

## SEDIMENTOLOGY AND DEPOSITIONAL ENVIRONMENTS OF THE EARLY MIOCENE NYALAU FORMATION, BINTULU AREA, SARAWAK, MALAYSIA

*Noureen Shoukat*<sup>1</sup>, *Numair Ahmed Siddiqui*<sup>1</sup>, *Abdul Hadi Abd Rahman*<sup>1</sup>, *Syed Haroon Ali*<sup>2</sup>

<sup>1</sup> *Department of Geosciences, Faculty of Geosciences and Petroleum Engineering Universiti Teknologi PETRONAS, 31750 Tronoh, Perak, Malaysia*

<sup>2</sup> *South East Asia Carbonate Research Laboratory (SEACARL), Department of Geosciences, Faculty of Geosciences and Petroleum Engineering, Universiti Teknologi PETRONAS, 31750 Tronoh, Perak, Malaysia*

Received May 22, 2019; Accepted August 16, 2019

---

### Abstract

This paper presents lithofacies types of exposed Nyalau Formation in areas around Bintulu town, Sarawak, Malaysia. The Early Miocene exposures of Nyalau Formation provide a unique opportunity to study the sedimentology and sequences at reservoir scale in order to understand the depositional and post depositional changes. Here, we describe the results of description of nine sections in general in the form of fifteen LFTs (Lithofacies Types) combined into nine FA (Facies Association). Later, Sungai Mas Camp section one of these nine sections describes in order to understand the lateral and vertical distribution of these facies associations. Overall, the facies associations varies from mangrove, tidal flat, tidal bar, subtidal flat, lower shoreface, upper shoreface, tidal influenced channels, tidal dominated channels, offshore settings depending on the location of studied sections. However, Sungai Mas Camp section presents fluctuations in mangrove FA9, to tidal influenced FA6, to again mangrove FA9, the sea level moved and setting become more towards upper shoreface FA3. Tidal flat to tidal bar become dominate in the area, with mangrove to tidal bar until termination of sediments in the area. The rise and fall in sea level could be linked to facies association governed by tectonic activities in the Sarawak basin.

**Keywords:** *Early Miocene; Nyalau Formation; Shallow marine setting; Sarawak.*

---

## 1. Introduction

The study area, Bintulu is located in the Miri Zone in NW Sarawak <sup>[1]</sup> (Figure 1). Mostly the Bintulu town and its surrounding areas are covered by the exposure of Nyalau formation (Oligocene-Miocene). This formation conformably rests on the Buan Formation (Figure 1A) and unconformably on the Belaga Formation <sup>[2]</sup>. In a coastal deltaic environment, the Nyalau Formation was deposited, as a result of major transgression over the Eocene substrate. It is a sequence of fine-grained argillaceous and/or calcareous sands alternating to clay and shales. Towards, west it is sandy and becomes muddier to the east, where it named as the Setap Shales <sup>[2]</sup>. The exposed section around Bintulu town comprises massive sandstones intervals, laminated clays, and brackish-shales and lignite. <sup>[3]</sup> The heterolithic silty mudstone facies, carbonaceous shale and shaley coal facies, planar to tough cross-bedded sandstone with thin mud drapes facies are common lithofacies in the area. These sedimentary features indicate wave and tidal dominance, within a shallow-marine environment <sup>[4]</sup>. This formation, and its offshore counterparts (Cycles I and II), in west Balingian province <sup>[5]</sup> are comprised of a thick succession of early Miocene clastics <sup>[4]</sup>. It is approximately 1000–2000 m of thick sandstones, mudstones and coals deposits <sup>[2]</sup>. The investigated succession in this study presents a broad variety of lithofacies types and lithofacies association with indications for deposition under wave, fluvial and tide-dominated processes. The main objectives of the paper are:

- (1) To establish the litho-facies types and their associations.
- (2) To understand the facies relationship in type section of Sungai Mas Camp section.

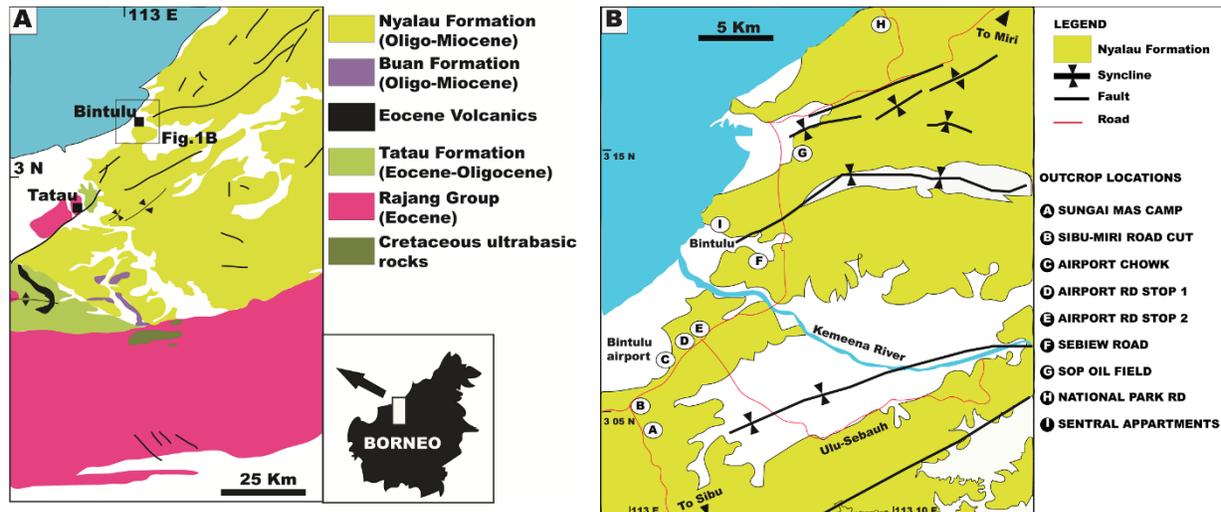


Figure 1. A) Geological map of Bintulu area, Sarawak, B) Location map of outcrops section studied near Bintulu area, with distribution of Nyalau Formation, Sarawak Malaysia, (modified after [8])

## 2. Methods and datasets

The sedimentological description of a type section with 112feet (34m) of Sungai Mas Camp section is used as type section for this study. However, the facies scheme has been established by description of additional eight field locations and are used here, secondarily for comparison (Figure1A, 1B).

The field work was conducted in Bintulu area, Sarawak basin for Nyalau Formation to collect the required information including sedimentological logging, observing the stratigraphic features and sample collections from outcrop for laboratory analysis. The sedimentological log is prepared on suitable scale to find the sedimentological characteristics of rock. Different significant number of sections are also sampled according to requirements.

## 3. Results and discussion

### 3.1. Lithofacies analysis

The Nyalau Formation has been subdivided into 15 lithofacies types based on sedimentary structures, grain sizes, traces fossils and lithology.

#### 1) LFT 1 Hetrolithic silty mudstone facies

Lithofacies LFT1 is hetrolithic bedding of shale, silt and sand with grain size vary from mud to fine (Figure 5). Fresh colour is black to dark grey and weathered colour is fresh grey. Lamination and wavy bedding are common sedimentary structures. Bioturbation is present to absent. The thickness of this facies varies from 1 m to 5 m.

#### 2) LFT 2 Wavy bioturbated sandstone facies

These lithifacies are medium to thick bedded bioturbated sandstone having grain size ranging from medium to coarse sand (Figure 6). Fresh colour is light grey to yellowish and weathered colour is dark brown to grey. Lenticular to wavy bedding is present with crossbedding. Top is marked with hardgrounds. The thickness of sandstone is approximately 1 -5 m.

### 3) LFT 3 Cross-bedded shaley sandstone facies



Cross-bedded shaley sandstone facies are mainly sandstone with intercalated shale that is medium to thick bedded (Figure 2). Grain size ranges from fine to medium. Fresh colour is light grey and white to yellowish is weathered colour. Laminated to wavy bedding with mud cracks at top. Bioturbation and crossbedding do exist in this facies. LFT3 is 1-4 m in thickness.

Figure 2. (A) White dashed line marked the boundary between LFT3 and LFT12 (Airport road stop 2 section)

### 4) LFT 4 Cross-laminated sandstone with iron concretions facies

This type of lithofacies are thin bedded with medium to coarse grained in terms of grainsize (Figure 6). Light grey is the fresh colour and weathered colour is yellow. Wavy to laminated bedding with the presence of iron concretions. LFT4 is highly bioturbated. The thickness of sandstone is approximately 1 m.

### 5) LFT 5 Planar to trough cross-bedded sandstone with thin mud drapes facies

Sandstone is medium to thick bedded and highly cemented. Grain size range from medium to coarse grained (Figure 3). Fresh colour is greyish white with weathered colour ranging in reddish to yellow colour. Trough –crossbedding is main sedimentary structure with flame structure, wavy, lenticular bedding and mud drapes. The sandstone beds geometry is wedge shaped. The thickness of this facies is more than 10m.

### 6) LFT 6 Thin bedded sandstone with coal lenses facies

This type of lithofacies are thin bedded and coarse grained in size. Sandstone is highly cemented with greyish to black fresh and weathered colour from dark grey to yellowish. Honeycomb weathering has been seen in this sandstone. Crossbedding and lenticular bedding is noted with lenses of mud and coal. Bioturbation can be seen in thin bedded sandstone. Generally, thickness of facies is 1-5m.

### 7) LFT 7 Thick bedded sandstone with shale intercalations facies

Facies LFT7 is mainly sandstone with intercalated shale (Figure 3). It is thick bedded and grain size range from fine to medium. Fine grain material is present at the base. Fresh colour is light grey to yellow and weathered colour is dark brown to yellow. Honeycomb weathering is also present. Lamination, wavy bedding, crossbedding and rhythmic sediments are most common sedimentary structures. Bioturbation sparse to absent. Approximately, thickness of sandstone is 1-4 m.

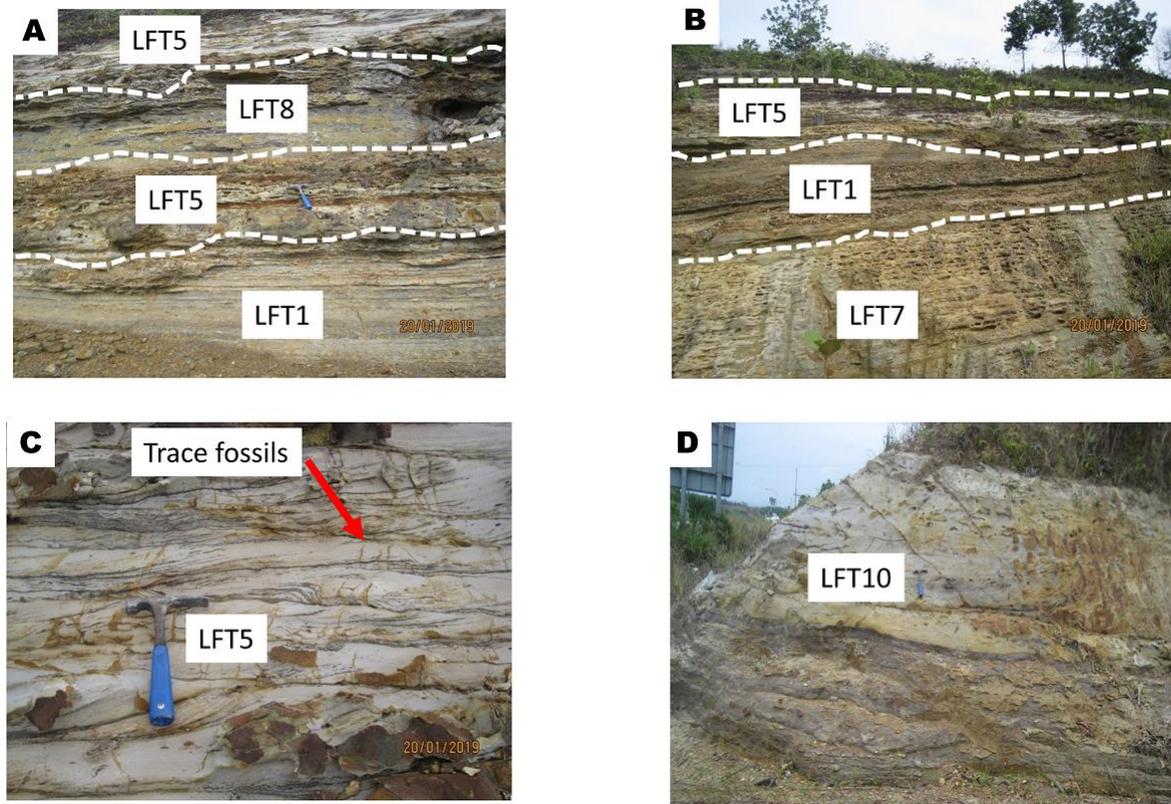


Figure 3. (A) and (B) Representation of LFT1, LFT5, LFT8 & LFT7 with white dashed lines (Sungai Mass Camp section), (C) Trace fossils marked by red arrow in LFT5 (section Sungai Mass Camp), (D) Channelized Geometry of LFT10 (Airport Chowk section).

### **8) LFT 8 Carbonaceous shale and shaley coal facies**

This facies consists of carbonaceous shale, siltstone and coal. It is mud to fine grained in size (Figure 4). Bedding fissility and lamination is common feature. Black to greyish is fresh colour and weathered colour is yellow to brown. Burrows and plant material is present. The thickness of this facie is very from 1- 10 m.

### **9) LFT 9 Mud clasts bearing sandstone facies**

LFT9 is composed of sandstone that is identified by the presence of sub-angular mud clasts. Size of the mud clasts range from few millimetres within a medium- to coarse-grained sand matrix. Fresh colour is dark brown to red and weathered colour is yellow (Figure 4). Cross-bedding is at high angle and bioturbation is also present, with lower part having lamination. Channel geometry in sandstones is observed. It is 1-2 m thick.

### **10) LFT 10 Channelized thick bedded sandstone facies**

Sandstone is thick bedded, coarse grained and loosely cemented. Pebbles are present at the bottom of the sandstone (Figure 3). Fresh colour is dark to light grey and yellow is the weathered colour. Channel geometry is a significant feature. It is cross bedded and bioturbation is moderate to intense. Thickness is more than 1 m.

### **11) LFT 11 Hummocky cross bedded sandstone facies**

This facies consists of fine to medium grained sandstone that is hummocky cross bedded (Figure 5), [6]. Light grey is the fresh colour while yellowish is the weathered colour. Iron lines can also be seen. Burrows are also present. LFT11 is about 1 m thick.

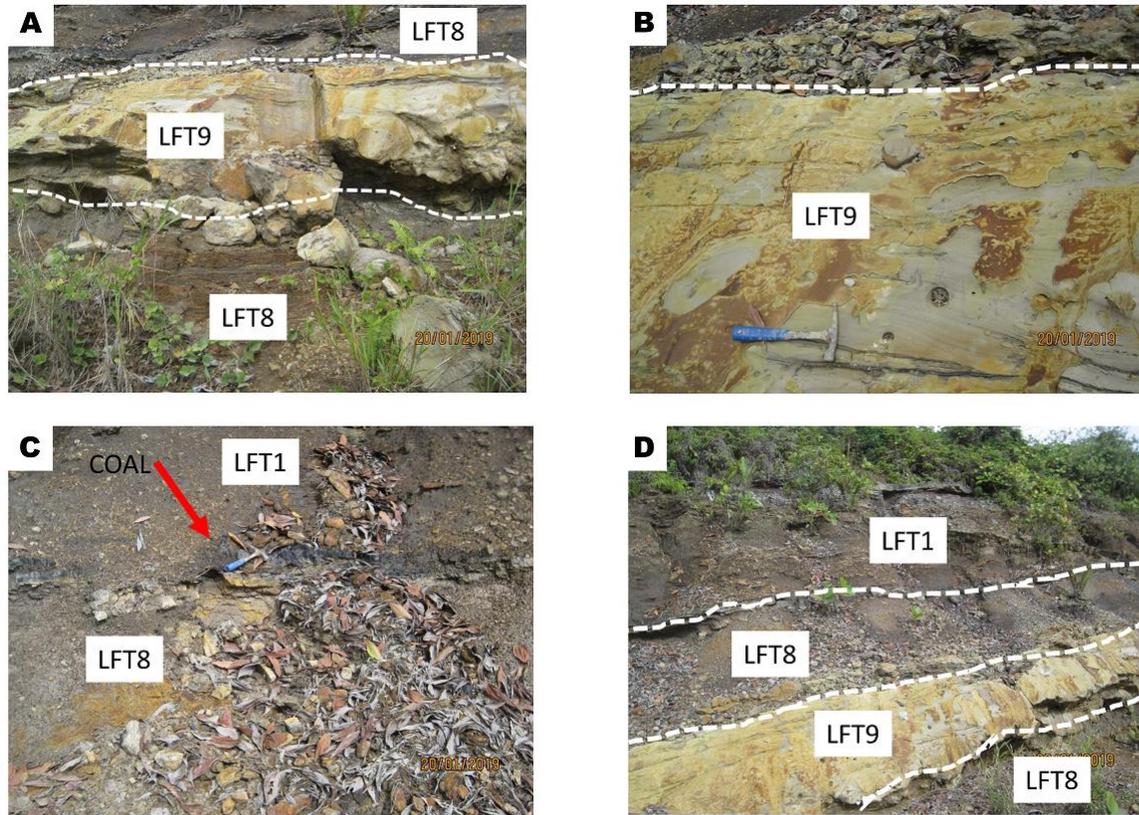


Figure 4. Different Lithofacies types present in (Sungai Mass Camp section), Nyalau Formation, Sarawak. (A) Represent the LFT8 & LFT9 (B) Showing close up of LFT9 (C) Red arrow marks the coal that display LFT8 at bottom & LFT1 at top of it (D) White dashed lines divide the boundaries of LFT8, LFT9 and LFT1.

### **12) LFT 12 Reddish bioturbated sandstone facies**

This type of lithofacies are medium to thick bedded, fine to medium grained (Figure 5). Reddish to orange is the fresh colour and maroon to dark brown is the weathered colour. Crossbedding is destroyed by burrows. It is laminated and highly bioturbated. Approximately, the thickness is 1-5 m.

### **13) LFT 13 Herring bone cross bedded sandstone facies**

It is composed of thin to thick bedded, medium to coarse grained sandstone (Figure 5), [7]. Grey to red is the fresh colour and weathered colour is dark grey. It is wavy, lenticular bedded with herringbone crossbedding as a main sedimentary structure. This facies range in thickness from 1-3 m.

### **14) LFT 14 Massive mudstone with hardgrounds facies**

It is massive to thick bedded mudstone. Fresh colour is grey and the weathered colour is light grey (Figure 5). Hardgrounds are present at the top of the mudstone. Some of the crossbedding is cut by fault slips. Bioturbation is absent to intense. It is 1-6 m thick.

### **15) LFT 15 Bioturbated shale facies**

This facies consists of non-carbonaceous shale intercalated with mud (Figure 6). Light grey is the fresh colour while the weathered colour is light grey. It is laminated and hard ground in the form of iron rings are present in the mid of the shale beds. Bioturbation is intense. The thickness of this facies is more than 2 m.

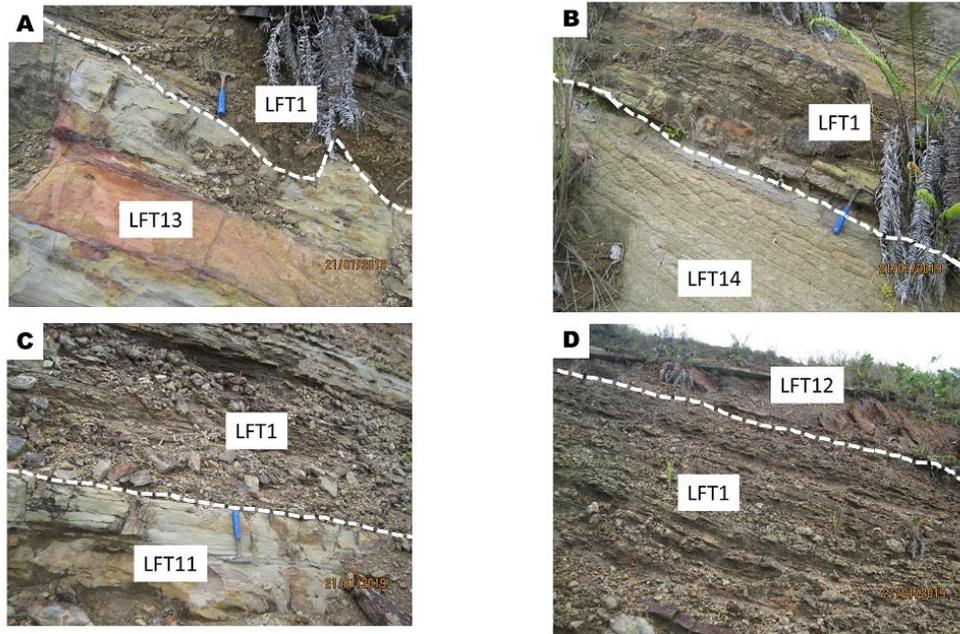


Figure 5. (A) LFT13 and LFT1 is differentiated by white dashed line (Airport road stop 2 section), (B) White dashed line mark the boundary between LFT14 and LFT1 line (Airport road stop 2 section), (C) and (D) demonstrate the LFT11, LFT1 and LFT12 (Airport road stop 1 section).

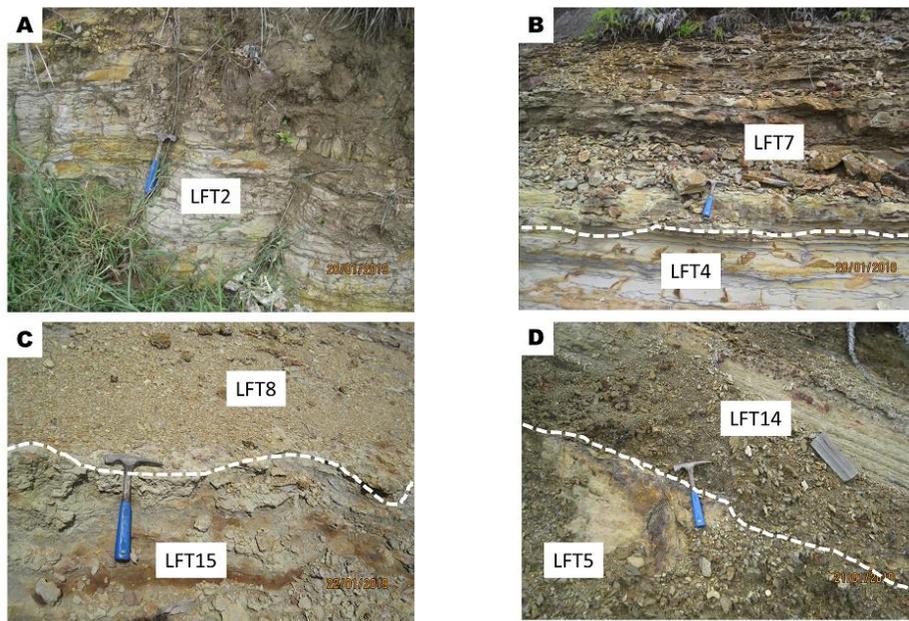


Figure 6. (A) Close view of LFT2 (section Sibul-Miri road cut), (B) White dashed line differentiate the LFT4 and LFT7 (section Sibul-Miri road cut), (C) and (D) Representation of LFT15, LFT8, LFT5 and LFT14 divided by white dashed line (National Park section).

### 3.2. Sungai Mas Camp section

Sungai Mas Camp section, is located about 25 km from Bintulu town.

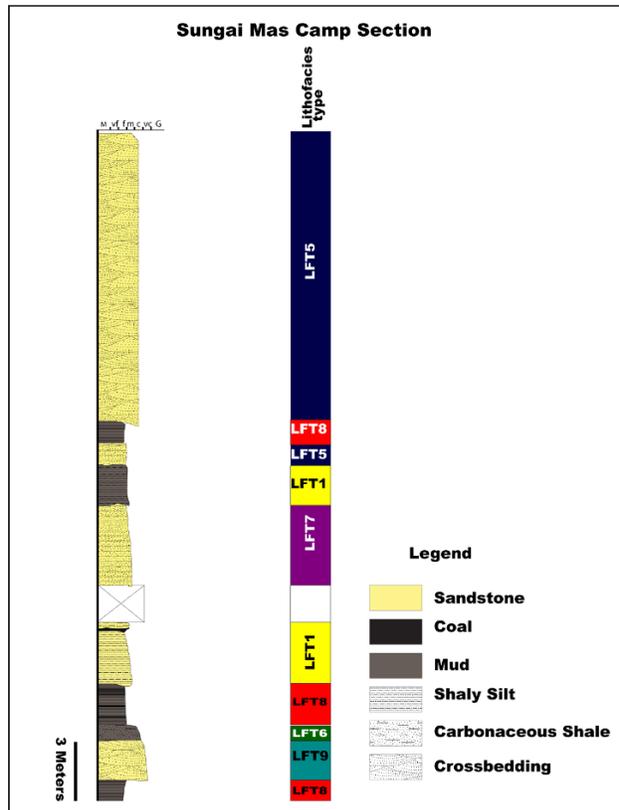


Figure 7. Facies vertical distribution in Sungai Mas Camp section, Sibul road, Bintulu, Sarawak, Malaysia

The sedimentological description of the type section revealed 112feet (34m) of Nyalau Formation. A total of seven lithofacies has been identified in this section including LFT1, LFT3, LFT5, LFT6, LFT7, LFT8 and LFT9 (Figures 7, 8, 9). However, LFT1 and LFT5 are repeated twice in the succession. Whereas, LFT8 is repeated thrice. One coal layer is present overlying the heterolithic facies LFT1. Base of the section is marked by carbonaceous shales. The section becomes progressively sand dominated towards the top. The deposition started in this section, mangrove FA9, to tidal influenced FA6, to again mangrove FA9, the sea level moved and setting become more towards upper shoreface FA3. Tidal flat to tidal bar become dominate in the area, with mangrove to tidal bar until termination of sediments in the area. Hence the area presents sea level fluctuations, with dominance of mud to sand to mud to sand changing in overall deposition. The coal and carbonaceous shales could be an indicator of relative flooding of the region. This flooding could be linked to tectonic subsidence that could have led to sea level to fluctuate and deposit various suit of facies.

### 3.3. Facies Associations (FA)

The Nyalau Formation LFTs has been grouped into 9 facies associations based on similar sedimentary characteristics and stratigraphical relationships.

- 1) Offshore FA1
- 2) Lower shoreface FA2
- 3) Upper shore faces FA3
- 4) Tidal bar FA4
- 5) Tidal flat FA5
- 6) Tide influenced channels FA6
- 7) Tide dominated channel FA7
- 8) Subtidal flat FA8
- 9) Mangrove FA9

#### 1) Offshore FA1

LFT 2, 12 and 15 are combined in Offshore FA1. FA1 is the facies associations, made up of normal grading, cross-stratification and symmetrical ripples, that indicates suspension and storm deposition below fair-weather wave base. The interpretation is being strengthened by presence of bioturbation in all three LFTs.

#### 2) Lower shoreface FA2

LFT3 and LFT11 are part of this facies association. The Lower Shoreface Facies Association (FA2) is characterised by successions of hummocky cross-stratified sandstone (HCS) and shaley sandstones represents storm and wave deposition above fair-weather wave base [8].

#### 3) Upper shore faces FA3

LFT4 and LFT7 are main constituent of this facies association. This facies association due to its higher sand content and presence of iron concretions, fine sediments at base indicates deposition in upper shore face.

Table1. Lithofacies code, Litho-Facies Types (LFTs) and Litho-Facies Associations (LFAs) of Nyalau Formation, Onshore Sarawak, Malaysia

Facies code	Litho-Facies Types (LFTs)	Litho-Facies Associations (LFAs)
LFT1	Heterolithic silty mudstone facies	Tidal flat FA5
LFT2	Wavy bioturbated sandstone facies	Offshore FA1
LFT3	Cross-bedded shaley sandstone facies	Lower shoreface FA2
LFT4	Cross-laminated sandstone with iron concretions facies	Upper shore faces FA3
LFT5	Planar to trough cross-bedded sandstone with thin mud drapes facies	Tidal bar FA4
LFT6	Thin bedded sandstone with coal lenses facies	Tide influenced channels FA6
LFT7	Thick bedded sandstone with shale intercalations facies	Upper shore faces FA3
LFT8	Carbonaceous shale and shaley coal facies	Mangrove FA8
LFT9	Mud clasts bearing sandstone facies	Tide dominated channel FA7
LFT10	Channelized thick bedded sandstone facies	Tide influenced channels FA6
LFT11	Hummocky cross bedded sandstone facies	Lower shoreface FA2
LFT12	Reddish bioturbated sandstone facies	Offshore FA1
LFT13	Herring bone cross bedded sandstone facies	Tide dominated channel FA7
LFT14	Massive mudstone with hardgrounds facies	Subtidal flat FA9
LFT15	Bioturbated shale facies	Offshore FA1

#### 4) Tidal bar FA4

LFT5 is the only lithofacies in this association. The occurrence of mud drapes and heterolithic nature of this, with planar to trough cross bedding is thought to be deposited in prograding, tidal bar setting.

#### 5) Tidal flat FA5

FA5 is made up of LFT1. The existence of heterolithic bedding made up of intercalations of sand, and muddy sediments, with wavy, lenticular and tidal bedding, indicate tidal flat environment.

#### 6) Tide influenced channels FA6

FA6 constitutes of LFT6 and LFT10. The development of channelized sandstone with, lenticular, wavy bedding, with sparse occurrence of coal and mud, can be indicator of a tide influenced channels near to fluvial and estuarine environment.

#### 7) Tide dominated channel FA7

LFT9 and LFT13 are main lithofacies of association FA7. The phenomenon of herringbone cross bedding, wavy, lenticular bedding and presence of mud clast, specifies the deposition in a tide dominated channel setting [8].

#### 8) Subtidal flat FA8

LFT14 is part of FA8. The predominance of mud versus sand with presence of hardgrounds in this facies indicates deposition in a restricted low energy subtidal flat environment.

### 9) Mangrove FA9

The most occurring LFT8 is element of FA9. The interbedding of carbonaceous shale, with thin coal beds, interpreted as mangrove deposition in close proximity to subtidal to tidal flat setting.



Figure 8. Facies lateral distribution in Sungai Mas Camp section, Sibul road, Bintulu, Sarawak, Malaysia

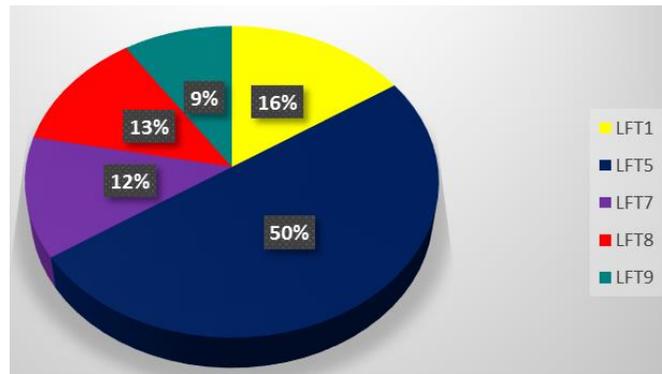


Figure. 9 Pi-chart for facies quantification in Sungai Mas Camp section, Sibul road, Bintulu, Sarawak, Malaysia

### 4. Conclusions

Hence, it is concluded that a shallowing upward trend has been observed in the studied sections. Coal layers are in abundant landward sections and can be used as a marker for correlation. Carbonaceous shales with coals could be an indicator of flooding in the basin. Depositional conditions in Nyalau formation range from offshore, lower shoreface, upper shoreface, tidal flat, tidal bar, tide dominated channels, tide influenced channels and mangrove setting

Sungai Mas Camp section was located under the influence of interchanging sub environments from mangrove FA9, to tidal influenced FA6, to again mangrove FA9, the sea level moved and setting become more towards upper shoreface FA3. Tidal flat to tidal bar become dominate in the area, with mangrove to tidal bar until termination of sediments in the area. Overall, Nyalau Formation lithofacies types and facies associations provides a comprehensive understanding of deposition under tide too wave dominated shallow marine setting, largely controlled by relative movements of sea level punctuated by tectonics.

### Acknowledgments

We gratefully acknowledge the support by Department of Geosciences, Universiti Teknologi PETRONAS and Institute of Hydrocarbon Research, Universiti Teknologi PETRONAS.

## References

- [1] Hutchison CS. The Rajang accretionary prism and Lupar Line problem of Borneo. Geological Society, London, Special Publications, 1996; 106(1): 247-261.
- [2] Liechti P, Roe FW and Haile NS. The geology of Sarawak, Brunei, and the Western Part of North Borneo. British Borneo Geological Survey Geological Survey, Department. British Territories in Borneo, Kuching 1960; 3:358.
- [3] Madon M, and Rahman AHA. Penecontemporaneous deformation in the Nyalau Formation (Oligo-Miocene), Central Sarawak, Bulletin of Geological Society of Malaysia, 2007; 53: 67-73.
- [4] Almond J, Vincent P and Williams LR. The application of detailed reservoir geological studies in the D18 Field, Balingian Province, offshore Sarawak, Bulletin of Geological Society of Malaysia, 1990; 27: 137-159.
- [5] Jia TY and Rahman AHA. Comparative analysis of facies and reservoir characteristics of Miri Formation (Miri) and Nyalau Formation (Bintulu), Sarawak, Bulletin of Geological Society of Malaysia, 2009; 55: 39-45.
- [6] Siddiqui NA, Rahman AHA, Sum CW and Murtaza M. Sandstone facies reservoir properties and 2D-connectivity of siliciclastic miri formation, Borneo. In ICIPEG 2016 Springer, Singapore: 581-595.
- [7] Siddiqui NA, Rahman AHA., Sum CW, Mathew MJ, Menier D and Hassaan M. Modeling of littoral sandstones reveal variance in reservoir flow patterns: an example from Nyalau Formation, East Malaysia. Research Journal of Applied Sciences, Engineering and Technology, 2015; 11(2): 176-184.
- [8] Hassan MHA, Johnson HD, Allison PA and Abdullah WH (2013). Sedimentology and stratigraphic development of the upper Nyalau Formation (Early Miocene), Sarawak, Malaysia: a mixed wave-and tide-influenced coastal system. Journal of Asian Earth Sciences, 2015; 76: 301-311.

---

*To whom correspondence should be addressed: Noreen Shoukat, Department of Geosciences, Faculty of Geosciences and Petroleum Engineering Universiti Teknologi PETRONAS, 31750 Tronoh, Perak, Malaysia*