Lower Miocene, larger benthic foraminifera fauna and depositional environment of limestone facies from Batu Luang, Klias Peninsula, Sabah

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Abstract: A limestone unit is exposed in Batu Luang exhibited well preserved larger benthic foraminifera. This limestone is in-situ and no sign of transported block due to its clear interbed with the argillaceous sediment in the sequence of the measured section. The argillaceous sediment in the surrounding area was mapped by previous researcher as a turbidite sedimentary sequence of the Setap Shale Formation. The aims of this study are to determine the age of the larger benthic foraminifera and the paleoenvironment of the limestone. Three samples of limestone were collected and thirty thin sections samples were prepared and analysed. A total of eleven species of larger benthic foraminifera were identified. One assemblage of larger benthic foraminifera can be recognised, namely Lepidocyclina (N.) verbeeki assemblage. This foraminifera assemblage is an indicative of Te5 or early Lower Miocene (Aquitanian) age. Two microfacies were characterised namely; 1) Coral-coraline algae boundstone microfacies (MF1) representing the reef flat environment and 2) Foraminifera packstone microfacies (MF2) which was related to the shallow open marine carbonate environment. The microfacies analysis and the outcrops observation show that the limestone unit at Batu Luang was a small reef deposited in shallow marine of carbonate environment. The limestone of Batu Luang could be the remnant bioherm that was developed during Te5 or early Lower Miocene (Aquitanian), associated with shoreline environment which negate the previous study.

Keywords: Larger benthic foraminifera, limestone, Lower Miocene, Klias

INTRODUCTION

The Limestone unit is located at the Batu Luang, Klias Peninsula, Sabah. This area was mapped as the Setap Shale Formation by Wilson (1964). The Setap Shale composed mainly of mudstone or clay and is confined to poorly exposed areas on Labuan Island and Klias Peninsula separating the underlying Crocker and Temburong Formations from the overlying Belait Formation (Wilson, 1964). The limestone unit in the Batu Luang area is in-situ and has no sign of transported block because this unit of rock is interbedded with the argillaceous sediment at the surrounding area and the limestone bedded has similar sedimentary structure and texture with the mudstone unit of the Setap Shale Formation at study area. This area has been studied for the sedimentological studies from varies researcher. However, none of these studies has so far reported the presence of larger benthic foraminifers in the Setap Formation in Sabah region. The limestone exhibited well preserved larger benthic foraminifera and that is essential to study them. The significance of larger benthic foraminifera is to determine the age of their host deposits and to give some information about their paleoenvironment conditions. The objectives of this study are to classify the taxonomy of the larger benthic foraminifera species found in the sequence under study and to determine the age and paleoenvironment of the limestone facies. Stratigraphically, this rock unit is equivalent to the Sibuti Formation, which is widely exposed in North Sarawak. The Sibuti Formation consists of the major argillaceous facies and minor limestone facies deposited in shoreline setting.

Figure 1: Geological map of Klias Peninsula (Wilson, 1964) and the stratigraphy of Klias Peninsula (Dayang Nor Asyilla & Sanudin, 2013).

GENERAL GEOLOGY

Klias Peninsula is underlain by Paleogene-Neogene sediments namely, the Crocker Formation, Temburong Formation, Setap Shale and Belait Formation (Wilson, 1964) (Figure 1). The Crocker Formation is dominantly arenaceous turbidite sediment deposit of Eocene to Miocene Age. The Temburong Formation is mainly argillaceous turbidite sequence characterised by rhythmic repetition of siltstone and shale (Mazlan, 1997; Tate, 1994; Hutchison, 2005). Based
on the planktonic foraminifera assemblage (Wilson, 1964), the age of the formation ranges from Oligocene to Lower Miocene. The Temburong Formation probably equivalent facies to that of upper part of the Crocker Formation. The age of the Crocker Formation has been determined from intercalations of the Temburong Formation, which contains significant age indicative fossils (Wilson, 1964). Planktic foraminifera of Late Oligocene to Late Early Miocene age occurs in the Temburong Formation at Tenom area as recorded by Junaidi et al. (2015) confirm the age of Temburong Formation.

The Setap Shale Formation comprises thick dark grey mudstone with minor sandstone intercalations. The Setap Shale formation is unconformably overlain by the Belait Formation and underlain by The Temburong Formation. However, the stratigraphic boundary between the Setap Shale and the Temburong is not exposed in Klias Peninsula. In offshore of Labuan Island, the Shell Company has reported a sharp contact between mudstone of the Setap Shale Formation and hard shale of Temburong Formation (Wilson, 1964). The age of the Setap Shale Formation in Klias Peninsula has been determined by the presence of Glogineriatella of Late Te5 to Tf1 age (Upper Miocene) (Wilson, 1964). Based on the study of planktic foraminifera at Labuan area, Basir (2002) and Basir et al. (1993) suggested that the age of the formation is Early Miocene to Late Miocene. The Belait Formation consists of conglomerate, cross-bedded sandstone, coal measures, and interbedded sandstone, siltstone and shale (Dayang Nor Asyilla & Sanudin, 2013). The age of the Belait Formation ranges from Upper Miocene to Pliocene (Wilson, 1964).

**OCCURRENCE OF LIMESTONE**

In Klias Peninsula, the limestone unit of the Setap Shale Formation is exposed at shoreline coast of Batu Luang area (Figure 1). The outcrop consists of limestone interbedded with thin calcareous mudstone (Figure 2). The thickness of limestone bed varies from 12 centimeters to 1.8 meters. This limestone is in-situ and no sign of transported block because this unit of rock is interbedded with the argillaceous sediment at the surrounding area. The limestone occurs as lenses in the Setap Shale Formation and thinly interbedded with argillaceous facies. Field observation shows that the limestone is grey in colour and consists of encrusting coral at the lower part of the limestone bed and the upper part is mostly massive limestone rich in larger benthic foraminifera. The limestone lenses can be seen intercalated with mudstone bed and some of the mudstone show hummocky cross-stratification.

**MATERIAL AND METHODS**

Three samples were collected from the limestone outcrop located along the coast of Batu Luang area. Thirty thin sections were prepared from three samples of limestone and analysed for petrographic and fossil analyses. Preparation for the thin section samples were based on Kerr (1977). The petrographic and classification of limestone were based on Dunham (1962). The age determination of larger benthic foraminifera was based on “letter Stage” classification published by Adams (1970) and Lunt (2013). The identification of larger benthic foraminifera was based on Adams (1970), BouDagher-Fadel (2008), BouDagher-Fadel & Price (2013), Cole & Bridges (1953), Junaidi & Basir (2015) and Lunt & Renema (2014).

**RESULTS AND DISCUSSIONS**

**Petrography and biostratigraphy**

Sample BLL01 which is dominated by encrusting coral and coralline algae is classified as the boundstone (Figures 3A & 3B). The sample BLL01 was taken from the lower part of limestone log section. Samples BLL02 and BLL03 are classified as packstone (Figures 3C & 3D) which comprised of grains up to 80%. The grains are made up of predominantly larger benthic foraminifera and the matrix is composed of the sparite and micrite. Other fossils have been identified in samples are crinoids, algae, gastropods and corals.

Eleven species of larger benthic foraminifera have been identified from three Samples (BLL01, BLL02 and BLL03) (Figure 4). The larger benthic foraminifers are as follows: Spirocyclus sp., Miogypsoides dehaarti (van der Verk), Miogysiodes sp., Lepidocyclina (Nephrolepidina) verbeeki Newton & Holland, Lepidocyclina (Nephrolepidina) sumatrensis Brady, Lepidocyclina (Nephrolepidina) parva Oppenkoor, Lepidocyclina (Nephrolepidina) acuta (Rutten),
Lower Miocene, Larger Benthic Foraminifera Fauna and Depositional Environment of Limestone Facies

Figure 3: Photomicrograph of thin section samples; A) BLL01 (boundstone) = frame of coral, B) BLL01 (boundstone) = showing the coralline algae surrounded by sparite, C) BLL02 (packstone) showing grains consisting of Lepidocyclina and Tansinhokella with sparite, D) BLL03 (packstone) showing Lepidocyclina which is dominant with some sparite.

Figure 4: The stratigraphic distribution of larger benthic foraminifera based on Adams (1970) and Lunt (2013) and the log sequence of limestone unit at Batu Luang.

Table 1: List of larger benthic foraminifera species identified in three samples of limestone.

<table>
<thead>
<tr>
<th>Larger Benthic Foraminifera Species</th>
<th>Limestone Samples</th>
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<tbody>
<tr>
<td>1. Austrotrilina sp.</td>
<td>X</td>
</tr>
<tr>
<td>2. Cyclocyclus sp.</td>
<td>X</td>
</tr>
<tr>
<td>3. Lepidocyclina Eulepidina sp.</td>
<td>X</td>
</tr>
<tr>
<td>4. Lepidocyclina (N.) acuta (Rutten)</td>
<td>X</td>
</tr>
<tr>
<td>5. Lepidocyclina (N.) parva Oppenoorth</td>
<td>X X X</td>
</tr>
<tr>
<td>6. Lepidocyclina (N.) sumatrensis Brady</td>
<td>X X X</td>
</tr>
<tr>
<td>7. Lepidocyclina (N.) verbeeki Newton &amp; Holland</td>
<td>X</td>
</tr>
<tr>
<td>8. Miogypsinoides sp.</td>
<td>X</td>
</tr>
<tr>
<td>9. Miogypsinoides dehaarti (van der Verk)</td>
<td>X X</td>
</tr>
<tr>
<td>10. Spirocyclopeus sp.</td>
<td>X</td>
</tr>
<tr>
<td>11. Tansinhokella sp.</td>
<td>X</td>
</tr>
</tbody>
</table>

Lepidocyclina (Eulepidina) sp., Tansinhokella sp., Austrotrilina sp. and Cyclocyclus sp. (Table 1) (Figures 5,6,7).

Miogypsinoides dehaarti (van der Verk) and Lepidocyclina (Nephrolepidina) verbeeki Newton & Holland were reported from Te5 of Letter Stage (Adams, 1970). The occurrences of Spirocyclopeus and Tansinhokella genus has been recorded from the Te2 to Te5 (Lunt, 2013). This assemblage allows a local biozone to be recognized, that is, the Miogypsinoides dehaarti Assemblage Zone (Figure 4). This Zone was characterised by the presence of Miogypsinoides dehaarti and Lepidocyclina (Nephrolepidina) verbeeki, which indicates the Te5 of Letter Stage early Lower Miocene.

Wilson (1964) considered the age of the Setap Shale Formation was thought to be younger than Lower Miocene based on the occurrence of planktic foraminifera Globigerinita sp. located at Bukit Linting area, south of Klias Peninsula. The genus of Globigerinita range from the N5 to N9 of Lower Miocene-early Middle Miocene. The present study of the larger benthic foraminifera from the Batu Luang area, which is proven that the age of the Setap Shale should be Early Miocene.

Microfacies and environment of deposition of limestone sequence

Based on the fabric characteristics and the dominant biotic components, two microfacies, namely the MF1, Coral-Coralline algae boundstone Microfacies and the
Figure 5: (1,2,6) Lepidocyclina (Nephrolepidina) sumatrensis Brady, equatorial sections; (3,4,5) Lepidocyclina (Nephrolepidina) sumatrensis Brady, oblique-vertical sections; (7,8,9,10) Lepidocyclina (Nephrolepidina) verbeeki Newton & Holland, vertical sections.

Figure 6: (1,2,3) Tansinhokella sp., vertical sections; (4,5) Miogypsinaoides dehaarti (van der Verk), equatorial sections; (6,7) Miogypsinaoides sp., vertical sections; (8) Austrotrilina sp., oblique section; (9,10,11,12) Lepidocyclina (Nephrolepidina) parva Oppenooirth, vertical-oblique sections; (13,14,15,16) Lepidocyclina (Nephrolepidina) acuta (Rutten), vertical sections.

Foraminifera Packstone Microfacies(MF2) were identified from the Limestone sequence at Batu Luang.

1) MF1, coral-coraline algae boundstone microfacies
This facies is characterized by the abundance of coral colonies and coralline algae that are mostly in growth position. This facies is associate with larger benthic foraminifera such as Lepidocyclina, Miogypsina and Astrotrilina. This facies appears at the lower part of the limestone sequence (BLL01).

Interpretation
This microfacies is interpreted have been formed by in-situ organisms as an organic reef (bioherm) on the margin of a platform and was located above the storm wave base. Some of the coral are fragmented and associated with larger benthic foraminifera and the coralline algae indicates that deposition occurred in the reef front. The presence of rare of micrite also suggests winnowing of the sediments and removing of the micritic matrix (Flügel, 2004; BouDagher-Fadel, 2008).

2) MF2, foraminifera packstone microfacies
This facies is characterized by moderate to coarse-grained packstone and dominated by larger benthic foraminifers. The
larger foraminifera consist of *Lepidocyclina*, *Tansinhokella* and *Miogypsina* group. The most dominant foraminifera in this facies are *Lepidocyclina* group. Other larger benthic foraminifera appeared with the minor occurrence in this facies are *Cycloclypeus*, *Spirocyclopeus*, and *Austrotrilina*. This facies occurs in Samples BLL02 and BLL03.

**Interpretation**

Abundant open marine skeletal fauna reflects well-lit water and oxygen content within the water column at the sediment surface. The low percentage of the matrix and larger benthic foraminifera suggests a middle ramp position and indicates the oligotrophic conditions (Flügel, 2004; Wilson, 1975).

The environment of deposition of limestone can be interpreted from the microfacies analysis. Only two microfacies have been identified which can be characterised into two belts of carbonate depositional environment, namely, reef flat and shallow open marine.

**Reef flat**

MF1 coral-coraline algae boundstone represents reef flat. The presence of larger benthic foraminifera (*lepidocyclinid*) associated with coral and coralline algae indicate that this reef was formed at the reef front facing an open sea. The colonization of coral and coralline algae form the basis of the community of the reef platform. The colonization of coral and coralline algae providing a hard framework for the marine organism in reef environment such as foraminifera could either attach themselves or used as shelter. The coarse grains of bioclasts and the low percentage of micrite indicate that the reef flat environment was deposited above the storm wave base which allow high-energy wave currents to wash away all the fine grains (BouDagher-Fadel, 2008; Junaidi & Basir, 2015).

**Shallow open marine**

The open marine or outer ramp environment was developed at the front of the mid ramp or reef environment facing the open sea. This environment was characterized by MF2 foraminifera packstone which is identified as Samples BLL02 and BLL03. It was in a shallow open marine setting with low amounts of coral debris mixed with a high percentage of coralline algae and perforated foraminifera (*lepidocyclinid* and *miogypsinid*). The Lack in corals and high occurrence of coralline algae, perforate foraminifera and micrite suggest that this facies forms in a medium to low energy open marine environment in between fair-weather wave base and storm wave base (Flügel, 2004; McMonagle et al., 2011; Noad, 2001).

The limestone unit from the Batu Luang area was interpreted as a bioherm in an open sea area. Field observation indicates that only a small occurrence of limestone was exposed at the beach area of Batu Luang (only 4m thick see Figure 3) and there was no continuity to other area in Klias Peninsula. The bioherm does not have any protected area or lagoon behind the reef. This indicates the absence of dominant imperforate foraminifera such as millioid group microfacies in this limestone of Batu Luang. This bioherm is a small reef flat and shallow open marine environment in the open sea and it has been developed during Te5 or Aquitanian, (Lower Miocene) age.

**CONCLUSIONS**

A small occurrence of the limestone unit from the Batu Luang consists of well-preserved larger benthic foraminifera. Eleven species of larger benthic foraminifera have been identified from the thin section analysis and this assemblage indicates Te5 or early Lower Miocene age. This finding suggests that the age of Setap Shale Formation is Lower Miocene and slightly older than previously thought. The limestone unit was divided into two microfacies namely 1) Coral-coraline algae boundstone microfacies (MF1) representing the reef flat environment and 2) foraminifera packstone microfacies (MF2) which is related to the shallow open marine of the carbonate environment. The limestone of the Batu Luang could be the remnant bioherm that was developed during Te5 or early Lower Miocene (Aquitanian).

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