Wireline Logging Data Interpretation on Coal Quality Value in The West Bangko Mining Area

T Millenia[1], Alimudin[1], DA Zulkarnain[2] and RC Wibowo[3,*]

[1]*Geophysics Engineering, Engineering Faculty, Universitas Lampung; Sumantri Brojonegoro Street no.1 Bandar Lampung City, Lampung, Indonesia, 35145*

[2]*PT. Bukit Asam, Tanjung Enim, South Sumatera, Indonesia*

[3]*Geological Engineering, Engineering Faculty, Universitas Lampung; Sumantri Brojonegoro Street no.1 Bandar Lampung City, Lampung, Indonesia, 35145*

[*]*Email: rahmat.caturwibowo@eng.unila.ac.id*

Article Information:

Received:
1 July 2025

Received in revised form:
17 December 2025

Accepted:
22 December 2025

Volume 7, Issue 2, June 2025
pp. 56 – 62

http://dx.doi.org/10.23960/jesr.v7i2.220

Abstract

This study uses the well-logging method and the proximate values of laboratory test results at West Banko Pit 1 Mine, Lawang Kidul District, Muara Enim Regency, South Sumatra Province. The aim is to determine the relationship between the log density and coal quality. The proximate values used are the ash content, total moisture, and calorific value. This research used wellCAD software to interpret the coal seam in three wells: TM 01, TM 02, and TM 03. Meanwhile, a relationship between log density values and coal quality was identified using Microsoft Excel. From this research, it is found that there is a relationship between density and coal quality: the lower the density (g/cc), the better the coal quality.

Keywords: *Coal Quality, West Banko PIT 1 Mine, Well logging.*

I. INTRODUCTION

Coal seams are generally relatively easy to identify and correlate to log data. The working principle of geophysical logging is to measure the depth variation of the physical properties of rocks using measuring instruments located in the wellbore such as the radioactive content value of rocks, resistivity and conductivity of rocks and so on.

The research area is located in the Muara Enim formation with coal reserve quality generally of the lignite type with a calorie content between 4800-5400 Kcal/kg. Coal quality parameters also have a strong relationship with geophysical logging parameters. These parameters are utilized by comparing them to estimated coal quality parameters such as ash content, volatile matter, moisture, and lithology of the coring rock [12].

Geology & Geophysics are widely used to evaluate coal layers that will be used to meet coal exploration needs, and to assist in designing and operating effective systems for coal mining, preparation, and utilization tasks [17].

This study tries to use one of the geophysical methods, namely well logging by connecting density log data to the proximate value of coal with statistical tests, so that through this approach the coal rank is known without having to send coal samples to be analyzed in the laboratory. So that it can reduce costs at the exploration stage.

A. *Regional Geology*

Coal is a sedimentary rock originating from plants that are deposited beneath the earth's surface and formed due to geological and chemical processes in it with its main composition being carbon, hydrogen, and oxygen [10].

The research area is included in the South Sumatra Basin which is the result of tectonic activities closely related to the subduction of the Indo-Australian plate moving north to northeast against the relatively still Eurasian Plate [13]. This basin is a back-arc basin bounded by the Barisan hills in the southwest and the Pre-Tertiary Sunda shelf in the northeast. In addition to tectonic activity throughout the Tertiary, sedimentation occurred in this basin, driven by global changes in sea level [7]. The regional tectonic setting of the island of Sumatra is shown in Figure 1, with the research area indicated by a black box.

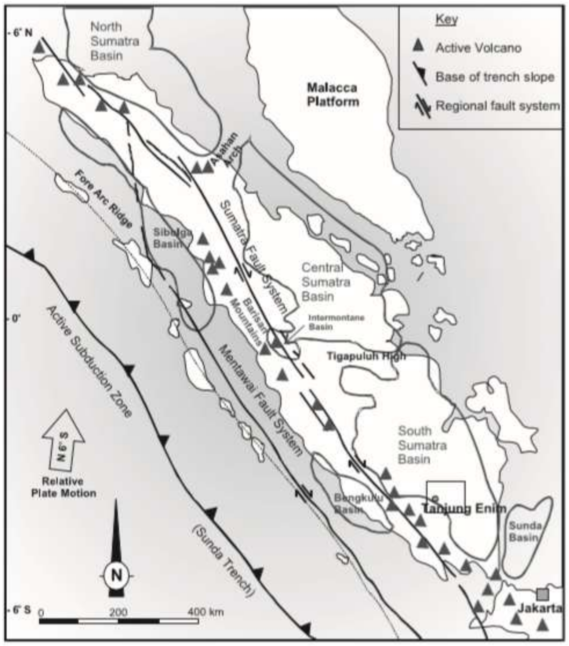

Figure 1. Regional Tectonic Setting of Sumatra Island [2].

The research area lies within the Muara Enim formation. This formation is a Middle Tertiary sediment with a back-arc basin tectonic setting. This formation is of Miocene-Pliocene age and was deposited in harmony above the Air Benakat formation, with lithology consisting of shale at the base, alternating tuff-mudstone in the middle, and coal-sandstone layers at the top. This indicates a change in the depositional environment from shallow seas, deltas, and terrestrial environments. The Muara Enim formation is approximately 450 to 750 meters thick, with 10-20% of the total thickness consisting of coal layers [3].

The Muara Enim Formation is divided into two, namely the lower MPa (Middle Palembang 'a') and the upper MPb (Middle Palembang 'b'). Both are then grouped again into M1-M4. MPa and MPb contain about 8 coal layers. The estimated maximum coal thickness is about 140 meters. Some thin coal layers are not connected, and there are also thick layers. The coal that is economical to mine is the upper part of MPa (Mangus, Suban, and Petai). In Tanjung Enim, the Mangus, Suban, and Petai coal are divided into two layers: upper Mangus (A1) and lower Mangus (A2); upper Suban (B1) and lower Suban (B2); and upper Petai (C1) and lower Petai (C2) [2]. Local stratigraphy of the Muara Enim Formation is shown in Figure 2.

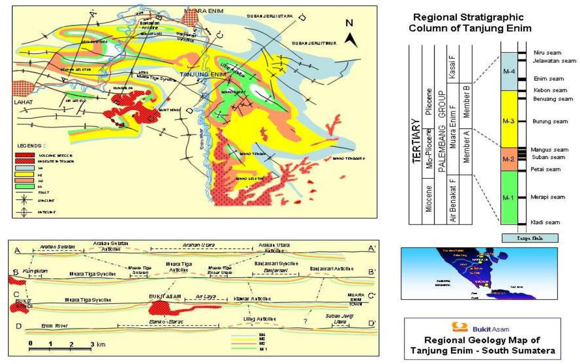

Figure 2. Local Stratigraphy Research area [12].

II. Materials and Methods

A. *Well Logging Method*

Well logging is a geophysical method that records rock properties in a drilling well using a sensor, commonly called a probe, by slowly pulling it from the bottom to the top to detect rock layers on the well walls. The advantage of this method is that it can describe subsurface conditions vertically, so that the lithology of each layer it passes through along the drill hole can be clearly depicted [1]. Well logging in geophysical exploration is widely used to identify layer depth and thickness, accelerate subsurface interpretation, minimize drilling risks, determine shale content, correlate layers, and determine porosity, density, and subsurface temperature [14].

In coal mining, well logging can be used for various applications, such as correlating strata from borehole to borehole, identifying coal seams, and quantifying their resources. Coal has several unique physical properties, including low natural radioactivity, low density, and high resistivity. This is in contrast to the properties of most other rocks in the coal-bearing sequence. The information obtained from these well logging measurements can be extrapolated vertically within the well and laterally to other wells for understanding the subsurface geology [16].

This study uses one of the applications of geophysical methods, namely geophysical logging, to determine the relationship between its characteristics and proximate values in coal layers. The geophysical logs used in this study are gamma-ray and density logs.

Gamma-ray logs record the Earth's natural radioactivity, originating from the decay of the elements Uranium (U), Thorium (Th), and Potassium (K). This type of log is usually used to distinguish shale and non-shale layers because the gamma rays used are very effective at distinguishing permeable and non-permeable layers based on radioactive elements that tend to be found in non-permeable shale and are not abundant in permeable rocks [18].

Density logs record every gamma ray collision that will cause an energy reduction, so it is often used to determine the electron density of the formation, which is related to the actual bulk density [9]. The density of the rock is also influenced by its compactness, with the density decreasing as the rock becomes more compact [18]. The unit of measurement on the logging tool (CPS) is inversely proportional to the rock density value (g/cm^3). Based on the relationship between rock density and the intensity of gamma rays captured by the detector, the following nonlinear equation is produced:

$$Y = -177598e^{-2,4325X} \tag{1}$$

Where X is the density value in units (g/cm^3), and Y is the density value in CPS units [15].

B. Log Analysis in Coal

Research on the relationship between logs and coal quality values has been conducted previously. It was found in the study that the comparison between coring and logging data had high similarities, so it can be used as a reference in determining coal quality, as shown in Figure 3. The gamma log will provide a low value response, and the density log will give a high response with the CPS unit in coal lithology [6]. The response curves of the gamma ray log and density log can be seen in Figures 4 and 5.

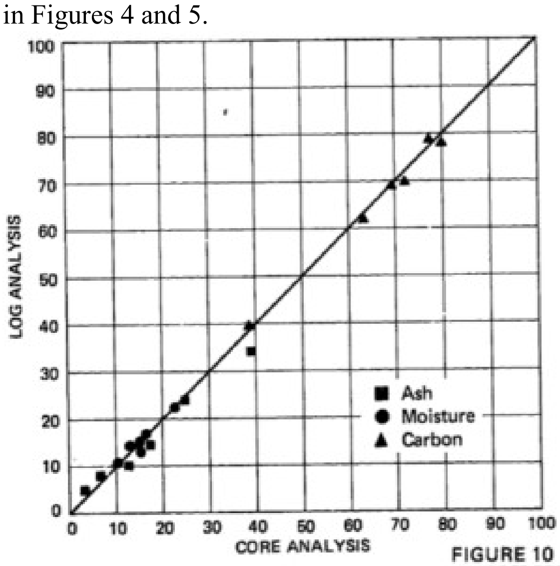

Figure 3. Comparison of Coring Result Data to logging data [8].

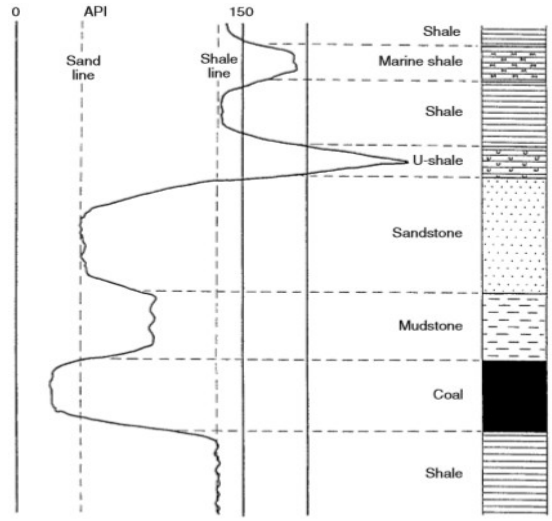

Figure 4. Gamma Ray Log Response to Lithology Sequence [8].

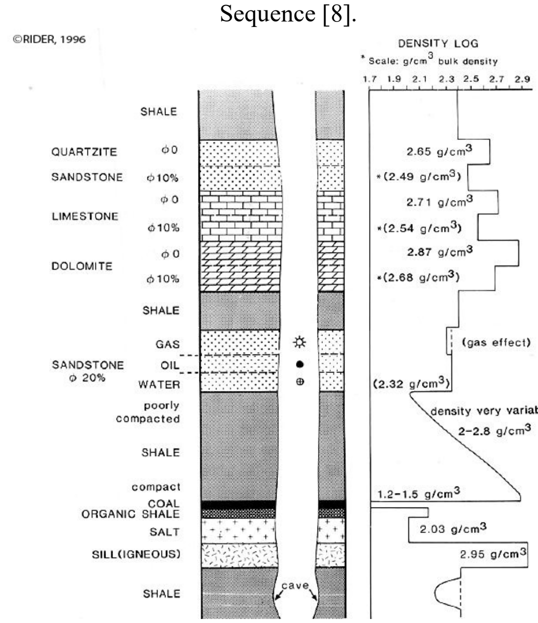

Figure 5. Density Log Response to Lithological Sequences [8].

C. Methods

A literature review was conducted by searching for references from previous studies and the regional geology of the research area. Interpretation of well logging data was performed by plotting the values of well logging measurement results into WellCAD software to produce a depth relationship curve for each log value (gamma ray and density). Lithology interpretation was conducted by analyzing the response value of each log to lithology. Coal can be recognized by its low gamma-ray log response and its high-density log response in count-per-second units. This interpretation was also based on rock-core photos, so it has a high confidence level. The coal quality values in question are in the form of ash content, moisture, and calorie content. This analysis was conducted using linear regression in Microsoft Excel to obtain a relationship between the two, namely the log value and coal quality (calories, moisture, and ash content). The values are as in Table 1.

Table 1. Coal Quality Value in the research area

Coal type	Calorific Value (Kcal/kg)	Ash (%)	Total Moisture (%)
A1	5191	2,4	25,8
A2	5246	2,6	25,9
B1	5269,5	2,35	25,1
B2	5223,5	2,05	25,2
C	5320,3	2,466	25

III. Results and Discussions

A. *Coal Interpretation*

From the results of the interpretation carried out, in the TM01 well, coal was found at a depth of 6 to 11 meters with type B1, at a depth of 27 to 31 meters with type B2, and at a depth of 68 to 7 meters with type C coal. In the TM02 well, at a depth of 49 to 60, type A1 coal was found. At a depth of 68 to 80 meters, type A2 coal was found. At a depth of 93 to 106 meters, type B1 coal was found. B2 coal was found at a depth of 113 to 117 meters, and type C coal was found at a depth of 156 to 166 meters. In the TM03 well, only two types of coal were found: B2 at depths of 6 to 11 meters and C at 48 to 59 meters. The results of the interpretation of each type of coal found in the TM 01, TM 02, and TM 03 wells were averaged based on the gamma ray log and density log values. The average result of this log value is used to find the relationship between the log value and coal quality. The log curves for each well are shown in Figures 6-8.

Table 2. Density log values

Coal type	TM01 (cps)	TM02 (cps)	TM03 (cps)	Average density (cps)
A1	-	1018,39	-	1018,39
A2	-	2013,74	-	2013,74
B1	1974,4	1935,96	-	1955,21
B2	1932,16	1918,53	2780,55	1925,34
C	2086,51	1973,44	1901,25	2029,97

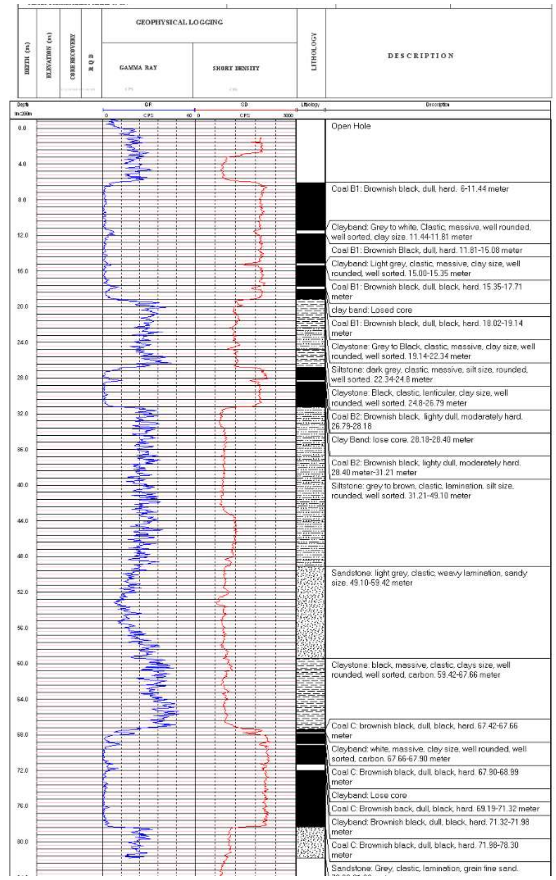

Figure 6. Well log curve TM01.

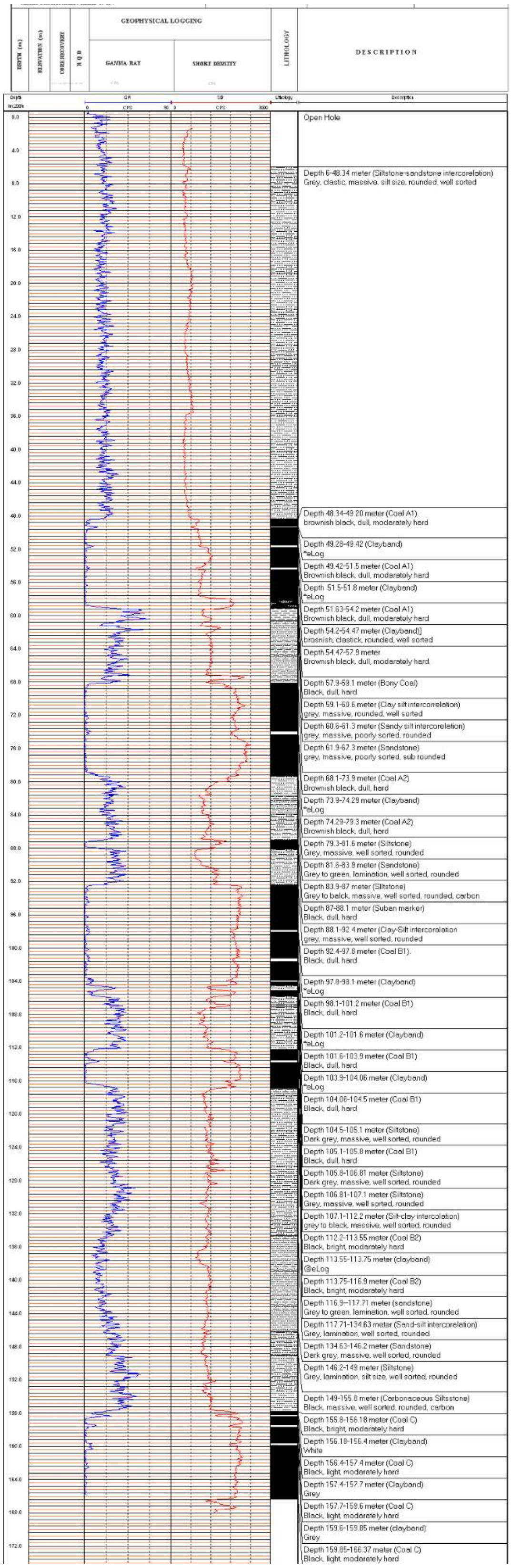

Figure 7. Well log curve TM02.

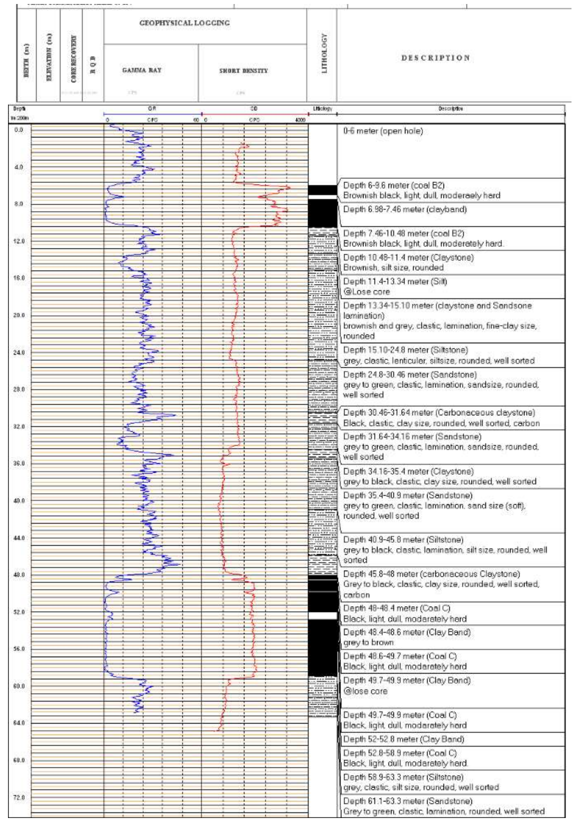

Figure 8. Well log curve TM03.

B. Ash Content vs Density

The first linear regression was performed on the ash content value. The results of this linear regression (graph of the relationship between log values and ash content) can be seen in Figure 9. From the graph, there it a strong correlation. With the determinant coefficient, which is a statistical measurement of covariance or association between two variables, with a value of R2 = 0.7771 or 77.71%. The author categorizes a strong correlation relationship with the position of the heavy line moving in a positive direction.

This can happen because the high and low densities of a rock are influenced by its mineral content, porosity, and degree of rock compactness. Rock compactness affects porosity: rocks with a high density (CPS) have lower porosity, and ash content is also lower because it cannot enter the coal. The meaning is inversely proportional: the smaller the density value, the greater the porosity value, so that ash content increases as more coal enters the ash content.

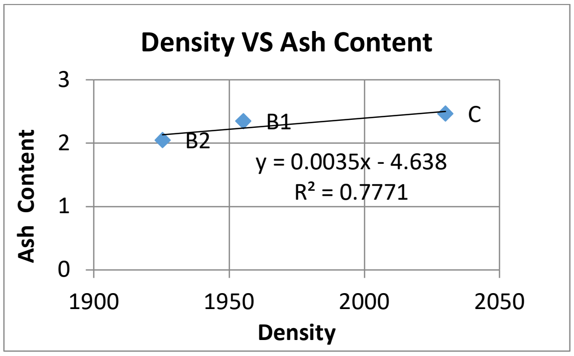

Figure 9. Relationship between log density value and ash content.

C. Total Moisture vs Density

The second linear regression was performed on the humidity (total moisture) value. The results of this linear regression (the relationship between log values and total moisture values) are shown in Figure 10. From the results of the correlation trendline analysis of bivariate scatterplots of the relationship between density and total moisture in the research area, the correlation coefficient $R^2 = 0.609$ (60.9%) was obtained. The author classifies the correlation as strong, with a tendency for the heavy line to move in a negative direction.

The negative-trending line can be interpreted as follows: the higher the coal density (CPS), the lower the total moisture, and vice versa. This can be associated with density and moisture, which a closely related. Physically, a coal that has a higher density will have a lower porosity, so that it will affect the moisture content of the coal, which will also be lower because there are no pores or cleats to absorb or as a path for fluid to enter.

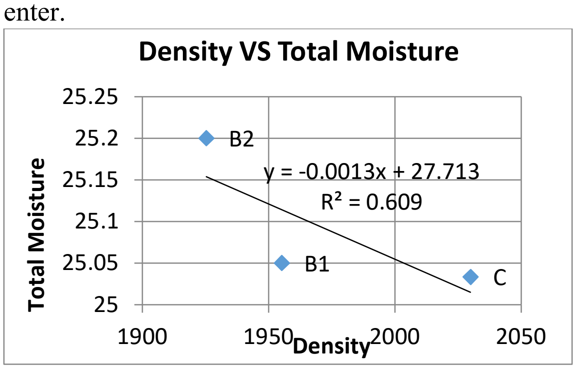

Figure 10. Relationship between log density value and total moisture.

D. Calorific Value vs Density

The third linear regression was performed on the calorific value. The results of this linear regression (the relationship between log value and calorific value) are shown in Figure 11. The relationship between density and calories, as measured by the correlation coefficient, has an R^2 value of 0.9549 (95.49%), indicating a robust positive correlation, with the heavy line moving in a positive direction.

This indicates that the higher the coal density value (CPS), the higher the calorific value, and vice versa. This is related to the physical relationship between density and coal calories, a coal with a higher density value (CPS) will have a lower porosity, so the moisture content of the coal will also be lower because there are no pores or cleats to absorb or as a path for fluid to enter the coal. This will improve the coal combustion process, resulting in a higher calorific value.

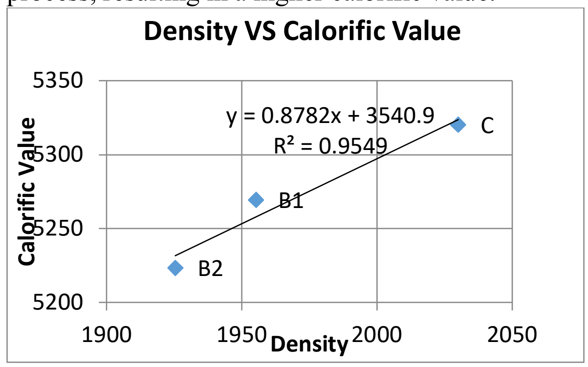

Figure 11. Relationship between log density value and calorific value.

IV. CONCLUSIONS

Based on the statistical relationship, it is concluded that the higher the density in count-per-second units, the better the coal quality. Well logging data and coal quality need to be more evenly distributed across the research area to increase trust and the accuracy of the research.

V. ACKNOWLEDGMENT

The author would like to thank PT. Bukit Asam Tbk Tanjung Enim South Sumatra, the Department of Geophysical Engineering, University of Lampung, and related parties who have provided advice and support in this research.

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