# Neogene coal characteristics and depositional environments in the Kikim Area of South Sumatra Basin; Insights from logging, proximate test, sulphur test and electrofacies

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## ABSTRACT

Neogene coal is the main producer in the Kikim area (Gumay Talang District, Lahat Regency) of South Sumatra Basin and is part of the Muaraenim Formation. However, the characteristic and depositional environment of this Neogene coal are still poorly understood. This research was conducted to determine the characteristics and distribution model of coal seams, as well as its depositional environment. Coal seam characteristics include thickness, description, coal rank, depositional structure, and coal seam depositional environment. The methods used in this research are well-logging, proximate and ultimate tests, and electro facies. Geophysical logging analysis was carried out at four drilling points. The results of the analysis from well logging found four seams in order from youngest to oldest seam, namely seam B, seam C, seam D, and seam E. Seam B has the most significant thickness, namely 9.55 meters, Seam C 2.29 meters, seam D 4.90 meters and Seam E 2.10 meters. The ASTM classification shows that the coal seam is included in the coal rank Sub-bituminous B – Sub-bituminous A. The determination of coal rank uses the ASTM D-388 classification, which aims to identify the coal grade. The parameters used in determining coal rank are fixed carbon content, calorific value, and volatile matter. The depositional structure found at the research location is split. The depositional environment interpretation of coal seams uses three parameters lithofacies, sulphur content and electro facies. Our research revealed that the study area's depositional environment is in the upper delta plain in the backswamp-floodplain section.

***Keywords***: *Neogene coal, Kikim, Muaraenim Formation, South Sumatra Basin*

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## INTRODUCTION

This research focuses on the characteristics and identification of depositional environments using logging data, proximate and sulphur tests, and electro facies developed in coal exploration. Indonesia is a country blessed with abundant natural resources, one of which is coal resources. South Sumatra is known as one of Indonesia's provinces with abundant coal resources because it is located in the South Sumatra Basin, a back-arc basin. This basin has two coal-bearing formations, namely the Muaraenim Formation and the Air Benakat Formation (Gafoer et al., 1986). Coal is a deposit composed of organic materials originating from plant remains that have undergone various stages of decay (decomposition) and changes in physical and chemical properties both before and after being covered by overlying deposits (Stach, 1982). Coal seams can be found in varying conditions, including extensive layers, irregular layers, regular layers, thinned layers, thickened layers, and diverse geometries. Geological structures, such as folds and faults, can influence the distribution and characteristics of coal seams (Ernia et al., 2020). Geological structures, such as folds and faults, can influence coal quality and seam geometry. According to Kusuma et al. (2012), the quality of coal is influenced by several factors, including sulphur content, ash content, moisture content, fixed carbon, and calorific value. Meanwhile, the parameters that influence the geometry of the coal seam include thickness, dip, distribution, shape, and continuity of the coal seam.

This research was conducted in an open-pit mining area that has already been mined and is managed by PT. Batu Alam Selaras. Administratively, the company is located in Tanjung Beringin Village, Gumay Talang District, Lahat Regency, South Sumatra. The main producer is Neogene coal; however, the characteristic and depositional environment of this Neogene coal are still poorly understood. This research was conducted to determine the characteristics and distribution model of coal seams, as well as its depositional environment. The method applied in this research uses the well-logging method; this method has a relatively high level of data accuracy. The well logging method is a way to continuously collect data by taking measurements in drill holes to explore variations in the physical properties of rocks found during the drilling process (Reeves, 1986 in Dwitama, 2019). Apart from being used to understand geological aspects, this method also helps in collecting various other types of data, such as depth, distribution, thickness, and quality of coal seams based on the density value and the volume of shale, as well as overcoming problems that arise when drilling, such as checking the actual depth of each layer, especially coal seams, including parting and other components (Dewanto, 2009).

According to Bakri et al. (2022), coal has different characteristics depending on the depositional environment and type of plant, so coal has a high level of physical and chemical variability. As a result of this variability, coal quality parameterization is carried out. Determining coal quality can be obtained by knowing the quality parameters of coal (Kusuma et al.,

2012). The parameters used to determine coal quality are total moisture content, ash content, calorific value, volatile matter (VM), carbon content (fixed carbon), and sulphur content (Hilmi et al., 2021). According to Givi et al. (2017), the depositional environment influences the thickness, distribution, continuity, roof, and sulphur content, as well as tectonic activity in the formation of coal seams. Based on Dissel (1992), the coal deposition environment influences the sulphur content. Coal with high sulphur content usually comes from topogenic swamp types with high water levels and pH, generally occurring in lower delta and tidal flat environments. On the other hand, coal with low sulphur content comes from topogenic peat with a low water table and pH, generally developing in terrestrial areas in upper delta plain and tidal flat environments. The depositional environment can also be determined by looking at the gamma-ray curve pattern, which is also called electro facies (Roslin et al., 2016). Electro facies is the basic principle of identifying log images related to depositional environments or depositional environment associations in well-logs. different (Schmitt, et al., 2013). According to Cant (1992) in Setiahadiwibowo (2016), there are five basic shape patterns of the log GR curve in response to the deposition process, namely cylindrical/box, funnel shape, bell shape, symmetrical – asymmetrical shape, and irregular. This research identified the depositional environment with three parameters including (1) lithofacies by looking at the lithology around the coal (interburden and overburden), (2) sulphur and ash content, and (3) electro facies by looking at the Gamma Ray curve graph. The C# programming language method in Python was used to solve the problem of estimating deviations in calculations for the ash estimation (Yusefi et al., 2019). This research is an update on previous methods, to better understanding the characteristics and depositional environment of Miocene coal in the Kikim Block at PT Batualam Selaras – Lahat - South Sumatra Basin.

## GEOLOGICAL SETTING

Based on geological mapping, the lithology of the rocks in the study area includes claystone, siltstone, sandstone, coal, and carbonaceous claystone (Figure 1). These are grouped into three rock units: the siltstone unit of the Muaraenim Formation, the coal intercalation of the Muaraenim Formation, and the sandstone unit of the Muaraenim Formation.

The South Sumatra Basin is a Tertiary back-arc basin that trends southeast-northwest. The southwestern part of this basin is bounded by the Semangko Fault and the Bukit Barisan Mountains, while the northeastern part is bordered by the Sunda Shelf and the Lampung High to the southeast, which separates it from the Sunda Basin. Additionally, it is bounded by the Duabelas Mountains and Tigapuluh Mountains to the southeast, separating it from the Central Sumatra Basin (De Coster, 1974; Pratiwi, 2013). According to Pulonggono et al., (1992) in Barber et al. (2005), the development of the South Sumatra Basin occurred through three tectonic phases: the Rifting Phase, the Extensional Phase, and the Compression Phase. The research area is a back-arc basin that is located in the South Sumatra Basin. The stratigraphy

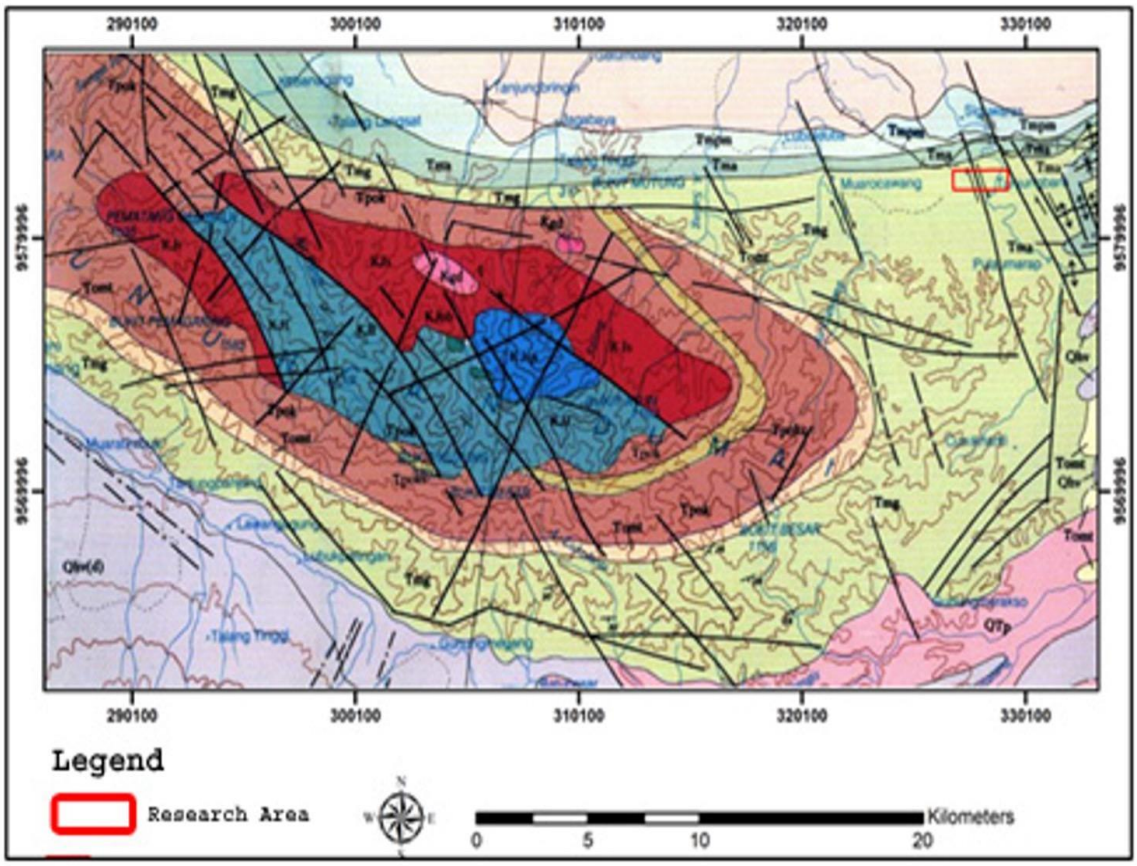



***Figure 1:*** *Geological map of Bengkulu Quadrangle, showing research area (red box) at the upper right corner of the map (Gafoer et al., 1993).*

of the research area includes the Muaraenim Formation, which consists of sandstone, mudstone, and tuff sandstone lithologies with lignite inserts (Gafoer et al., 1993). The Muaraenim Formation is coal-bearing and wide open on the anticline side. In this formation, large amounts of coal outcrops were found; all are part of the M4 coal seam group (Shell, 1978).

Based on Pulunggono et al., (1992) in Barber et al., (2005), there are three tectonic phases of Sumatra Island that form the characteristics of each different sub-basin, including structural patterns, thickness of sedimentary deposits and hydrocarbon traps, which is formed. The first phase is the compression phase (Early Jurassic-Cretaceous Age). In this phase, Jurassic intrusion into Cretaceous age granite and wrench movement produces the WNW - ESE dextral strike-slip fault. In the second the extensional phase (Late Cretaceous-Early Tertiary), there was a change in the direction of tectonic forces, which produced a fault in the N-S direction, sedimentary material from the Lahat Formation began to fill the basin which developed along with volcanic activity. Moreover, Miocene or Intra Miocene tectonics caused the basin edge was lifted. Clastic material began to be deposited, namely the Talangakar Formation, Baturaja Formation, Gumai Formation and Airbenakat Formation. The third phase is the Middle Miocene-Recent compression phase in which the basin

experienced fault reactivation resulted uplift and formation of significant anticlinoriums in the South Sumatra Basin, such as the Gumay, Muaraenim, Pendopo-Benakat, and Palembang Anticlinoriums. When this phase occurred, Bukit Barisan was oriented N 320°E and created a third phase called the Bukit Barisan orogenesis. As a result, structures developed in the form of horizontal faults during the Middle Miocene, accompanied by increased volcanic activity.

## DATA AND METHODS

The research methodology includes data collection, analysis, and interpretation of research results. Data collection consists of primary data and secondary data. The primary data was obtained from the results of field geological mapping, and secondary data is supporting data provided by the company from previous researchers. Data analysis for well-logging according to Yusefi et al. (2019), is a measurement carried out to obtain subsurface data using measuring instruments inserted into drill holes, which are used to identify rock lithology, depth, thickness, and quality of coal. Logging analysis was carried out using Well Cad software. Proximate and ultimate test methods are used to determine coal quality.

According to Dwivedi et al., (2022), within the scope of coal quality analysis, the proximate test has several parameters, namely Moisture Content, Volatile Matter, Fixed Carbon, Ash Content, and Calorie Value (Calorific Value). This Proximate Test was carried out on three coal samples. Taken from composite samples of the three seams namely seam B, seam C, and seam D. The ultimate test consists of several parameters including sulphur, Carbon, Hydrogen, and Oxygen contents. In this study, only sulphur and ash contents that were used. The samples used are the same as those used in the proximate test. The coal deposition environment can be determined by ash and sulphur contents. The depositional environment can also be seen from logging data in gamma-ray curve patterns on each coal seam, called the electro facies method.

## RESULTS AND DISCUSSION

The lithology found is siltstone, mudstone, coal, and sandstone. Geophysical logging analysis was carried out at four drilling well locations. There are four seams that are observed in the research area. These seams from youngest to oldest seam are seam B, seam C, seam D, and seam E. Seam B has the most significant thickness, 9.55 meters, Seam C 2.29 meters, seam D 4.90 meters, and Seam E 2.10 meters.

Based on proximate tests, seam B has a CV (moisture-mineral matter free basis / mmmf) value of 10392 Kcal/kg. Seam C has a CV (mmmf) value of 10639 Kcal/kg, and seam D has a CV (mmmf) value of 10368 Kcal/kg, according to the ASTM Classification of coal seams at PT. Batualam Selaras is included in the coal rank Sub-bituminous B – Sub-bituminous A. The depositional structure found at the research location is split. Splitting occurred in Seam C. In seam C, parting was found to indicate splitting in the eastern part of the study area. Apart from that, in seam D, there is also splitting, thickening, and thinning of the coal seam, which is caused by the influence of the sinking process during the deposition process. If the sinking occurs quickly, the formed layer will be thick, and vice versa.

**Table 1.** Depth, Thickness, and Coal Seam

| WELL ID | FROM | TO | THICKNESS | TRUE THICKNES | LITHOLOGY | SEAM | Vshale (%) | Density (gr/cc) |
|---|---|---|---|---|---|---|---|---|
| P-03 | **7.1** | **10.3** | **3.2** | **2.45** | **Coal** | **C** | 0.6 | 1.24 |
| | **41,1** | **50,4** | **9.3** | **7.1** | **Coal** | **B1** | 2 | 1.24 |
| | **50.6** | **53,2** | **2,6** | **1.99** | **Coal** | **B2** | 0.3 | 1.28 |
| P-04 | **30.9** | **32.15** | **1.25** | **0,95** | **Coal** | **E1** | 2.6 | 1.27 |
| | **38** | **38,9** | **0.9** | **0.68** | **Coal** | **E2** | 1.5 | 1.32 |
| | **41,1** | **42** | **0,9** | **0.68** | **Coal** | **D1** | 4.3 | 1.49 |
| | **43** | **43.2** | **0.2** | **0.15** | **Coal** | **D2** | 1 | 1.3 |
| | **44.2** | **46.7** | **2.5** | **1,92** | **Coal** | **D3** | 1 | 1.25 |
| | **47.7** | **49.6** | **1.9** | **1.45** | **Coal** | **D4** | 0.3 | 1.3 |
| | **49.8** | **50.1** | **0.3** | **0.22** | **Coal** | **D5** | 0.16 | 1.4 |
| | **73.2** | **75.9** | **2.7** | **2.06** | **Coal** | **C** | 0.6 | 1.2 |
| P-05 | **7.4** | **9.2** | **1.8** | **1.38** | **Coal** | **E1** | 1 | 1.13 |
| | **11.48** | **13.1** | **1.62** | **1.24** | **Coal** | **E2** | 1.3 | 1.2 |
| | **16.4** | **17.2** | **0.8** | **0.61** | **Coal** | **D1** | 0.6 | 1.24 |
| | **18.83** | **19.05** | **0.22** | **0.16** | **Coal** | **D2** | 0.8 | 1.3 |
| | **19.92** | **23.4** | **3.48** | **2.67** | **Coal** | **D3** | 1 | 1.28 |
| | **24,1** | **27.2** | **3.1** | **2.37** | **Coal** | **D4** | 0.6 | 1.27 |
| | **27.6** | **29,8** | **2.2** | **1.68** | **Coal** | **D5** | 0.6 | 1.25 |
| | **39.7** | **40,9** | **1.2** | **0,91** | **Coal** | **C1** | 2 | 1.23 |
| | **41.4** | **42.9** | **1.5** | **1.14** | **Coal** | **C2** | 0.5 | 1.27 |
| P-06 | **10.5** | **12.67** | **2.17** | **1.66** | **Coal** | **D1** | 0.24 | 1.28 |
| | **14.95** | **16** | **1.05** | **0.8** | **Coal** | **D2** | 0.3 | 1.26 |
| | **17.7** | **17.82** | **0.12** | **0.09** | **Coal** | **D3** | 0.21 | 1.56 |
| | **18.35** | **19.73** | **1.38** | **1.05** | **Coal** | **D4** | 1 | 1.25 |
| | **19.94** | **20.1** | **0.16** | **0.12** | **Coal** | **D5** | 1.3 | 1.37 |
| | **37.65** | **40** | **2.35** | **1.8** | **Coal** | **C1** | 3 | 1.29 |
| | **40.1** | **40.97** | **0.87** | **0.66** | **Coal** | **C2** | 1 | 1.34 |

**Table 2.** Average Thickness of Coal Seam Table 1 Depth, Thickness, and Coal Seam

| *SEAM* | *Thickness* | *True Thickness* |
|---|---|---|
| *B* | *12,5* | *9,55* |
| *C* | *2,99* | *2,29* |
| *D* | *6,44* | *4,9* |
| *E* | *2,76* | *2,1* |

If the sinking occurs slowly, then the layer formed will thin.

Based on the sulphur content, the coal seams at the study are generally have a low sulphur content, which indicates the upper delta plain environment. According to Erkoyun et al. (2017), the higher the ash content in the same type of coal, the lower its calorific value. If a coal seam contains many partings, the ash content will be high, and the calorific value will decrease. Based on the ash content, seam C has the highest ash content with a parting. The presence of parting in coal seams can influence the value of ash content compared to coal seams that do not have parting. The presence of partings in coal seams is caused by flood runoff after coal deposition, after which the coal is deposited again so that partings (insertions) originating from sedimentary material are formed. Judging from the electro facies, the gamma-ray log curve pattern of the coal seam has a cylindrical/boxcar curve pattern, which characterizes the depositional environment of fluvial channels. Based on the lithology found in the field in the form of mudstone, siltstone, and basal sandstone from fluvial material which was deposited in a flood plain - back swamp environment so that the depositional environment is included in the upper delta plain, supported by the presence of parting in the form of mudstone in the coal seam.

## Drilling Analysis

At the research location, there are four wells with a distance of approximately 200 meters from one well to another, namely wells P-03, P-04, P-05, and P-06 (Figure 4). The P-03 well has a drilling depth of 68.48 m; the P-04 well has a depth of 79.68 m, the P-05 well has a depth of 68.18 m, and the P-06 well has a drilling depth of 84.34 m. The following is an analysis of drilled wells at the research location (Table 1).

The drilling angle must be adjusted to the coal geometry and the deposit shape perpendicular to the seam to obtain true thickness data (Table 2). Vertical drilling is measured at a 90-degree angle from the horizontal surface of the earth, while inclined drilling is measured at an angle less than 90 degrees from the horizontal surface of the earth.

$$True\ thickness = w \sin \sin\ (dip + drilling\ angle)$$

## Seam Analysis of Coal

Lithological interpretation is based on the response of gamma-ray and density logs, which are then presented as subsurface stratigraphic profiles using Well Cad software. Each rock shows a different response, influenced by the rock's physical properties, specific gravity, and porosity. Mudstone and silt, for example, have a denser log response due to their fine grain size, so the gamma-ray beam detects slowly. In contrast, in coal, gamma-ray logs tend towards the minimum with low Log ASCII Standard (LAS) values, while long-density and short-density logs tend towards the maximum, so they are inversely proportional to the response of the gamma-ray log (Agnes, 2019). LAS is a commonly used file format in the petroleum and well industries for effectively storing information. The LAS file format is a binary file format specifically designed to store lidar point cloud data. It was developed and is maintained by the American Society for

Photogrammetry and Remote Sensing (ASPRS) as a standard format for data exchange and lidar interoperability. This research was conducted at four drilled well points in the Kikim Block PT. Batualam Selaras. Based on the results of logging data analysis at four drill points, four coal seams were found.

The distribution of Seam B was only found in the P-03 well (Figure 2). Based on logging data, seam B has a thickness of 11.9 meters. Seam B in this well has IB in the form of discontinuous bone coal. Based on the gamma-ray log graph, Seam B has a cylindrical/boxcar electro facies pattern.

The distribution of seam C was found in wells P-03, P-04, P-05, and P-06 (Figure 3). In well P-05, seam C was found to have Inter-burden (IB) in the form of mudstone. Inter-Burden refers to the layer of overburden that lies between two coal seams. Judging from the log graph, gamma ray seam C has a cylindrical/boxcar electro facies pattern.

The distribution of seam D was found in wells P-04, P-05, and P-06 (Figure 4). Based on logging data, seam D has Inter-burden (IB) as mudstone. Inter-Burden refers to the layer of overburden that lies between two coal seams. Judging from the gamma ray log graph, seam D has a cylindrical/boxcar electro facies pattern.

The distribution of seam E was found in wells P-04 and P-05 (Figure 5). Based on logging data, seam E has Inter-burden (IB) as mudstone. Inter-Burden refers to the layer of overburden that lies between two coal seams. Judging from the log graph, gamma ray seam E has a cylindrical/boxcar electrofacies pattern.

**Coal Quality Analysis**

Coal ranking is determined using three parameters based on the American Standard for Testing and Material (ASTM) D-388 classification. This classification refers to the rank of coal or the level of metamorphosis that occurs during the coalification process from lignite to anthracite (Ardinata, 2019). The parameters used in determining coal ranking are fixed carbon content, calorific value, and volatile matter. Kusuma, (2012) in Nuramila, (2019) state that for high-rank coal (fixed carbon ≥ 69%), the relevant parameters are the amount of fixed carbon and volatile matter. Meanwhile, the parameter used is the calorific value for low-rank coal (fixed carbon ≤ 69%). In testing the coal proximate analysis at PT. Batualam Selaras, the coal proximate test results were obtained according to ASTM (American Society for Testing) standards as follows:

- Ash Content

According to Thomas (2013), ash content is the residual matter left after the combustion process. Ash is typically formed from mineral matter.

- Moisture

Moisture is the water content found in coal. There are three types of moisture: (1) Free Surface Moisture: Water present on the surface of the coal. (2) Inherent Moisture: Water naturally bound within the coal's structure. (3) Total Moisture: The total amount of water content in the coal.

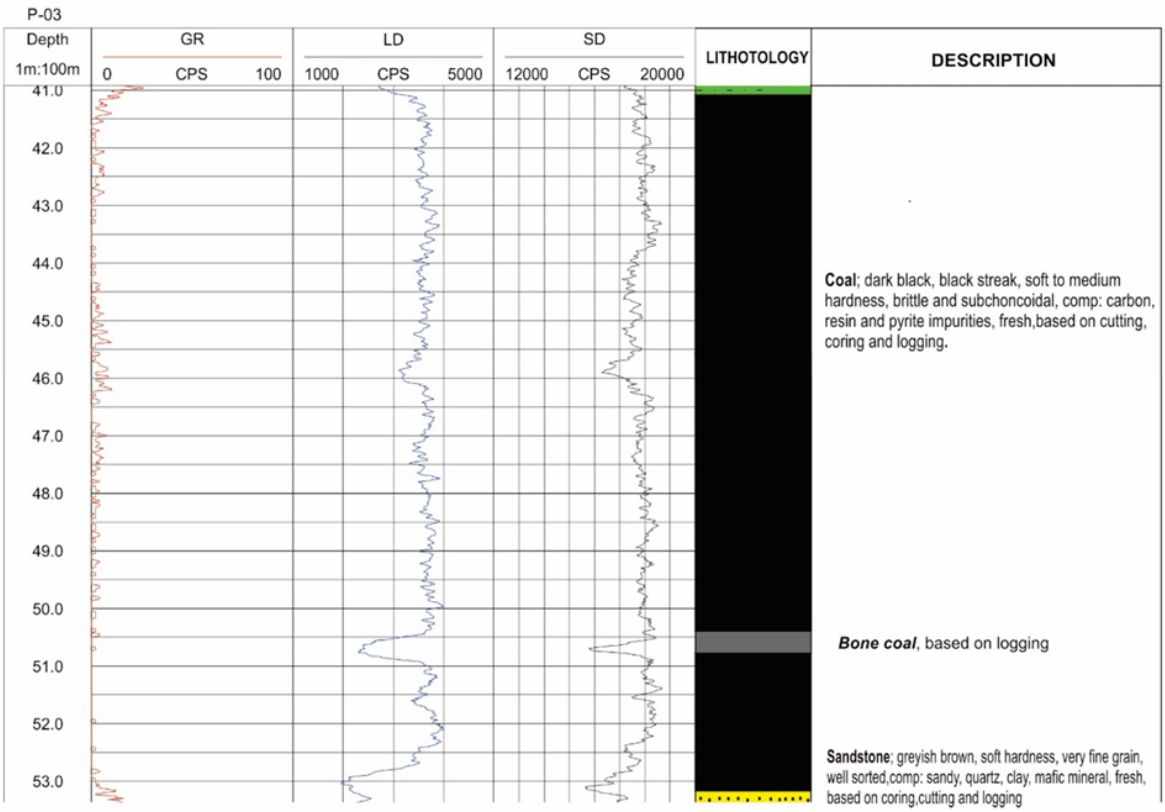



***Figure 2:*** *Seam B in well P-03.*

- Calorific Value

Calorific value is the amount of energy obtained from the combustion of coal.

- Fixed Carbon

Fixed carbon is the amount of carbon remaining in coal after the moisture, ash, and volatile matter content are removed. The higher the fixed carbon (FC) content, the higher the calorific value of the coal.

- Volatile Matter

Volatile matter is the organic component in coal that vaporizes when heated to a specific temperature.

- Sulphur Content

The sulphur content in coal consists of several components: pyritic sulphur, sulphate sulphur, organic sulphur.

- Air Dried Basis (ADB

Air Dried Basis (ADB) refers to the quality value of coal after it has undergone a drying process in the air. The coal sample is spread out and left to dry at room temperature in a laboratory until it reaches equilibrium with the room temperature.

To convert the content of carbon, volatile matter from the as-determined basis (adb) to the dry, mineral-matter-free basis (dmmf) and moist, mineral-matter-free basis (mmmf), the following formulas are generally used:

Btu = 1,8185 x CV(adb)

$$CV(mmmf) = \frac{(Btu - 50xS)100}{(100-(1{,}08xA+0{,}55xTS))}$$

$$FC\ (dmmf) = \frac{(FC - 0{,}15\ X\ S)\ 100}{(100-(M+1{,}08xA+0{,}55xTS))}$$

VM (dmmf) = 100 - FC (dmmf)

Key:

Btu = British Termal Unit

FC = % Fixed Carbon (adb)

VM = % Volatile Matter

M = % Moisture (adb)

A= % Ash (adb)

TS = % Total Sulphur (adb)

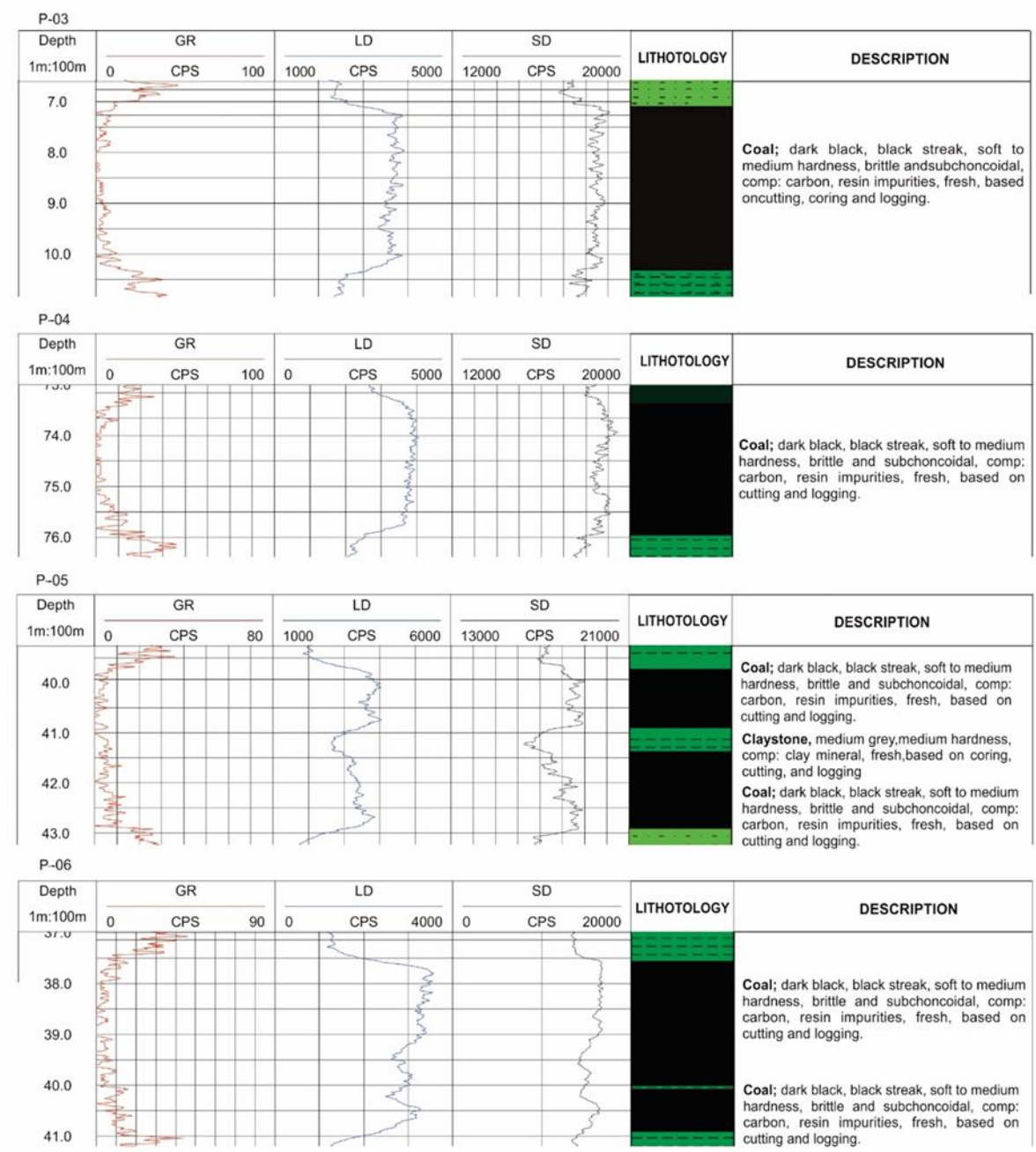



***Figure 3:*** *Seam C in wells P-03, P-04, P-05 and P-06*

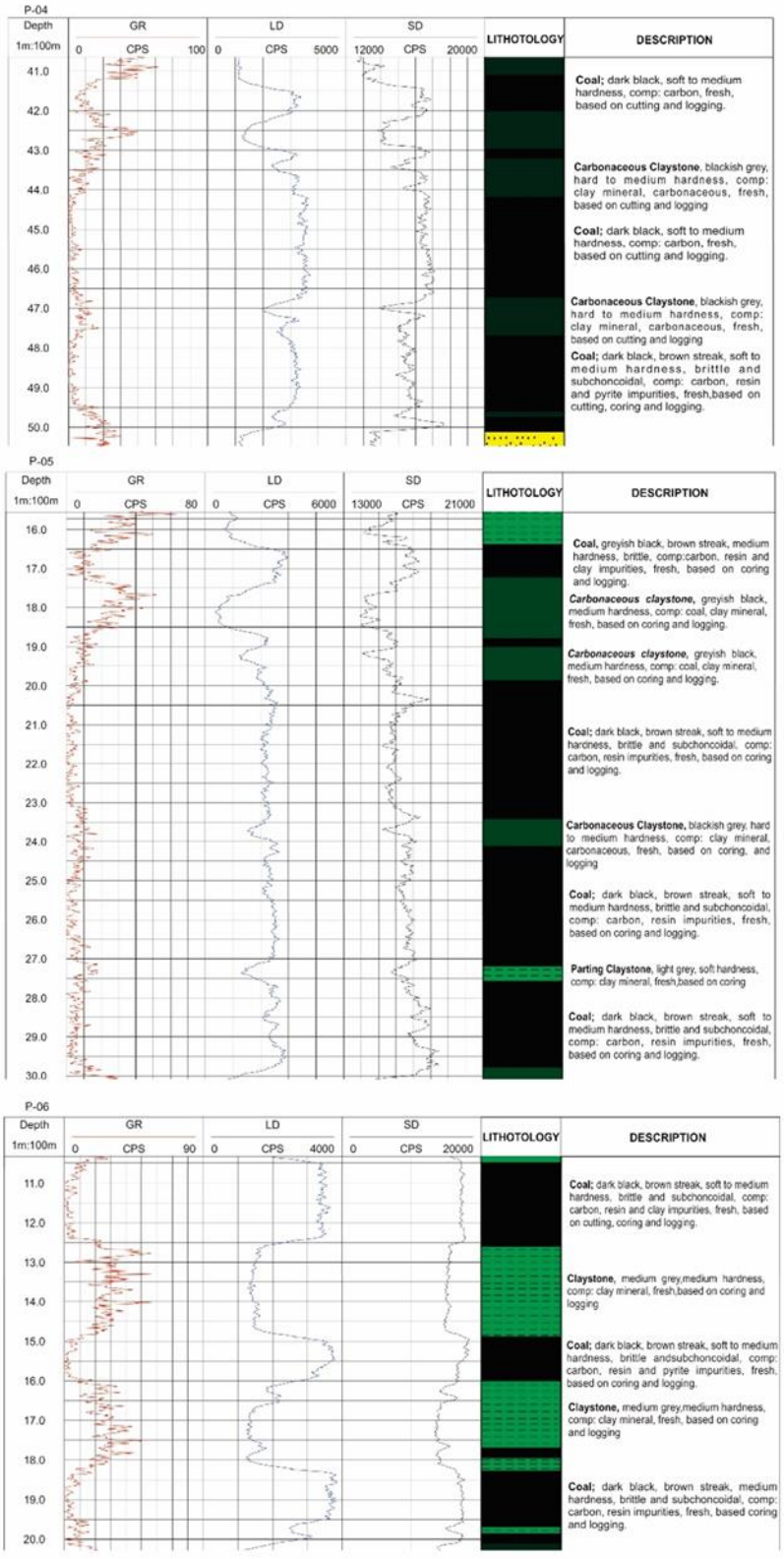



***Figure 4:*** *Seam D in wells P-04, P-05, and P-06*

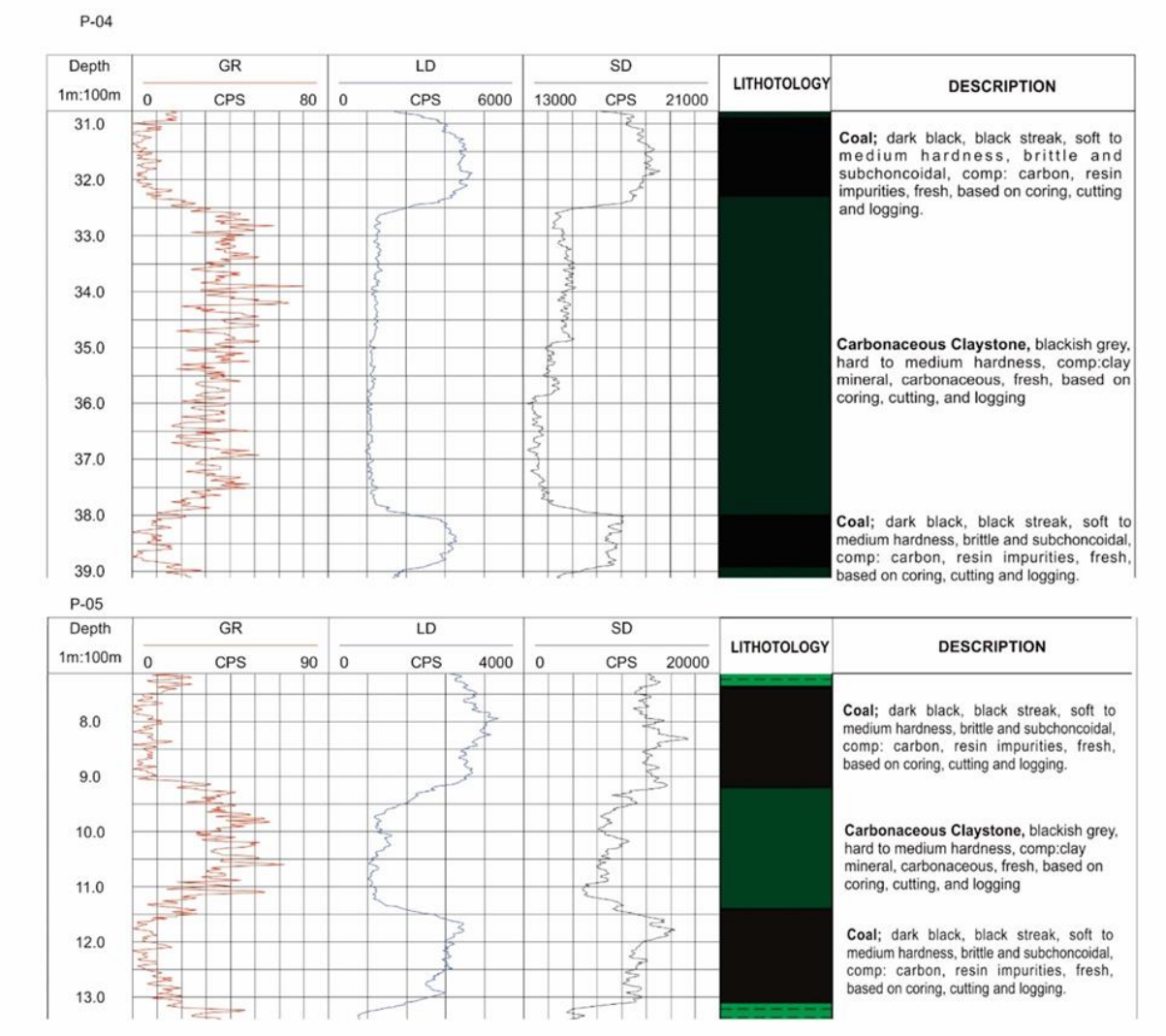



***Figure 5:*** *Seam E in wells P-04, and P-05*

**Table 3.** Coal Test Results (air-dried basis [adb])

| NO | SEAM | SAMPLE CODE | TM | IM | ASH | VM | FC | TS | CV | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % (AR) | % (ADB) | % (ADB) | % (ADB) | % (ADB) | % (ADB) | (AR) | (ADB) | (DAF) |
| 1 | B | PIT/BAS/B/COMP | 34.63 | 15.84 | 4.33 | 41.19 | 38.64 | 0.17 | 4274 | 5503 | 6893 |
| 2 | C | PIT/BAS/C/COMP | 31.25 | 14.15 | 9.24 | 41.01 | 35.60 | 0.46 | 4256 | 5314 | 6936 |
| 3 | D | PIT/BAS/D/COMP | 34.29 | 15.73 | 5.66 | 40.55 | 38.06 | 0.44 | 4228 | 5422 | 6897 |

**Table 4.** Conversion Results of Proximate Test Basis Adb (Air Dry Basis) to mmmf (Moist Mineral Matter Free)

| NO. | SEAM | SAMPLE CODE | CV<br><br>Kcal/kg (MMMF) |
|---|---|---|---|
| 1 | B | PIT/BAS/B/COMP | 10392 |
| 2 | C | PIT/BAS/C/COMP | 10629 |
| 3 | D | PIT/BAS/D/COMP | 10398 |

**Table 5.** Classification of coal ranks based on ASTM

| NO | American Classification | | Fixed Carbon dmmf (%) | Volatile Matter dmmf (%) | Calorific Value mmmf (Btu/lb) |
|---|---|---|---|---|---|
| | Class | Group | | | |
| 1 | Lignite | B | | | <6300 |
| | | A | | | 6300-8300 |
| 2 | Sub-bituminous | C | | | 8300-9500 |
| | | B | | | 9500-10500 |
| | | A | | | 10500-11500 |
| 3 | Bituminous | High volatile C | | | 11500-13000 |
| | | High volatile B | | | 13000-14000 |
| | | High volatile A | <69 | >31 | >14000 |
| | | Medium-volatile bituminous | 69-78 | 22-31 | |
| | | Low-volatile bituminous | 78-86 | 14-22 | |
| 4 | Anthracitic | Semianthracitic | 86-92 | 14 - 22 | |
| | | Anthracitic | 92-98 | 02-Agu | |
| | | Meta-anthracitic | >98 | <2 | |

Based on the ASTM classification of coal seams at PT. Batualam Selaras is included in the Sub-bituminous B – Sub-bituminous A coal rank.

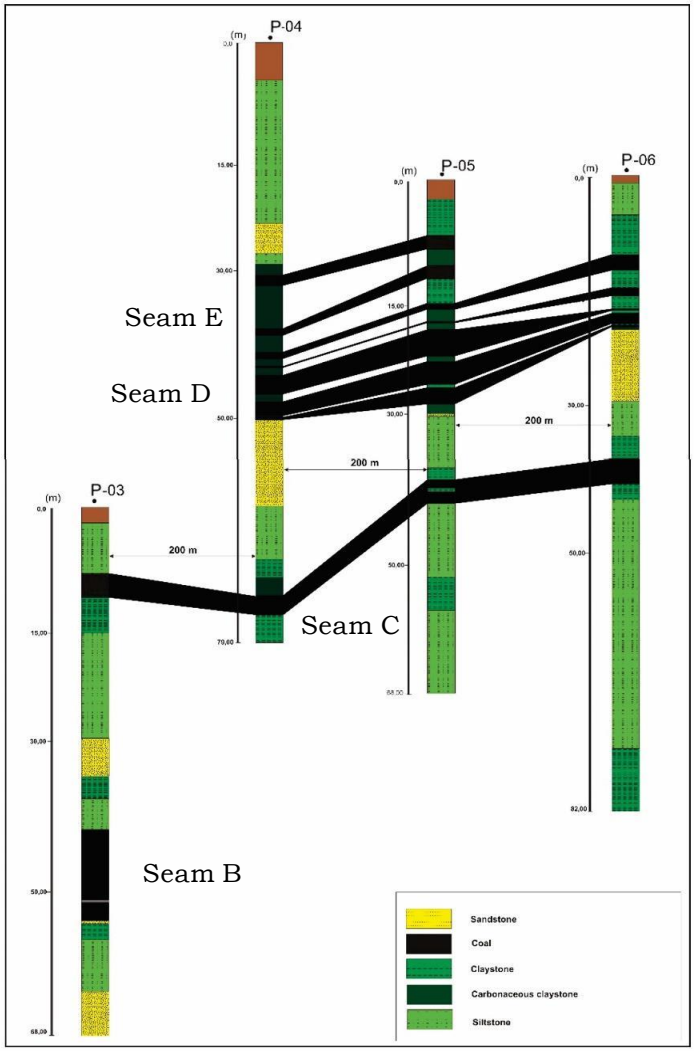



***Figure 6:*** *Coal well logging correlation.*

## Coal Seam Correlation

There are four drilled well points with a distance of approximately 200 meters from one drilled well to the drilled well (Fig 6), namely well P-03, well P-04, well P-05, and well P-06. Well P-03 has a drilling depth of 68.48 m, and seams B and C were found in this well. Well P-04 had a depth of 79.68 m, and three coal seams were found: seam C, seam D, and seam E. Well P- 05 has a depth of 68.18 m, and three coal seams were found, namely seam C, seam D, and seam E. Well P-06 had a drilling depth of 84.34 m, and two coal seams were found, namely seam C and seam D.

Based on the well logging correlation, seam B was only found in well P-03, and seam C was found in wells P-03, P-04, and P-05. Seam D was found in wells P-04 and P-5 and seam E was found in wells P-04 and P-05 (Figure 6). In seam C and seam D, parting indicated splitting in the eastern part of the research area. Seam D experiences thickening and thinning of the coal seam due to the influence of the basin subsidence process during the deposition process. According to Parwati (2022), if the subsidence of the basin occurs rapidly, the coal layers that form tend to be thicker. On the other hand, if the basin subsidence occurs slowly, the coal layers formed tend to be thinner. The basin subsidence speed factor is an essential parameter in forming the structure and characteristics of the coal seam in seam D.

## Coal Seam Depositional Environment

According to Dissel (1992), coal with high sulphur content comes from topogenic swamp types with high water levels and pH. This generally occurs in lower delta and tidal flat (intertidal-subtidal) environments, where the swamp often experiences seawater invasion. In contrast, coal with low sulphur content comes from topogenic

peat with a low water table and pH. This swamp type develops in terrestrial environments, especially in upper delta plain and tidal flat (supratidal-intertidal) environments (Figure 7).

Based on the table 6, the sulphur content of the three seams is low, indicating that the coal seams' depositional environment at this research location is the upper delta plain environment. Based on the ash content, seam C has the highest ash content because seam C has a parting. The presence of parting in coal seams can influence the value of ash content compared to coal seams that do not have parting. The presence of partings in coal seams is caused by flood runoff after coal deposition, after which the coal is deposited again so that partings (inserts) originating from sedimentary material are formed. If seen from the gamma-ray log curve pattern, the coal seam has a Cylindrical/Boxcar curve pattern that characterizes the fluvial channels' depositional environment. Based on field data, the lithology found at the research location is mudstone, sandstone, coal, and siltstone. This material originates from a fluvial deposition in a flood plain–back swamp environment (e.g. Horne et al., 1978; Parwati, 2022).

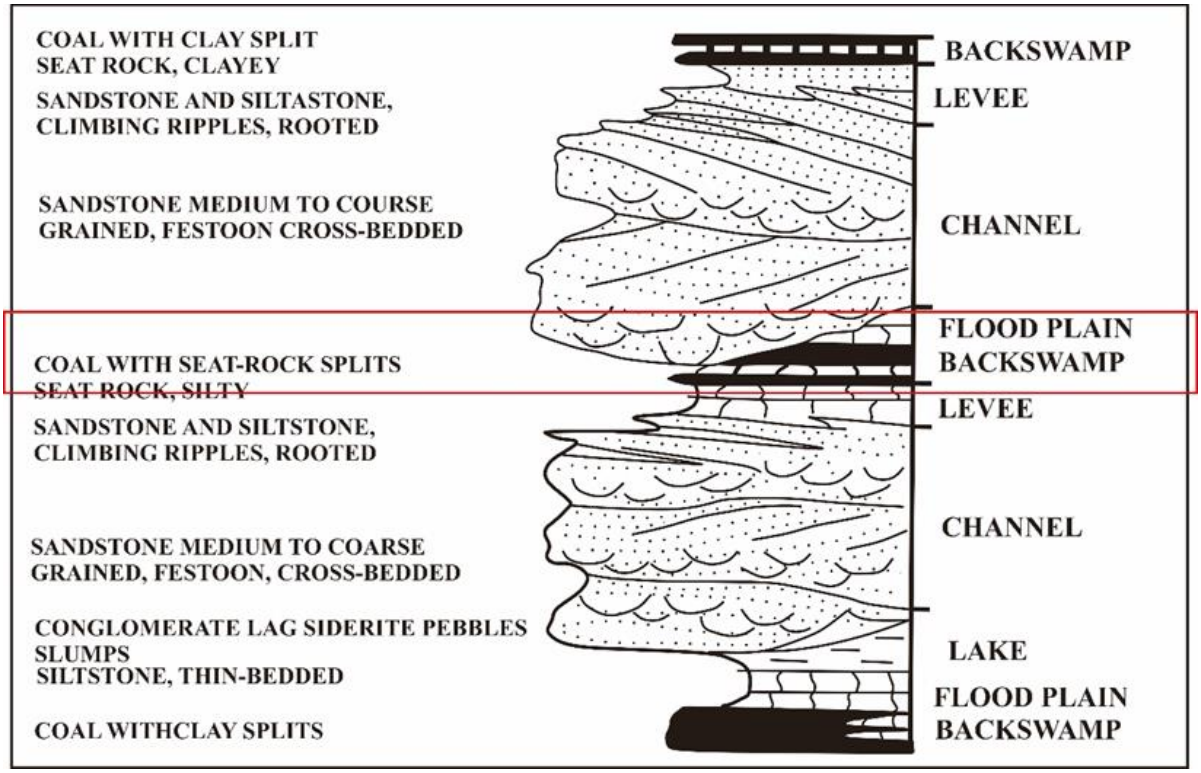



***Figure 6:*** *Depositional environment of the research area based on vertical depositional sequences in the upper delta plain – fluvial depositional environment (Home, et al., 1978).*

## CONCLUSIONS

This work has focused on the analysis of Neogene coal at the Kikim area of South Sumatra Basin, and concluded that:

**Table 6.** Classification of Sulphur Content and Ash Content of Research Locations according to (Hunt, 1984)

| SEAM | ASH % (ADB) | TS % (ADB) | SULPHUR CONTENT | ASH CONTENT |
|---|---|---|---|---|
| B | 4.33 | 0.17 | Low | Low |
| C | 9.24 | 0.46 | Low | High |
| D | 5.66 | 0.44 | Low | Medium |

- The research area is in the Muaraenim Formation, which has a depositional age of Middle Miocene-Pliocene with lithology in siltstone, mudstone, coal, and sandstone.
- The four coal seams in the research area are categorized as Sub-bituminous B and Sub-bituminous A coal rank.
- The flood plain – back swamp environment so that the depositional environment, including the upper delta plain, is also supported by the presence of partings in the form of mudstone in the coal seam.


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