Macrolithotype and gas content of shallow low-rank coal of Muaraenim Formation at Musi Banyuasin, South Sumatera Basin

by Basuki Rahmad

Macrolithotype and gas content of shallow low-rank coal of Muaraenim Formation at Musi Banyuasin, South Sumatera Basin

To cite this article: V Fintaru *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **212** 012020

Macrolithotype and gas content of shallow low-rank coal of Muaraenim Formation at Musi Banyuasin, South Sumatera Basin

V Fintaru[1*], B Rahmad[1], J Setiawan[1], A A Dewa[1] and M A Ibrahim[2]

[1]Department of Geological Engineering, UPN Veteran Yogyakarta, Condongcatur, Sleman, Special Region of Yogyakarta, Indonesia
[2]The Center of Mineral Resources, Coal and Geothermal, Soekarno Hatta No.444 Street, Pasir Luyu, Bandung, West Java, Indonesia

*corresponding author: vikifintaru@rocketmail.com

Abstract. The macrolithotype method has already proven as an early method to determine high-rank coal gas content which is related to organic and inorganic materials, and also coal diagenesis level. This study aims to determine the relationship between macrolithotype and shallow low-rank coal gas content in Muaraenim Formation. Based on analysis result, coal seams exposed at depth of <300m have thickness varying from 0.5 to 10m. All seams in the research area were present in the Late Miocene and classified as lignite. Macrolithotype coal varies from durain - bright clarain with bright band percentage reaching 90%. Petrographic analysis showed that vitrinite reflections ranged from 0.24 to 0.36%. Proximate analysis showed that moisture content ranged from 10,64-12,9 wt.%, volatile matter 40,83-44,96 wt.%, and calorific value 4509-6035 kcal/kg and also Ultimate analysis showed that carbon content 72,48-74,02 wt.%. Gas desorption showed that gas content per seam varies from 0.27-29,84 scf/ton. According to the result between bright band vs depth and gas content vs depth, there was no relation between bright band and gas content due to very poor trend line value. This result was probably due to the low level of coal diagenesis that the bright band content did not show a linear trend line.

1. Introduction

1.1. Background

Indonesia has the potential of Coal Bed Methane (CBM) resources of 453 Tcf spread over 11 basins. South Sumatra Basin is the largest CBM potential basin in Indonesia that has 183 Tcf [12]. The South Sumatra Basin has a major coal seam concentrated in two horizons within the Muaraenim Formation. The lower horizons contain Seam Mangus, Suban and Petas while the upper horizons contain several layers called Hanging Seam [10]. CBM export activities are suitable to be done in the Muaraenim Formation coal layer since the content of ash and sulphur from Muaraenim coal is very low. This low ash and sulphur content will increase the gas content in coal.

The purpose of CBM exploration is to know the amount of gas content in coal. The coal gas content is the volume of gas per unit of coal weight in units of cubic feet/ton. One of the factors that affect coal gas content is the vitrain band of coal. The content of vitrain band of coal/lithotypes is influenced by organic, inorganic and coal diagenesis levels [13].

Lithotype is a macroscopical description that classified coal by its luster (bright and dull), fracture patterns, color, streak of coal, textures, and some kind of stratification [3]. For low-rank coals (lignite and sub-bituminous), lithotype observations are performed only on color and texture [14]. In this study, the authors focused on the description of lithotype on bright band content. This aspect also has been discussed by previous researchers.

Previous research has shown that the relationship between lithotypes and gas content is still not known for certain [1]. However, the results of those study were further refuted by another study showing that coal with bright lithotypes and no dull band tend to have higher gas content than coal with bright lithotypes and dull band [6] [16] and also coal composition affect the coal gas content [4]. Interestingly those researches were done on the rank of sub-bituminous coal or higher rank coal.

There are only a few researches about the influence of lithotypes on coal gas content done in Indonesia because of its low-rank coal. Therefore, this lithotype analysis were performed to determine lithotype relationship with low-rank coal gas content. The research was conducted on Muaraenim Formation coal in Musi Banyuasin Regency, South Sumatera which is included in South Sumatera Basin. The objectives of this research were: (1) To know the vitrain band content of coal, (2) To know the coal gas content and (3) To know the relationship between lithotypes and coal gas content.

1.2. Research Location

The research located in Musi Banyuasin Regency, South Sumatra. It took about 6 hours driving by car from Sultan Mahmud Badaruddin II Airport to the research location (Figure 1).

Figure 1. Research Location

1.3. Local Geology.

Geological mapping and core analysis were carried out to determine local geology condition. Based on the results of geological mapping and core analysis showed that there are two stratigraphic units in the research area. The oldest unit in this area is Muaraenim Formation (Late Miocene) with Delta Plain depositional environment. Above Muaraenim Formation, there are Alluvium deposits with a continental depositional environment (Figure 2). The Muaraenim Formation is composed of claystone, carbonaceous claystone, siltstone, carbonaceous siltstone, quartz sandstone, and coal, whereas this coal were used for gas content research. The Alluvium deposits contain unconsolidated material. The geologic structure is not well developed in the research area. The geologic structure found in this area is only jointing.

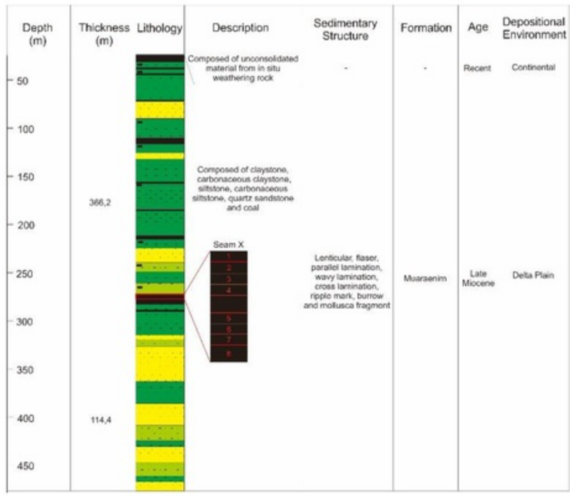


Figure 2. Local Stratigraphy in the research area. Seam X is the studied coal

2. Methode and Materials

2.1. Methods

The method used in this research was by combining field work's analysis and laboratory analysis. Fieldwork was carried out by drilling within 500 m depth to retrieve full coring data. The cores then described through macrolithotype analysis to determine bright band percentage coal. The laboratory analysis was done by doing gas content analysis, vitrinite reflectance analysis, ultimate analysis, and proximate analysis. The purpose of laboratory analysis was to determine coal rank and coal gas content. This result then combined to know the relationship between macrolithotype and gas content of low-rank coal in the research area. The research flow can be seen in Figure 3.

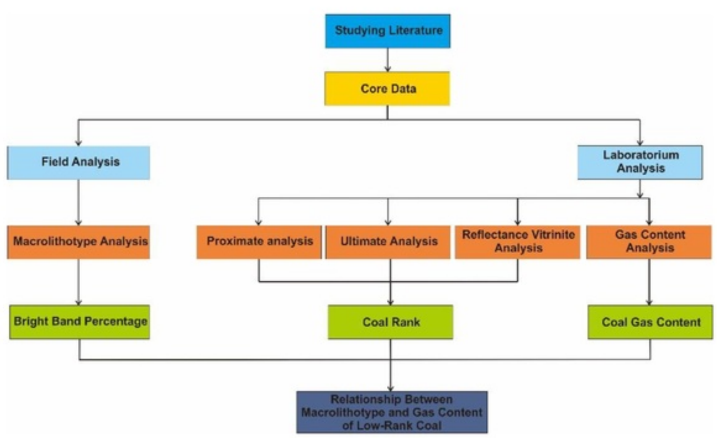


Figure 3. Flowchart

2.1.1. Gas Content Analysis.

Method for gas content analysis using ASTM D.7965-10 method. In general, the desorption procedure uses three measurements: Q1 (lost gas), Q2 (measured gas) and Q3 (Residual gas) [7]. Gas measurements were carried out with a canister with an inner diameter of 7.3 cm and 60 cm long.

Q1 is a gas that disappears when a coal sample exits from subsurface to surface until coal is inserted in a canister. The time required for coal samples to rise from below the surface to be locked in a canister, subsurface temperatures, and coal sample handling must be performed according to standard procedures. Q2 is the gas content calculated when the coal has been locked in the canister. The Q2 calculation measures the coal gas content up to nearly 0 % by inserting the canister in the water and removing the gas into the manometer according to a predetermined time. Q3 is the remaining gas content in coal after calculation of Q2 is done. The calculation of Q3 is only done after the gas content in coal is estimated to be almost 0 %. Coal in the canister is removed, inserted in a vacuum container and crushed to 250 μm in size. The Q3 content is generally very small or may be absent because it only calculates the remaining coal gas estimated at <1 %. Finally, the gas content of the cores is the sum of the lagging gases, the gas absorbed in the canister and the gas loss, as in the following equation:

$$Q_{total} = Q3 + Q2 + Q1$$

Where :

Qtotal = Coal gas content in the formation, scf / ton
Q3 = Gas residual in core, scf / ton
Q2 = Gas released by cores in the canister, scf / ton
Q1 = Gas lost from cores in coring process, scf / ton

2.1.2. Proximate Analysis

Proximate analysis is an analysis which estimates the composition of the overall coal content which includes moisture, ash, volatile matter, fixed carbon, and calorific value. Proximate analysis is presented in percentage units based on the air-dried basis with standard ASTM D.7582-12 method and calorific value analysis by standard method ASTM D.5865-13.

2.1.3. Ultimate Analysis

The Ultimate Analysis is an absolute analysis to determine the constituents of coal in percentages of sulfur, nitrogen, oxygen and carbon and hydrogen elements. This ultimate analysis is done by standard method ASTM D.5373-14, where data analysis result is presented in percentage unit with dry ash free basis.

2.1.4. Vitrinite Reflection Analysis

The vitrinite reflection analysis is related to the temperature and history of coal deposits, which will be related to the maturity level of coal. The method of measuring vitrinite reflection using laboratory procedures is based on ASTM D.2798.

2.1.5. Lithotype Analysis

Lithotype analysis is a macroscopic analysis of the outer texture of coal by observing the luster (bright and dull) and the texture of the outside of the coal. Lithotype analysis using Hower classification et. al. (1990). This analysis measures the percentage of each lithotype on the core every 5 cm interval and then recorded on the description sheet. This analysis aims to identify the initial composition of coal.

2.2. Materials

2.2.1. Core. Core data helps in knowing local stratigraphy of research areas, characteristics, and coal gas content. There are 11 seams of coal up to a depth of ± 300 m, but only qualified coal will be analyzed. The depths used for commercial methane gas production range from 200 to 1000 m [2]. Therefore, lithotype analysis was performed on seam X which has a depth of > 200 m and a thickness of ≥ 0.6 m in the Muaraenim Formation. Based on the core cross-section, the seam X lies at a depth of 261.15 - 271.1 m with a thickness of 9.95 m. However, seam X lithotypes analysis can only be carried out at depths of 261.15 - 266.3 m or 5.15 m from the total thickness of 9.95 m due to the limitation of the canister in the calculation of coal gas content. So the total cores that can be analyzed are only 8 cores (Figure 2).

2.2.2. Previous Research. This stage is a step undertaken to support research that will be conducted through literature reviews, previous research reports, studies of journals and publications related to the local and regional research area.

3. Result

3.1. Proximate Analysis

The moisture content in Seam X has a percentage of about 10.64 - 12.92% with an average of 11.58%, ash has a percentage of about 3.38 - 4.20% with an average of 3.56%, volatile matter have a percentage range from 40.83 - 44.96% with average 43.33%, fixed carbon has a percentage range between 40.13 - 42.84% with average 41.52%, and the calorific values range between 5641 - 5929 Kal/gr with average of 5831 Kal/gr.

3.2. Ultimate Analysis

Carbon content has a percentage between 72.48 - 74.02% or 73.23% on average, hydrogen has a percentage between 4.98 - 5.34% or an average of 5.15%, nitrogen has a percentage of about 1.28 - 1.47% or 1.37% average, sulfur has a percentage of about 0.20 - 0.44% or an average of 0.28%, and oxygen has a percentage of about 19.09 - 20.64% - an average of 19.98%.

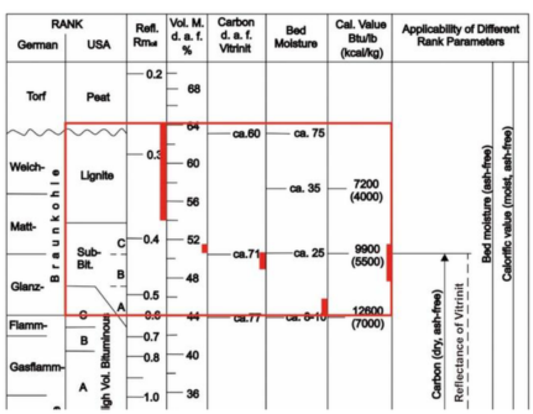
3.3. Vitrinite Reflection Analysis

Based on the results of laboratory analysis, coal in the research area has a percentage of vitrinite reflections range from 0.28 to 0.36% with an average of 0.32%. In general, a high percentage of vitrinite reflections represent a high rank of coal and vice versa.

3.4. Coal Rank Analysis

The determination of the rank of coal in the research area is based on the German and North American (ASTM) scheme [13]. Rank analysis can be known through several parameters, including proximate analysis (moisture content, volatile matter, and calorific value), ultimate analysis (carbon content) and vitrinite reflection analysis. To use this scheme, the parameter basis must be adjusted to the dry ash free basis that used in the coal rating scheme. Based on these parameters, the coal in the research area is included in the rank of lignite – sub-bituminous coal (Table 1).

Table 1. Parameters to determine coal rank of seam "X"



3.5. Lithotype Analysis

Based on the result of coal rank analysis, the coal in the research area can be classified as lignite coal – sub-bituminous rank. The basic lithotype concepts of humic coal with moderate-high rank (bituminous

IOP Conf. Series: Earth and Environmental Science **212** (2018) 012020 doi:10.1088/1755-1315/212/1/012020

and anthracite) are vitrain, clarain, durain, and fusain. The widely used classifications include the classification of Howel et al. (1990) (Figure 4), where this classification can also be used in low-ranking coals.

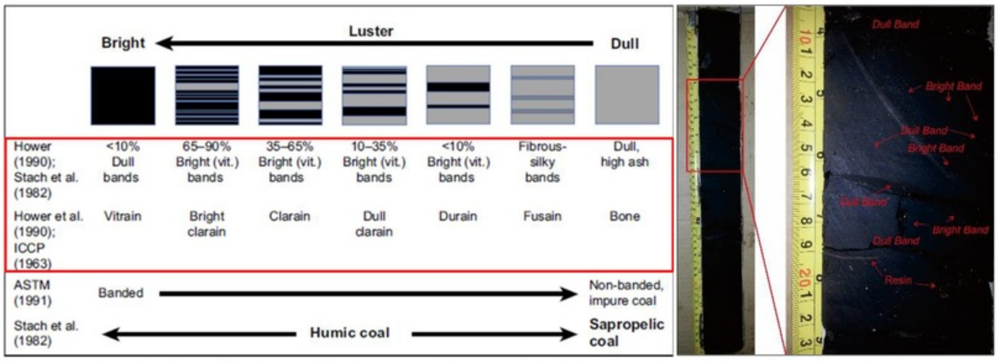


Figure 4. (Left) Classification of lithotypes [4] and (Right) examples of lithotype descriptions on one coal core interval

Lithotype description was done on coal cores stored in a canister with length 45 - 55 cm. The description was done by measuring the percentage of each lithotype on cores with an interval of 5 cm. Then the result was summed to get the bright band and dull ratio value in one body of coal cores (Figure 4). The result of lithotype description in canister number 1 - 8, found that coal core body consists of various kinds of lithotype, that are durain, dull clarain, clarain and bright clarain with the percentage of total bright band ranged between 1-90% (Table 2).

Table 2. Description of coal lithotypes seam "X"

Canister Code	Seam	Depth (m)	*Bright band* (%)	Lithotype (Hower et. al., 1990)
1	X	261,15 – 261,70	5 - 90	Durain - Bright Clarain
2		261,70 – 262,30	3 - 30	Durain - Dull Clarain
3		262,30 – 262,85	2 - 40	Durain - Clarain
4		262,85 – 263,40	5 - 20	Durain - Dull Clarain
5		264,20 – 264,75	2 - 90	Durain - Bright Clarain
6		264,75 – 265,30	5 - 80	Durain - Bright Clarain
7		265,30 – 265,85	5 - 70	Durain - Bright Clarain
8		265,85 – 266,30	1 - 20	Durain - Dull Clarain

3.6. Gas Content Analysis

The coal gas content consists of methane, carbon dioxide, carbon monoxide, nitrogen, and ethane. The amount of gas that can be stored in coal depends on several factors such as pressure, temperature, pyrite content and coal structure. Based on the measurement, the results showed values of Q1 content ranged from 92.8 to 197.96 ml with average 136.12 ml, the result of the value of Q2 content ranged from 637.5 to 960.5 ml with an average of 861.37 ml and the result value of Q3 content is 0 ml. Qtotal content is the total gas content stored in coal. Qtotal can be known by summing Q1, Q2 and Q3 then

IOP Conf. Series: Earth and Environmental Science **212** (2018) 012020 doi:10.1088/1755-1315/212/1/012020

divided by the weight of coal in the canister. Based on the measurement results, it is known that the Qtotal content range from 14.33 - 29.84 scf / ton with an average of 19.57 scf / ton (Table 3).

Table 3. Coal gas content of seam "X"

Canister Code	Seam	Depth (m)	Q1 (ml)	Q2 (ml)	Q3 (ml)	Qtotal (ml)	Qtotal (scf/ton)
1	X	261,15 – 261,70	147,5	897,5	0	1045	20,50
2		261,70 – 262,30	137,2	960,5	0	1097,7	21,54
3		262,30 – 262,85	121,21	857	0	978,21	19,19
4		262,85 – 263,40	197,96	952,5	0	1150,46	22,57
5		264,20 – 264,75	106,18	938,5	0	1044,68	20,50
6		264,75 – 265,30	184,8	785	0	969,8	19,03
7		265,30 – 265,85	101,3	862,5	0	963,8	18,91
8		265,85 – 266,30	92,8	637,5	0	730,3	14,33

3.7. *Relation of Lithotype and Low rank coal gas content*

Lithotype analysis showed that the coal in the research area can be classified as durain–dull clarain with clarain and bright clarain found locally on the body of coal cores. The bright band content varied from 1 - 90% in one body of coal cores, but in general the dull band content is more dominant than the bright band content. The result of gas content analysis showed that the total gas content of coal in research area range between 14.33 - 29.84 scf/ton with average 19.57 scf /ton. The coal gas content varied considerably even within the same seam

Table 4. Bright band and coal gas content of seam "X"

Canister Code	Seam	Depth (m)	*% Bright band*	Qtotal (Scf/ton)
1	X	261,15 – 261,70	5 - 90	20,50
2		261,70 – 262,30	3 - 30	21,54
3		262,30 – 262,85	2 - 40	19,19
4		262,85 – 263,40	5 - 20	22,57
5		264,20 – 264,75	2 - 90	20,50
6		264,75 – 265,30	5 - 80	19,03
7		265,30 – 265,85	5 - 70	18,91
8		265,85 – 266,30	1 - 20	14,33

To find out the relationship between the bright band and coal gas content, it is necessary to create a graphic of bright band vs depth and also graphic of gas content vs depth. These graphics show that bright bands and coal gas content will decrease as the increasing in depth. The graph of bright band relationship and coal gas content is shown in Figure 5.

IOP Conf. Series: Earth and Environmental Science **212** (2018) 012020 doi:10.1088/1755-1315/212/1/012020

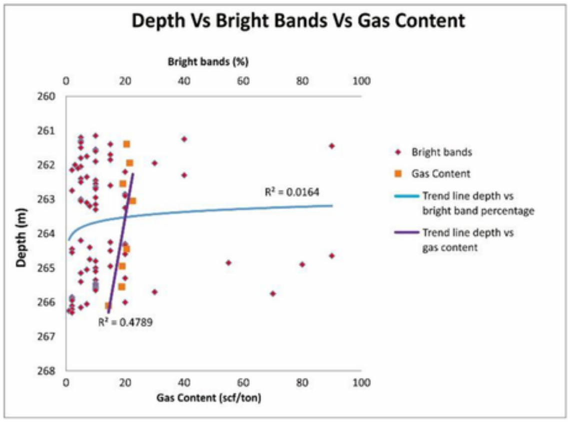


Figure 5. Depth vs bright band vs gas content graphic of Seam X Coal

4. Discussion

4.1. Lithotype

Based on the result of lithotype analysis of coal seam X, there is a significant difference between bright band and dull band in one body of coal cores, as shown in Table 2. The description of coal lithotypes on seam X shows that the percentage of bright bands ranges from 1 - 90% or included in the classification of durain - bright clarain. Previous research has shown that the bright band content will increase as the increasement of depths due to physical and chemical processes that change the elements of coal's constituent material [4]. The depth vs bright band graphic shows that there is a tendency of negative trend line between bright band content with coal sample depth, where the bright band content decreases with increasing of coal depth and trend line value (R2) equal to 0, 0164 (Figure 5). The difference between the author's research with previous research was probably due to the number and location of the coal sample. Other factors might be insignificant physical and chemical processes that made the organic elements of coal has only slight change and a slight degradation in the coalification process which commonly occurs in low-rank coal. These factors affect the absence of positive trend line on the bright band vs depth graphic.

4.2. Coal Gas Content

Based on the results of the gas content analysis, it can be seen that the gas content in coals is quite varied even within interval 50 cm depth. The difference in coal gas content distribution values is caused by several factors such as temperature, pressure, moisture content, vegetation type, the degree of decomposition of organic materials and minerals [4]. However, in general, the gas content will tend to increase as the depth increases due to the influence of temperature and pressure [4] [16]. The graphic of depth vs gas content indicates that there is a tendency of negative trend line along with the increase in depth of coal samples (Figure 5). The difference of the author's research with the previous research can be caused by how much controlling factor of coal formation or technical factor such as the limitation of the tool to calculate the gas content and the depth of coal gas extraction which is considered still near the surface so that the gas content might have loss to the surface.

4.3. Relation Between Lithotype and Low-Rank Coal Gas Content

Researches on the effect of lithotypes on gas content have been done by many researchers [7] [9] [17]. All of these studies were conducted on medium to high-rank coal (sub-bituminous - anthracite) and the results showed a harmonious relationship between the bright band content and the gas content, whereas the more bright band content the more coal gas content would be.

The harmonious relationship between the bright band content and the gas content is due to the microscopic porosity of coal constituents (maseral vitrinite, liptinite, and inertinite) [4]. Based on the relationship between porosity and lithotypes, bright coal with vitrinite rich is more porous than dull coal, therefore bright coal (vitrinite rich lithotypes) has a higher adsorption capacity than dull ones (rich inertinite or fusain lithotypes). Another related point is the rate of gas desorption. Coal with rich bright vitrain tape has the slowest desorption rate, which is directly related to the high number of micropores and the unallocated mineral breaking system.

Based on the explanations above, the trend line between the two coal parameters should have a harmonious relationship but the results of this study showed the opposite. Although both bright band and gas content value decrease along with the increase of coal depth, but the trend line value is very poor (0.0164 or < 0.3). This small trend line value means that the number of data variables does not have a fitting comparison so the trend line value is bad and can not describe the relationship between variables. This suggests that with this data, it remains unclear whether the lithotype / bright band has a relationship that is aligned with the low-rank coal gas content even though it should be.

Furthermore, research on the effect of low-rank coal lithotypes and gas content should include the content of organic coal materials as strong supporting data to determine the correlation between lithotypes and low-rank coal gas content.

5. Conclusions

Based on the discussions above, it can be concluded several points as below :

- Muaraenim Formation coal in Musi Banyuasin area was considered as low-rank coal. The parameters used to determine this are proximate analysis (moisture content, volatile matter, and calorific value), ultimate analysis (carbon content) and vitrinite reflection analysis using the Stach scheme (1982).
- Coal lithotypes in canister numbers 1 - 8, showing variations of lithotypes, namely durain, dull clarain, clarain and bright clarain with a total percentage of bright bands ranged from 1-90%.
- Qtotal can be determined by summing Q1, Q2 and Q3 then divided by the weight of coal in the canister. Based on the measurement results, it is known that the Qtotal content ranged from 14.33 - 29.84 scf/ton with an average of 19.57 scf/ton.
- There was no relationship between lithotypes and low-rank coal gas content. Although both bright band and gas content value decrease along with the increase of coal depth, the trend line value is very poor ($R^2 = 0.0164$ or < 0.3).

Acknowledgment

The authors would like to appreciate and be thankful to the PSDMBP Bandung and UPN "Veteran" Yogyakarta for the implementation of this research. We would also like to thank the ICEMINE committee for supporting and publishing this research. We also thank to all members of CBM PSDMBP team in the field and laboratory and Mrs. Rita Susilawati as well as Mr.Untung Triyono for their ideas and motivation. Finally, the authors would like to thank all of the previous researchers for their precious references.

References

[1] Butland C I and Moore T A 2008 Secondary biogenic coal seam gas reservoirs in New Zealand: A preliminary assessment of gas controls *Int. J. of Coal Geology* **76** 151–165
[2] Barker G J 2008 Application of the PRMS to coal seam gas *Proc. SPE Asia Pacific Oil & Gas Conf. and Exh.* (Perth : Society of Petroleum Engineers Inc) p 13
[3] Diessel C F K 1992 *Coal-Bearing Depositional Systems* (Berlin : Springer-Verlag) p 721
[4] Flores R M 2014 *Coal and Coalbed Gas : Fueling The Future* (USA : Elsevier) p 705
[5] Hower J C Esterle J S Wild G D and Pollock J D 1990 Perspectives on coal lithotype analysis *J. of Coal Quality* **9** 48-52
[6] Ilyas S Ibrahim D and Fatimah 2000 *Pengkajian endapan batubara di dalam cekungan sumatra*

selatan, daerah sekayu, kabupaten musi banyuasin, propinsi sumatera selatan (Jakarta : DSM Report) p 10
[7] Mares T E and Moore T A 2008 The influence of macroscopic texture on biogenically-derived coalbed methane, Huntly coalfield , New Zealand *Int. J. of Coal Geology* **76** 175-185
[8] Moore T A 2012 Coalbed methane : a review *Int. J.of Coal Geology* **101** 36 – 81
[9] Moore T A Flores R M Stanton RW and Stricker G D 2001 The role of macroscopic texture in determining coal bed methane variability in the anderson-wyodak coal seam, powder river basin, Wyoming *Proc. 18th Annual Meeting of the Soc. of Org. Petro*ed C R Robinson (Houston : The Society of Organic Petrology) pp 85-88
[10] Ruiz I S and Filho J G M 2017 *Geology : Current and Future Developments : The Role of Organic Petrology in the Exploration of Conventional and Unconventional Hydrocarbon Systems* (UAE : Bentham Science Publishers) p 371
[11] Shell 1978 *Explanatory notes to the geological map of the South Sumatra coal Province* (Jakarta, DSM Report) p 18
[12] Speight J G 2015 *Handbook of Coal Analysis* vol 2 ed M F Vitha Second Edition (New Jersey : John Wiley & Sons) p 367
[13] Stach E M Mackowsky T M Teichmuller G H Taylor D Chandra R Teichmuller G Bwnfraeger and Sfuftgarf 1982 *Stach's Textbook of Coal Petrology* (Berlin : Gebruder borntraeger) p 535
[14] Stevens S H and Hadiyanto 2004 Indonesia : coalbed methane indicators and basin evaluation *Proc. SPE Asia Pacific Oil and Gas Conf. and Exh.* (Perth : Society of Petroleum Engineers Inc) p 8
[15] Taylor G H Teichmüller M Davis A Diessel C F K Littke R Robert P 1998 *Organic Petrology* (Berlin : Gebrüder Borntraeger) p 704
[16] Thomas L 2013 *Coal Geology* (United Kingdom : Wiley –Blackwell) p 456
[17] Trippi M H Stricker G D Flores R M Stanton R W Chiehowsky L A and Moore T A 2010 *Megascopic lithologic studies of coals in the Powder River basin in Wyoming and in adjacent basins in Wyoming and North Dakota* (Colorado : U.S. Geological Survey Open-File Report 2010–1114) p 17

Macrolithotype and gas content of shallow low-rank coal of Muaraenim Formation at Musi Banyuasin, South Sumatera Basin

ORIGINALITY REPORT

6%	%	6%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	B Rahmad, S Raharjo, Ediyanto, E W Pramudiohadi. "Coal porosity and coal microscopic characteristic for coalbed methane (CBM) analysis of the Warukin Formation in Barito Basin, Idamanggala, Hulu Sungai Selatan, South Kalimantan", IOP Conference Series: Earth and Environmental Science, 2018 Publication	6%

Exclude quotes	On	Exclude matches	< 2%
Exclude bibliography	On		