Available online at:
Al-Fiziya: Journal of Materials Science, Geophysics, Instrumentation and Theoretical Physics
Website: http://journal.uinjkt.ac.id/index.php/al-fiziya
Vol.5 No. I Tahun 2022, 33 - 45

Identification of Characteristics and Distribution of Subsurface Coal Using the 2D Geoelectric Method in Tanjung Palas Timur District, North Kalimantan

Putri Sekar Ayu Ningsih[1,†], Sutrisno[1], Tati Zera[1], Egie Wijaksono[2]

[1]Physics Study Program, Faculty of Science and Technology, State Islamic University Syarif Hidayatullah Jakarta, Ir. H. Djuanda Rd. No.95, Cempaka Putih, Ciputat, South Tangerang City, Banten 15412, Indonesia.
[2] Center for Disaster Risk Reduction Technology (PTRRB)-Agency for the Assessment and Application of Technology (BPPT), Building 820, PUSPIPTEK, South Tangerang City, Banten 15314, Indonesia.

[†]putri.sekar17@mhs.uinjkt.ac.id

Submitted: November 2021; Revised: April 2022; Approved: June 2022; Available Online: October 2022

Abstract. *Based on regional geology, Tanjung Palas Timur Subdistrict is included in the only formation, which includes coal seams. The depletion of oil and gas energy sources in Indonesia results in the need for other alternative energy sources, one of which is coal. This study aims to determine the characteristics of coal in the study area. This research was conducted in Tanjung Palas Timur Subdistrict, North Kalimantan using the geoelectric resistivity method with a pole-pole configuration and 8 tracks which are divided into 2 track blocks. The resistivity geoelectric method is used because it is very suitable for mining exploration. Data processing was done in 2D using Res2dinv software and 3D using Rockworks15 software. The results of the geoelectric data processing of line 1 to 8 show that the coal seam in the study area has a resistivity of 10-30 Ωm with a thickness varying from 17.22 m - 60 m as a type of lignite coal. In addition, the research area is also dominated by layers of clay and sandstones. The continuity of the coal seam is also seen in block 1 from line 3 in the southwest direction to line 1 in the northeast direction.*
Keywords: *Coal, Geoelectric Resistivity, Pole-Pole Configuration, Res2dinv, Rockworks15*

DOI: *10.15408/fiziya.v5i1.23106*

INTRODUCTION

Oil and gas are natural resources that are mostly used to meet daily needs and as a contributor to the country's foreign exchange. However, as human needs increase in their daily activities, the consumption of oil and gas energy increases. Meanwhile, the energy sources needed are dwindling due to uncontrolled energy exploitation. Therefore, alternative energy is needed as a substitute for fuel oil and gas, one of which is coal.

Coal potential in Indonesia is spread over 4 regions that have the largest pockets of coal reserves, namely South Sumatra, South Kalimantan, Central Kalimantan and East Kalimantan based on the Ministry of Energy and Mineral Resources 2020 sources and North Kalimantan is ranked 9th province with the largest coal reserves. Coal has played

Copyright©2019, Published by **Al-Fiziya: Journal of Materials Science, Geophysics, Instrumentation and Theoretical Physics**
P-ISSN: 2621-0215, E-ISSN: 2621-489X

an important role for a long time, creating electric power and being the basic fuel for steel and concrete manufacture and other industrial activities. Coal is also the fastest growing source of fuel compared to oil, gas, nuclear, or other alternative energy [1]. Several studies using the resistivity geoelectric method to determine the distribution of coal include Sugeng and Widodo conducted research on coal prospects in the Muara Muntai area using the Schlumberger configuration modeled by manual curve matching [2], Hamid Umar conducted research on the potential of coal so that he could calculate the amount of coal reserves in the Massenrengpulu area [3], Elvira Azizah conducted a study that aims to determine the distribution of coal using the Wenner configuration in Tulungagung Regency [4], and M. Zainul he studied the distribution of coal using the geoelectric method of induced polarization in the Klatak area [5]. Meanwhile, this study aims to determine the characteristics and distribution of coal using geoelectric resistivity with a pole-pole configuration in order to obtain a deeper depth of coal.

Based on the regional geological sheet of Tanjung Redeb, the Tanah Kuning area has a sajau formation. The sajau formation includes interspersed clay, silt, sandstone, conglomerate, interspersed with coal seams. The presence of coal in the Tanah Kuning area, North Kalimantan is a potential to develop power plants or other industrial materials. One of the surveys that can be used to understand the potential distribution of coal below the surface is a geophysical survey using the geoelectrical resistivity method. Basically, the geoelectric method is based on Ohm's Law which considers a single current-carrying cylinder.

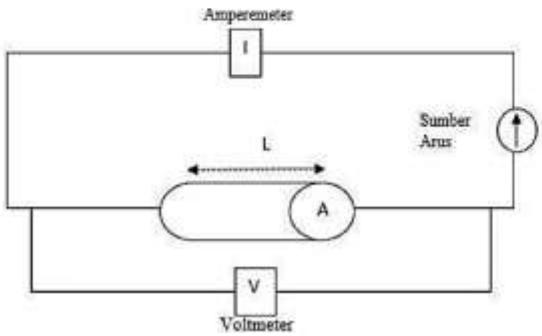

Figure 1. Parameters used in determining resistivity [6].

From figure 1, it can be seen that the electric current I flowing in a cylindrical material with a potential difference at both ends ΔV will be proportional to the cross-sectional area A and inversely proportional to the length L:

$$\rho = R\,\frac{A}{L} \tag{1}$$

Where ρ is the resistivity (Ωm), L is the length of the conductor cylinder (m), A is the cross-sectional area of the conductor cylinder (m2), and R is the resistance (Ω). Meanwhile, according to Ohm's law, resistance R is formulated as follows:

$$R = \frac{V}{I} \tag{2}$$

R is resistance (Ω), V is potential difference (Volts), and I is current (Amperes). If equation 2 is substituted into equation 1, the resistivity value is:

$$\rho = \frac{VA}{IL} \quad (3)$$

In geoelectrical measurements, the subsurface medium is assumed to be homogeneous isotropically so that the generated electric current will spread throughout the medium with the same value. If an electric current meets a certain rock layer, there will be a deviation from the ideal condition, because each rock layer has a certain resistivity value. So that the quantity ρa can be formulated by

$$\rho_a = K \frac{\Delta v}{I} \quad (4)$$

where K is the geometry factor of the electrode configuration used. In field measurements, this research uses a pole-pole configuration.

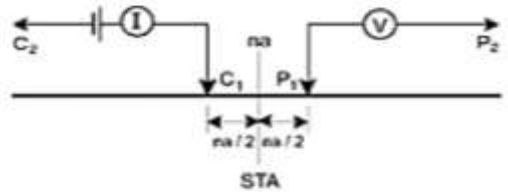

Figure 2. Pole-pole configuration electrode arrangement [7].

The apparent resistivity value obtained from this pole-pole configuration is expressed by the following equation:

$$\rho = 2\pi a R \quad (5)$$

where is the apparent resistivity, a is the electrode spacing, which is the space between the C1 and P1 electrodes, and R is the resistivity measured in the field. The geometric factor of the configuration of the poles above is 2πa.

To determine the value of the resistivity of coal, it is necessary to interpret the 2d modeling that has been processed by referring to the following references.

Table 1. Rock and mineral resistivity values [8].

Types of Rocks and Minerals	Resisivity (Ωm)
Clay	1 – 100
Silt	10 – 100
Sandstone	50 – 500
Conglomerat	$2x10^3 – 10^4$
Breccia	75 – 200
Bituminous Coal	$0.6 – 10^5$
Anthracite	$10^{-3} – 2x10^4$
Lignit	9 – 200
Granite	$5x10^3 – 10^6$
Groundwater	0.5 - 300

Vol.5 No. I Tahun 2022, 33 - 45
P-ISSN: 2621-0215, E-ISSN: 2621-489X

METHODS

The research location is in Tanjung Palas Timur District, Bulungan Regency, North Kalimantan. The research started from December 2020 to March 2021. The data used was in the form of secondary geoelectric resistivity data belonging to the Center for Disaster Risk Reduction Technology (PTRRB), the Agency for the Assessment and Application of Technology (BPPT).

The resistivity geoelectric method is a method that can see or get a mine layer that has a resistivity difference with the surrounding layer. This method is used with the principle of injecting electric current through two current electrodes which is then measured the value of the resulting potential difference according to the arrangement of the electrodes used, then the apparent resistivity value will be obtained.

In this study using the geoelectric resistivity method. The resistivity geoelectric method is one of the geophysical methods that can be used to see the subsurface structure of the earth. This research uses geoelectric resistivity Pole-pole configuration method. The Pole-pole configuration is used because of its very wide horizontal coverage and its very deep depth investigation [9].

The research map shows that there are 2 blocks where block 1 consists of track 1 Ety, track 2 Ety, track 3 Ety, track 7 Yati and track 8 Yati. While in block 2, there are paths of Merana, namely trajectories of 4 Merana, trajectories of 5 Merana, and trajectories of 6 Merana. On each track has a length of 710 m with an electrode spacing of 10 m. Data processing is done using Res2dinv software to produce 2d modeling in order to identify subsurface rock types in the research area by looking at the resistivity value range and Rockworks 15 software is used in 3d modeling to see the distribution and continuity of coal and its total reserves.

Figure 3. Measuring trajectory point.

RESULT AND DISCUSSION

The results of data processing resulted in 8 tracks with each track length of 710 m and electrode spacing of 10. The results of the 2D cross-section obtained from the Res2dinv software were correlated with regional geological data and resistivity tables or other supporting data to obtain an accurate interpretation. The following is the result of a 2D cross-section of each track:

Vol.5 No. I Tahun 2022, 33 - 45
P-ISSN: 2621-0215, E-ISSN: 2621-489X

Track 1 Ety

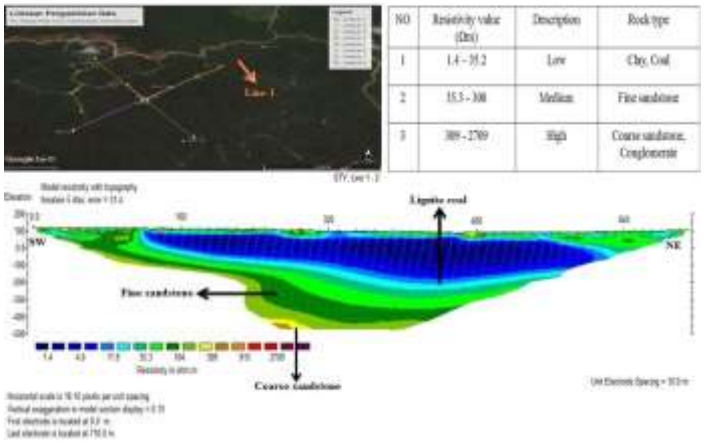

Figure 4. Cross section of the inversion of the path 1 Ety.

In this path, low resistivity values are shown in dark blue to light blue with resistivity ranging from 1.4 – 11.9 Ωm. This layer is thought to contain lignite type coal inserts because of its low resistivity value which is embedded in the clay layer. Coal was found at electrode 125 at a depth of 66.43 m to 113.44 m with a thickness ranging from 29 m. While the light green to dark green color has moderate resistivity values ranging from 36.3 Ωm to 104 Ωm which is suspected as a layer of fine sandstone. This fine sandstone layer is below the coal seam at electrode 40 at a depth of ±80.6 m which is spread evenly up to electrode 475. And for high resistivity values with yellow to red colors, resistivity from 309 Ωm to 2709 Ωm is deposited in the lowest layer of the surface with depth of 518 m at electrodes 270 – 325 m is suspected to be coarse sandstone. So, it can be seen that on the track 1 ety there are coal deposit which are summarized in table 2.

Table 2. Distribution of lignite coal.

Place the electrodes	Depth (m)	Resistivity (Ωm)
125	66.43 – 113.44	11.9 – 35.2

Track 2 Ety

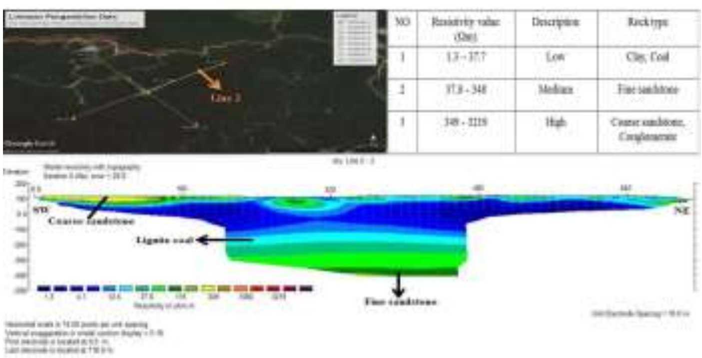

Figure 5. Cross section of the inversion of the path 2 Ety.

This path is dominated by low resistivity values indicated by dark blue to light blue with resistivity ranging from 1.3 Ωm – 12.4 Ωm. This layer contains inserts of lignite type coal at a depth of 293 – 331 m spread over 250 – 455 electrodes and a thickness of ±30m. While the light green to dark green color has a moderate resistivity value ranging from 37.8 m to 115 m which is still occupied by a layer of sandstone. A layer of sandstone is spread on the subsurface from the electrodes 220 – 460 m with a depth of 417 – 464 m. And for high resistivity values with yellow to red colors having resistivity from 349 Ωm to 3219Ω m which are on the west side of the track with a depth of 4.2 m at electrodes 0 – 120 m, it is suspected as coarse sandstone.

Table 3. Distribution of lignite coal.

Place the electrodes	Depth (m)	Resistivity (Ωm)
250	293	4.1 - 12.4
455	331	12.5 – 37.7

Track 3 Ety

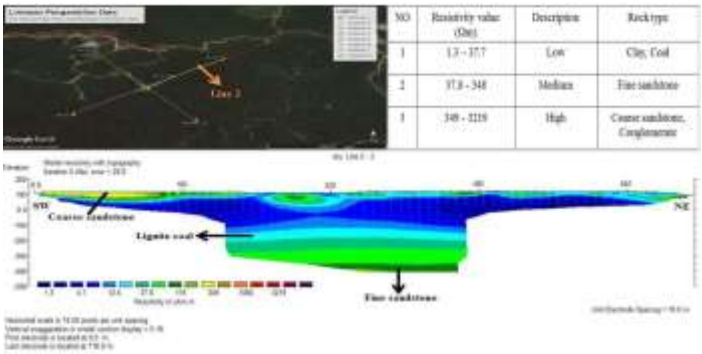

Figure 6. Cross section of the inversion of the path 3 Ety.

In the cross-section of the resistivity of the 3 ety path, it can be seen that the distribution of the layers is still the same as in the previous path. The upper layer consists of a layer that has a low resistivity value of 1.3 – 12.5 Ωm as a layer containing lignite coal because it is located around the clay layer. This coal seam starts from electrode 5 at a depth of 4.2 - 21.42 m with a layer thickness of ±25 m. Then in the layer below the coal which is the base, it is suspected to be sandstone which has a resistivity of 117 - 356 Ωm which is located at the 195 electrodes at a depth of ±255 m and crosses from the west to the east of the track. Furthermore, in the third layer, namely the lowest layer with a depth of ±470, coarse sandstone is deposited with a resistivity of 1089 Ωm.

Table 4. Distribution of lignite coal.

Place the electrodes	Depth (m)	Resistivity (Ωm)
5	4.2 – 21.42	12.5 – 38.1

Track 4 Merana

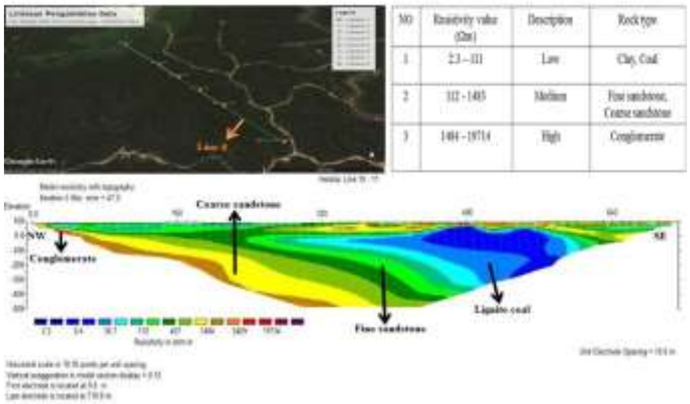

Figure 7. Cross section of the inversion of the path 4 Merana.

The picture above shows a yellow to brown color pattern with a high resistivity between 1484 Ωm – 5409Ω m which is interpreted as a rock layer containing coarse sandstone. This layer is at the electrodes with 31 m to 518 m. Dark green to light green color which has a resistivity of 112 Ωm – 407 Ωm is interpreted as a fine sandstone layer. The sandstone layer is between the coarse sandstone layer and the coal seam. Furthermore, the dark blue to light blue color with a resistivity of 30.7 Ωm is interpreted as containing coal seams. The coal seam is at a depth of 113 m at electrodes 395 to 545 electrodes with a layer thickness of ±39 m.

Table 5. Distribution of lignite coal.

Place the electrodes	Depth (m)	Resistivity (Ωm)
395 - 545	113	9 – 30.7

Track 5 Merana

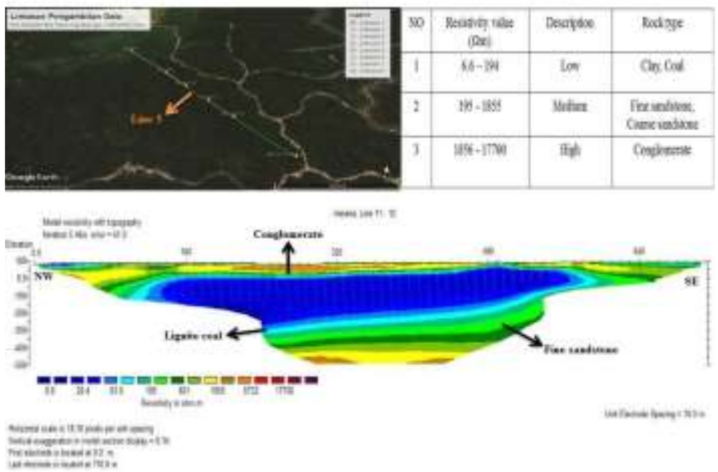

Figure 8. Cross section of the inversion of the path 5 Merana.

On track 5 Merana, the penetration depth reaches ±520 m. From the cross section, there are at least 3 rock layers with low, medium, and high resistivity. The first layer in this cross-section has a high resistivity between 1586– 5732 Ωm (yellow to brown), this layer is probably a layer of conglomerate rock that has been weathered so that it is above the surface of the electrodes 150 – 460 m which crosses from northwest to southeast at depth of 4.2 m. The second layer is with a low resistivity between 6.61 – 20.4 Ωm (dark blue to light blue) which allows the presence of coal types starting at electrodes 135 to 535 at a depth of 153.14 m and the thickness of coal in this layer reaches ±60 m. And the third layer is a layer with a medium resistivity of 195 - 601 Ωm (light green to dark green) at a depth of 415 m from the ground surface. This layer is probably a sandstone layer.

Table 6. Distribution of lignite coal.

Place the electrodes	Depth (m)	Resistivity (Ωm)
135 - 535	153.14	6.61 – 20.4

Track 6 Merana

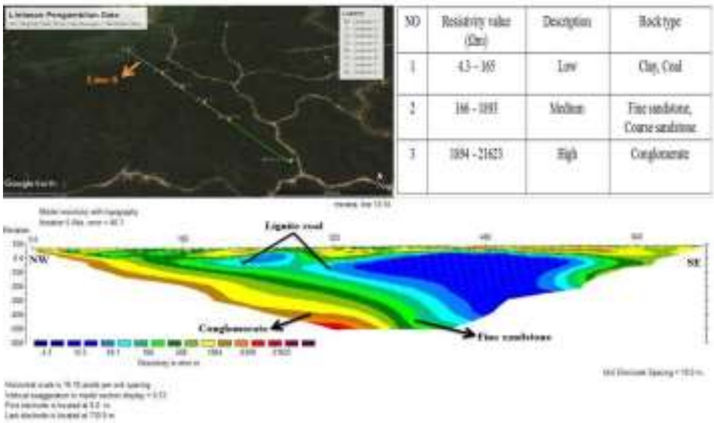

Figure 9. Cross section of the inversion of the path 6 Merana.

From the 2D cross-section above, a yellow to brown color pattern can be seen on the left side of the track with a resistivity of 1894– 6399 Ω m which is interpreted as conglomerate rock. Dark blue to light blue color with low resistivity of 14.5– 49.1 Ωm which is interpreted to contain coal seams. Coal seams were found at electrodes 240 and 335 - 535 m at a depth of 132.35 m with a thickness of coal in this layer reaching ±60 m. Furthermore, between the conglomerate and coal layers there is a moderate resistivity between 166 - 560 Ωm which is interpreted as a sandstone layer. This sandstone layer is widely spread from near the surface to the subsurface.

Table 7. Distribution of lignite coal.

Place the electrodes	Depth (m)	Resistivity (Ωm)
240	100 – 132.35	30.5 - 49.1
335 - 535	132.3	49.1

Track 7 Yati

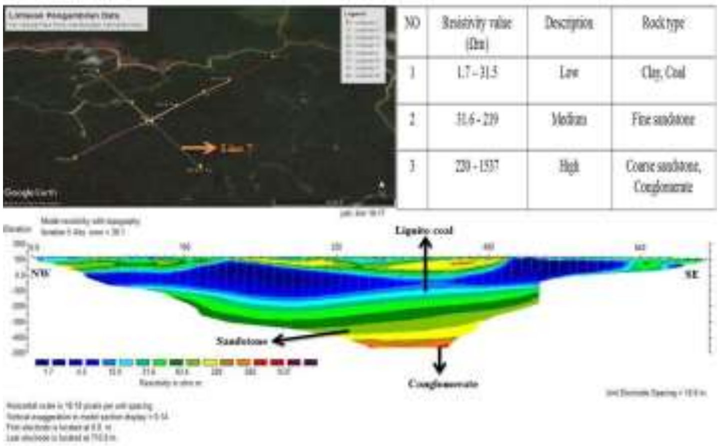

Figure 10. Cross section of the inversion of the path 7 Yati.

From the picture above it can be seen that it consists of 3 layers, the first layer of light blue color with a low resistivity of ~12 Ωm at electrodes 55 to 505 m at a depth of 96.26 m is interpreted as coal seam. This layer has a thickness of ±17.22 m and is located in a layer of clay so that it has a low resistivity value. The second layer is a layer which is interpreted as a fine sandstone layer having a resistivity of >83.4 Ωm at a depth of 113.44 m at electrodes 55 to 455 m which is spread under the coal seam and above the clay layer. And the third layer is at a depth of ±518 m with a resistivity of ~1060 Ωm which is interpreted as a conglomerate layer.

Table 8. Distribution of lignite coal.

Place the electrodes	Depth (m)	Resistivity (Ωm)
55 - 505	96.26	12 – 30

Track 8 Yati

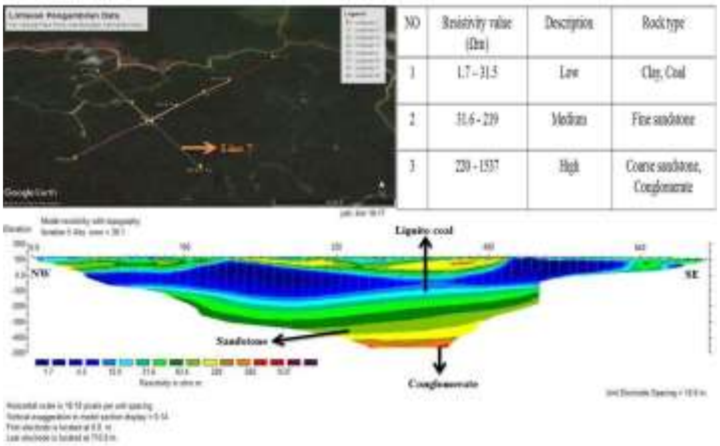

Figure 11. Cross section of the inversion of the path 8 Yati.

From the cross-sectional image above, it can be seen that at the bottom layer there is a high resistivity ranging from 1569 Ωm (red color) at a depth of 518 m which is interpreted as conglomerate rock. Then on the top layer of the conglomerate, there is a medium resistivity layer with a resistivity of ~200 Ωm (yellow color) which is interpreted as a sandstone layer at a depth of ±420 m. After that, the layer with a resistivity >10 Ωm is interpreted as a low type coal seam at electrodes 145 to 445 m with a depth of 21.42 m and a thickness of ±20 m.

Table 9. Distribution of lignite coal.

Place the electrodes	Depth (m)	Resistivity (Ωm)
145 - 445	21.42	10.1 - 27

Based on the interpretation of each path above, it can be seen that there are variations in the resistivity values of rocks in the study area as shown in table 10.

Table 10. Interpretation of the resistivity value of the research area.

Resistivity value (Ωm)	Information	Rock type
10 – 30	Low	Lignit Coal
104 – 1506	Middle	Fine sandstone and coarse sandstone
1506 - 6400	High	Conglomerat

From the results above, it can be seen that the geoelectric resistivity pole-pole configuration method can be used to determine the distribution of coal with a depth of up to 300 m compared to using the induced polarization geoelectric method which reaches a depth of 30 m [5].

Coal Distribution Analysis

After interpreting the results of the 2d resistivity inversion on each track, it can be seen the estimation of the distribution pattern of coal in the research location based on the xyz data from the Res2dinv inversion using the Rockworks 15 Software. Rockworks 15 software is software that can be used to estimate mineral reserves from point data drill used [10]. In making 3d modeling at Rockworks this research uses Res2dinv inversion xyz data which has been interpreted according to regional geology and made into drill point data.

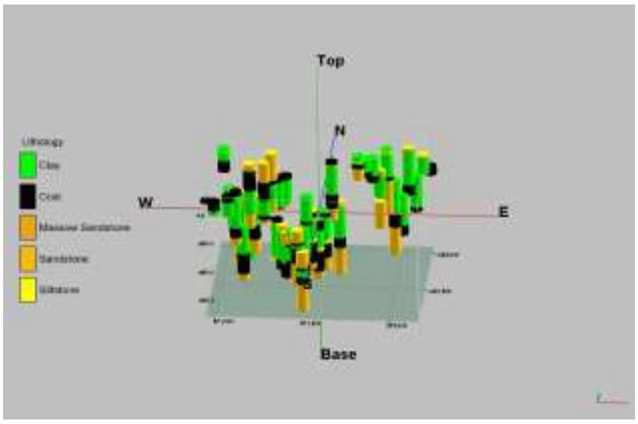

Figure 12. 3D block drill points cross section 1.

This modeling uses 44 drill point data with a drill point distance of 50 meters which is composed of clay, coal, sandstone and silt lithology. From the results of the modeling of the block 1 lithology section above, it is known that the dominant lithology in the study area is clay by 38% with a volume of 419,000,000 tons and coal lithology as the research target of 25% with a volume of 270,600,000 tons of the total existing lithology.

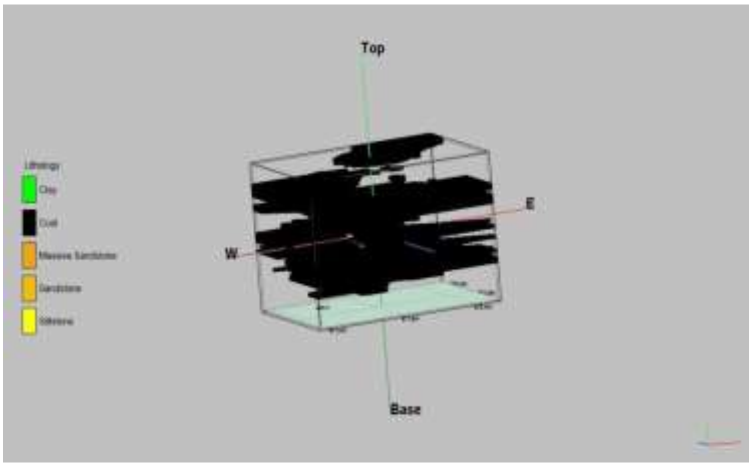

Figure 13. 3D cross-section of coal lithology block 1.

The image above is the distribution of coal obtained from 3D modeling of block 1 at Rockworks. It can be seen that the direction of the distribution of coal is from west to east to north to south. In the section above, the coal depth starts from a depth of 4.2 m at drill point LE2-405 and ends at drill point LY8-445 at a depth of 329 m. From the picture above, it can also be seen that the distribution of coal in the study area is actually only found in the upper and lower layers of coal. Below is a modeling image of the top layer of coal in block 1.

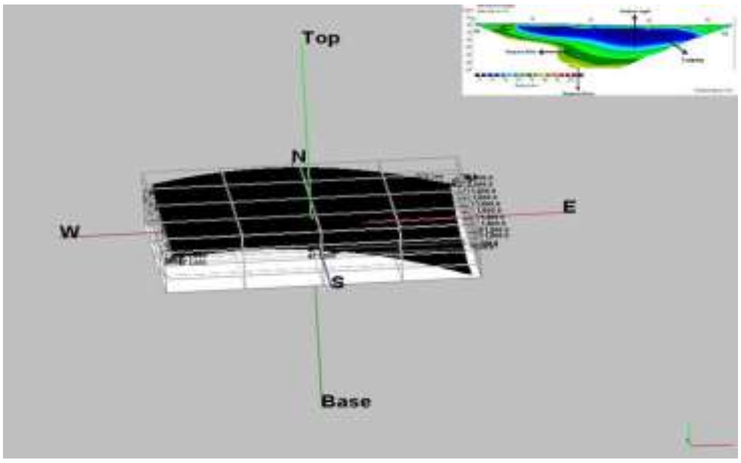

Figure 14. Block top layer coal seam.

Coal Seam Continuity

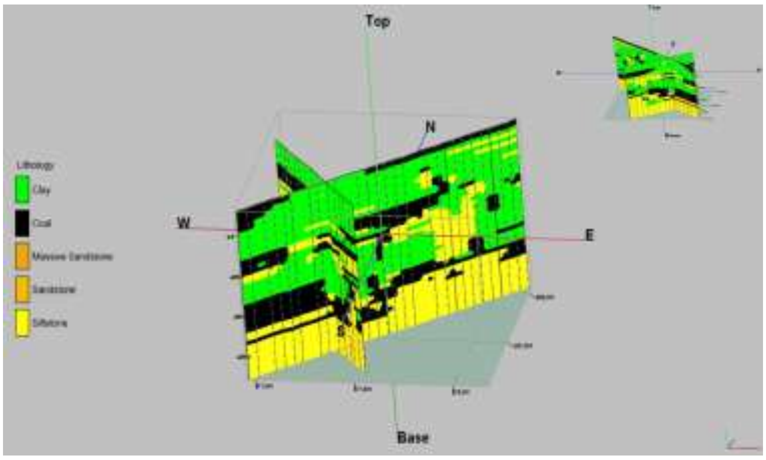

Figure 15. Block lithology continuity display.

The picture above is a combination of paths 1, 2, 3 which intersect with paths 7, 8 in block 1. Based on the image above, it can be seen the continuity of the intersection of each path. The point of intersection is on track 3 and line 7, the coal seam can be seen continuing from the southwest to track 1 which is in the northeast. The continuity of this coal seam is only found at the bottom of the coal layer which is at a depth of 258 m.

CONCLUSION

Based on the interpretation results that have been carried out in the previous chapter by correlating resistivity data and geological data in the Tanjung Palas Timur District, North Kalimantan Province, in general it can be concluded as follows:

1. Characteristics of the coal seam identified in the Tanjung Palas Timur District, North Kalimantan Province, which has a low resistivity value because it is flanked by clay rocks above and sandstones below. So, when viewed from the classification of coal types, the type of coal in this research area is included in the type of lignite coal.
2. The resistivity value of the coal in the study area as seen from the 2D cross-section that has been correlated with regional geology, rock resistivity tables, and the resistivity values of previous studies were obtained from track 1 with a range of 1.4 m –11.9 m, track 2 ety 1.3 m -12.4 m, track 2 3 ety 1.3 m - 12.5 m, track 7 yati 1.7 m - 12 m, track 8 yati 1.3 m - 10.1 m which is incorporated in block 1, while track 4 languishes from 2.3 m - 30.7 m, track 5 languishes 6.6 m - 20.4 m, track 6 languishes 4.3 m - 49.1 m which is incorporated in block 2. It is concluded that block 1 has a coal resistivity value of 10 m - 12.5 m with a depth ranging from 4.2 m to 293 m and a thickness of 17.22 m to 30 m, while block 2 has a resistivity value of 20.4 m - 49 m with a depth of 113 m to 153 m and a thickness of 39 m to 60 m
3. Based on the 3D modeling of the coal distribution pattern using Rockworks Software, we can see continuity in block 1 of the research area. This continuity can be seen from the southwest on track 3 to the northeast on track 1 which is in the bottom layer of coal at a depth of 258 m.

REFERENCES

[1] Anonim, *Sumber Daya Batubara (Tinjauan Lengkap Mengenai Batu Bara)*. World Coal Institute, 2005.

[2] T. Y. dan S. Widodo, "Identifikasi Penyebaran Dan Ketebalan Batubara Menggunakan Metode Geolistrik Resistivitas (Studi Kasus Daerah X Kabupaten Kutai Kertanegara Kalimantan Timur)," *Berk. Fis.*, vol. 11, no. 2, pp. 59–66, 2008.

[3] Hamid Umar, "Analisis Potensi dan Cadangan Batubara dengan Metode Geolistrik Resistivity di Daerah Massenrengpulu Kecamatan Lamuru Kab.Bone, Prov.Sulawesi Selatan," vol. 6, pp. 978–979, 2012.

[4] E. Azizah and A. Basid, "Aplikasi Metode Geolistrik untuk Mengetahui Sebaran Batubara di Kabupaten Tulungagung Jawa Timur," vol. 2, no. 1, pp. 51–58, 2020.

[5] M. Z. Muhlisin, "Identifikasi Sebaran Batubara Menggunakan Metode Geolistrik Polarisasi Terinduksi (IP) (Studi Kasus Daerah Klatak Kecamatan Besuki Kabupaten Tulungagung)," 2019.

[6] J. M.Reynolds, *An Introduction to Applied and Environmental Geophysics*. John Wiley & Sons Ltd, 1997.

[7] M. . Loke, *Tutorial : 2-D and 3-D electrical imaging surveys By*. 2004.

[8] W. M. Telford, *Applied Geophysics, Second Edition*, 1990th ed. Cambridge University Press.

[9] P. Kearey, *An Introduction to Geophysical Exploration*, 3rd ed. Blackwell Science, 2002.

[10] D. Adrian and B. S. Mulyatno, "Identifikasi Dan Estimasi Sumber Daya Batubara Menggunakan Metode Poligon Berdasarkan Intepretasi Data Logging Pada Lapangan "Ada", Sumatera Selatan," *J. Geofis. Eksplor.*, vol. 4, no. 1, pp. 94–111, 2020, doi: 10.23960/jge.v4i1.8.