JGE (Jurnal Geofisika Eksplorasi)
Vol. 11 No. 03, November 2025 (204-216) https://doi.org/10.23960/jge.v11i2.495

THE EFFECT OF INTRUSION ON THE PHYSICAL AND CHEMICAL PROPERTIES OF COAL

PENGARUH INTRUSI TERHADAP SIFAT FISIKA DAN KIMIA BATUBARA

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Received: 2025, July 31st
Accepted: 2025, November 13th

Keywords:
Air Laya;
Coal characteristics;
Intrusion;
Proximate analysis.

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How to cite this article:
Ogara, E.R., Wahyuni, T., & Rizqi, A.H.F. (2025). The Effect of Intrusion on The Physical and Chemical Properties of Coal. *JGE (Jurnal Geofisika Eksplorasi)*, 11(03), 204-216.

Abstract. Coal is a deposit of organic matter derived from plant remains that have undergone diagenesis process to form a coal seams. This study aims to determine the impact of intrusion on the physical and chemical characteristics of coal. The location of this research is in the Air Laya mining area, PT Bukit Asam Tbk, Tanjung Enim, South Sumatra and is part of the South Sumatra Basin which is well known as one of the coal bearing formation areas. Four (4) coal samples were analysed including proximate analysis, total sulphur content, and calorific value to measure moisture content, volatile matter, fixed carbon, ash content, and calorific value of the coal. Petrology and well log analysis was used to determine lithology and regression analysis was used to assess the effect of intrusion on coal characteristics. The results of the coal analysis in the research area reveal significant differences between coal samples located near the intrusion and those farther away. Coal located near the intrusion exhibits black colour, vitreous and conchoidal fracture. In contrast, coal farther from the intrusion shows a dull, blackish-brown, brownish streak, and uneven fracture. Coal near the intrusion shows lower moisture (1.5–1.7%) and volatile matter (17–25%), but higher ash content (7.9–8.2%), fixed carbon (67–73%), calorific value (7700–7968 kcal/kg), and sulphur (0.7–0.8%). In the other hand, coal farther from the intrusion has higher moisture and volatile matter, but lower fixed carbon, calorific value, and sulphur. The findings conclude that proximity to intrusion increases fixed carbon and calorific value but also raises sulphur levels, which may pose environmental and operational concerns.

Abstrak. *Batubara merupakan endapan bahan organik yang berasal dari sisa-sisa tumbuhan yang telah mengalami proses diagenesis hingga membentuk lapisan batubara. Penelitian ini bertujuan untuk mengetahui* *dampak intrusi terhadap karakteristik fisik dan kimia batubara. Lokasi penelitian berada di area penambangan Air Laya, PT Bukit Asam Tbk, Tanjung Enim, Sumatera Selatan, dan merupakan bagian dari Cekungan Sumatera Selatan yang dikenal sebagai salah satu daerah pembentukan batubara. Empat (4) sampel batubara dianalisis, meliputi analisis proksimat, kandungan total sulfur, dan nilai kalor untuk mengukur kadar air, zat terbang (volatile matter), karbon tetap (fixed carbon), kadar abu, dan nilai kalor batubara. Analisis petrologi dan well log digunakan untuk menentukan litologi, sedangkan analisis regresi digunakan untuk menilai pengaruh intrusi terhadap karakteristik batubara. Hasil analisis batubara di daerah penelitian menunjukkan perbedaan signifikan antara sampel batubara yang berada dekat zona intrusi dan yang berjarak lebih jauh. Batubara yang berada dekat intrusi menunjukkan warna hitam pekat, mengkilap, dan memiliki patahan konkhoidal. Sebaliknya, batubara yang lebih jauh dari intrusi tampak kusam, berwarna hitam kecokelatan, dengan goresan kecokelatan dan patahan tidak merata. Batubara dekat intrusi memiliki kadar air lebih rendah (1,5–1,7%) dan zat terbang lebih rendah (17–25%), tetapi kadar abu lebih tinggi (7,9–8,2%), karbon tetap lebih tinggi (67–73%), nilai kalor lebih tinggi (7700–7968 kcal/kg), serta kandungan sulfur lebih tinggi (0,7–0,8%). Sementara itu, batubara yang jauh dari intrusi memiliki kadar air dan zat terbang lebih tinggi, tetapi karbon tetap, nilai kalor, dan sulfur lebih rendah. Temuan ini menyimpulkan bahwa kedekatan terhadap zona intrusi meningkatkan karbon tetap dan nilai kalor batubara, namun juga meningkatkan kadar sulfur, yang dapat menimbulkan masalah lingkungan dan operasional.*

1. INTRODUCTION

Full-waveform Inversion (FWI) is a Coal is a type of rock formed from the remains of plant material that has undergone a process of diagenesis and formed coal seams (Yenni & Prabowo, 2021). The quality of coal varies from one region to another, influenced by several factors such as the type of plant material, geological controls, and depositional environment (Zahar et al., 2020; Suhayadi & Sriyanti, 2022). The quality of coal can be determined based on physical and chemical aspects. In general, the physical aspects of coal can be identified through its colour, lustre, streak, and hardness, while the chemical aspects can be determined through proximate analysis, which includes total moisture (TM), fixed carbon (FC), volatile matter (VM), and ash content (Ash). In addition, total sulphur (TS) analysis and calorific value (CV) are also important indicators.

The research area is in Lawang Kidul Subdistrict, Muara Enim Regency, South Sumatra Province. To the north, it borders Muara Enim Regency, and to the northwest, it borders Merapi Timur Subdistrict (**Figure 1**). The coal in this area is indicated to have been in contact with igneous rock intrusions. This intrusive process generates heat that can increase the coalification rank, leading to changes in both the physical and chemical properties of the coal (Purnama, 2021).

Coal that has been thermally altered by igneous intrusions and has undergone rank enhancement can be found in the Air Laya Mine (TAL) area, Tanjung Enim, South Sumatra. The intrusion in this region occurred after the deposition of the Muara Enim Formation, which contains coal seams formed during the Late Miocene to Pliocene (Maulana & Anggara, 2020). This study aims to determine the impact of igneous intrusions on changes in the physical and chemical characteristics of coal.

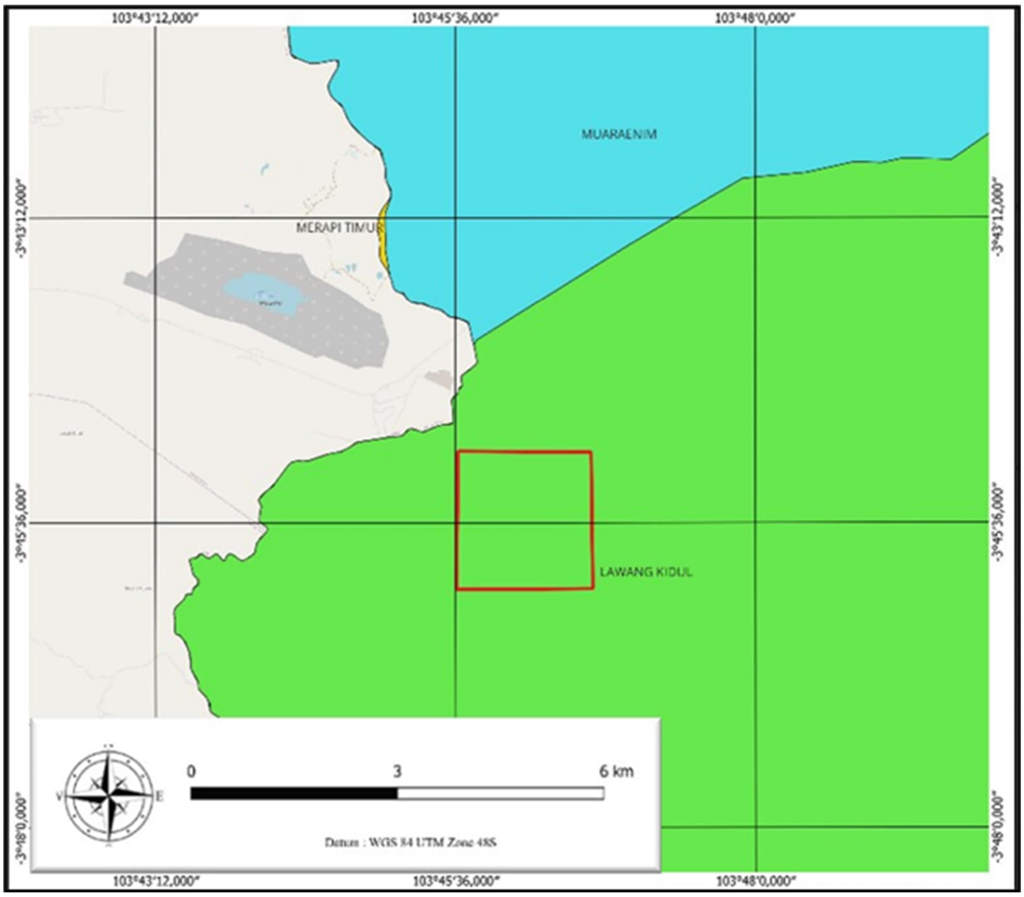

Figure 1. Research area.

2. LITERATURE REVIEW

2.1. Geological Background

Study area is in The Palembang Zone, which is part of the South Sumatra Basin. This basin is Tertiary in age and trends in a northwest-southeast direction. It is bounded by the Great Sumatran Fault and the Bukit Barisan Mountains to the southwest, and by the Sunda Shelf to the southeast, which separates the South Sumatra Basin from the Sunda Basin. To the northwest, the Tiga Puluh Mountains separate it from the Central Sumatra Basin (Siallagan et al., 2019).

The stratigraphy of the South Sumatra Basin is divided into two main groups: the Telisa Group, which formed during a transgressive phase, and the Palembang Group, which formed during a regressive phase. The study area is part of the Palembang Group, as it lies within the Muara Enim Formation as coal bearing formation.

The Muara Enim Formation is associated with a regressive depositional cycle and is well-known for containing coal deposits and it was deposited during the Late Miocene to Pliocene. The formation is subdivided into four members (M1, M2, M3, and M4), each of which has distinct characteristics, such as varying sediment thicknesses and specific roof and floor layers for each coal seam (Mijnbouw, 1976; Bamco, 1983) (**Figure 2**).

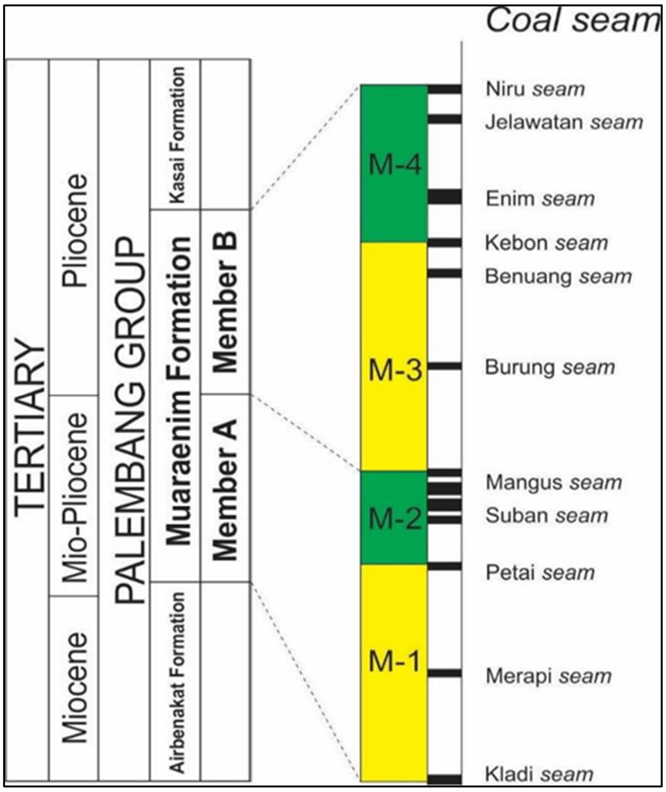

Figure 2. Stratigraphic sequence of Tanjung Enim (Bamco, 1983).

2.2. Well logging

Well logging is one of the methods used in coal exploration to understand subsurface geological conditions. In coal exploration, the well logging method is highly effective because it can provide a clear and relatively accurate vertical profile of the subsurface conditions (Khasanah et al., 2019). In this research, the well logging methods used are gamma ray log and density log.

2.2.1. Gamma Ray Log

The gamma ray log is one of the commonly used methods for interpreting lithology types based on the gamma radiation emitted by rocks. The naturally occurring radioactive elements present in rocks include Thorium, Uranium, and Potassium (Harsono, 1993).

2.2.2. Density Log

The density log is a curve that shows the density of the rock penetrated by the borehole, which is related to the rock's porosity and is measured in units of grams per cubic centimetre (gr/cc) (Harsono, 1993).

2.3. Physical Properties of Coal

The determination of the physical characteristics of coal/lithotypes can be observed directly in the field. The parameters used in identifying coal lithotypes include color, streak, and luster (Diessel, 1992). Coal that has a shiny black color is rich in vitrinite macerals, which are derived from macroscopic plants such as wood, wood fibers, etc., while dull coal is rich in liptinite macerals, which originate from microscopic plants such as spores, algae, cuticles, etc. Black color indicates a high rank coal (bituminous to anthracite), while brown color indicates a low rank coal (lignite). Streak is related to the rank of coal. Lignite has a brown streak, while bituminous to anthracite coal has a dark brown to black streak. The luster of coal depends on its type and rank. Dull luster is generally found in low rank coal, while coal with vitreous (glassy) luster typically has a high rank coal.

2.4. Chemical Properties Of Coal

2.4.1. Proximate Analysis

Proximate analysis is a method used in laboratories to determine total moisture (TM), volatile matter (VM), fixed carbon (FC) and ash content. Total moisture refers to the present water in coal in the form of inherent and adherent moisture, measured under conditions when the coal sample is taken (as sampled) or when the coal is received (as received). Below is the calculation formula used to determine the moisture content according to ASTM D3173-17.

$$TM = \left[\frac{M2-M3}{M2-M1}\right] X\ 100\% \quad (1)$$

Volatile matter is the percentage of volatile products such as CO_2, CH_4, CO etc. that are found in coal that can evaporate when the coal sample is heated at a specified temperature and time. Here is the formula for calculating volatile matter ASTM D3175-15.

$$VM = \left[\frac{M2-M3}{M2-M1}\right] X\ 100\% \quad (2)$$

Ash content is the amount of residue from the remaining inorganic substances contained in coal. The ash consists of various inorganic minerals such as silica, alumina, iron oxide, calcium, magnesium, and other compounds that do not combust (Sugiarto et al., 2023). Below is the formula used to calculate ash content according to ASTM D3172-13.

$$Ash = \left[\frac{M2-M3}{M2-M1}\right] X\ 100\% \quad (3)$$

Fixed carbon in coal refers to the carbon present in the solid residue left behind after the volatile matter has been released. High fixed carbon can produce a high amount of heat energy during combustion. Below is the formula for calculating fixed carbon (ASTM D3172-13).

$$FC = 100\% - \%TM - \%Ash - \%VM \quad (4)$$

2.4.2. Calorific value

The calorific value is the amount of heat energy released by coal during the combustion process, because of the reaction between hydrocarbon compounds and oxygen. The Net Calorific Value (NCV) measures the available energy without accounting for the energy from the condensation of water vapor, whereas the Gross Calorific Value (GCV) measures the total energy released during combustion, including the energy from the condensation of water vapor (Agung et al., 2019).

2.4.3. Total Sulphur

Sulfur in coal can form through various processes, including the influence of roof and floor rocks during deposition, the impact of seawater during sedimentation, microbial activity, and changes in pH (potential hydrogen) during coal formation. Generally, the presence of sulfur in coal is associated with several minerals such as pyrite sulfate, chalcopyrite, and sulfide (Pamekas & Nurdrajat., 2019).

2.4.4. Regression Analysis

Linear regression is a statistical method used to analyze the relationship between two variables, aiming to determine how strong the relationship is between the variables being tested. In regression analysis, the variable that is influenced is called the dependent variable (y), while the variable that influences is called the independent variable (x) (Ogara et al., 2023).

3. 3. RESEARCH METHODS

3.1. Lithology Analysis

Lithology analysis in this study was carried out using two methods: direct field observation (rock description), which includes color, texture, and rock structure. Subsurface lithology determination was conducted using drilling data, specifically gamma ray logs and density logs.

3.2. Coal Characteristics

The characteristics of coal are determined based on physical and chemical aspects. Physical characteristics are observed directly and include color, streak, lustre, and fracture. Chemical characteristics are analysed using four coal samples from seam A2, taken from four points based on their proximity to the intrusion zone (**Figure 5**). Proximate analysis was performed by using a furnace and ASTM standards (ASTM D3173-17, D3175-15, D3174-12 and D3172-13) total sulphur content and calorific value was performed by using LECO Sulphur analyser and Bomb calorimeter. This analysis aims to compare the characteristics of coal located near the intrusion zone with those farther away from it.

3.3. Regression Analysis

In this study, a regression analysis was conducted to determine the correlation or influence of the distance from the intrusion on the values of TM (Total Moisture), FC (Fixed Carbon), VM (Volatile Matter), Ash, TS (Total Sulfur), and CV (Calorific Value) in the study area.

4. RESULT AND DISCUSSION

4.1. Petrology and Intrusion Zone

Based on surface data, the northeastern part of the study area has relatively tight spaced contours, which may be caused by rocks with higher resistance compared to other surrounding rocks. In the area with tight spaced contours, Andesite rock was found, characterized by its dark to grey color, porphyritic texture, and massive (**Figure 3**).

Based on well logging data (Log B), it is indicated that there is an Andesite intrusion at depths of 8.01–36.25 meters and at 112–116 meters (**Figure 4**). The presence of the intrusion zone in the study area is part of the Muara Enim Formation, which is estimated from Pliocene to Pleistocene, and consists of three main bodies: dike intrusion, Suban sill intrusion, and volcanic cone intrusion (Darman & Sidi, 2000). Based on the lithology distribution and contour, the delineation of the intrusion zone is in the north to northeast part of the study area. Well logging B is the sampling point closest to the intrusion, followed by well logging C, D, and A (**Figure 5**).

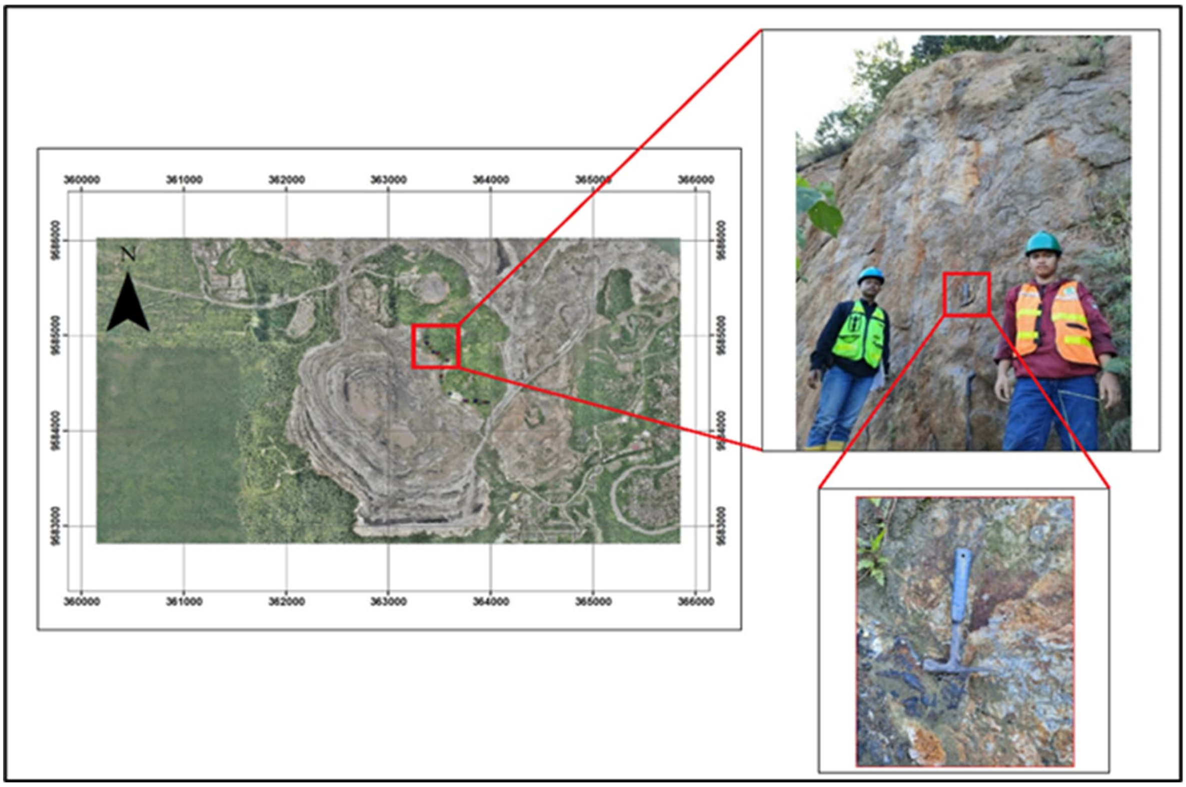

Figure 3. Andesite outcrop in research area.

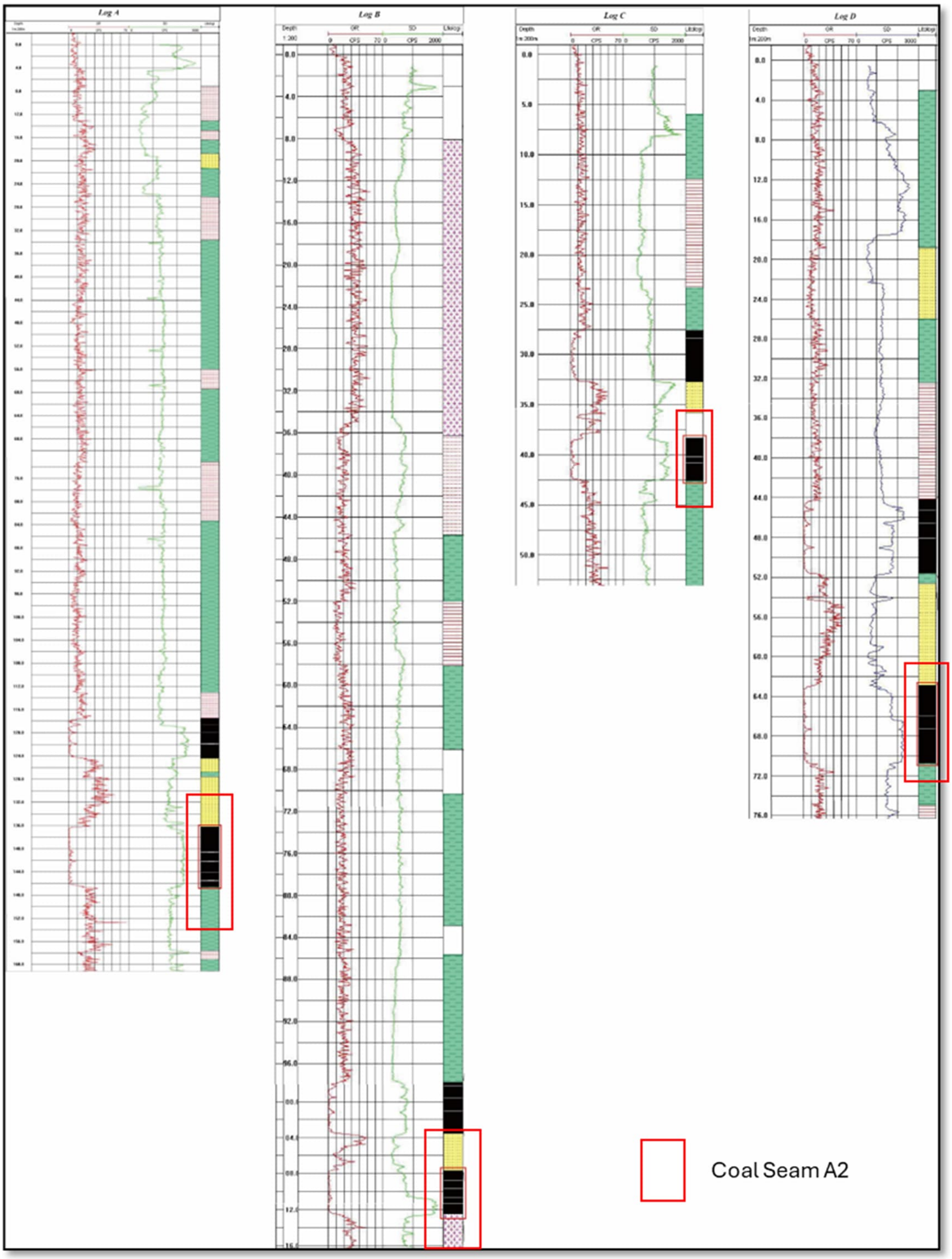

Figure 4. Well Loging Interpretation.

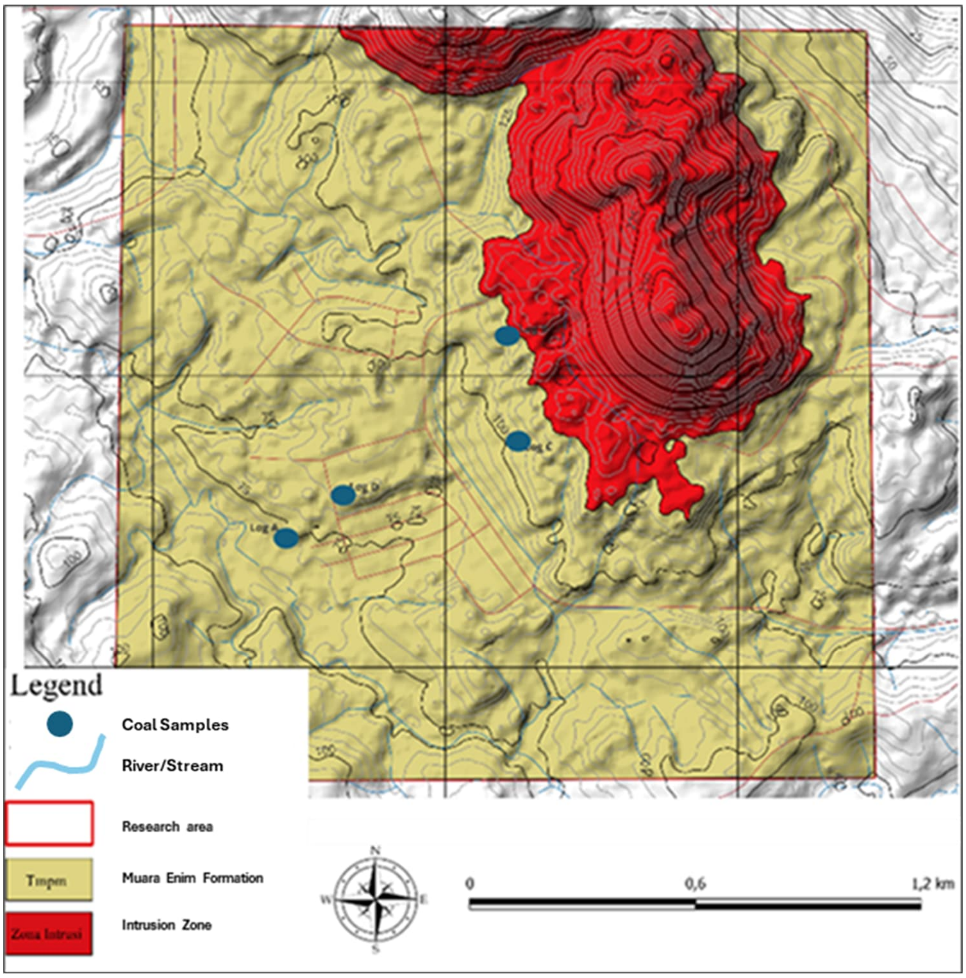

Figure 5. Delineation of intrusion zone.

4.2. The Effect of Intrusion on Coal

4.2.1. Physical Properties of Coal

Based on field data, the coal in seam A2 shows differences in physical characteristics at several locations. Coal located near the intrusion zone (loc B and loc C) is black and shiny, with a black streak, conchoidal fracture, and is flanked by tuffaceous sandstone and claystone. In contrast, coal located farther from the intrusion zone (loc D and loc A) tends to be brownish black in color, with a more brittle texture, brownish-black streak, dull black luster, and it's also flanked by tuffaceous sandstone and claystone (**Table 1**).

Table 1. Coal Petrology.

Description	Seam A2			
	Loc. B	Loc. C	Loc. D	Loc. A
Distance from intrusion	0 m	300 m	800 m	900 m
Color	Shiny black	Shiny Black	Black	Black
Streak	Black	Black	Brownies black	Brownies black
Luster	Bright	Bright	Dull	Dull
Fracture	Conchoidal	Conchoidal	Uneven	Uneven
Contact – Roof	Tuffaceous Sandstone	Tuffaceous Sandstone	Tuffaceous Sandstone	Tuffaceous Sandstone
Contact – Floor	Claystone	Claystone	Claystone	Claystone
Photo				

4.2.2. Chemical Properties of Coal

Based on chemical properties, coal exhibits differences between coal located near an intrusion zone and coal located farther from the intrusion zone. The (TM) in seam A2 ranges between 1.5–13.5%,

Volatile Matter (VM) ranges from 17–41.5%, Ash content ranges from 2–8%, Fixed Carbon (FC) ranges between 43–73%, Total Sulfur (TS) ranges from 0.2–0.8%, and Calorific Value (CV) ranges between 6300–7900 Kcal/Kg **(Table 2).**

Table 2. Comparison of chemical properties of coal with respect to the distance from the intrusion.

Name	Distance from Intrusion	Seam	Proximate Analysis				Total Sulphur (%)	CV (Kcal/Kg)
			TM (%)	VM (%)	Ash (%)	FC (%)		
Loc B	0 m	Seam A2	1.5	17.2	8.2	73.2	0.8	7968
Loc C	300 m	Seam A2	1.72	25.1	7.9	67.4	0.7	7763
Loc D	800 m	Seam A2	12.5	39.1	6.33	47.6	0.3	6879
Loc A	900 m	Seam A2	13.5	41.5	2.37	43.7	0.2	6331

The effect of intrusion on total moisture and volatile matter can be seen in **Figure 6**. The graph shows that Loc B, which is directly affected by the intrusion, has 1.5% of total moisture and 17.2% of volatile matter, while Loc A, which is the furthest from the intrusion zone, has 13.5% and 41.5%. From this data, it can be concluded that the closer the location is to the intrusion zone, the lower the total moisture and volatile matter (positive relationship). This is supported by a coefficient of determination of R^2 above 0.90 which means total moisture and volatile matter is influenced by the distance from the intrusion (**Table 3**). Intrusion causes the moisture content in coal, both in the form of free moisture and inherent moisture, to evaporate (Yao et al., 2011) and the heat generated from the intrusion causes volatile matter which consists of components such as carbon monoxide, methane and nitrogen to evaporate and be released easily. In addition, heat from the intrusion reduces the moisture and volatile matter content, thereby increasing the proportion of fixed carbon and ash content (Thomas, 2013; Sugiarto et al., 2023).

Table 3. Regression test of the influence of TM, Ash, FC, total sulfur and CV on intrusion distance.

	Coefficients	Standard Error	t Stat	P-value	R^2
Intercept	581.6591111	640.0870955	0.908719	0.393709	-
TM	-1.45535489	14.08266074	-0.10334	0.920589	0.9227
VM	19.48660969	11.38279587	1.711935	0.130641	0.998
Ash	-15.7663074	14.09751968	-1.11837	0.300313	0.6889
FC	-10.2190075	20.29215288	-0.50359	0.630005	0.984
Total Sulphur	-122.723188	175.5924498	-0.69891	0.507159	0.9307
CV	0.012236853	0.166935503	0.073303	0.943616	0.9751

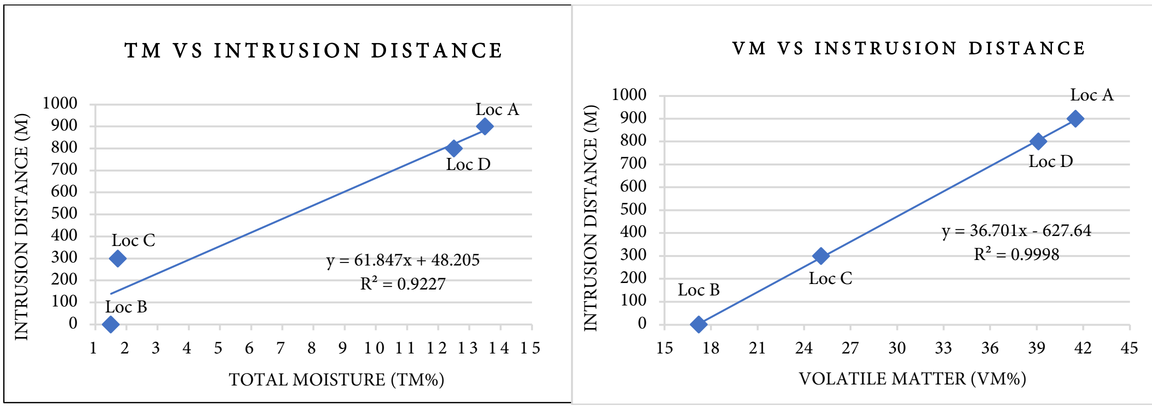

Figure 6. The effect of intrusion distance on total moisture (left) and volatile matter (right).

The effect of intrusion on fixed carbon, calorific value, total sulphur and ash content shows a similar trend (**Figure 7**). The figure shows negative relationships, closer to the intrusion zone, the higher the fixed carbon, calorific value, total sulphur and ash content. Location B, where the coal is near the intrusion zone, has a calorific value of 7968 Kcal/kg, while Locations C, D, and A have calorific values of 7763, 6879, and 6331 Kcal/kg, respectively. In addition, coal close to the intrusion zone has fixed carbon of 73.2%, while coal far from the intrusion zone has a fixed carbon value of 43.7%. The heat resulting from the intrusion can reduce or eliminate the moisture and volatile matter content in the coal, thereby increasing the percentage of fixed carbon. Fixed carbon and calorific value have a positive relationship, where an increase in fixed carbon results in a higher calorific value as well (Yao et al., 2011).

The coal seam located near the intrusion zone has 0.8% of total sulfur and 8.2% of ash content. Meanwhile, coal samples are far from the intrusion of 0.2% of total sulfur and 2.37% of ash content. This may be attributed to the influence of the intrusive rock acting as the surrounding host rock. The intrusion potentially carries sulfur, which then undergoes infiltration into the adjacent coal layers. However, it is important to consider the origin of sulfur in coal. In addition to the influence of the host rock, sulfur may also originate from the organic matter or plant material from which the coal was formed (Yao et al., 2011).

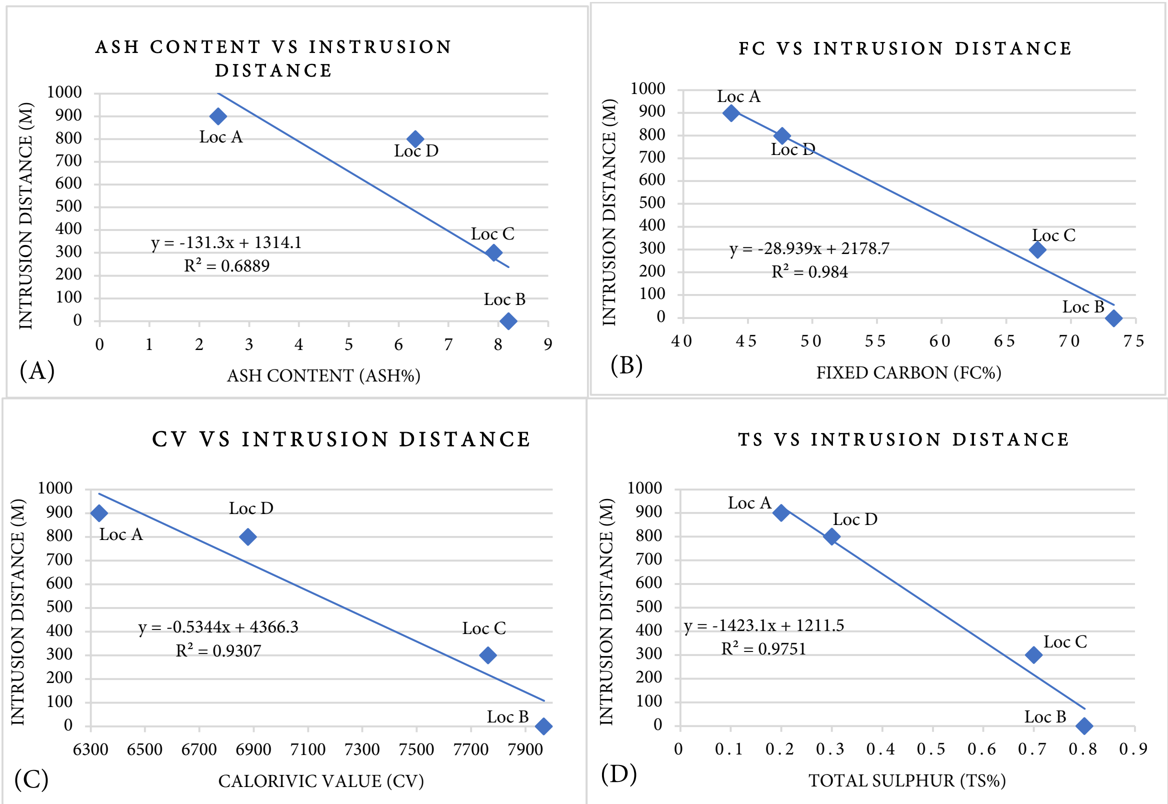

Figure 7. The effect of intrusion distance on ash content, (B) fixed carbon, (C) Calorific value, and (D) Total sulphur.

Based on the regression test results, the coefficient of determination (R^2) ranges between 0.6 and 0.9. This indicates that intrusion influences total moisture, volatile matter, ash content, fixed carbon, calorific value, and total sulfur. However, it should be noted that the P-value is greater than 0.05 ($P > 0.05$), which means that these variables do not have a statistically significant effect, or the dataset used may be too small.

5. CONCLUSION

The intrusion has a significant influence on the physical and chemical characteristics of the coal. The physical characteristics of coal located near the intrusion zone include black colour, vitreous lustre, black streak, and conchoidal fracture. In contrast, coal located farther from the intrusion zone shows a blackish-brown colour, dull lustre, brownish-black streak, and uneven fracture.

According to the proximate analysis, calorific value, and total sulphur of seam A2 at four locations with varying distances from the intrusion zone, there is a trend showing that moisture content and volatile matter decrease as the coal gets closer to the intrusion zone (positive relationship). Moisture content in coal near the intrusion ranges from 1.5% to 1.7%, while it ranges from 12% to 13.5% in coal farther from the intrusion. Volatile matter in coal near the intrusion ranges from 17% to 25%, whereas in coal farther from the intrusion it ranges from 39% to 41.5%.

Ash content, fixed carbon, calorific value, and total sulphur tend to increase as the coal gets closer to the intrusion zone (negative relationship). Seam A near the intrusion zone has an ash content ranging from 7.9% to 8.2%, fixed carbon between 67% and 73%, calorific value between 7700 and 7968 kcal/kg, and total sulphur between 0.7% and 0.8%. On the other hand, seam A farther from the intrusion zone has ash content ranging from 2.3% to 6.3%, fixed carbon between 43% and 47%, calorific value between 6300 and 6879 kcal/kg, and total sulphur between 0.2% and 0.3%.

It can be concluded that intrusion affects the characteristics and quality of coal. The closer to the intrusion zone, the higher the coal quality tends to be, in line with increased calorific value and fixed carbon. However, it should be noted that the increase in fixed carbon and calorific value is also accompanied by an increase in sulphur content. High sulphur content has negative impacts such as air pollution during combustion and corrosive effects.

REFERENCES

Agung, N. M., Nugroho, W., & Hasan, H. (2019). Hubungan Kandungan Total Sulphur Terhadap Gross Calorific Value Pada Batubara PT. Carsurin Samarinda. *Jurnal Teknologi Mineral FT UNMUL*, 7(1), 1–8. https://doi.org/10.30872/JTM.V7I1.2422

Bukit Asam Mine Constructors (Bamco) (1983). *Bukit Asam Drilling Campaign, Report on Geology-Coal Quality.* Bukit Asam Coal Mining Development and Transportation Project, Morrison-Knudsen International Company Inc. and Rheinbraun Consulting GmbH, Cologne, 90 pp. (Unpublished).

Darman, H. & Sidi, F. H. (2000). *An Outline of the Geology of Indonesia.* Indonesia Association of. Geologists. 192 p.

Diessel, C.F.K. (1992). Coal-Bearing Depositional Systems (pp. 5-261). *Springer-Verlag.*

Harsono, A. (1993). *Pengantar Evaluasi Log.* Schlumberger Data Services, Jakarta.

Khasanah, U., Supriyanto, S., & Djayus, D. (2019). Analisis Nilai Log Gamma Ray dan Log Density Terhadap Variasi Kecepatan Perekaman Metode Well Logging Robertson Geologging (Rg). *Geosains Kutai Basin,* 2(1). https://doi.org/10.30872/GEOFISUNMUL.V2I1.400

Maulana, A. & Anggara, F. (2020). Karakteristik Batubara Terpengaruh Intrusi di Tambang Air Laya, Sumatra Selatan, dan Potensinya Sebagai Material Untuk Pembuatan Grafit Sintetis Buletin Sumber Daya Geologi. https://buletinsdg.geologi.esdm.go.id/index.php/bsdg/article/view/BSDG_VOL_15_NO_3_2020_4

Mijnbouw, N.V.S. (1976). *Geological Study of The Bukit Asam Coal Mines*, Jakarta, 18 pp. (unpublished).

Ogara, E.R., Fadhilah, A., & Ilham, A. (2023). Penentuan Peringkat dan Pengaruh Karakteristik Batubara Terhadap Nilai Kalori. *JGE (Jurnal Geofisika Eksplorasi)*, 9(2), 122–130. https://doi.org/10.23960/jge.v9i2 .275

Pamekas, S.F., Nurdrajat, & Ghani, R.M.G. (2019). Kerangka Sekuen Pengendapan Batubara Berdasarkan Analisis Nilai Sulfur dan Kadar Abu Daerah Bentarsari, Kecamatan Salem, Kabupaten Brebes, Provinsi Jawa Tengah. *Geoscience Journal*, 3(4), 281–286. http://jurnal.unpad.ac.id/geoscience/article/view/23194

Purnama, A. (2021). Pengaruh Intrusi Terhadap Lapisan Batubara E (Keladi) Formasi Muara Enim, Sub-cekungan Palembang Selatan, Sumatera Selatan. *Jurnal Teknologi Mineral dan Batubara,* 17(1), 13–25. https://doi.org/10.30556/JTMB.VOL17.NO1.2021.1096

Siallagan, F., Dewanto, O., & Mulyatno, B.S. (2019). Analisis Reservoar Migas Berdasarkan Parameter Petrofisika Dari 7 Sumur di Cekungan Sumatera Selatan. *JGE (Jurnal Geofisika Eksplorasi)*, 3(2), 52–64. https://doi.org/10.23960/JGE.V3I2.1040

Sugiarto, W., Listyani R.A.T., & Winarti. (2023). Pengaruh Kandungan Abu Terhadap Kualitas Batubara Pada Formasi Labanan. *Kurvatek*, 8(1), 1–6. https://doi.org/10.33579/KRVTK. V8I1.4020

Suhayadi, F. & Sriyanti (2022). Kajian Lingkungan Pengendapan Berdasarkan Karakteristik Batubara Formasi Pulau Balang. *Jurnal Riset Teknik Pertambangan,* 1–8. https://doi.org/10.29313/JRTP.V2I1.779

Thomas, L. (2013). *Coal Geology.* John Wiley & Sons.

Yao, Y., Liu, D., & Huang, W. (2011). Influences of Igneous Intrusions on Coal Rank, Coal Quality and Adsorption Capacity in Hongyang, Handan and Huaibei Coalfields, North China. *International Journal of Coal Geology,* 88(2–3), 135–146. https://doi.org/10.1016/ J.COAL.2011.09.004

Yenni, F. R. & Prabowo, H. (2021). Management Pengendalian Kualitas Batubara Berdasarkan Parameter Kualitas Batubara Mulai Dari Front Sampai ke Stockpile di PT. Budi Gema Gempita, Merapi Timur, Lahat, Sumatera Selatan. *Journals Mining Engineering: Bina Tambang*, 6(1), 110–120. https://doi.org/10.24036/BT.V6I1.111689

Zahar, W., Hawa, N., Anggayana, K., & Widayat, A. H. (2020). Analisis Lingkungan Pengendapan Batubara PT. Marunda Graha Mineral Kabupaten Murung Raya Mineral, Kalimantan Tengah. *JTK (Jurnal Teknik Kebumian),* 5(2), 37–46. https://doi.org/10.22437/JTK.V5I2.8210