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Macrofossil Characteristics and Bathymetric Environment of Sumber Makmur Village, Muara Sahung, Kaur, Bengkulu

Dita Maulia, Idarwati*
[1] Universitas Sriwijaya, Palembang, Indonesia
*e-mail: idarwati@ft.unsri.ac.id

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Abstract

The research location is administratively located in Sumber Makmur Village, Muara Sahung District, Kaur Regency, Bengkulu Province. In the study area, outcrops that had fossils were found, which were shown by the presence of carbonate rock lithology. The study was conducted to determine the deposition environment in the research area. The method used is a previous literature study that aims to determine the physical geological conditions and regional stratigraphy of the research area. Furthermore, field observations and laboratory analysis were conducted in the form of paleontological analysis to determine the characteristics and types of fossils found in the study area. Paleontological research was conducted on two formations, namely the Lemau Formation and the Simpangaur Formation. In the Lemau Formation, several species of benthic foraminifera were found, namely *Cibicides praecinestus*, *Elphidium macelium*, *Marginopora vertebralis*, *Elphidium articulatum*, and *Planorbulina mediterranensis*. Then, in the Simpangaur Formation, several species of benthic foraminifera were found, namely *Streblus beccari*, *Bolivina schwageriana*, *Anomalinella rostrate*, *Cibides praecinestus*, *Cibides margaritiferus*, Lagena sulcata, *Quinqueloculina bradyana*, and *Lenticulina calcar*. In addition, macrofossils were found in marine life with phylum mollusks such as *Lunatia elevatum*, *Murex vanuxemi*, *Turritella terebra*, *Conus sauridens*, and *Plocostoma neumayeri*. Based on these data, it can be interpreted that the depositional environment in the study area is in the Transition-Edge Neritic marine environment.

1. Introduction

The research location is administratively located in Sumber Makmur Village, Muara Sahung District, Kaur Regency, Bengkulu Province. This research is interesting because, in the study area, rock outcrops containing macrofossils and microfossils were found. The abundant presence of fossils in the study area makes it easy to interpret the depositional environment of the area. A depositional environment is a place where sedimentary material deposits accumulate that have chemical, physical, and biological conditions that characterize the mechanism of certain depositions. Regionally, the research area is located in the Bengkulu Basin, which is one of the forearc basins in Indonesia [1]. The forearc region is a zone in front of the volcanic arc, including the accretionary complex. The formation of the forearc basin occurs in the Neogene, and the filled sediments come from the transport of the Barisan Hills [2]. The NE-SW Bengkulu Basin is different from the NW-SE-oriented formation of Sumatra. In the formation process, the Bengkulu Basin experienced a rifting phase in the Paleogene–Eocene, which resulted in the formation of graben [3]. The development of the Bengkulu Basin began in the Early Tertiary. Then, in the Early Miocene, we experienced subsidence slowly. The uplift of the Barisan Mountains in the Late Miocene triggered magmatism.

The stratigraphic development of the Bengkulu Basin began in the Early Tertiary. The Late Cretaceous–Early Tertiary formation of the Bengkulu Basin opened up space in bedrock [4]. The opening of this space was accompanied by the deposit of rocks and lava originating from the Barisan Hills, which is the process of formation of the Upstream Formation. During the Paleocene–Eocene Period, fluvial deposits derived from alluvial fan-shallow marine were deposited, resulting in the creation of the Seblat

Formation, which was deposited at the maximum peak of the transgression phase [4]. Plutonic rocks such as granite and diorite of the Middle Miocene age break through the Upstream Formation and Seblat Formation [5]. Then, in the Middle Miocene–Late Miocene, there was a regression phase that formed the Lemau Formation, which was composed of breccia fragments of dacite, sandstone, claystone with coal inserts, limestone, and limestone. Then, in the Late Miocene–Pliocene, the Simpangaur Formation was deposited in harmony with the Lemau Formation, consisting of claystone, siltstones, sandstone inserts, tuffaceous sandstones, and mollusk sandstones [5]. The Simpangaur Formation has sandstone lithology containing mollusks with abundant availability [6]. The Bintunan Formation is composed of tuff lithology, polemic conglomerates, and claystone with lignite inserts deposited in the Plio-Pleistocene in harmony with the Simpangaur Formation, which forms an interfingering Quaternary alluvium composed of the lithology of chunks, gravel, sand, silt, mud, and clay deposited in the Quaternary and is the youngest rock unit in the Bengkulu Basin [7]. (Figure 1).

The research area consists of three formations arranged from old to young, namely the Lemau Formation, the Simpangaur Formation, and the Andesite-Basalt Lava Volcano Unit. The Lemau Formation is of the Middle-Late Miocene age and is composed of limestone, sandstone, and claystone. The Simpangaur Formation is of Late Miocene-Pliocene age and is composed of tufa sandstones and sandstones containing mollusks. The andesite-basalt lava volcano unit consists of andesite-basalt breccia rock units of Holocene age.

Fossils are the remains of bodies, shells, or traces of organisms that lived in the past and were preserved naturally for millions of years. Traces of life in the past can be recognized in geological knowledge by the presence of fossils [8]. Fossils are generally found in sedimentary rocks, especially sedimentary rocks containing carbonates. Fossils are indicators of past events reflected in animal or plant life lithified in rocks called fossils to determine the relative age and environment of the deposition. Fossils based on their size are divided into two types, namely macrofossils that can be seen with the ordinary eye and microfossils that can only be seen with the help of tools such as binocular microscopes [9]. Macrofossils are mostly bones and teeth from vertebrates. Often, they are also found in the form of shells from mollusks and brachiopods, as well as exoskeletons from crustaceans, coral organisms, and woody parts from plants [7].

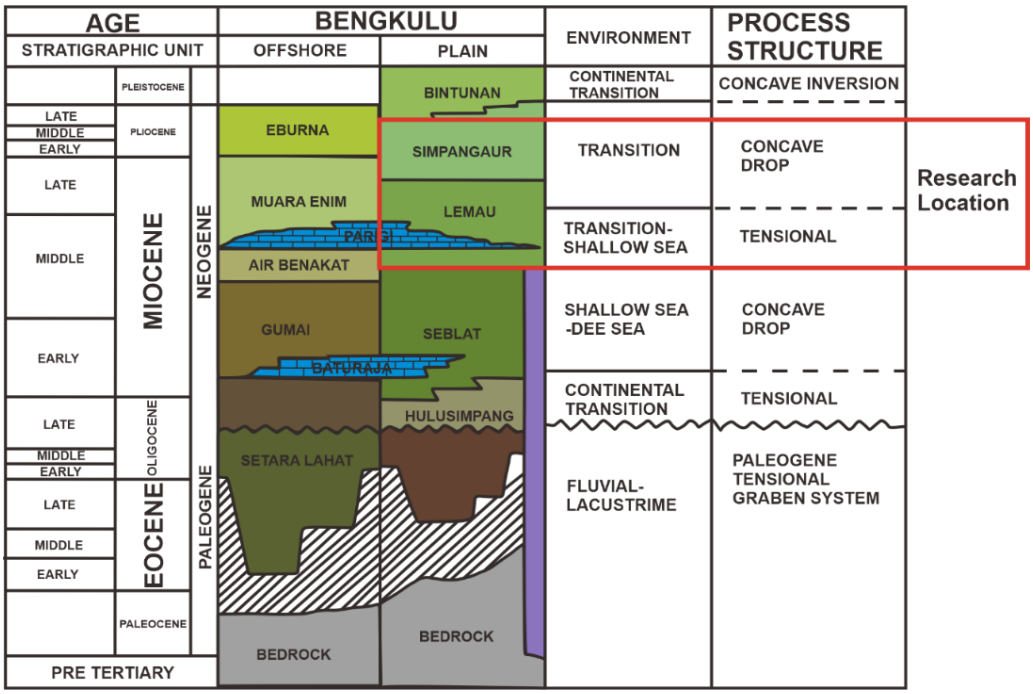

Figure 1. Regional Stratigraphy of the Study Area

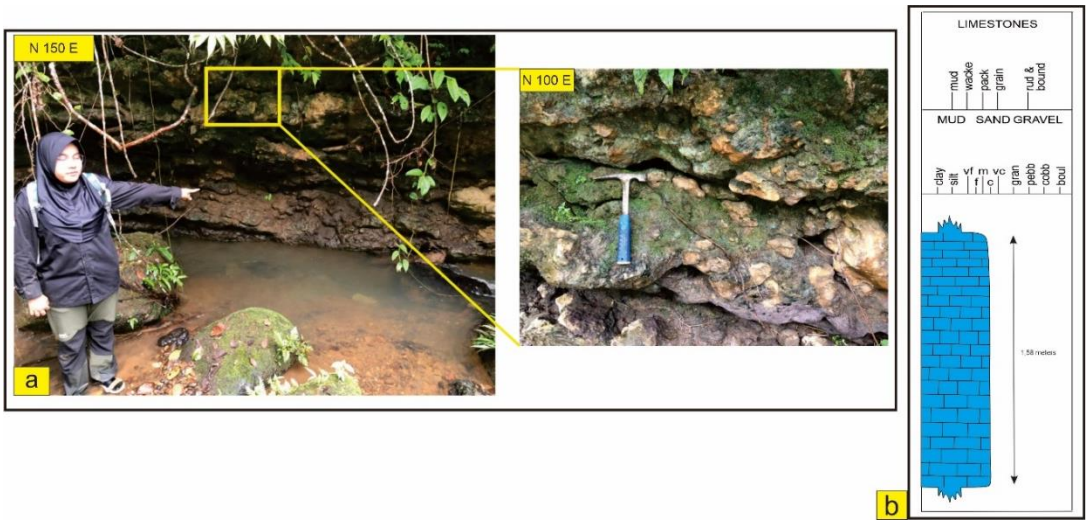

Figure 2. a) Research Location 2, b) Stratigraphic Profile of Research Location 2 in Simpanggaur Formation

In comparison, most microfossils are found in the form of fossils from foraminifera. Foraminifera are single-celled organisms that live in the ocean. Foraminifera first appeared in the Jurassic Period, then expanded rapidly into the Tertiary and Quaternary Periods. Foraminifera has a small size of around 0.005 mm, and the foraminifera is referred to as a microfossil. Foraminifera have locomotion in the form of pseudopodia [10]. Pseudopodia are also used as a means of predation and self-defense by such organisms. Foraminifera have shells that form chambers connected by a foramen. The substances that form the shells of foraminifera, such as limestone, silica, chitin, and agglutin, have a high level of resistance, so many of these groups are preserved as fossils. Foraminifera are very sensitive to environmental conditions and are often associated with certain environments [11]. This is why foraminifera fossils are often used by paleontologists to reconstruct the environment of the past. Fossils that can generally be used to determine the depositional environment are benthic foraminifera that live on the ocean floor [12]. Benthic foraminifera are abundant in the ocean. Benthos is an organism that lives in water, either sessile or vagile. The existence of benthos is influenced by two factors, namely biotic factors in the form of benthos food sources themselves and abiotic factors in the form of chemical and physical factors such as temperature, current, oxygen demand, and depth. Benthic foraminifera fossils are also known as bathymetric fossils. The bathymetric zone is divided into five [13], namely:

- Littoral is a coastal area or shore that is a place of tides and tides.
- Neritic is a marine environment with a depth of 0–200 meters. In this zone, many types of organisms are found, such as shellfish and coral reefs.
- Bathyal is a marine environment that has a limit of 200–4000 meters.
- Abyssal is a marine environment with a depth of 4000–5000 meters. This zone has high pressure and is dark and cold.
- Hadal is a marine environment with a depth of >5000 meters, also called a “trough.”

Research on fossils conducted in the Sumber Makmur area, Muara Sahung District, Kaur Regency, Bengkulu Province, is very interesting because in this area there has been no research that discusses the characteristics of fossils found in the study area so that later the depositional environment and the relative age of the Lemau and Simpangatur Formations can be known.

2. Methodology

The research methods used are literature studies, field observations, analysis of paleontological data, and interpretation of research results. Literature studies from various previous studies were used to determine the regional geological conditions and regional stratigraphy of the research area. Next, field observations took the form of identifying outcrops and taking rock samples containing fossils in the research area. The laboratory analysis process consists of paleontological analysis which includes preparing rock samples using H2O2 (hydrogen peroxide), which aims to clean fossil shells from attached sedimentary material so as to facilitate the observation process and determine the type of fossil, both

macrofossils and microfossils. After the preparation process continues with picking fossils using a needle which is viewed using a binocular microscope. Then, after the picking process, the microfossils are named which will later be used to determine the bathymetric environment of the research location. In paleontological analysis, macrofossil observations were carried out on five types of fossils and microfossil observations on thirteen types of fossils.

3. Results and Discussions

The research area consists of three formations: the Lemau Formation, the Simpangaur Formation, and the Andesite-Basalt Lava Volcano Unit. In the Lemau Formation, lithology was found in the study area in the form of limestone, sandstone, and claystone. In the Simpangaur Formation in the study area, there are mollusk sandstones and tufa sandstones. In the volcanic quarter, andesite-stacked breccia lithology was found. Based on field observations, only two formations contain fossilized rocks, namely the Lemau and Simpangaur Formations

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3.1 Lemau Formation

The location of this research is Ulak Bandung Village, precisely on a tributary of the Luas River. At the location of this study, lithology was found that is carbonate, which indicates that the lithology most likely contains fossils. The lithology found at this research site is limestone. Here is the appearance of the outcrop from study site 2 (Figure 2).

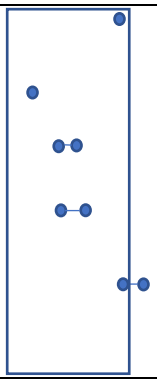
Limestone at this location has a weathered blackish-brown color and creamy fresh color, a palm grain size of 1/16–2 mm, a moderate sorting degree sorted to well sorted, rounded roundness, and is carbonate. After paleontological analysis, five types of benthic foraminifera were found, namely *Cibicides praecinestus* (37 ft), *Elphidium macelium* (6 ft), *Marginopora vertebralis* (15–20 ft), *Elphidium articulatum* (16–25 ft), and *Planorbulina mediterranensis* (38–40 ft).

a) *Cibicides praecinestus*

Cibides praecinestus is a species of benthic foraminifera. This fossil has been found in as many as seven species. *Cibides praecinestus* has a polythalamous chamber arrangement with a uniformed type and includes uniserial. The test form of this species is planispiral. *Cibides praecinestus* has a round shell to the right (dextral) and an aperture is a simple aperture in the last chamber. This species is found at a depth of 37 fathom.

Figure 3. Appearance of Benthic Foraminifera Fossils Found at Study Site 2:
(a) *Cibicides praecinestus* (37 ft), (b) *Elphidium macelium* (6 ft), (c) *Marginopora vertebralis* (15–20 ft), (d) *Elphidium articulatum* (16–25 ft), and (e) *Planorbulina mediterranensis* (38–40 ft).

Table 1. Determination of the Bathymetric Environment of the Research Location 2 Lemau Formation

No	Bathymetric Environment of Benthonic Foraminifera	Transition	Neritic			Bathyal		Abyssal
			Inner	Middle	Outer	Upper	Lower	
		0	20	100	200	500	2000	5000
a	*Cibicides praecinestus (37f)(C)*							
b	*Elphidium macelium (6ft)(C)*							
c	*Marginopora vertebralis (15-20ft(C)*							
d	*Elphidium articulatum (16-25ft) (C)*							
e	*Planorbulina mediterranensis (38-40ft)(R)*							

b) *Elphidium macelium*
Elphidium macelium is a species of benthic foraminifera. This fossil is common in about six species. *Elphidium macelium* has a polythalamous chamber arrangement with a uniformed type and includes uniserial. *Elphidium macelium* has a shell rotation to the right (dextral) and involute and has an aperture that is a simple aperture in the last chamber. This species is found at depths of 6 fathom.

c) *Marginopora vertebralis*
Marginopora vertebralis is a species of benthic foraminifera. This fossil is common in about eight species. *Marginopora vertebralis* has a monothalamous chamber arrangement with a tabular test shape. This species has a simple aperture that is at the base of the aperture face and is found at depths of 15–20 fathom.

d) *Elphidium articulatum*
Elphidium articulatum is a species of benthic foraminifera. This fossil is common in about eight species. *Elphidium articulatum* has a polythalamous chamber arrangement with a uniformed type and includes uniserial. This species has dextral and involute shells. *Elphidium articulatum* has a simple aperture that is in the last chamber and is found at depths of 16–25 fathom.

e) *Planorbulina mediterranensis*
Planorbulina mediterranensis is a species of benthic foraminifera. This fossil has only been found in three species. *Planorbulina mediterranensis* has a polythalamous chamber arrangement with a uniformed type and belongs to the uniserial. This species has a round shell towards the right (dextral). *Planorbulina mediterranensis* has a simple aperture that is in the last chamber and is found at depths of 38–40 fathom. The following features of the benthic foraminifera at study site 2 can be seen below (Figure 3).

Based on the results of paleontological data analysis, in the Transition-Neritic Edge Sea, some quite abundant fossils were found, such as *Cibicides praecinestus*, *Elphidium macelium*, *Marginopora vertebralis*, and *Elphidium articulatum*, so it can be interpreted that the Lemau Formation was deposited in the Transition-Neritic Edge marine environment [14].

B. Simpangaur Formation

The research location is located in Talang Padang Village. At this research location, lithology was found in the Simpangaur Formation, which contained fossils, namely mollusk sandstones. In this lithology, several macrofossils of marine life, such as mollusks, were also found. Here is the appearance of the outcrop from study site 74 (Figure 5).

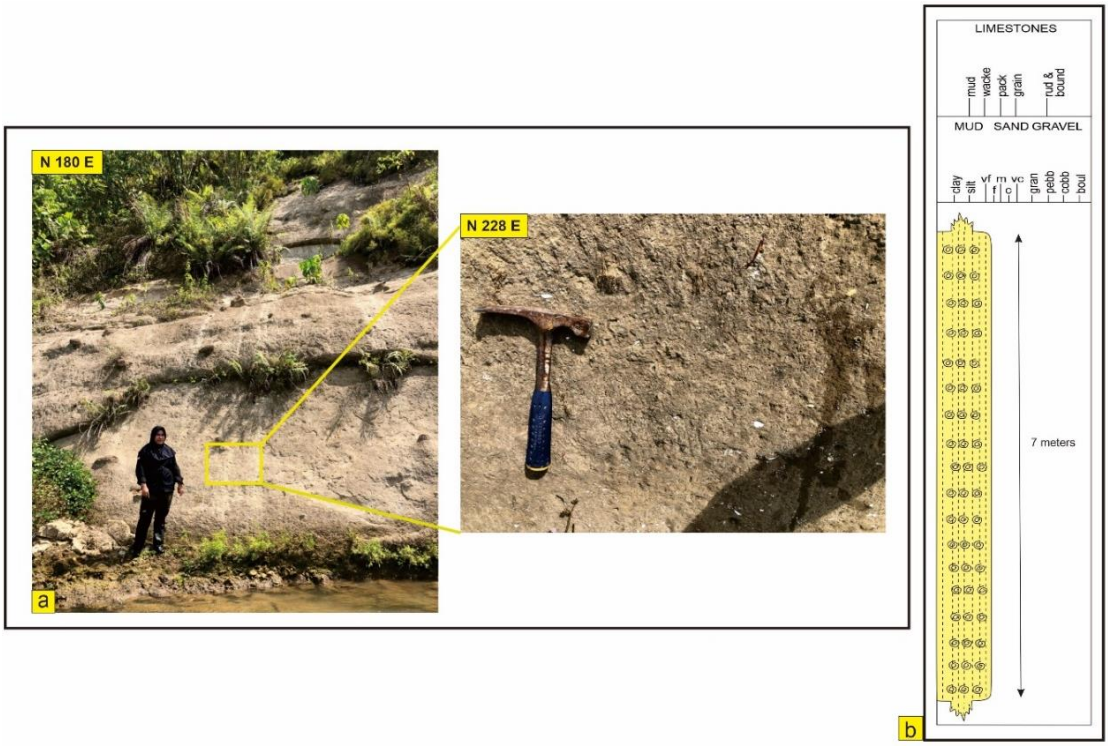


Figure 5. a) Research Location 76; b) Stratigraphic Profile of Research Location 76 in the Simpangaur Formation

Based on observations, the sandstone at this study site has a dark brown weathered color and a fresh brownish-gray color. It has a fine sand grain size of 1/8–1/4 mm with a degree of well-sorted and rounded dressing. These rocks are carbonate and contain macrofossils in the form of marine life (mollusks). After paleontological analysis, several types of benthic foraminifera were found, namely *Streblus beccari* (8 ft), *Bolivina schwageriana* (37 ft), *Anomalinella rostrate* (37 ft), *Cibides praecinestus* (37 ft), *Cibides margaritiferus* (95–100 ft), *Lagena sulcata* (20–60 ft), *Quinqueloculina bradyana* (38–40 ft), and *Lenticulina calcar* (95–100 ft).

a) *Streblus beccari*

Streblus beccari is a species of benthic foraminifera. This fossil is abundantly found in about twenty species. *Streblus beccari* has a polythalamous chamber arrangement with a uniformed type and includes uniserial. The test form of this species is planispiral and has a round shell to the right (dextral). Planispiral is a test formation that only rotates on one flat plane. Planispiral is divided into two, namely involute and evolute. *Streblus beccari* has an evolved test formation. This species has a simple aperture that is in the last room and is found at a depth of 8 fathom.

b) *Bolivina schwageriana*

Bolivina schwageriana is a species of benthic foraminifera. This fossil is common in about seven species. *Bolivina schwageriana* has a polythalamous chamber arrangement with a uniform type and includes biserials. Biserial is a form of test that is composed of two rows of rooms located alternately. This species has an aperture, a simple aperture, which is in the last room and is found at a depth of 37 fathom.

c) *Anomalinella rostrata*

Anomalinella rostrata is a species of benthic foraminifera. This fossil is found in abundance in about eighteen species. *Anomalinella rostrata* has a monothalamous chamber arrangement with a zigzag test shape and a shell rotation to the right (dextral). This species has a simple aperture that is in the last room and is found at a depth of 37 fathom.

d) *Cibides praecinestus*

Cibides praecinestus is a species of benthic foraminifera. This fossil is common in about six species. *Cibides praecinestus* has a polythalamous chamber arrangement with a uniformed type and includes uniserial. Uniserial is a form of room that consists of one arrangement of rooms and a row of rooms. The test form of this species is planispiral. This species has a round shell to the right (dextral) and an aperture that is a simple aperture in the last chamber. This species is found at a depth of 37 fathom.

e) *Cibides margaritiferus*
Cibides margaritiferus is a species of benthic foraminifera. This fossil is rare; it is only found in about two species. *Cibides margaritiferus* has a polythalamous chamber arrangement with a uniformed type and includes uniserials. The test form of this species is planispiral. It has a shell rotation to the right (dextral) and an aperture that is a simple aperture in the last room. This species is found at depths of 95–100 fathom.

f) *Lagena sulcata*
Lagena sulcata is a species of benthic foramimnifera. This fossil is common in about eight species. *Lagena sulcata* has a monothalamous chamber arrangement in the form of a test bottle (flarka-shaped). The monothalamous is a form of foraminifera chamber consisting of only one chamber. This species has a simple aperture at the base of the aperture face. This species is found at depths of 20–60 fathom.

g) *Quinqueloculina bradyana*
Quinqueloculina bradyana is a species of benthic foramimnifera. This fossil is found in abundance in about 23 species. Q*uinqueloculina bradyana* has an arrangement of monothalamous chambers with a hemispherical test shape. This species has a simple aperture at the base of the aperture face. This species is found at depths of 20–60 fathom.

h) *Lenticulina calcar*
Lenticulina calcar is a species of benthic foraminifera. This fossil has been found in only four species. *Lenticulina calcar* has an arrangement of monothalamous chambers with a zigzag test shape. This species has a simple aperture at the end of the aperture face. This species is found at depths of 95–100 fathom.

Based on the results of paleontological data analysis, the Transition-Neritic Edge Sea found some abundant fossils, such as *Streblus beccari*, *Anomalinella rostrata*, and *Quinqueloculina bradyana,* and found fossils with moderate abundance, namely *Bolivina schwageriana* and *Cibides praecinestus,* so that it can be interpreted that the Lemau Formation was deposited in the Transition-Neritic Edge marine environment [14].

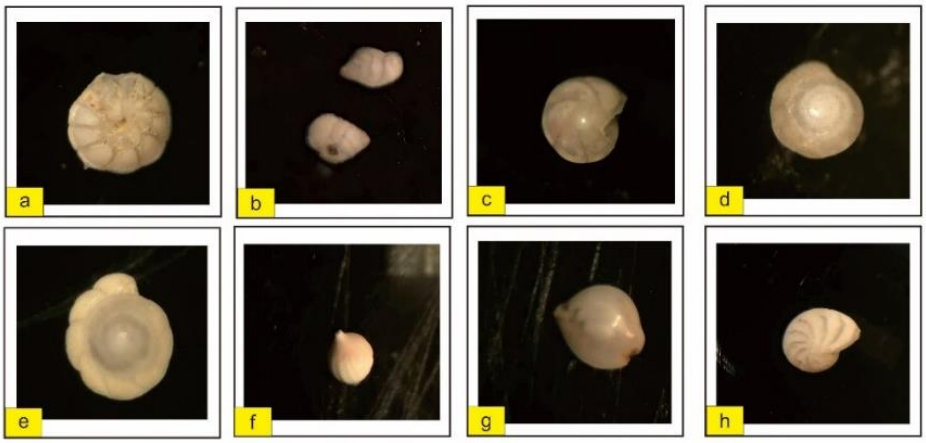


Figure 6. Appearances of Benthic Foraminifera Found at Study Site 76: (a) *Streblus beccari*, (b) *Bolivina schwageriana*, (c) *Anomalinella rostrata*, (d) *Cibides praecinestus*, (e) *Cibides margaritiferus*, (f) *Lagena sulcata*, (g) *Quinqueloculina bradyana*, and (h) *Lenticulina calcar*

Table 2. Determination of the Bathymetric Environment of the Research Location 2 Lemau Formation

No	Bathymetric Environment of Benthic Foraminifera	Transition	Neritic			Bathyal		Abyssal
			Inner	Middle	Outer	Upper	Lower	
		0	20	100	200	500	2000	5000
a	*Streblus beccari (8 ft)(A)*							
b	*Bolivina schwageriana (37 ft)(C)*							
c	*Anomalinella rostrata (37 ft)(A)*							
d	*Cibides praecinestus (6 ft)(C)*							
e	*Cibides margaritiferus (95–100 ft)(R)*							
f	*Lagena sulcate (20–60 ft)(R)*							
g	*Quinqueloculina bradyana (20–60 ft)(A)*							
h	*Lenticulina calcar (95–100ft)(R)*							

In addition to benthic foraminifera fossils, these rocks also contained macrofossils in the form of marine life (Mollusca). Here are some of the species found at the study site, as follows:

a) *Lunatia elevatum*

Lunatia elevatum belongs to the phylum Mollusk, class Gastropoda, order Caenogastropoda, family Tylosmatidae, and genus *Lunatia*. Lunatia elevatum is a predatory type of snail. This species has a shell measuring 5–6 cm. The color is brownish, and there are fine stripes on the shell with a limestone composition. *Lunatia elevatum* has a shell that rotates to the right (dextral). This species lives by creeping, is solitary, and lives in warm-temperature environments. This species lives in marine environments and can be found in the Transition-Neritic Zone (0–200 m). Based on Mc. Graw-Hill (1952), this species is Miocene-Resent [15].

b) *Murex vanuxemi*

Murex vanuxemi belongs to the phylum Mollusk, class Gastropoda, order Neogastropoda, with the family Muricacea and genus *Murex*. *Murex* is a type of sea snail that acts as a predator and is a carnivorous animal. According to Pondes & Vokes (1988), *Murex* is spread throughout the Indo-Pacific region. This species has a shell measuring 5–6 cm, and the spiny part, which is usually used to protect itself from prey during its lifetime, has a tapered shell at the top. This species has a round shell towards the right (dextral). This species has a shell that is brownish-white in color, and there are firm stripes on the shell with a limestone composition. This species lives in a creeping and solitary manner. This species lives in the Transition-Neritic marine environment (0–200 m).). This species is Eocene-Resen [15].

c) *Turritella terebra*

Turritella terebra belongs to the phylum Mollusk, class Gastropoda, order Caenogastropoda, with the family Turritellidae and genus *Turritella*. *Turritella* belongs to the predatory sea snail family and has an operculum. The operculum is a body structure in the class of gastropods that serves as a cover or protector [15]. *Turritella* has radula teeth that contain toxins harmful to annelids and nematodes. This species has a shell size of about 6–7 cm and a tapered and long conical shell that is brownish, and there are fairly firm lines in the shell that are limestone in composition. This species has a round shell that is directed to the right (dextral). *Turritella* lives by creeping below the surface of the sea and lives solitary. *Turritella* used to live in mangrove forest areas, and the sea receded to the offshore sea and warm coastal reefs [16]. This species lives in the Transition-Neritic marine environment (0–200 masl). This species is Eocene-Recent [15].

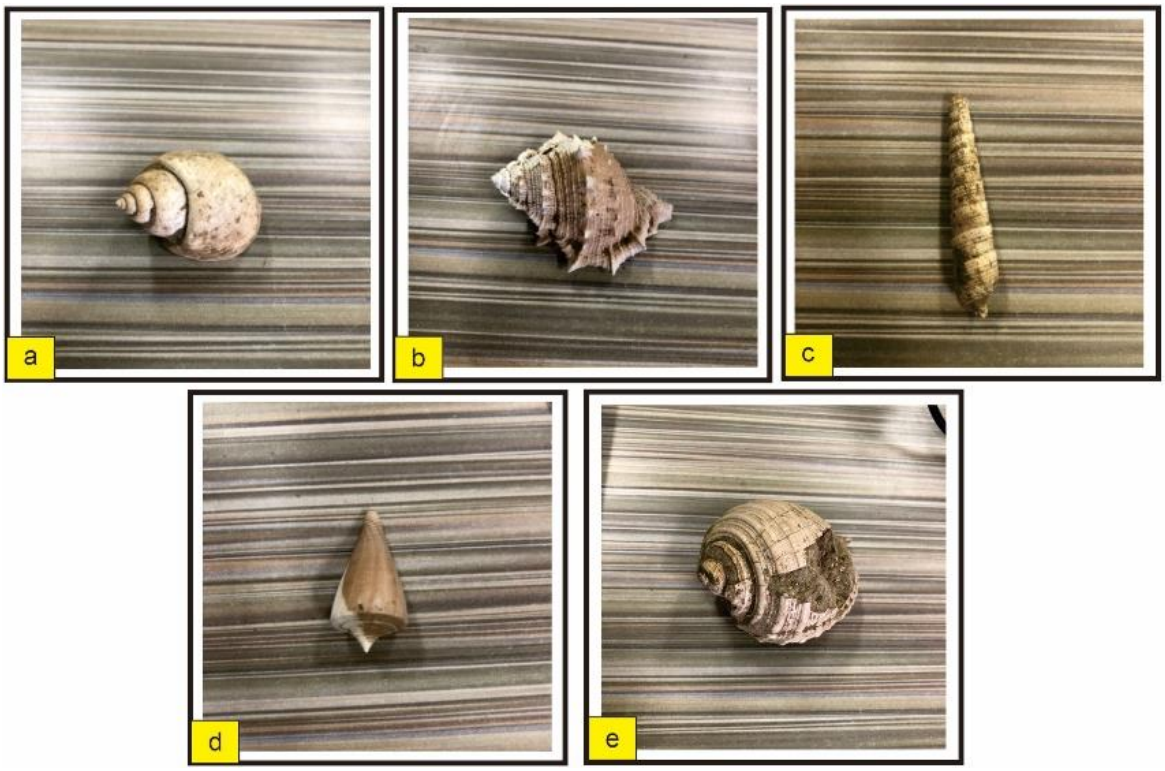


Figure 7. Macrofossil Features at Study Site 74: a) *Lunatia elevatum*, b) *Murex vanuxemi*, c) *Turritella terebra*, d) *Conus sauridens*, and e) *Plocostoma neumayri*

d) *Conus sauridens*

Conus sauridens comes from the phylum Mollusk, class Gastropoda, order Neogastropoda, family Conidae, and genus *Conus*. Conus has a unique shape and is very easy to recognize, including toxic marine invertebrates [17]. This species has a shell with a size of about 4–5 cm and is tapered at the bottom and slightly pointed at the top, which is included in the category of abconical shape (Mudjiono, 1989). This species has a round shell towards the right (dextral). It has a brownish shell with smooth lines and a limestone composition. *Conus sauridens* have radular teeth that contain neurotoxin venom that is used for hunting down and paralyzing their prey. This species lives solitary, creeping on the surface of the sea, and is often found on coral fragments and rocks. *Conus* is a nocturnal animal but is quite active when the sun is approaching sunrise and sunset. Conus is abundant in the Indo-Pacific and Western Pacific oceans with tropical climates. This species lives in the Transition-Neritic marine environment (0–200 m). The species is of Eocene-Recent age [15].

e) *Plocostoma neumayri*

Plocostoma neumayri comes from the phylum Mollusk, class Gastropoda, order Neogastropoda, family Naticidae, and genus *Plocostoma*. *Plocostoma neumayri* has a shell with a size of about 4-5 cm and a shell shape that tends to be round at the bottom, slightly chalked at the top, and brownish-white in color with a limestone composition. This species lives alone, creeping on the surface of the sea. Plocostoma neumayri usually lives in warm climates and in transitional-neuritic marine environments (0–200 m). The species is of Eocene-Recent age [15]. (Figure 7).

4. Conclusion

Paleontological analysis conducted on the Lemau Formation and the Simpangaur Formation can conclude that the benthic foraminifera fossils in the Lemau Formation found in moderate numbers *are Cibicides praecinestus, Elphidium macelium, Marginopora vertebralis*, and *Elphidium articulatum*. Based on these fossils, it can be concluded that the bathymetric environment of the location is in the Transitional-Neritic Edge Sea. Fossils of benthic foraminifera in the Simpangaur Formation found in abundant numbers are *Streblus beccari, Anomalinella rostrata,* and *Quinqueloculina bradyana*. In comparison, fossils found in moderate numbers are Bolivina schwageriana, Cibides praecinestus, and

Lagena sulcata. Based on these fossils and the classification of Barker (1960), it can be concluded that the bathymetric environment at the two research sites is the same, namely in the Transition-Neritic Edge Sea. In the Simpanggaur Formation, macrofossils were also found, which all come from the phylum Mollusk. Judging from the macrofossils found, the results of the analysis show that all of them live in the Transition-Neritic marine environment, which adds to the strong evidence that the depositional environment in the study area is the Transition-Neritic Edge marine environment. Based on observations, all macrofossils found come from the phylum Mollusk with the class Gastropoda, which has a round shell to the right (dextral), which indicates that the climate in the environment was tropical (warm).

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