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An Analysis of Coal Seam Lithology using The Well-logging Method for Correlation of Location X, Musi Banyuasin Coalfields, South Sumatra

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Abstract - South Sumatra region has abundant potential coal reserves, but the lack of structural and stratigraphic data makes it not be easy to map their total extent and to understand the genesis. These limitations can be partially resolved using the borehole well-logging methods. The aim of this research was to investigate correlation of coal seam lithology using the well-logging methods in a coalfield, location X, Musi Banyuasin, South Sumatra. The several exploration activities were conducted using the well-logging method to acquire gamma-ray logs and density logs data from seven boreholes, namely PMCBS12, PMCBS13, PMCBS14, PMCBS15, PMCBS16, PMCBS17, and PMCBS19 sites. WellCAD software was used during the data processing to derive logging data (gamma-ray and density logs), and Minex software was utilized to analyze the physical parameter correlation among boreholes. Borehole data analysis was carried out by analyzing the lithology contained in the borehole, especially to analyze the characteristics of the coal seam, such as depth and thickness. The results suggest that the thickness of the existing coal seam in area X is at seam 6 from a depth of about 2.95-19.95 m, with a coal seam thickness ranging from 1.85 m in the PMCBS12 to a thickness of 3.6 m in the PMCBS19 well. Two to three - vertically spread seams were found in each borehole with a thickness of about 0.35-3.6 m at various depths. Correlation results among boreholes show that the distribution of coal seams extends from the northwest to the southeast with a distribution direction of N300˚E/6˚.

Keywords: coal, borehole, loging data, correlation

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Introduction

Background

Coal formation is a fundamental process involving organic matters, mainly terrestrial plants, that burry, die, and are decomposed under the sediments to form peat, and finally transformed into coal. The average coal cycle involves the formation of lignite, subbituminous, bituminous, and finally anthracite (Sukandarrumidi, 1995). The type and variety of coal reflect the basin formation, burial conditions, temperature, and sediments (Sulistiawati, 1992), which could be investigated by mapping the coal seal layers. Therefore, this work shows the mapping of coal seams in South Sumatra, Indonesia (Figure 1).

In Sumatra, coal mining history started in 1849 at Ombilin area and 1919 at Bukit Asam mine in the South Sumatra region (Belkin *et al*., 2009). In South Sumatra Province, for example, Musi Banyuasin has abundant coal resources, and has become one of the most important coal mining regions in Indonesia (Thomas, 2005), but the estimated exact of coal production is poorly known (Daulay, 2015). The Musi Banyuasin mining area is in the Muara Enim Formation, located in South Sumatra Basin (Figure 1). The basin is tectonically active, and the coal in some parts has been affected by igneous activity. The basin sits on the rifted crust, which was later part of the tectonic convergence during the Early Paleogene as a back-arc basin, northeast of the Barisan Mountains (Belkin *et al*., 2009; Mills, 2011). The Muara Enim Formation is one of the most potential coal bearing formations. The formation is composed of sandstone, claystone, and coal seams. Musi Banyuasin area is one of the critical areas for coal mining, which could provide new data on the stratigraphic and structural setting of the coal formations. Well-logging geophysical methods are employed to map and to understand the basin structural and stratigraphic architecture.

The geophysical well-logging is the well-known and the most common-used method in coal exploration (*e.g*. Kayal, 1979; Hofman *et al.,* 1982; Fullagar *et al*., 1999; Fallon *et al.,* 2000; Yegireddi and Uday, 2009; Zhou and O'Brien, 2016, Huang *et al*. 2018; Zhou and Guo, 2020). This method can describe the subsurface conditions vertically, so that the lithology of each seam can clearly be seen and relatively accurate for determining the depth and the thickness of a seam using a combination of gamma-ray and density (Ardhityasari *et al.,* 2018). Geophysical well-logging data can determine the distribution of coal seams, so that the character of each seam can be distinguished and the potential can be analyzed. A coal explora-

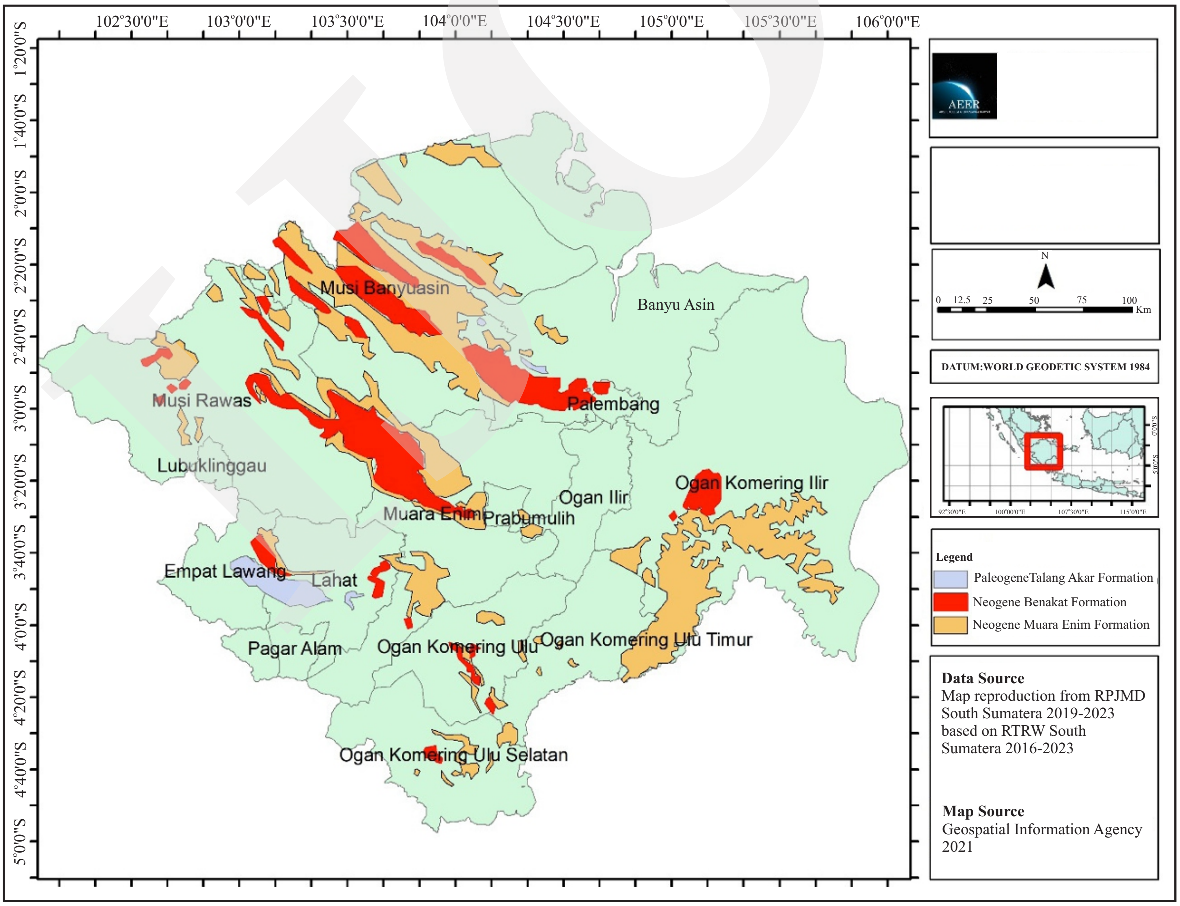

Figure 1. Potential coal distribution in South Sumatra Province (Harahap *et al*., 2021).

tion using the well-logging method to find coal resources has been carried out by Faisal (2012) in area X, East Barito Ampah, Kalimantan Island. The characteristics of coal that can be known from this research are coal seams, coal thickness, and coal depth (Faisal, 2012). This research discusses the correlation of the coal seam lithology using the well-logging method at location X Musi Banyuasin, which is combined with outcrop data. This research is expected to accurately determine the distribution of coal in the researched area that can be used for energy resources.

Tectonics and Geological Settings

The basin formation observed by examining rocks, structures, and sediments in South Sumatra indicates the sedimentation took place on pre-Tertiary metamorphic and igneous rocks. The contact is unconformable indicating erosion and faulting occurred before the sedimentation. The sedimentation in the basin started when the region was rifted during Late Paleocene to Early Miocene, which resulted in the formation of north-trending normal faults with prominent horst and graben structures. The faulting was followed by a period of relative quiescence with normal faulting from Early Miocene to Early Pliocene. The E-W tectonic extension was followed by tectonic compression during Pliocene to Recent, which created reverse faults, inversion of normal faults, and formation of new folds and thrust faults (Suhendan, 1984). There is structural and sedimentological evidence that tectonic extension formed the basin, and later those normal faults were reactivated as reverse faults during tectonic compression in Miocene to Plio-Pleistocene (Zeliff *et al.*, 1985; Moulds, 1989; Sudarmono *et al.*, 1997).

Muara Enim Formation is the primary coal formation covered in the paper, which is of Late Miocene to Pliocene. It was deposited when the region was undergoing tectonic compression, and the deposition was in shallow marine to continental conditions suggested by the presence of sands, muds, and coals (Hutchinson, 1996).

Methods and Materials

Methods

This research was conducted at location X Musi Banyuasin (Figure 2), South Sumatra, using the well-logging method. Before data acquisition in the field, a field survey was conducted to assess and to estimate the accessibility and coal outcrops in the researched area. The data used in this research is geophysical logging data from seven boreholes, namely PMCBS12, PMCBS13, PMCBS14, PMCBS15, PMCBS16, PMCBS17, and PMCBS19 sites. The data obtained from the well-logging results are gamma-ray logs and density logs. Data acquisition is made using instrument logging. One of the instruments in the logging tool is a probe. The probe has four detectors, and each detector has a function to capture the log response to the rock in the borehole. The detector consists of detectors to capture the response of gamma-ray logs, long-density logs, high-resolution density logs, and calliper logs.

Then, analysis and interpretation of the logging data were carried out, which aims to determine the lithology of the seams contained in the borehole, especially to analyze the characteristics of the coal seam, such as depth and thickness. Correlation analysis was carried out to determine the correlation of coal seam lithology generated from the data of each borehole. The 2D and 3D modelling results from logging data to see the distribution of coal seams were processed using Minex 6.5.0 software.

Results

The results of logging data are presented in the form of four curves; among others the gamma-ray log curve is marked with a blue curve, the calliper log is red, the long density is black, and the high-resolution density is green. The results of data analysis from the gamma-ray log curve and density log curve from each borehole obtained two to three - coal seams at different thicknesses and depths. This interpretation is obtained from gamma-ray and density log

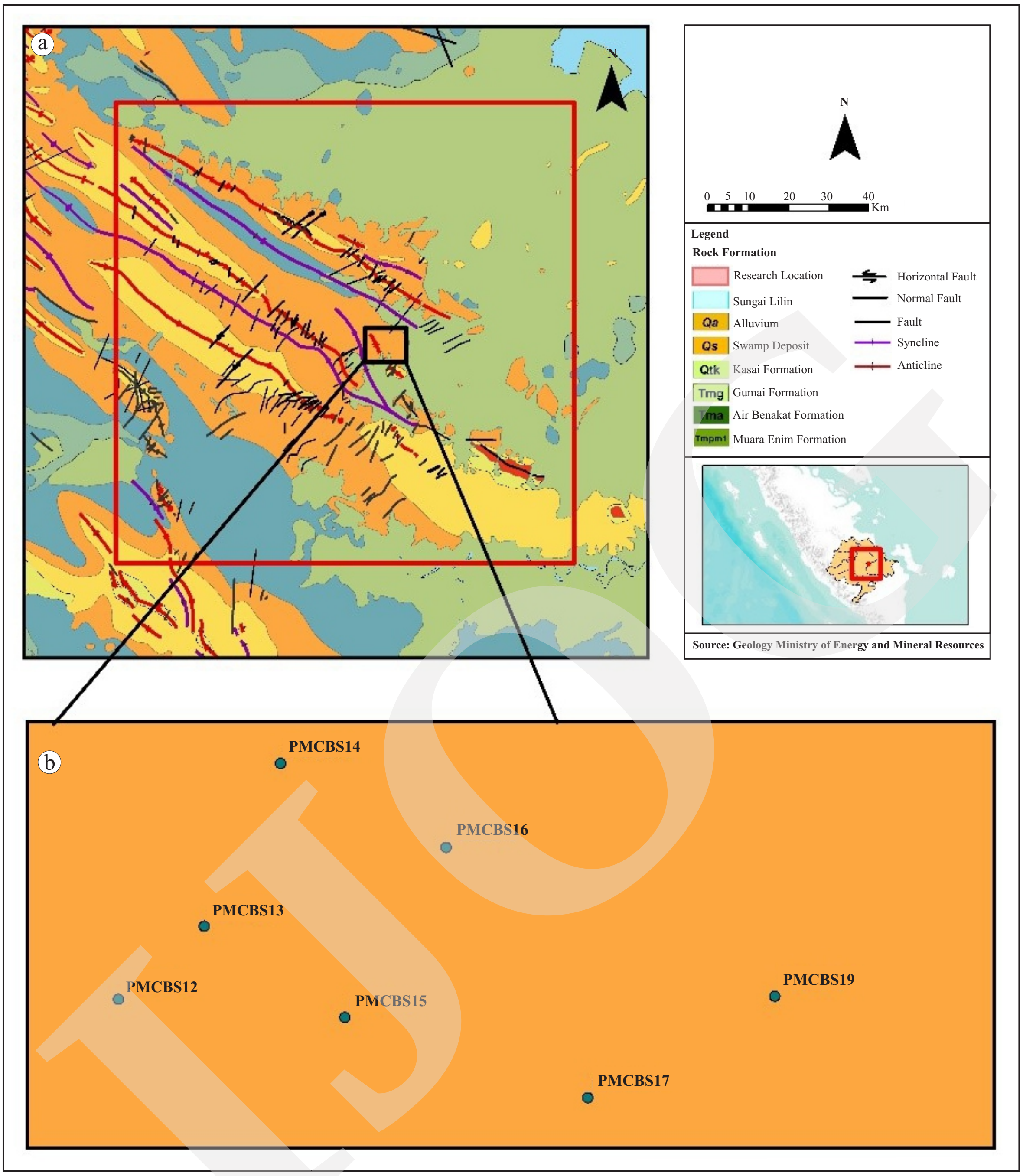

Figure 2. Studied area located in Musi Banyuasin, South Sumatra. a). Geological Map of Sungai Lilin. b). Boreholes location map (blue dates).

response to rocks. The response of gamma-ray logs and density logs in each rock type is different. In clay and silt, the response from gamma-ray logs tends to be denser due to the influence of fine grain size, so that the gamma-ray beam detects slowly. Meanwhile, the gamma-ray log response in coal tends to a zero value, and the density log tends towards a higher value. The Log ASCII Standard (LAS) gamma-ray scale is 0–200 CPS (Count Per Second), and the LAS log density scale is 0-10,000 CPS. The results of the log curve response of gamma-ray and density for each borehole are shown in Figure 3.

After getting the results of the log curve, data processing was carried out using Minex 6.5.0 software to obtain a 1D stratigraphic profile for

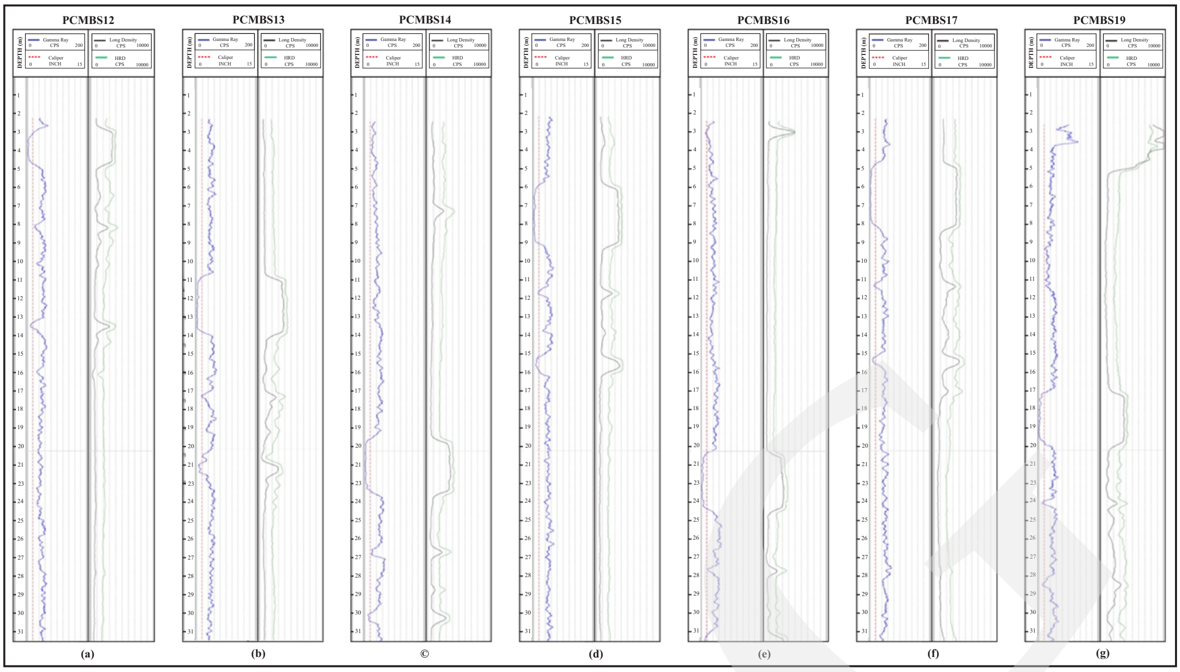

Figure 3. The result of the response curve of the borehole log at PMCBS12, PMCBS13, PMCBS14, PMCBS15, PMCBS16, PMCBS17, and PMCBS19 sites.

each drilled well. The lithology model of each well shows various types of layers, including soil (orange), claystone (green), siltstone (yellow line), sand (yellow), and coal (black). The results of the 1D lithology model in each borehole show that the first layer is a layer of soil at a depth of about 0-2.50 m. The most common constituent layers in each borehole are sand and claystone, with a layer thickness of about 5-40 m. The coal seam that existed at the point of this research was still considered as a young coal seam with a thickness that was still categorized as a thin layer. Stratigraphic profiles for each well can be seen in Figure 4.

Correlation is a step in determining stratigraphic units and structures with the same time, age, and position. In this research, the borehole correlation uses an inorganic method to connect stratigraphic units not based on the content of organisms (organic data), but on the associated rock physical properties (Koesoemadinata, 1978). The results of the correlation indicate that there is a continuity that occurs in area X. In addition, the borehole correlation helps to show the distribution of coal seams in the researched area. The correlation results also show three distributions of coal seams, including seams 6, 7U, and 7L.

Correlation results also show that the topography in the researched area is relatively flat and weakly wavy. The borehole correlation shown in Figure 5, indicates the distribution of coal seams in three boreholes in the researched area, namely PMCBS12, PMCBS13, and PMCBS14 boreholes with slightly different seam depths among boreholes. Figure 5 also shows the distribution of coal seams from the correlation results of three boreholes, namely PMCBS13, PMCBS15, and PMCBS17. Then, a 3D model of the correlation of seven boreholes showed the distribution of coal seams shown in Figure 6. The results of this data interpretation are also supported by the geological conditions in the researched area, where there are coal outcrops on the surface.

Discussion

This research was conducted at location X Musi Banyuasin, South Sumatra, part of the Muara Enim Formation in the South Sumatra Basin. The Muara Enim Formation is one of the most potential coal

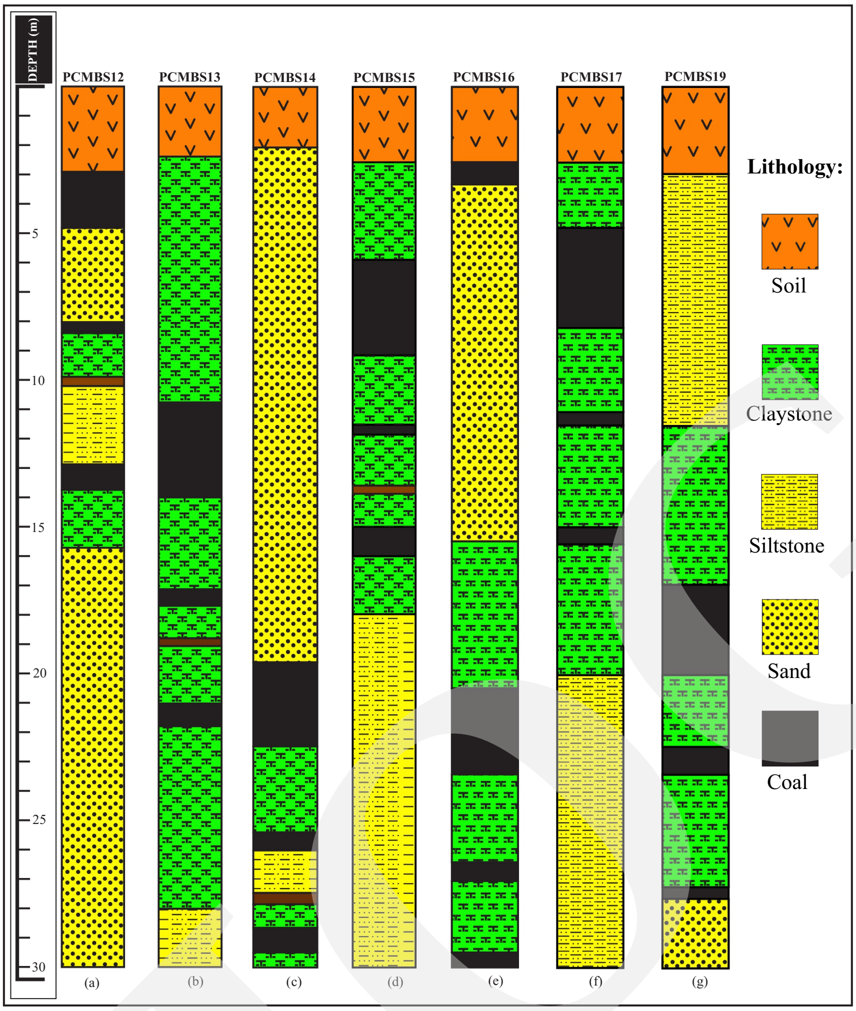

Figure 4. 1D stratigraphic profile of wells of PMCBS12, PMCBS13, PMCBS14, PMCBS15, PMCBS16, PMCBS17, and PMCBS19 sites.

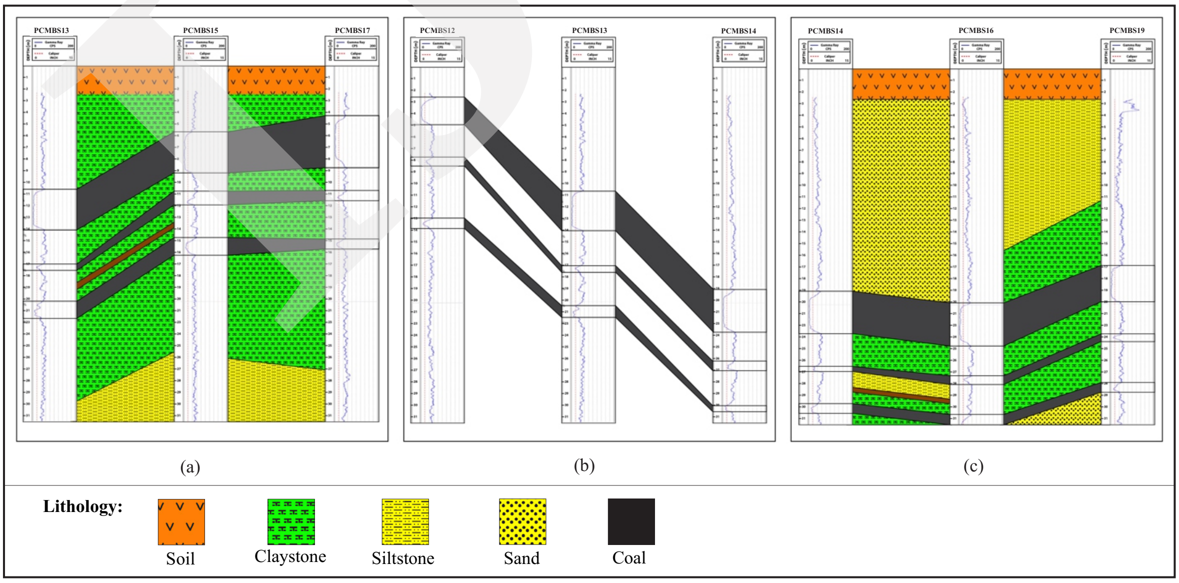

Figure 5. Well correlations of: a). PMCBS1, PMCBS15, and PMCBS17, b). PMCBS12, PMCBS13, and PMCBS14, and c). PMCBS14, PMCBS16, and PMCBS19.

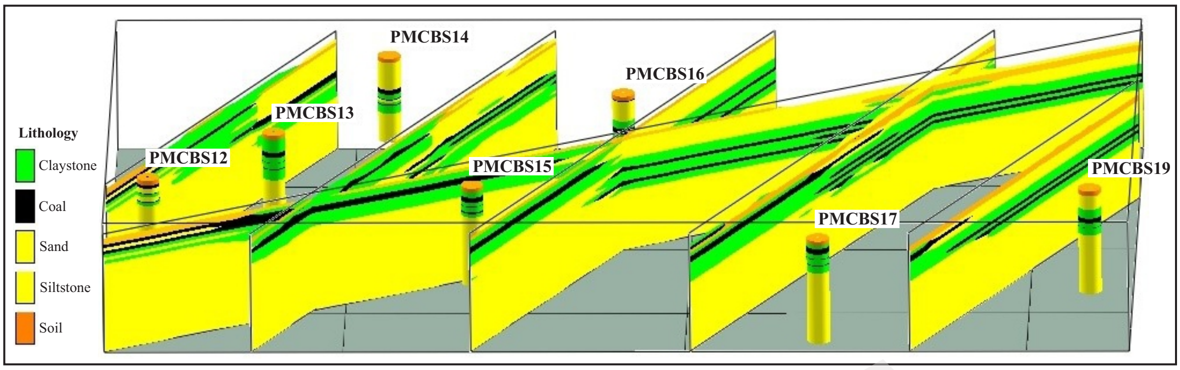

Figure 6. 3D well correlation at location X Musi Banyuasin, South Sumatra.

carrier formations. Data processing results are then obtained through curves of gamma-ray logs and density logs. Gamma-ray log data and density logs are interpreted to determine the lithology at each depth below the earth surface. Each rock has a unique response to the log curve, so the lithology type can be easily determined (Adrian *et al*. 2010). The response of gamma-ray log to coal seam is of low value, while the response of the density log to coal seam is also of low value (in units of gamma-ray/cc) (Ismawati, 2012). In this research, the unit for density log is CPS, where CPS is inversely proportional to the unit of (gamma ray/cc). To determine the combined coal with the gamma-ray value based on the density value, the smaller the gamma-ray value, the greater the density value. This is because coal has a higher density value than rock density value around them (Nazeer *et al.,* 2016).

Gamma-ray and density logs are a reference in interpreting the lithology of the researched area. The lithology results show the presence of two to three coal seams in each borehole in the researched area. The coal seams are located at different depths and with different seam thicknesses. The thickness of existing coal seam in area X is at seam 6 from a depth of about 2.95−19.95 m, with a coal seam thickness ranging from 1.85 m in the PMCBS12 to a thickness of 3.6 m in the PMCBS19 well. The lithology results also show the presence of other constituent rocks in the researched area, such as claystone, siltstone, and soil. The making of drill point correlation is one of the stages in data processing, which aims to determine the distribution of coal seams below the surface. Correlation results between drilled wells show that the distribution of coal seams is continuous and elongated with the distribution direction N300˚E/6˚.

Conclusion

The research that has been done shows that the researched area X Musi Banyuasin, South Sumatra, has two to three - coal seams from vertical measurements. The results of lithology model show that the boreholes PMCBS12, PMCBS13, PMCBS14, PMCBS15, PMCBS16, PMCBS17, and PMCBS19 sites had two to three - coal seams at varying depths with a seam thickness of about 0.35 - 3.6 m. The dip influences the condition of coal seam, so that each layer is at a different depth. The correlation among boreholes shows that the distribution of the coal seam extends from the northwest to the southeast (N300˚E/6˚). The correlation between the seven boreholes is also obtained as a 3D model.

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