

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

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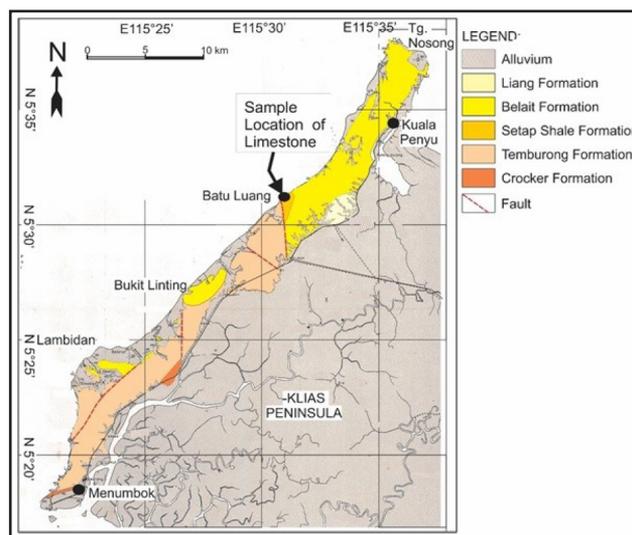
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**Abstract:** A limestone unit is exposed in Batu Luang exhibited well preserved larger benthic foraminifera. This limestone is *in-situ* and no sign of transported block due to its clear interbed with the argillaceous sediment in the sequence of the 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 the 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



**Figure 2:** Outcrop of the limestone unit at Batu Luang. A) the limestone section shows the thick bed of coral dominant limestone at the lower section. B) interbedded thin packstone limestone and mudstone at the upper part of the section. The limestone lenses can be seen in the mudstone bed and some of the mudstones show hummocky cross-stratification.

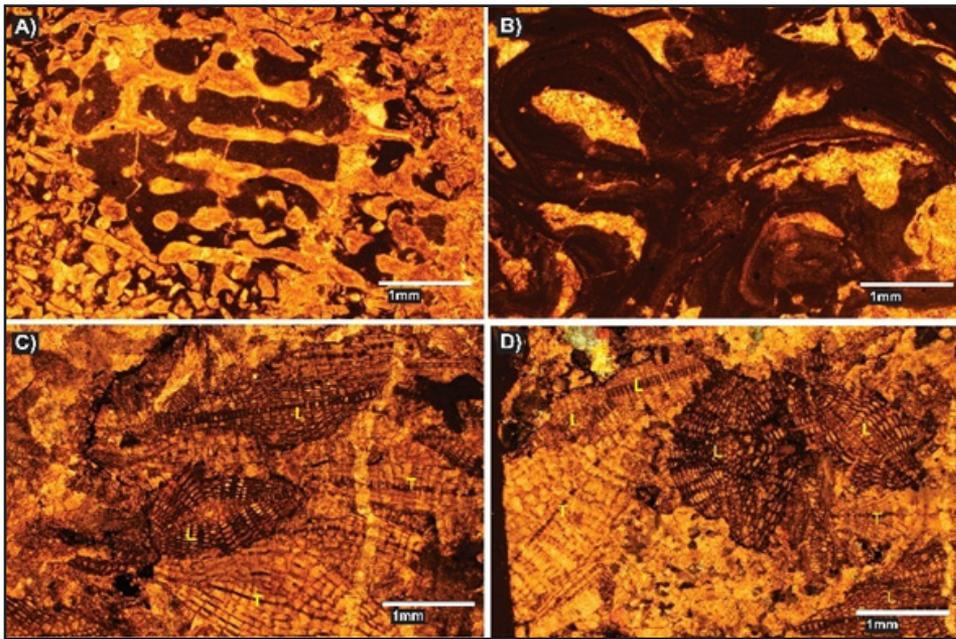
were based on Dunham (1962). The age determination of larger benthic foraminifera was based on “letter Stage” classification published by Adams (1970) and Lunt (2013). The identification of larger benthic foraminifera were based on Adams (1970), BouDagher-Fadel (2008), BouDagher-Fadel & Price (2013), Cole & Bridges (1953), Junaidi & Basir (2015) and Lunt & Renema (2014).

## RESULTS AND DISCUSSIONS

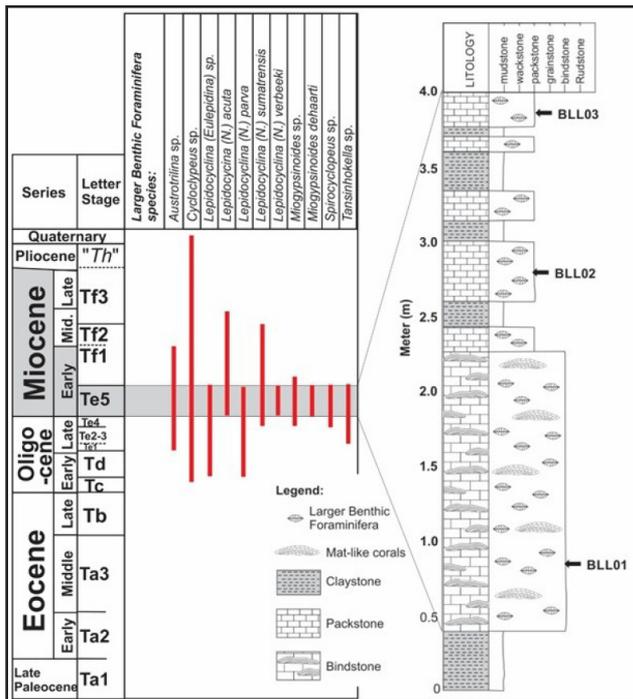
### Petrography and biostratigraphy

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 foraminifera are as follows: *Spirocyclopeus* sp., *Miogypsinoides dehaarti* (van der Verk), *Miogypsinoides* sp., *Lepidocyclus* (*Nephrolepidina*) *verbeeki* Newton & Holland, *Lepidocyclus* (*Nephrolepidina*) *sumatrensis* Brady, *Lepidocyclus* (*Nephrolepidina*) *parva* Oppenoorth, *Lepidocyclus* (*Nephrolepidina*) *acuta* (Rutten),



**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 *Lepidocyclus* and *Tansinhokella* with sparite, D) BLL03 (packstone) showing *Lepidocyclus* 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.

*Lepidocyclus (Eulepidina) sp.*, *Tansinhokella sp.*, *Austrotrilina sp.* and *Cycloclypeus sp.* (Table 1) (Figures 5,6,7).

*Miogypsinoidea dehaarti* (van der Verk) and *Lepidocyclus (Nephrolepidina) verbeeki* Newton & Holland were reported from Te5 of Letter Stage (Adams, 1970). The *Lepidocyclus (Nephrolepidina) acuta* (Rutten) ranged from Te5 to Tf3 and *Lepidocyclus (Nephrolepidina) sumatrensis* Brady was ranged from Te4 to Tf2 (Adams, 1970). The *Lepidocyclus (Eulepidina)* and *Lepidocyclus (Nephrolepidina) parva* Oppenoorth have very long range

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

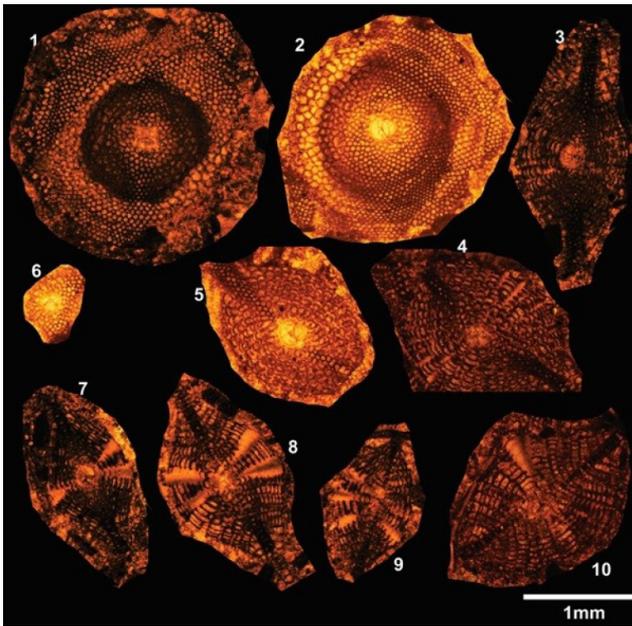
Larger Benthic Foraminifera Species	Limestone Samples		
	BLL 01	BLL 02	BLL 03
1 <i>Austrotrilina sp.</i>		X	
2 <i>Cycloclypeus sp.</i>		X	
3 <i>Lepidocyclus Eulepidina sp.</i>		X	X
4 <i>Lepidocyclus (N.) acuta</i> (Rutten)			X
5 <i>Lepidocyclus (N.) parva</i> Oppenoorth	X	X	X
6 <i>Lepidocyclus (N.) sumatrensis</i> Brady	X	X	X
7 <i>Lepidocyclus (N.) verbeeki</i> Newton & Holland		X	
8 <i>Miogypsinoidea sp.</i>		X	X
9 <i>Miogypsinoidea dehaarti</i> (van der Vlerk)		X	X
10 <i>Spiroclypeus sp.</i>		X	X
11 <i>Tansinhokella sp.</i>	X	X	X

from the Td to Te5 (Adams, 1970). The occurrences of *Spiroclypeus* 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 *Miogypsinoidea dehaarti* Assemblage Zone (Figure 4). This Zone was characterised by the presence of *Miogypsinoidea dehaarti* and *Lepidocyclus (Nephrolepidina) verbeeki*, which indicates the Te5 of Letter Stage early Lower Miocene.

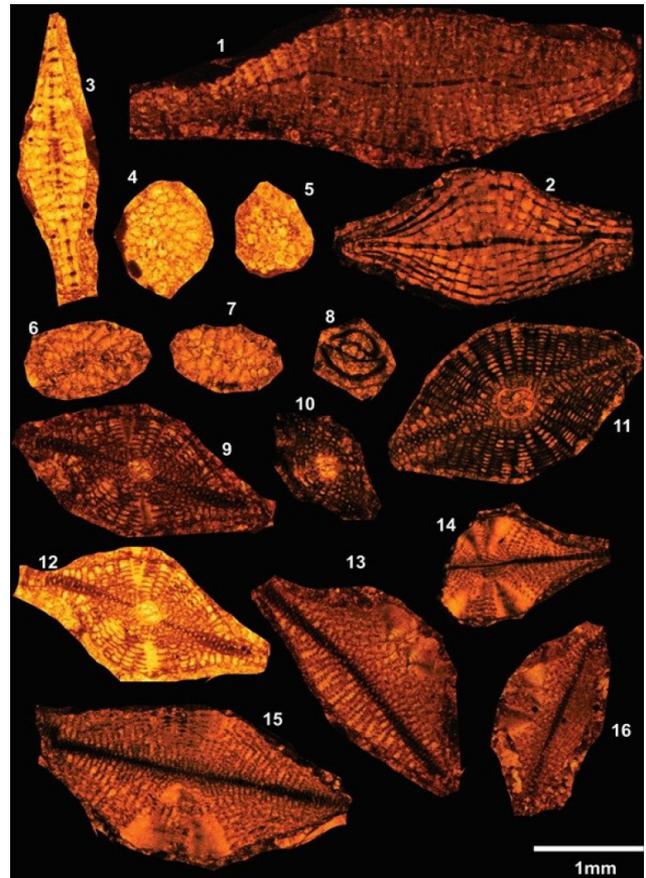
Wilson (1964) considered the age of the Setap Shale Formation was thought to be younger than Lower Miocene based on the occurrence of planktic foraminifera *Globigerinatella sp.* located at Bukit Linting area, south of Klias Peninsula. The genus of *Globigerinatella* range from the N5 to N9 of Lower 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**

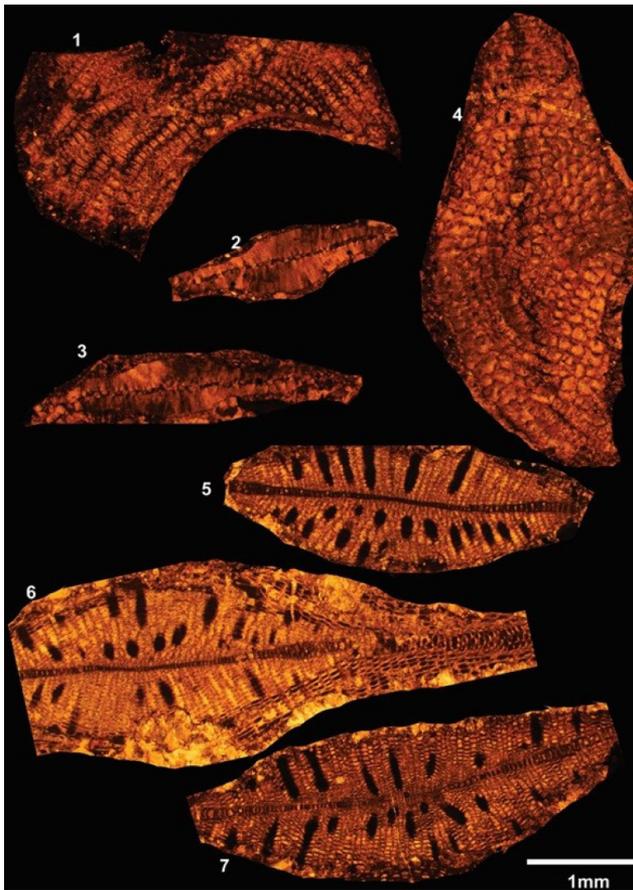
Based on the fabric characteristics and the dominant biotic components, two microfacies, namely the MF1, Coral-Coralline algae boundstone Microfacies and the



**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) *Miogypsinooides dehaarti* (van der Verk), equatorial sections; (6,7) *Miogypsinooides* sp., vertical sections; (8) *Austrotrilina* sp., oblique section; (9,10,11,12) *Lepidocyclina (Nephrolepidina) parva* Oppenoorth, vertical-oblique sections; (13,14,15,16) *Lepidocyclina (Nephrolepidina) acuta* (Rutten), vertical sections.



**Figure 7:** (1) *Cycloclypeus* sp., oblique-equatorial section; (2,3) *Cycloclypeus* sp., vertical sections; (4) *Tansinhokella* sp., oblique-equatorial section; (5,6,7) *Lepidocyclina (Eulepidina)* sp., vertical sections.

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

#### 1) MF1, coral-coralline 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 associated 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 to 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 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 foraminifera. The

larger foraminifera consist of *Lepidocyclina*, *Tansinhokella* and *Miogyopsina* group. The most dominant foraminifera in this facies are *Lepidocyclina* group. Other larger benthic foraminifera appeared with the minor occurrence in this facies are *Cyclocypeus*, *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-coralline 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 front 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 miogyopsinid). 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 milioid 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-coralline 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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