 1935 or *Nummulites miscella* d'Archiac and Haime, 1835 is a large foraminifera from the Miscellaneidae family. Miscellanea lived during the Paleocene (Boudaugher-Fadel, 2018). The Miscellanea individuals found in the rock sections of this study were limited to vertical parallel sections (Fig. 7d) with sections that were less able to show every part of the morphology, making their morphological appearance difficult to identify. This limitation results in uncertainty regarding the identity of larger foraminifera fossils, considering that morphological observations of larger foraminifera require identification of horizontal and vertical sections.

e. *Distichoplax biserialis*

Distichoplax biserialis (Dietrich, 1927) is a species of red algae belonging to the subfamily Lithophylloideae. This algal species is commonly used to date Late Paleocene (Thanetian) (Fig. 8a). The abundance of Distichoplax biserialis was generally accompanied by the presence of geniculate coralline algae, non-geniculate Sporolithon, and large benthic foraminifera such as Orthophragminida before its eventual extinction due to the Paleocene-Eocene Thermal Maximum (PETM) and Larger Foraminiferal Turnover (LFT) (Sarkar, 2018).

f. *Parachaetetes* sp.

Parachaetetes is a genus of red Solenoporacean algae (Fig. 8b) that is a major reef builder in carbonate shelf environments.

The association of large foraminiferal fossils and identified algae indicates that the limestone formed in Zone Ta1 or equivalent Late Paleocene biostratigraphic units (Table 2) based on the occurence of index fossils such as *Ranikhotalia* sp., *Miscellanea* sp., algae *Distichoplax biserialis*, and algae *Parachaetetes* sp.

Table 2. Interpretation of relative ages based on the association of large foraminiferal fossils (indicated by red boxes)

	Late Paleocene	Early Eocene	Middle Eocene	Late Eocene	Early Oligocene	
Index Fossilf of the Indo-Pacific region	Ta1	Ta2	Ta3	Tb	Tc	Td
Discocyclina	🟩	🟩	🟩	🟩		
Ranikothalia	🟩					
Nummulites (radial/sigmoid)	🟩	🟩	🟩	🟩	🟩	🟩
Miscellanea	🟩					
Distichoplax biserialis	🟩					
Parachaetetes	🟩					

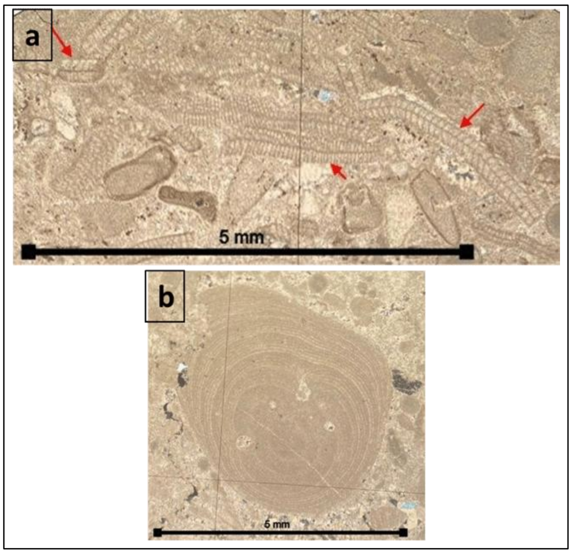

Fig. 8. (a) Concentration of *Distichoplax biserialis* in limestone sample SIK-6 (red arrow); (b) Appearance of algae *Parachaetetes* sp. in thin section (crossed nicol view) of limestone sample SIK-2.

The results of this research analysis show that the limestone olistolith of Jatibungkus Hill were deposited in a carbonate slope environment during Late Paleocene. Hall (2012) mentioned that the Indo-Australian oceanic plate has been subducting beneath the Eurasian continental plate since the Early Cretaceous resulting in the formation of Karangsambung accretionary-collisional complex. Therefore, it can be seen that the deposition of the limestone olistolith ccured after the initial subduction event which produced the mélange complex. The termination of subduction and uplift of the Luk Ulo Mélange Complex happened due to the reduction in subduction velocity resulting in no fossils of Early Paleocene rocks (Asikin, 1994). During this period carbonate began to form, as explained by Putra and Praptisih (2020) which stated that in Middle Paleocene, a shallow marine to deep marine depositional environment developed in this area, ideal for reef development. Reefs began to dominate deep to shallow marine areas on a limited carbonate shelf. These conditions were also supported by a global warming climate in the Late Paleocene and the rapid resurgence of larger foraminifera following the Late Cretaceous mass extinction (Boudaugher-Fadel, 2018).

In Late Paleocene, limestone was formed, currently exposed in the study area, the Jatibungkus Hill. It is known that the carbonate exposure continued to develop until the Middle Eocene (Lunt & Allan, 2004). This statement is supported by the presence of Early Eocene limestone olistoliths within mudstones located in the Sana River, which is only a few hundred meters from the Jatibungkus Hill. Evidence of the presence of Middle Eocene planktonic foraminifera is also common around the study area, indicating that the carbonate formation environment in the study area continued to develop until the Middle Eocene (Putra & Praptisih, 2020).

It should be emphasize that the result of relative age interpretation in this study refer to the age of limestone olistolith that are fragments within the Karangsambung Formation. According to Asikin (1974), the Karangsambung Formation itself was formed in the Middle Eocene – Oligocene. The presence of large sizes olistolith can be explained by landslide mechanisms, slumps, or turbidite sedimentation due to gravity transport in an accretionary tectonic environment (Harsolumakso & Noeradi, 1996). Therefore, it can be interpreted that the limestone olistolith of Jatibungkus was mixed with other olistoliths during the depositional of the Karangsambung Formation.

7. Conclusions

Based on the analysis of the association of large benthic foraminifera fossils and algae, it was concluded that the limestone in the Jatibungkus Hill was formed in the biostratigraphic unit of Zone Ta1 or equivalent to the Late Paleocene, characterized by the presence of characteristic fossils namely Discocyclina sp., Ranikothalia sp., Nummulites sp., Miscelanea sp., Distichoplax biserialis, and Parachaetes sp. The limestone unit was formed in a slope area in a limited carbonate exposure environment, this was obtained based on the analysis of standard microfacies included in SMF 4, 5, and 6 which are part of the rimmed platform setting facies zone (FZ 4).

This research has limitations, especially in the identification stage of index fossils, which requires an ideal section to reveal the key morphology for identification, but this is not always achieved considering that the position of fossil grains in the rock is not uniform. Eventhough microfacies analysis is a powerful tool for determining the depositional environment of limestone, it has several major limitations such as diagenetic alteration which often destroy the original features making it difficult to determine the original microfacies. In addition, the certain microfacies type can be formed in several environments creating ambiguity in interpretation.

Despite of these limitations, this study contributes to clarifying the position of the Jatibungkus limestone as an olistolith within the Karangsambung Formation. The age analysis of the Karangsambung Formation itself needs to be further investigated by analyzing its matrix samples, although this can be difficult due to the potential for olistolith whose lithological characteristics resemble the matrix, which could potentially lead to misinterpretation.

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