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The Lithofacies Association of Brown Shales In Kiliran Jao Subbasin, West Sumatra Indonesia

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Abstract - The lithofacies association, mainly lithology and depositional sequences of the Brown Shale Unit of Pematang Group was studied based on recent fieldwork at Karbindo Coal Mine, in Kiliran Jao Subbasin,West Sumatra, Indonesia. The lower part of the Brown Shale Unit consists of coal and limestone facies which were deposited in a marginal lacustrine area. The limestone was generated by evaporatic processes characterized by the presence of primary calcite crystals. The upper part of the unit, from bottom to top, is composed of six facies associations, among all: amalgamated massive thick bedded shales, interlaminated shales and siltstones, interbedded grey and red shales, fossiliferous shales, massive thick bedded shales, and interlaminated shale and sandstone facies. Those facies were deposited in a shallow to deep water lacustrine environment, characterized by their lithology compositions, sedimentary structures, and fossil contents. The unit has such as high content of reworked organic matters-bearing shales and mudstones. Turbiditic sedimentary structures, gastropods, and bivalves are common.

Keywords: Brown Shale, lacustrine, lithofacies, Kiliran Jao Subbasin

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Introduction

Background

The studied area is located in Kiliran Jao Subbasin, where PT Karbindo Abesyapradhi coal mine occurs. It is located approximately 60 km to the east of the Ombilin Basin (PT BA Ombilin), and south-southwest of Central Sumatra Basin (Figure 1). Lithostratigraphically, the area consists of Pretertiary basement, Paleogene sedimentary unit, and Holocene deposits, but the study is more emphasized in the Pematang Group of the Paleogene sediments (Figure 2). This basin is a coal producing depression in Sumatra Island. The main objective of this paper is to recognize the lithofacies association, mainly to identify lithology and depositional sequences of Brown Shale Unit based on a recent fieldwork in Karbindo Coal Mine which is part of the Pematang Formation as defined by some previous investigators (Aswan *et al*., 2009; Carnell *et al*., 2013; Widayat *et al*., 2013).

The Pematang Formation was informally divided into three lithological units consisting of Lower Red Beds in the lower part, Brown Shales in the middle part, and Upper Red Beds in the upper part. Caughey *et al*. (1994, in De Smet and Barber, 2005) stated that the Lower Red Bed unit is composed of sandstones, shales, and conglomerate, deposited in alluvial and fluvial environments. The Brown Shale Unit mainly consists of dark brown to black shales deposited

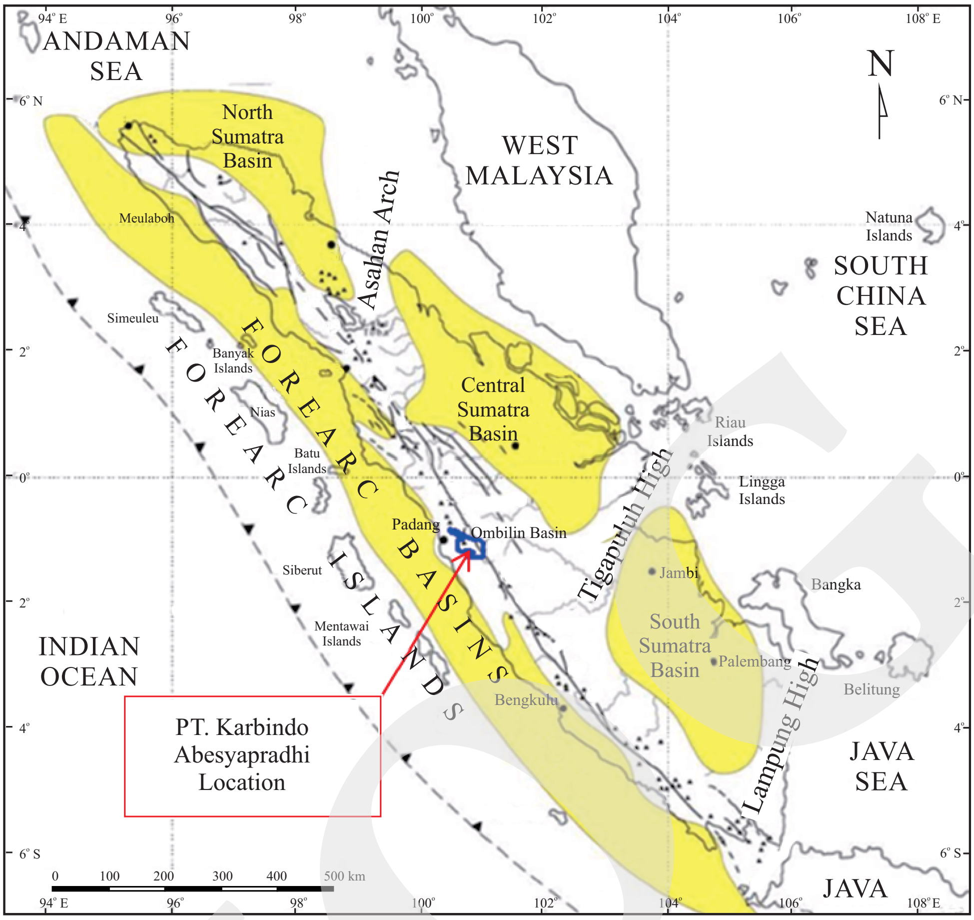

Figure 1. The locality map of the studied area situated in Kiliranjao Sub-basin, West Sumatra (modified from Barber, 2005).

in a lacustrine environment, whilst the Upper Red Bed is composed of fine- to coarse-grained sandstones, siltstones, and claystones deposited in a fluviatile environment. The Brown Shale Unit is well exposed in the Karbindo Coal Mine area as an overburden rock formation overlying a coal seam.

The studied area is situated to the east of Padang, West Sumatra, that administratively belongs to Kemang Baru Subregency of Sijunjung Regency. The region has been regionally mapped by Silitonga and Kastowo (1995). The geology of this area has also been studied by Coster (1974), Darman and Sidi (2000), and Carnell *et al.* (2013). Several researchers*, i.e.* Carnell *et al.* (1998), Aswan *et al.* (2009), Widayat *et al.* (2013), and Iqbal *et al.* (2014) concluded that the Eocene-Oligocene sediments in Kiliran Jao Subbasin was deposited in lacustrine to brackish environments associated with a coal deposition.

Methods

The base map used is a topographic map of Sungai Lansat sheet scale 1:50.000, from Bakosurtanal, Indonesia. The study focused on lithological successions exposed as a working face at Karbindo Coal Mine area. The succesions are composed of constituents of Brown Shale Unit of the Pematang Formation (Figure 3). The fieldwork was conducted to identify the lithological type and any general/special characteristics (mineral composition, grain size, weathering, diagnostic sedimentary structure, and fossils content), lateral and vertical stratigraphic distribution. Petrographic studies and XRD analysis performed on lithologic samples are for the purposes of mineralogy composition, rock texture, and structure determination, as well as environmental interpretation. Moreover, palynological investigation was also carried out to obtain the age and depositional environment.

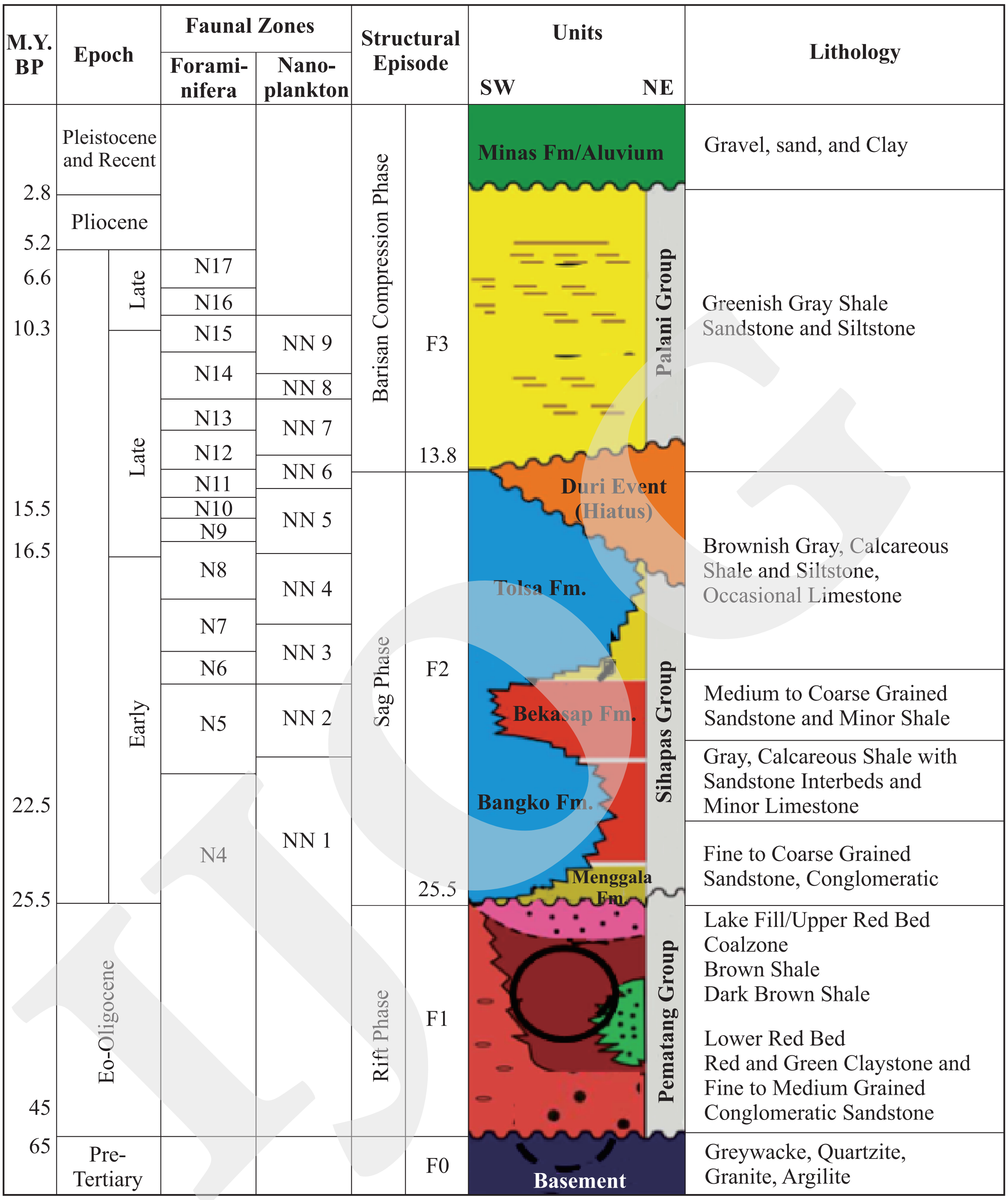

Figure 2. The tectonostratigraphic chart of Central Sumatra Basin (after Heidrick and Aulia, 1993; the Pematang Group is shown in a black circle).

Results

Lithofacies association succession developing in the observed Brown Shale Unit from lower to upper part shows a repetition of a sedimentation cycle that can be divided into facies association (Figure 3) as follows:

1. Coal and limestone facies (A)
2. Amalgamated massive thick bedded shale facies (B)
3. Interlaminated shale and siltstone facies (C)
4. Interbedded grey and red shale facies (D)
5. Fossiliferous shale facies (E)

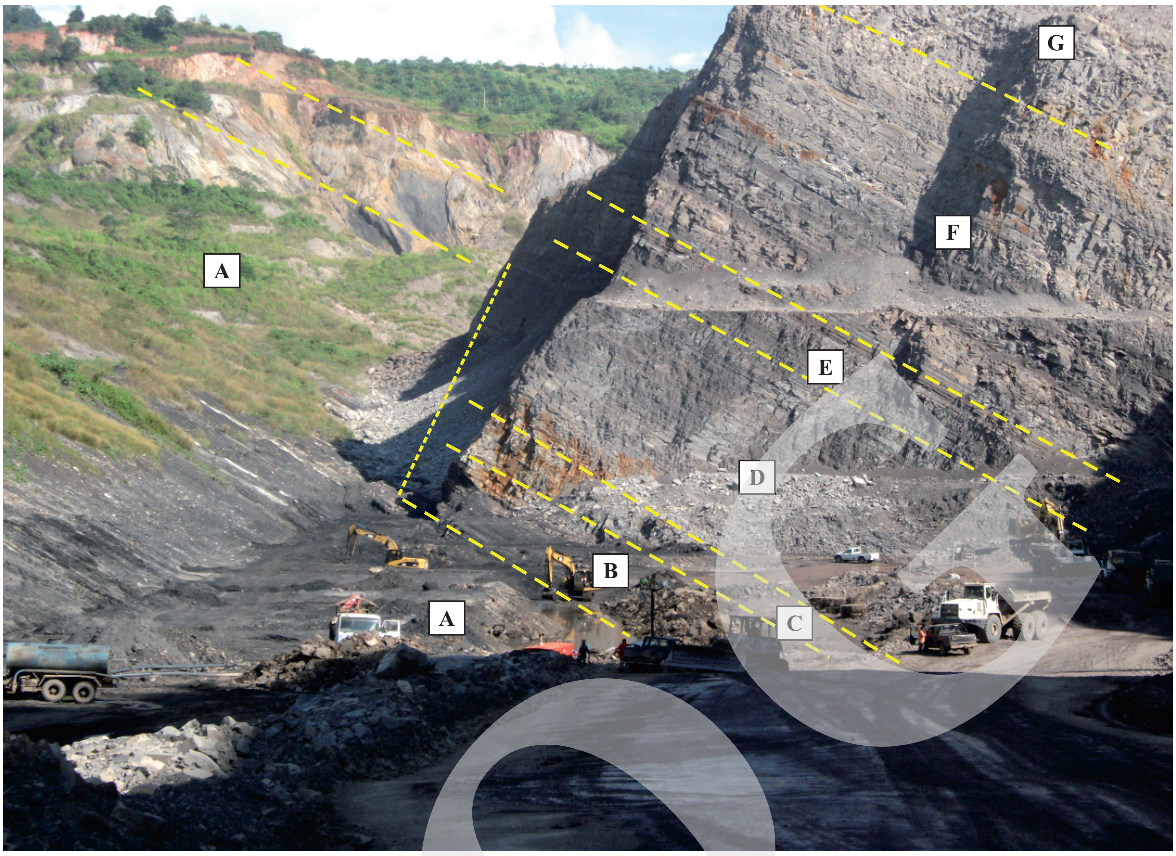

Figure 3. The photograph of outcrop of the Brown Shale lithofacies association in the Karbindo Coal Mine. A: Coal and limestone facies; B: Amalgamated massive-thick bedded shale facies; C: Interlaminated shale and siltstone facies; D: Interbedded grey and red shale facies; E: Fossiliferous shale facies; F: Massive-thick bedded shale facies; G: Interlaminated shale and sandstone facies.

6. Massive bedded shale facies (F)
7. Interlaminated shale and sandstone facies (G)

Coal and Limestone Facies (A)

Coal and limestone facies (Figure 4) comprise several coal beds tending to show thinning upward. The coal beds are black, vitreous, conchoidal fractured and jointed with face and butt cleats, occasionally filled by pyrites. The coal beds are occasionally intercalated by limestones or interbedded with limestones.

The limestones also consist of several beds intercalated within or interbedded with coals. In general, the limestones are light brown in colour, hard, very fine-grained or micritic; often contain thin layers of carbonaceous matter. The thickness of limestone beds ranges from 3 cm to 1 m. Microscopically, the limestones are mainly supported by calcite crystalline and containing organic matter laminae, which is consistent with the result of XRD analysis indicating that the limestones are mostly composed of calcite minerals (Figure 5).

Amalgamated Massive Thick Bedded Shale Facies (B)

Massive facies (Figure 6) is characterized by interbedded - amalgamated aggradational thick, massive (almost structureless) beds of shales. The shales are dark brown, calcareous, carbonaceous, and contain sandy silty matters, occasionally forming discontinuous and continuous parallel laminations. The thickness of this facies is about 6.5 m.

Interlaminated Shale and Siltstone Facies Association (C)

Interlaminated shale and siltstone facies association (Figure 7) contains tight laminations

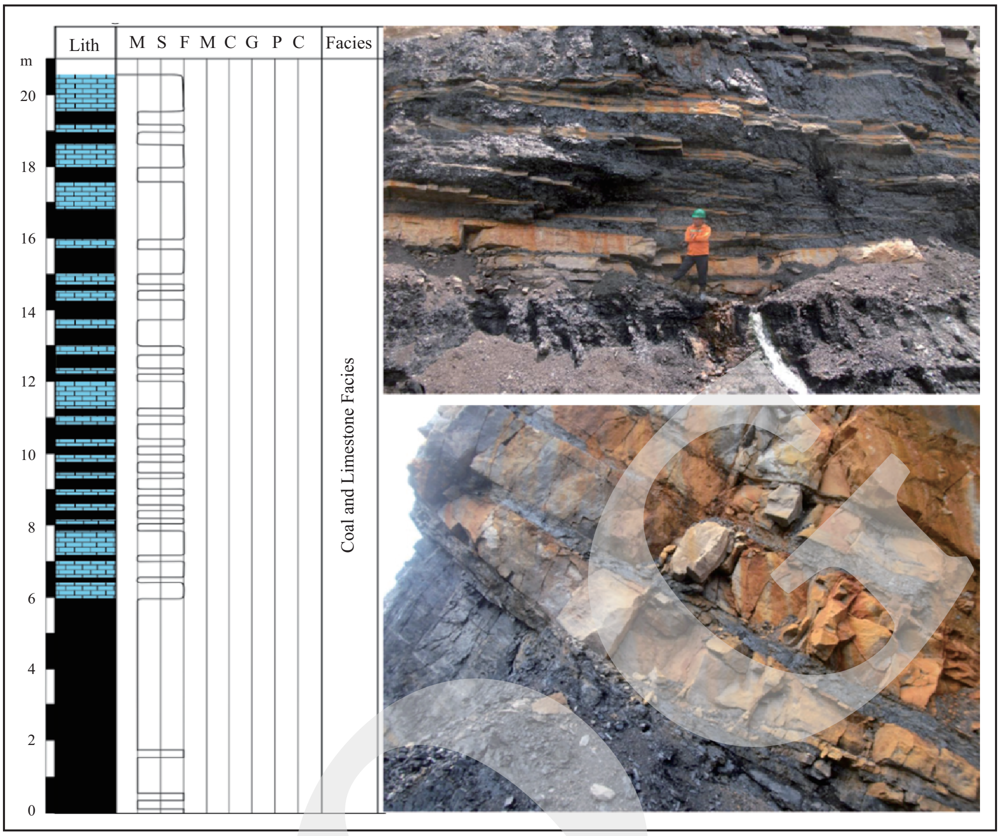

Figure 4. Photograph of interbedded coals and limestones showing the repetition of thickening and coarsening upward cycles; a few limestone wedges out into coal seams.

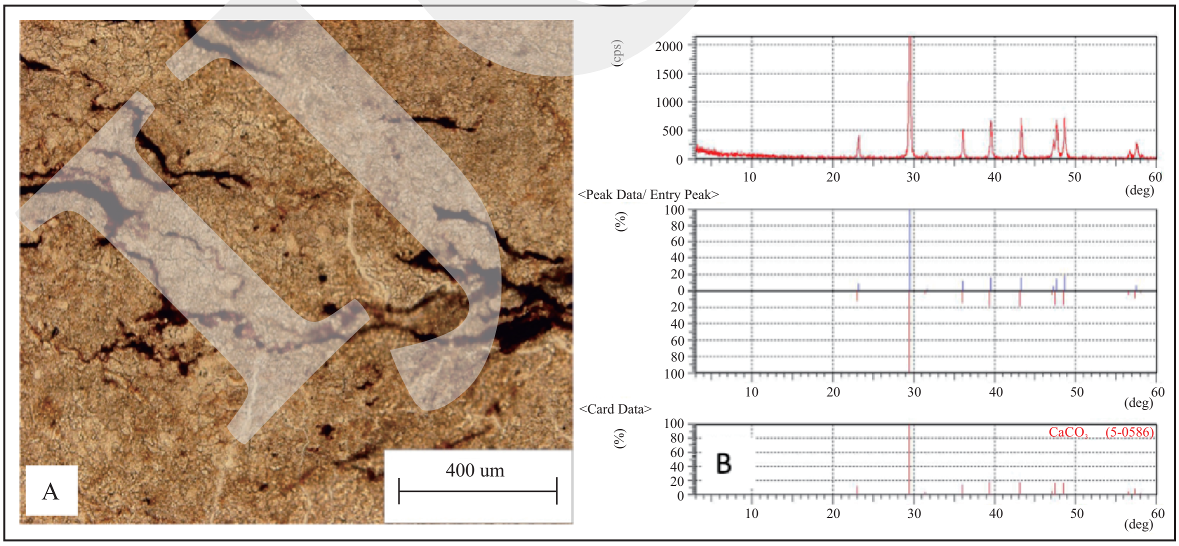

Figure 5. A. Photomicrograph of crystalline limestone supported by calcite and contains organic matter laminae (P 10, X-nicol). B. Mineralogy data record, a result of XRD analysis of limestone showing the rock contains only calcite (CaCO3).

(<1cm) formed by silty- and sandy-calcareous shales, and carbonaceous shales. The thickness of this facies is about 20 m. Microscopically, it shows wavy laminations of calcite, mud or clay, iron oxide, and carbonaceous matters (Figure 8A). X-RD analysis result indicates that the rocks are composed of calcite, kaolin, siderite, and quartz (Figure 8B).

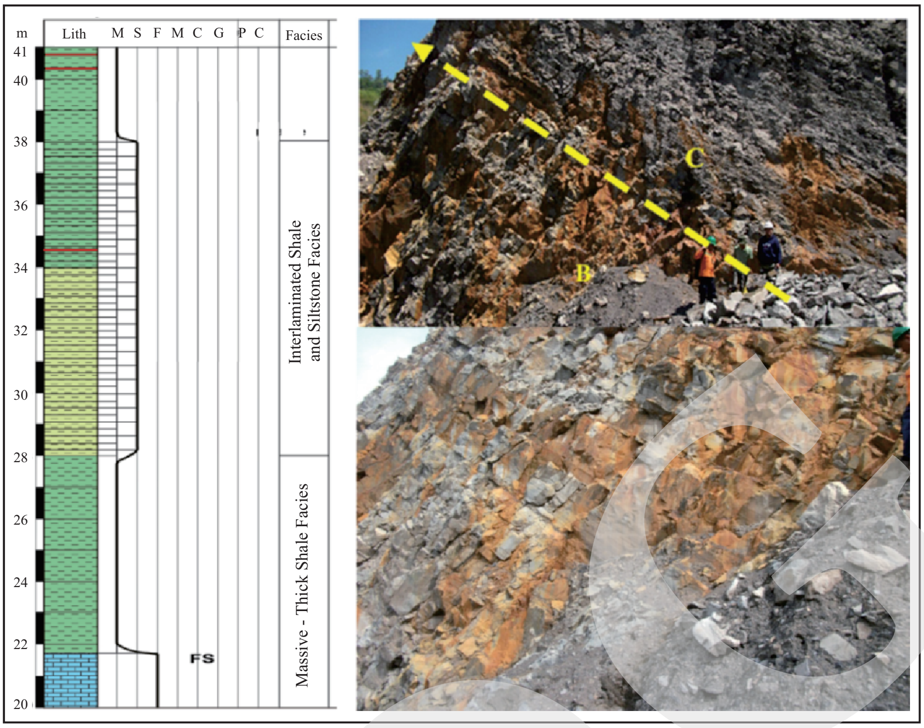

Figure 6. Photograph of thick bedded calcareous and carbonaceous silty-sandy dark brown shales of massive shale facies association.

Figure 7. Photograph of interlaminated shale and siltstone facies association containing shales, calcareous sand, and calcareous siltstones.

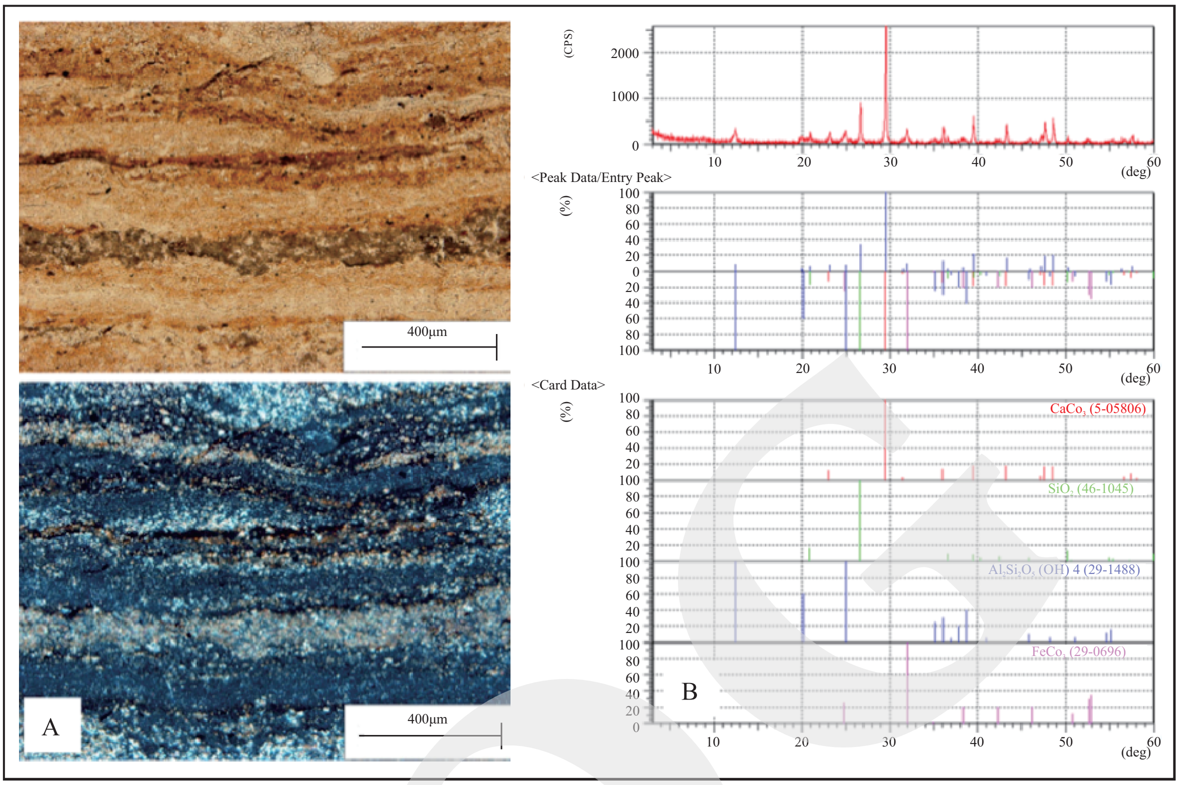

Figure 8. A. Photomicrographs indicating interlamination of clay or shale, calcite, siderite, and carbonaceous matters (P20, X-nicol). B. Mineralogy data record of interlaminated shale, a result of XRD analyses containing calcite, kaolin, quartz, and siderite.

Interbedded Dark Grey Shale and Red Mudstone Facies (D)

Interbedded dark grey shale and red mudstone facies (Figure 9) are almost similar to the underlying interlaminated shale and sandstone facies. The differences are on the less sedimentary structure development. This facies is mainly composed of interbedded amalgamated massive thick bedded shales and mudstones intercalated by sandstones, siltstones, and claystones. The shales are dark brown, dark grey to black in colour, carbonaceous, and calcareous, containing abundant organic matters. Mudstones are reddish brown, calcareous, 5 - 15 cm thick. The sandstones are calcareous, grey - greenish grey, very fine to fine-grained, and often show very thin graded bedding structures. The siltstones are grey and commonly present as a laminated body. The claystones are white, thin, to very thin forming part of sedimentary structures.

Fossiliferous Shale Facies (E)

The fossiliferous shale facies (Figure 10) overlies the massive shale facies with a gradual contact. This facies consists of interbedded dark brown - black shales, and red shales containing rich angular fragments (1-2 cm) of gastropods and minor bivalve mollusks (up to 4 cm in diameter). Those fossils are commonly concentrated in the bottom of the layer and more scattered in the upper part of the beds, occasionally forming graded bedding structure-like. Aswan *et al.* (2009) stated that the fossils comprised *Brotia* sp., Thiara sp., and *Paludina* sp. The thickness of the fossiliferous fossils on the section is 13.5 m.

Massive Thick Bedded Shale Facies (F)

Massive thick bedded shale facies (Figure 11) conformably overlies the fossiliferous shale facies. It comprises homogeneous, amalgamated massive thick bedded shales intercalated by broken white clay and red mudstones. The shales and mudstones are dark brown to black, calcareous and carbonaceous, commonly contain abundant organic content. The thickness of shale beds ranges from 30 cm to 1.5 m, and they occasionally

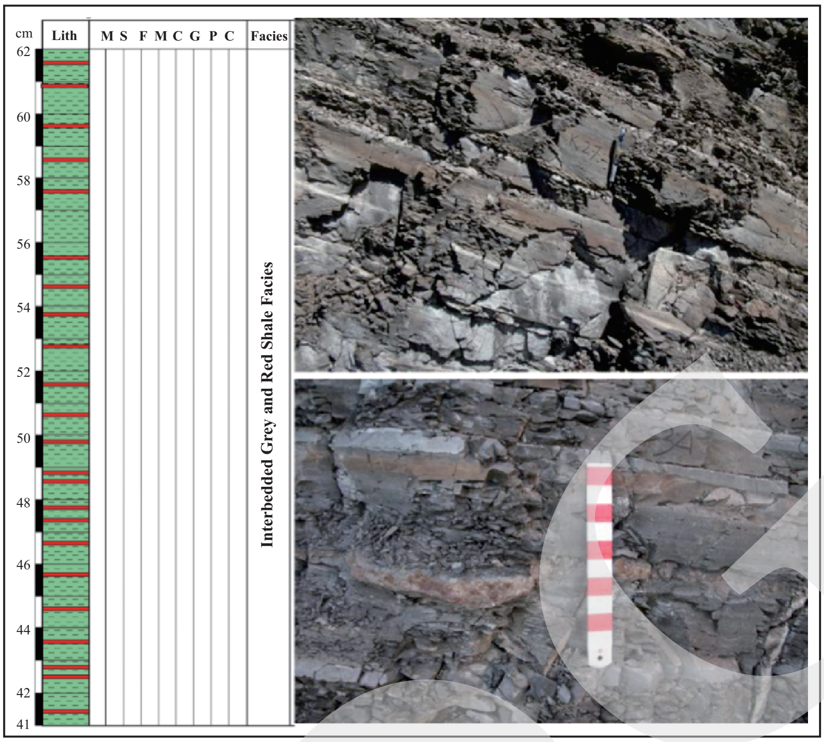

Figure 9. Photograph of interbedded calcareous shales and sandstones. The sandstones show graded bedding and load cast structures. Interbedded thick shales and very thin-laminated white claystones occur.

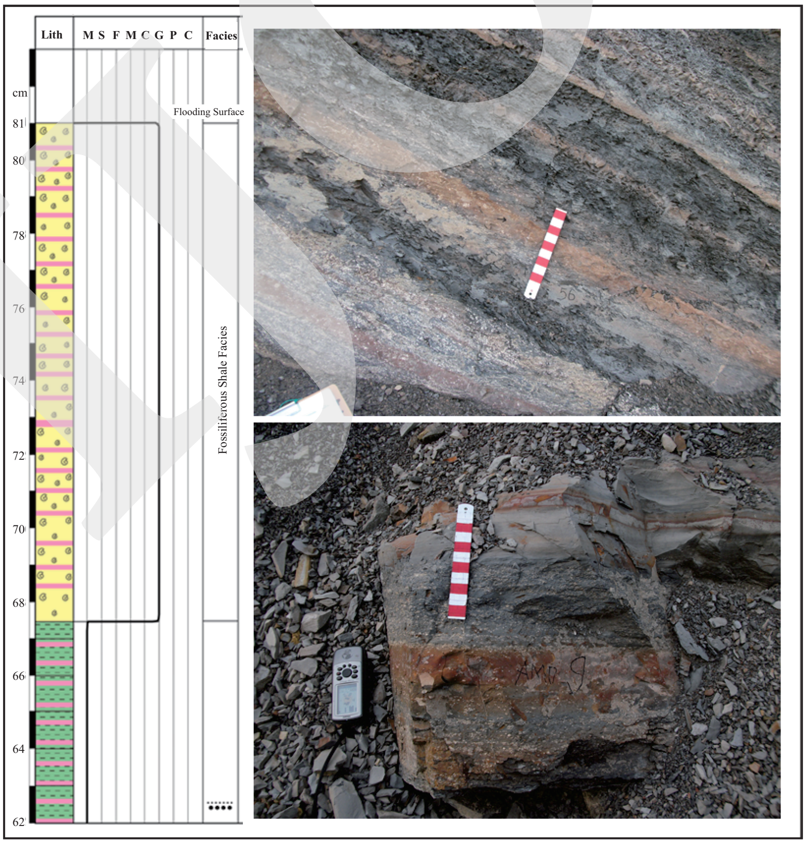

Figure 10. Photograph of fossiliferous red and dark grey shales showing graded bedding and parallel lamination structures rich in fragments of gastropods.

show parallel laminations formed by carbonate grains. Petrographically, several shales show good parting or fissility features (Figure 12A). The claystones are broken white in colour, less than 1cm -20 cm thick. Based on XRD analysis, these claystones are composed of kaolin, calcite,

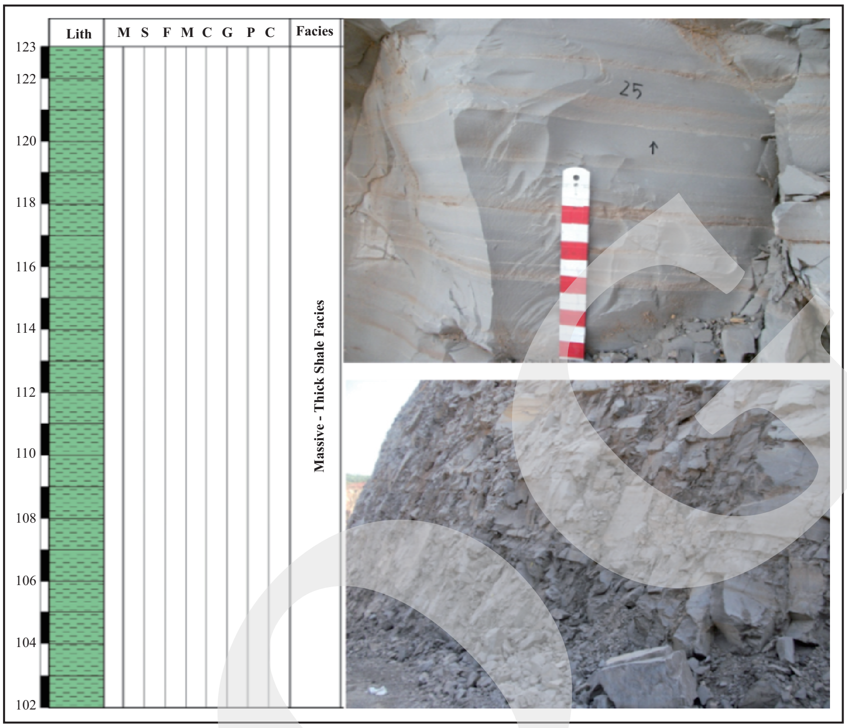

Figure 11. Photograph of massive shale facies containing rich organic matter. The sediments are interbedded shales and calcareous sandy laminations, containing iron oxides and also pyrites; graded bedding structure.

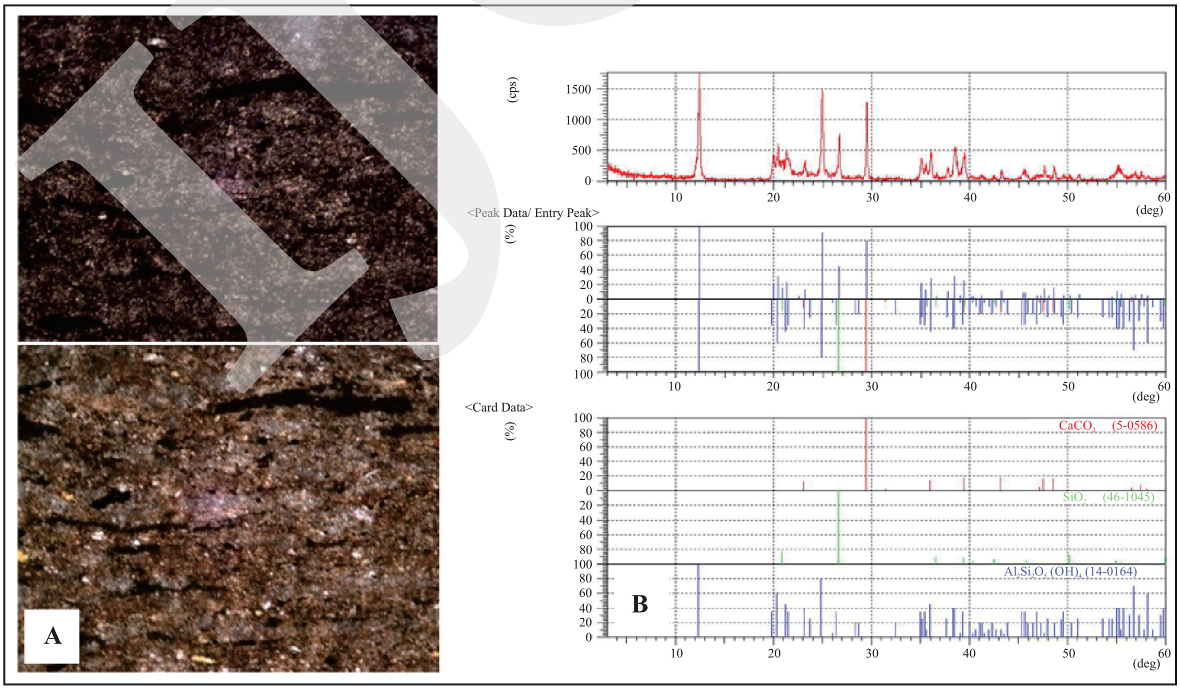

Figure 12. A. Photomicrographs of fissility or parting on shale composed of muddy and organic matters. B. Broken white claystones consisting of kaolinite, quartz, and calcite.

siderite, and quartz (Figure 12B). They contain parallel lamination structures and slump features. The thickness of this facies in the measured section is approximately 60.5 m.

Interlaminated Thin Bedded Shale and Siltstone Facies (G)

The interlaminated thin bedded shale and siltstone facies (Figure 13) are present as the uppermost facies in the section, consisting of interlaminated - very thin bed of mudstones, shales, sandstones, and siltstones. Those rocks are composed of shally, sandy, silty, muddy calcareous and carbonaceous matters. Petrographically, those rocks predominantly consist of mudstones and shales which do not show fissility parting. Sandstones are fine-grained composed of grains of feldspar, carbonate, organic matters, and clay matrix indicating the rocks are feldsphatic wacke (Figure 14). Lithologically, the facies contains tight or very closed laminated forming repetition of parallel, wavy-ripple, slump, and graded bedding sedimentary structures. The thickness of this facies is about 81.50 m on section.

Discussion

Generally, it is very difficult to determine the age of coal and limestone facies in this area because there are no index fossil for the age determination. However, the presence of (?) *Florschuetzia trilobata* in Lithofacies A suggests that the age of the sample probably ranges from Eocene to Oligocene.

On the basis of lithology and their sedimentary structures, the coal facies was deposited in a freshwater to brackish swampy mire. This is supported by the presence of brackish water polen of *Dicolpopollis* sp.

The limestone facies was deposited in a stagnant water in pool or depression and or swampy environment underwent evaporation during a long period of dry season or airy condition producing evaporation minerals such as calcium carbonate (calcite). On the basis of those data, it can be suggested that the limestones were deposited in a freshwater environment.

The amalgamated shale facies (Lithofacies B) was deposited in a low energy and deeper water

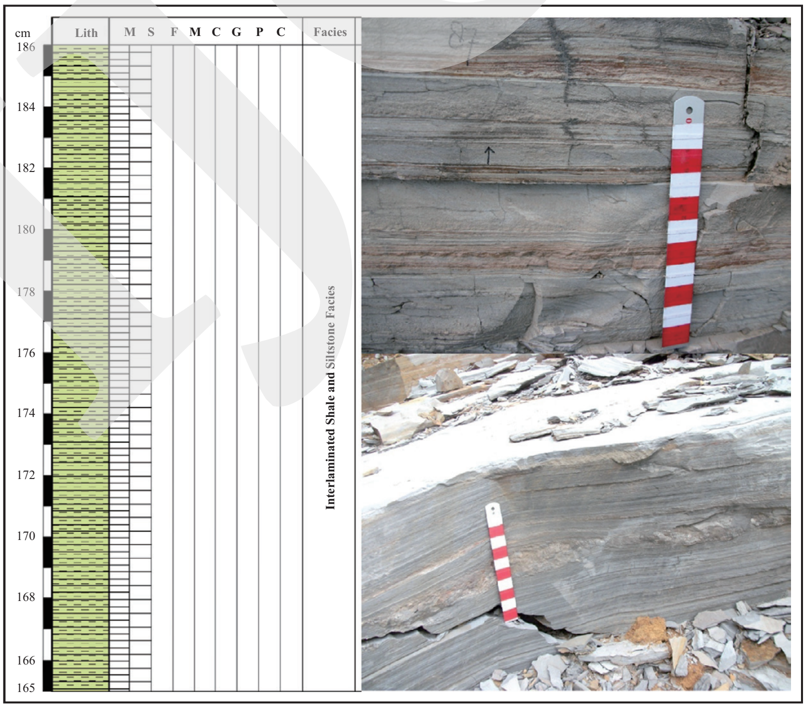

Figure 13. Photograph of interbedded very fine - to fine grained sandstones and mudstones showing repetition of graded-bedding, and parallel and ripple laminations, composed of carbonates, iron oxides, and pyrites. Load cast and parallel lamination occur within calcareous, carbonaceous sandy, silty, muddy matters.

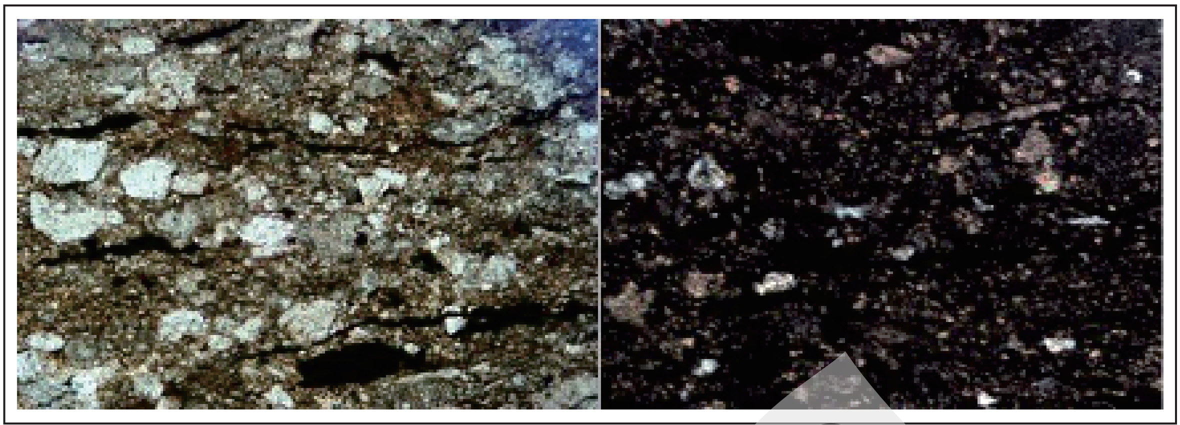

Figure 14. Photomicrographs of feldsphatic wacke composed of clay minerals, lime mud, carbonate grains, K-feldspar, and organic matters (P10, X-nicol).

environment compared to the coal and limestone units. It was probably deposited during a long period of wet season causing shoreline of lake moved landwards and suspended influx sediments filled the basin. Due to the sequence of beds showing aggradation stacking pattern, it suggests that during their deposition the rate of subsidence is equivalent to this of rate influx sediments.

The interlaminated shale and siltstone facies (Lithofacies C) was deposited in a shallow water lake with low oxygen and low acidic condition indicated by the presence of siderite ($FeCaCO_3$) and also tight wavy - current ripple lamination structures. The presence of tight wavy-ripple sedimentary structures indicates that the structure formation was influenced by a wave activity blown by the wind. Thus, the base of water should be a shallow water environment. The presence of calcite, kaolin, and quartz minerals in the rock suggests those minerals were probably transported from fluvial and marginal lake sediments.

The sedimentary structures developed in interbedded grey and red shale facies (Lithofaces D) are commonly in small scales comprising graded bedding, parallel lamination, current ripple lamination, and slump structures, which are probably as turbidity structures. The thickness of this massive thick shales and siltstones is about 29.5 m, accumulated in deep water characterized by the presence of sedimentary structures consisting of graded bedding, load cast, current ripple, and slump laminations. Whereas the thick beds of shale were deposited in suspended ways in low energy condition.

The fossiliferous shale facies (Lithofacies E) was deposited in a deep water environment characterized by the presence of gastropods fragments, which were probably transported by density current from a beach or shallower environment. Although the environment was in deep water, this facies was accumulated more proximal than the dark grey shale and red mudstone facies.

The massive thick beds of shale facies (Lithofacies F) was accumulated in deep water characterized by the presence of graded bedding, parallel, and slump lamination sedimentary structures which were usually formed by density current. The environment is more distal than this of fossiliferous shale facies. The calcite, quartz and kaolin were transported away from the land.

The interlaminated shale and sandstone facies (Lithofacies G) was deposited in deep water but more proximal than the massive thick bed shale facies. The facies is characterized by the presence of sedimentary structures such as graded bedding, load cast, parallel, ripple-wavy, and slump laminations, usually formed by density or turbidity currents. The constituent of the rocks was probably derived or reworked from land or shallower environments.

The arrangements of the seven lithofacies which are denoted from A to G are associated within a facies-belt model as illustrated in Figure 15.

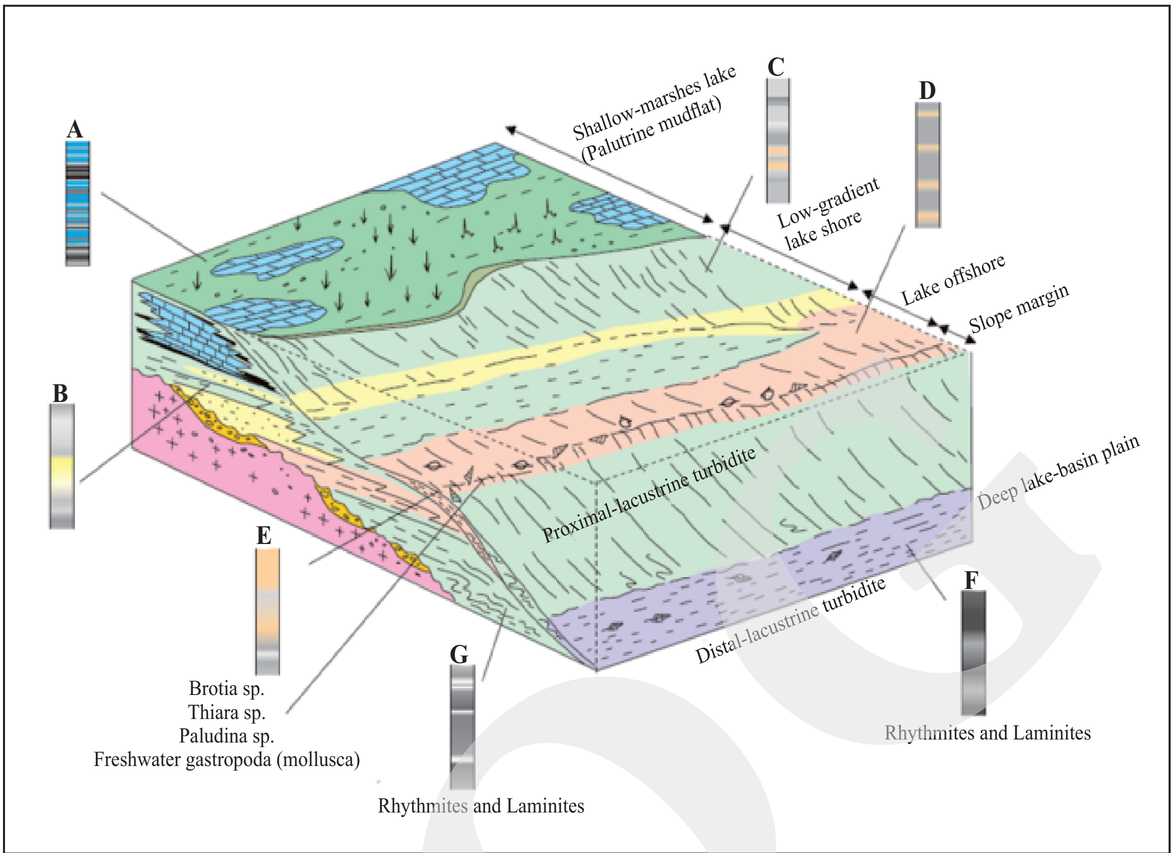

Figure 15. The facies-belt, lacustrine depositional system, Kiliran Jao Subbasin.

The entire lithofacies are considered to represent a lacustrine depositional system started from a shallow-lake marshes or palustrine mudflat (Platt and Wright, 1991) at the shallowest part of the system, then the lake shore, lake offshore (Cabrera and Saez, 1987), and the deep-lake basin-plain at the deepest part of the system. Facies A represents shallow-lake marshes, where the lake level fluctuations can occur during dry and wet seasons. The association of peat and freshwater limestones might be formed under this situation. Facies B and C represent the low-gradient lake shore environments characterized by the presence of wavy cross-stratification. Facies D represents a deep-offshore lake, where in this environment turbidity current can occur caused by a hyperpycnal flow. Facies E representing a biogenic facies was deposited on the edge of lake-offshore, most likely formed when the lake level rose accompanied by a very low sediment supply. Facies F and G represent a distal and proximal lacustrine turbidite, respectively, which then extending into a deep-lake basin-plain. Those two facies are characterized by the laminite deposits.

Conclusions

Recent fieldwork points out that the Tertiary lithostratigraphic units exposed in the Karbindo Coal Mine and its surrounding areas are probably part of the Pematang Formation as defined by previous investigators. It provides the valuable information to support exploration activities regarding hydrocarbon source rocks. Two lithological units of the Pematang Formation are exposed, namely the Lower Red Bed and Brown Shale.

The lithofacies association developed in the Brown Shale Unit from lower to upper part shows a repetition of sedimentation cycles divided into seven facies associations as follows:

1. Coal and limestone facies (A), presumed to be deposited in a fresh water depression.
2. Amalgamated massive thick bedded shale facies (B), deposited during a long period of wet season causing a shoreline of a lake moved landwards and suspended influx sediments filled the basin.
3. Interlaminated shale and siltstone facies (C) was deposited in a shallow water lake with low oxygen and low acidic condition.
4. Interbedded grey and red shale facies (D) accumulated in deep water is characterized by the presence of turbidity structures.
5. Fossiliferous shale facies (E) deposited in a deep water environment and characterized by the presence of gastropods fragments, were probably transported by density current.
6. Massive thick bedded shale facies (F) accumulated in deep water is characterized by the presence of sedimentary structures which are usually formed by a density current.

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