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The Neogene Depositional History of Lemau and Bintunan Formations in Bengkulu Basin

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Abstract

The Neogene sedimentation within the North Bengkulu is the northern part of Bengkulu Basin was occurred transgressive towards regressive phase during Neogene graben system. Sedimentation ended on Plio-Pleistocene increased volcanic activity extend Bukit Barisan Orogeny and influenced by pyroclastic materials. The research area is located in North Bengkulu, Bengkulu Province. The methods are combines laboratory analysis and field observation such as geological mapping, measured section, paleontology, petrography, and make a depositional model to determine depositional environment and correlation between Lemau and Bintunan Formations. The result shown sedimentation of Lemau Formation lies between back barrier–shallow marine system with facies i.e. tidal flat, foreshore, shoreface, lagoon and swamp-marsh with coarsening upwards and locally fining upwards pattern influenced by tide and wave dominated and generated by transgressive owing to shoreface retreat during sea level rise. Paleontology analysis had abundant benthic foraminifera in coastal plain-shallow marine fauna. Bintunan Formation shown fluvial deposits within polymict conglomerate, tuffaceous claystone with fine–medium clastic sediment in grain size and occurrence elongated channel and floodplain with fining upward succession. Lemau and Bintunan Formations have unconformity contact by erosional surface and approximate hiatus during Late Miocene-Pliocene sedimentation on the research area. Lemau Formation mostly has major sand bodies and silty with coal intercalation. The study of depositional in the research area can easily to understanding of subsurface analysis in North Bengkulu and will be useful to implication geological resources.

Keywords: facies, bintunan, lemau, shallow marine.

Introduction

Bengkulu basin is the Tertiary fore-arc basin that located in the southern part of the Sumatra and covered both offshore and onshore. The trending of Bengkulu Basin is NE-SW parallel to Sumatra and bounded by Barisan Mountain to the northeast and Mentawai Ridge to the southwest. The Middle to Late Miocene was expressed the rejuvenation of pre-existing tensional fault (second transtensional) and forming Ipuh Graben (Figure 1) in the northwest. In this time, the regressive sequence of shallow marine to lagoonal was deposited with sand intercalated muds, coal and limestone called Lemau Formation (Yulihanto et. al, 1995). The research area is located in North Bengkulu, Bengkulu

Basin (Figure 2) covered Paleogene and Neogene depositional systems.

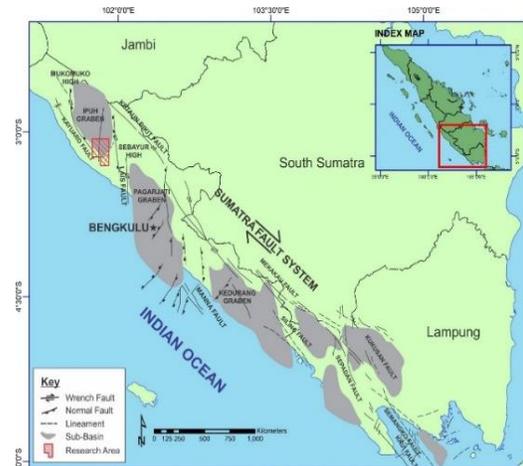


Figure 1. Structural configuration of Paleogene – Eocene graben system which formed Bengkulu Basin (Yulihanto et al.,1996)

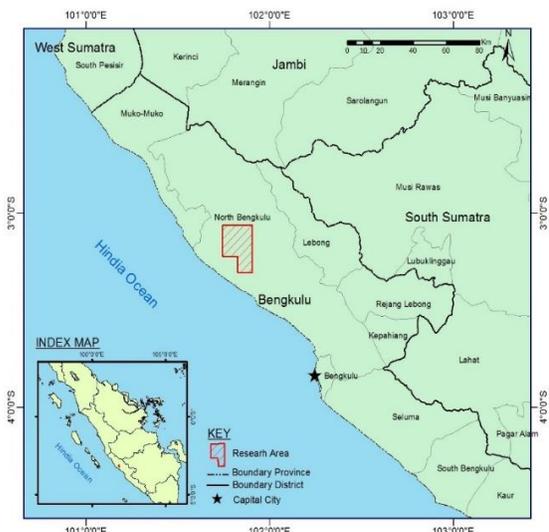


Figure 2. Index map location in the research area.

The Paleogene depositional consist of Hulusimpang and Seblat Formations. Neogene depositional consist of Lemau, Simpangaur and Bintunan Formations. Lemau Formation is similiar in age to Air Benakat, Muara Enim and Parigi

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Equivalent Formations on the offshore area. Lemau Formation was the coal-bearing formation in the Bengkulu Province. From south to the north, some mining company was produced the coal. Lemau Formation was a good source rocks for hydrocarbon potential that are immature to early mature (Panggabean and Heryanto, 2009). The depositional in the research area ended with Bintunan Formation that shown fluvial deposits and filled by Pleistocene volcanic. The objective of this paper are to identify facies and depositional environment of Lemau and Bintunan Formations based on sedimentary structure, mineral and lithology association, biogenic structure and fossil content. Facies and depositional study is one of the important things in exploration or exploitation project and its implication for geological resource in North Bengkulu such as coal and oil gas.

Methods

The purpose of the research area is to determine facies and sequence stratigraphy in North Bengkulu. The methods in this research are based on field observation and laboratory analysis (paleontology and petrography). Field observation consists of geological mapping, lithology description (grain size, sediment structure, organic material and trace fossils) to classify the facies association and measured section in several outcrops in Tanjungdalam, Pondokbakil, Air Lelang and Gunung Payung Sub-district as mining area (Table 1).

Table 1. Coordinate Location of Measured Section

No	Location	Y	Z	Thickness
1	Tanjungdalam	808619	9648234	78 m
2	Airlelangi	813544	9643650	15.1 m
3	Pondokbakil	816559	9641206	26,2 m
4	Gunung Payung	819432	9637920	33,4 m

Result and Discussion

Geological mapping was conducted to find out the spreading of formation and geological structure that affected for the research area. Lemau Formation was deposited from west to south-southeast of research area with NW-SE direction (Figure 3). Characteristics of Lemau formation consists of fine-coarse sandstone, siltstone, limestone, silt intercalated carbonate sandstone, coal and trace fossils from coastal plain-shallow marine. Bintunan Formation is the youngest formation consists of tuffaceous claystone, sandstone, polymict conglomerate, tuff and they were deposited in the west of Lemau Formation with volcanic influence. Based on kinematic analysis, direction of the research area is SSW-NNE. Pulunggono (1992) explained compression in the Late Miocene-Recent in Sumatra generated SSW-NNE direction and relatively similar direction to the research area that was deposited in the same time.

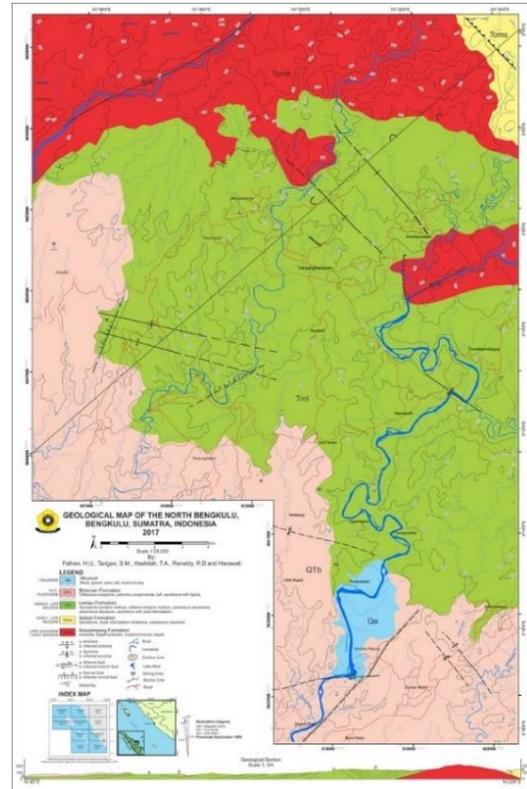


Figure 3. Geological map of the research area.

Marsh - Swamp

The marsh-swamp facies are associated by lagoon, tidal flat and foreshore comprises massive clay to sandy mudstone with coal intercalation and related to onshore area. Marsh-swamp occur in low energy and relatively stable sedimentation. Coal have classified into three seams from younger to older that are Seam A, B and C with 0,3-6.5 m in thickness and coal distribution extend kilometers with NW – SE direction (Picture 1). In some layers contained by sand material that increased the supply sediment energy and indicate as flooding surface. Marsh-swamp are displayed in M_{0-18,7} (Figure 6)



Picture 1. The lowest part of Lemau Formation shows marsh-swamp facies in Pondokbakil Sub-District.

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Foreshore

The foreshore facies spread evenly and associated with marsh/swamp facies, lagoon and tidal flat up to 8,2 m in thickness (Picture 2). Foreshore characterized by fine and medium sand and shown sedimentary structure such as dominated cross stratification, lamination, and herringbones. Two directional deposition indicated the barrier zones that separated shallow marine zones and back barrier land. Lenses carbon, intercalated coarse sand and siderite bands were found in this facies. Root plain was found in several outcrops. Foreshore facies are displayed in M_{18,7-25} and M_{57,9-65} (Figure 6).



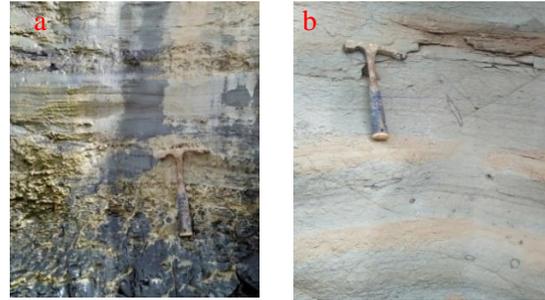
Picture 2. Upper part Lemau Formation shows foreshore facies and overlain with channel deposits at Tanjungdalam Sub-District.

Lagoon

Lagoon facies associated by swamp/marsh and shoreface facies and characterized by coarsening upward pattern and multiple medium-coarse sandstone, dominantly silt up to 7,7 m in thickness (Picture 3). Medium-coarse sand are found as intercalated cause of the high supply energy from a bay between barrier. The bentonic shows *Nonion depressulum*, *Nonion of asterizons* in neritic environment. Sedimentary structure that found are wavy lamination and lamination contact with coal with minor bioturbation (Picture 4). Lagoon deposited in the stable energy with storm and tide current influence and formed the interbed coarse detritus sediment. Lagoon facies are displayed in M_{25-32,5} (Figure 6).



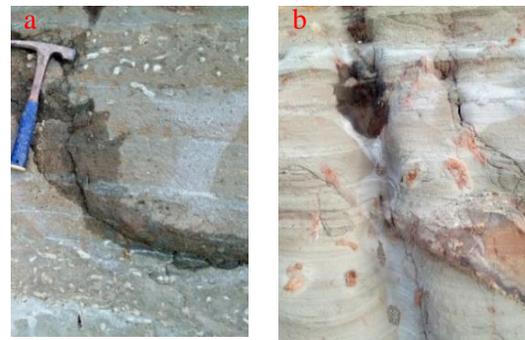
Picture 3. Lower part of Lemau Formation shows lagoon and shoreface facies at Tanjungdalam Sub-District.



Picture 4. (a) Siltstone lamination contact with coal. (b) siltstone and sandstone intercalation with minor bioturbation.

Shoreface

The shoreface facies that extends in the research area was deposited during N12 - N14. Shoreface divided into 2 facies which are lower and middle shoreface. Lower shoreface is characterized by fine-medium sandstone, crossbed, wavy, laminae, and the present of bioturbation is abundant in the lower part but decreasing to the upper part (Picture 5a). The increasing of energy rate affected to the existance of bioturbation present. Skolithos was found and identified as medium to high energy in the intertidal environment (Picture 5b). Shoreface are displayed in M_{32,5} – M₄₃ (Figure 6).



Picture 5. The Shoreface Facies (a) Sandstone with lamination structure and skolithos in vertical and horizontal (b) Sandstone with lamination structure and vertically skolithos with calcareous sandstone as a nodul

In several outcrops were found calcareous sandstone as a nodule and spread continuously. This is constrained by bentonic evidence such as *Streblus beccari*, *Elphidium craticulatum*, *Nanionella bradii* and *Astronion stelligerun* that present in neritic enviroment. Middle shoreface is characterized by siltstone, shell fossil abundant, laminae, relatively deep and associated with offshore transition (Picture 6).

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Picture 6. Middle Part of Lemau Formation shows shoreface facies and overlain unconformity contact Bintunan Formation at Gunungpayung Sub-District



Picture 8. Unconformities contact of tuff and calcareous siltstone at Gunung Payung Sub-District.

Tidal Flat

The tidal flat facies is associated with foresore and swamp/marsh facies with local distribution and found in several outcrops of the research area. The sediments are characterized by medium-coarse sandstone up to 2,3 m in thickness with poorly sorted, oxidized, mud drops structure and rare foraminifera content. Sedimentary structure that found are flaser bedding, cross bedding and laminae with two directional deposition and relatively landward, it indicates tidal environment (Picture 7). Tidal flats are displayed in $M_{43} - M_{45,5}$ (Figure 6).



Picture 7. Fine-medium sandstone with flaser bedding shows tidal flat facies at Tanjungdalam Sub-District.

Floodplain

Floodplain facies is the most upper facies in the research area and dominated by interbedded silt, tuffaceous clay, carbonaceous shale, tuff (4,2 m in thickness) and highly oxidized. Sedimentation occur in the stable energy with extent area. Unconformity contact between Lemau and Bintunan Formations shows floodplain deposits overlain with calcareous siltstone contained molluca (Picture 8). Floodplain are displayed in $M_{65-70,6}$, $M_{75,7-80,7}$, $M_{86,4-88}$ (Figure 5).

Fluvial Channel Deposits

Fluvial channel deposits spread evenly in some places in the research area and associated with floodplain products with polymict conglomerate and fine-coarse sand. Conglomerate is characterized by igneous fragment (andesite, basalt, and basalt-andesitic) and clastic sediment (sandstone and limestone) with couple-boulder fragment, tuffaceous matrix and sandy texture. Increasing energy rapidly reflected as interbedded fine-coarse sand, wavy lamination and recurrence laminae that found in the sandstone. High dimension of channel indicated as braided river and multiple channel eroded with 8m in thickness. This facies found at Bintunan Formation. In some outcrops, channel were found and eroded the coal and shoreface facies in Lemau Formation. Channel Facies are displayed in $M_{70,4} - 75,7$, $M_{80,7-86,4}$, M_{88-90} (Figure 5).

Initial deposition of Lemau Formation started by coastal plain to shallow marine environment. Coal within siliclastic sediment identified as tidal delta plain environment and associated with terrestrial environment. The rapid sea level rise caused the soft sediment above the coal scoured by coarse sediment and replaced by fine-medium sand with parallel to wavy lamination. Coarsening upward identified as higher energy. In some cases, the presence of bioturbation and trace fossils as a layer indicated the low energy condition. Facies map section shows the depositional of Lemau Formation deeper to the northeast (Figure 4). Accretionary prism in southwest part changes to land environment and indicated as source sediment in Late Miocene (Mukti et al., 2011). In that condition, the shoreline moved towards land in the southwest and deeper to the northeast part. The depositional setting is dominated by wave and tide with sand materials, trace fossils and the abundance of glauconite minerals. In the late depositional of Lemau Formation is characterized by erosional surface and no show of Simpangaur Formation due to uplifted fault block in Late Miocene.

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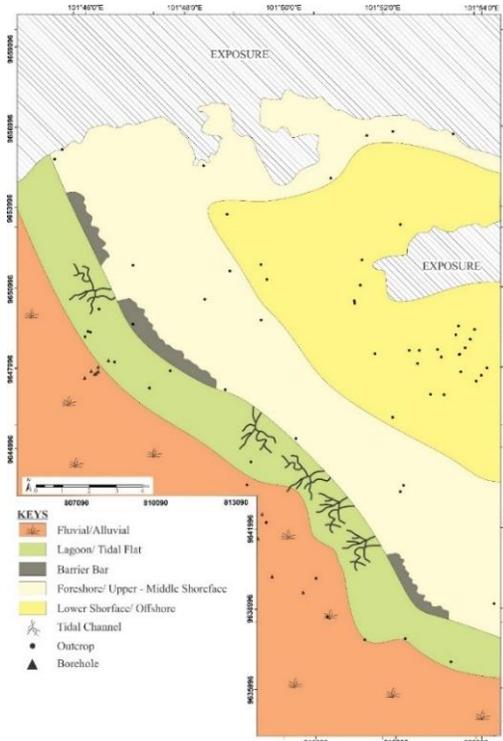


Figure 4. Facies map reconstruction of North Bengkulu during Late Miocene in Lemau Formation showing environmental setting.

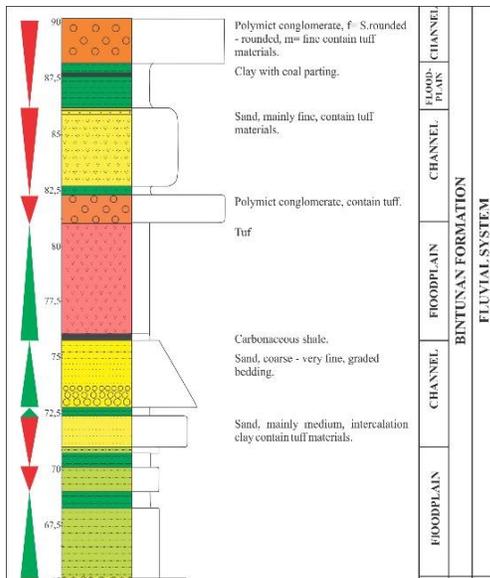


Figure 5. General stratigraphy column of Bintunan Formation

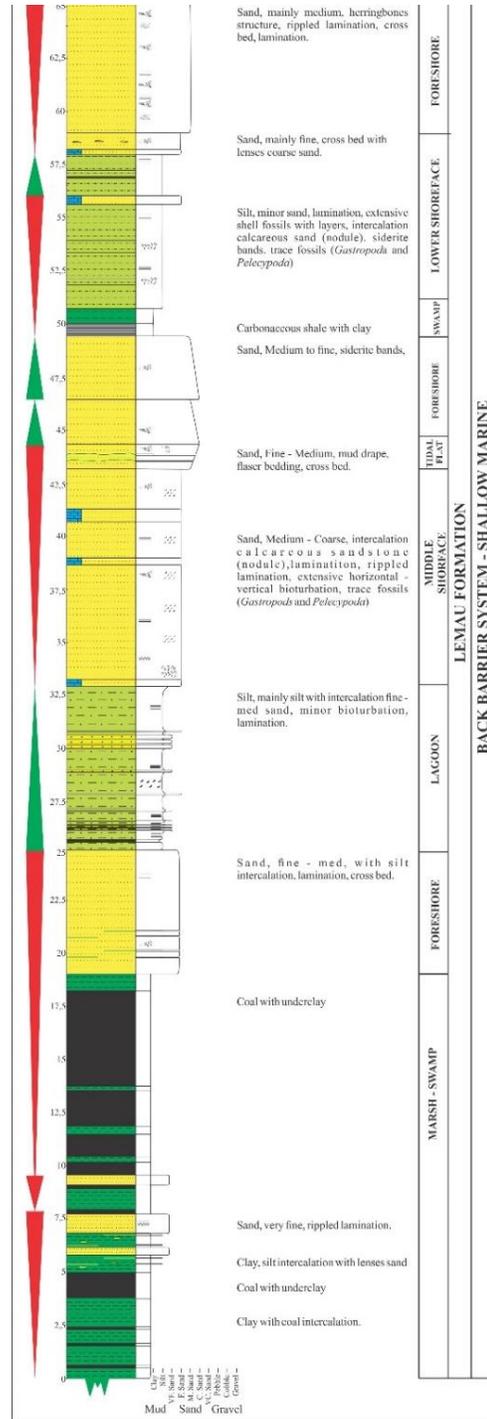


Figure 6. General stratigraphy column of Lemau Formation.

Petrography Analysis

Samples were collected for mineral identification. Petrographical analysis of sandstone thin section reveals

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bluish gray color with quartz, glauconite, feldspar, biotite, and opa_q minerals. Sandstones are dominated by quartz and glauconite that indicated shallow marine environment and weathered as clay mineral and spread 30-80 μm in size. Planktonic foraminifera and benthonic were found in the thin section such as *Globigerina* and *Globorotalia*. Cement between grain filled by calcite mineral. Bending structure shows resistance of minerals in the sandstone section. Sandstone is classified as Calcareous Glauconite Quartz Arenite (Pettijohn, 1972).

Facies Relationship and Depositional Model

The Neogene sedimentation influenced by rapid transgressive sea level rise. The pattern of vertical cross section shows the land sediment was eroded or deposited with shallow marine sediment. The sedimentation within Lemau Formation begun in the low energy where marsh/swamp and lagoon formed. Sandstone in shoreface, foreshore, and tidal flat facies was deposited by tide and wave dominated influence. Foreshore facies has responsible in barrier formation caused by high storm current and foreshore retreat. In the lower part of Lemau Formation consist of claystone intercalated with sandstone and coal, while the middle-upper part is dominated by sandstone.

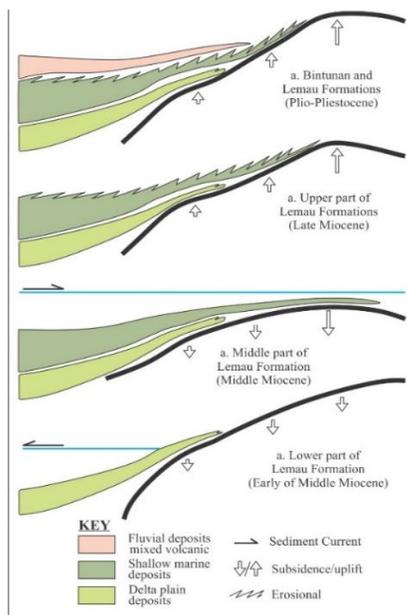


Figure 7. Schematic of sedimentation development in the Lemau and Bintunan Formations.

In the Late Miocene, the faulted block was uplifted and changed transgressive phase into regressive phase (Yulihatanto et al., 1995) and sedimentation in the research area changes to the terrestrial. In Late Miocene, Lemau Formation arise to the surface and indicated a hiatus. There is unconformity contact with volcanic product dominant

which eroded by channel and floodplain, then characterized as Bintunan Formation in the research area. In the barrier-island setting composite more than a single environment (Reinson, 1992). The sediment influx in the transgressive toward to regressive phase as the result by Neogene tectonic event in the located (Figure 7).

Conclusions

- The depositional of Lemau Formation in the North Bengkulu area is defined by back barrier system to shallow marine and Bintunan Formation in fluvial system with higher volcanic influence.
- The shifting from coastal plain to shallow marine is southwest to northeast direction where terrestrial material deposited in the shallow marine.
- Back barrier- shallow marine have five facies i.e. tidal flat, foreshore, shoreface, lagoon and swamp-marsh with tide and wave dominated.
- Fluvial system in Bintunan Formation is dominated by silty-muddy sediment with coarsening upward in channel and floodplain deposits and contains volcanic debris materials.
- Lemau and Bintunan Formation have unconformity contact cause of the uplift in the Late Miocene and significantly changes the depositional environment.

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