Coal porosity and coal microscopic characteristic for coalbed methane (CBM) analysis of the Warukin Formation in Barito Basin, Idamanggala, Hulu Sungai Selatan, South Kalimantan

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Coal porosity and coal microscopic characteristic for coalbed methane (CBM) analysis of the Warukin Formation in Barito Basin, Idamanggala, Hulu Sungai Selatan, South Kalimantan

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Abstract. Research Characteristics of petrology and porosity Coal Formation Warukin, Barito Basin aims to determine the relationship with the permeability of coal coal seam B 11 and A 10. Sampling was conducted at PT Antang Gunung Meratus in Central Warukin Formation coal in seam 11 and 10 by channel sampling. Maceral analysis, vitrinite reflectance and porosity were performed on the above samples. The problem in this research is how the relationship with coal porosity in Warukin Formation low rank to coal methane gas reservoir. Based on the characteristics of the porosity in the coal seam B 11 upper and B 11 lower have a porosity range of 2. 35 to 2.71% while the permeability has a value of 170. 9 – 281.94 mDarcy and on seam coal A 10 upper, A 10 middle, and A 10 lower have porosity 3.05 - 3.99% , permeability of 224.9 – 282.55 mDarcy. Maceral composition consists of vitrinite (desmocolonite and telocolinite) 54.6% - 85%, liptinite (suberinite) 1% - 3%, and inertinite (semifusinite and sclerotinite) 3% - 26.4%. Reflectant virtinite (RV) of the five samples 0.29 - 0.35. The strong relationship between the magnitude of porosity and the presence of vitrinite, semifusinte has a strong positive relationship where the greater the value of semifusinite will increase the value of porosity and permiability. Liptinit has a weak and negative relationship. The presence of semifusinite will increase the value of porosity and permeability, this is because the fusinite has pores larger than the other maceral.

Keywords: porosity, maceral, vitrinite, inertinite, liptinite

1. Introduction

Coalbed methane (CBM) is a form of natural gas (hydrocarbon) with methane gas as its main component. This methane gas is formed naturally in the formation of coal. This gas is trapped and adsorbed into coals in the form of cleat and matrix, so that the pores' structure, depth, maceral composition, and coal rank are some important factors in the development of coalbed methane gas field [1]. Methane gas is not the only gas contained in coals, but this gas can provide 90-95% of the total gas contained in coals. Different kinds of coals have different levels of absorbency [2]. The success of coalbed methane is very dependent to the gas flow rate, the gas price, and economy of the

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gas [3]. Gas flow rate is reliant on porosity and permeability. This gas is expected to be an alternative energy in Indonesia that needs to be developed.

There are two kinds of porosity in coalbeds, porosity that's located in cleats and matrix. Pores classification is classified into micropores (pores that have diameter less than 2 nm), mesopores (diameter of 2-50 nm), and macropores (diameter bigger than 50 nm) follows International Union of Pure and Applied Chemistry [4]. Pores in a matrix have various structures that are not even and irregular surface. Porosity is affected by the composition and characteristics of maceral and chemical structure in coalbed [5], other than that porosity is also affected by the rank of coal [1]. According to the size of pores in matrix, there are two kinds that are macropores and micropores, macropores are found in low-grade coals while micropores are found in high-grade coals [1].

Coal maceral have an influence on pore's surface area and volume. Coal with vitrainous lithotypes composed by vitrinite and inertinite macerals have micro pores, while coal with fusing lithotypes have mesopores [1]. According to Liwen G et al., 2012 when coal has a vitrinite percentage of less than 82% of pores that develop mesopore size composed by inertinite, the micropores are composed by vitrinite. If the vitrinite percentage is more than 82%, mesopore in vitrinite and micropore dominance is arranged inertinite.

This research is to know the relationship between porosity with maceral in lignite coal Formation of Warukin in Idamanggala area, Sungai Raya, Sungai Selatan District, South Kalimantan Province.

1.1 Location of Research

The research area is located at PT Antang Gunung Meratus in Idamanggala, Sungai Raya, Hulu Sungai Selatan-South Kalimantan Barito Basin, which is one of the Tertiary Basins in South Kalimantan (Figure 1).

Figure 1. The location of research area is to element tectonics of Barito Basin

1.2. Sampling

Sampling is done in the open mine of PT Antang Gunung Meratus approximately 10 km north of Tapin city. In this open pit, there are 20 layers of coal contained in the Central Warukin Formation. Sampling was conducted by ply-by-ply based and channel sampling on lithotypes along the outcrop of

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mineout wall. The samples were wrapped in aluminium foil, stored in plastic bags and transported to the laboratory.

Samples were taken at the top and bottom for 11 layers of coal and the coal layer 10 at the top, middle, and bottom. Sampling method with channel sampling method from coal seam 11 and coal layer 10.

The total thickness of each of the coal seams is the top 11 coal layer having a thickness of 6 meters, the bottom 11 coal layer has a thickness of 15 meters, and the coal layer 10 with a thickness of 40 meters with thin parting found with a thickness of 5-10 cm. (Figure 2) The physical properties of coal have a dull glow.

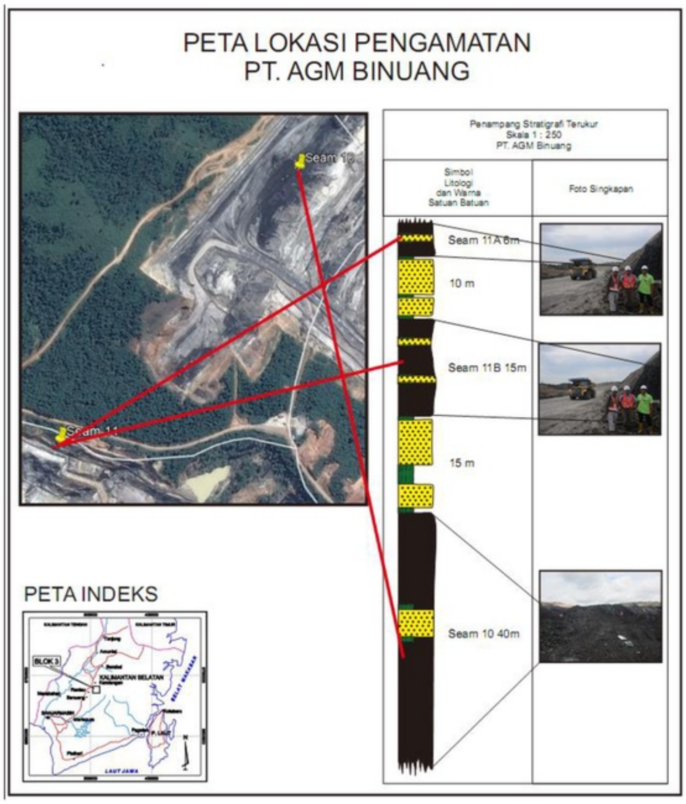

Figure 2. Seam Profile 10 and 11.

2. Methodology

There are 5 (five) coal samples from the Warukin Formation coal in Sungai Raya district, South Kalimantan. Sampling is done by channel sampling method. Samples were taken in seam B 11 and A 10, seam B 11 consisting of top and bottom seam. Seam A 10 samples are taken at the bottom, middle and top.

Porosity measurement is done by cutting the coal sample into beam shape with size 2 cm and length 2,5 cm. Next, place the dry sample into the vacuum desiccator to be expressed for 1 hour and then saturated with kerosene, then the weighing process is done.

The coal samples were then crushed to a maximum size of 1 mm and placed in resin blocks. The sample blocks were polished with a specified polisher. Microscopic investigation was carried out with

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a Carl-Zeiss Axio Imager.A2m reflected-light microscope. During maceral analysis, 500 points with a minimum distance of 0.2 mm between each point were counted from the polished sections. The maceral composition is stated as percent (% volume). Maceral classification used in this study refers to Australian Standard AS2856 (1986).

The work of maceral analysis in the laboratory includes:

Microscopic analysis of coal to identify the composition of maceral, mineral and vitrinite reflectant values. Conto coal taken by drill core and then prepared for polishing incision. In the sample preparation required some tools and materials such as:

Coal samples
1. Resin powder (transoptic powder)
2. Crusher
3. Size size 16, 20, and 65 mesh
4. Mold polished briquette, heater, thermometer, and press
5. Polishing tools (grinder-polisher)
6. Silicon carbide size 800 and 1000 mesh and alumina oxide size 0.3; 0.05; and 0.01 microns
7. Glass preparations and candles.

The coal sample obtained from the outcrop is reduced by coning and quartering to obtain the appropriate number of samples for analysis needs. Furthermore, the coal samples were crushed manually and sieved by using a mesh size of 16 mesh and 20 mesh, the grain size of 16-mesh coal +16 mesh obtained was used for coal petrography analysis.

Coal fraction size -16 mesh +20 mesh is then mixed with resin powder (transoptic powder) with a ratio of 1: 1. The mixture is further inserted into the mold and heated to 200 ° C. After the temperature reaches 200°C the heater is turned off and the mold is pressurized to 2000 psi. Briquette can be removed after the temperature reaches room temperature. The next stage is briquette polishing that begins with cutting using a polishing tool (grinder-polisher) then smoothed with silicon carbide size 800 mesh and 1000 mesh above the glass surface. Further, it polished by using alumina oxide size 0.3 micron, 0.05 micron, and last size 0.01 micron above silk cloth or silk cloth. The resulting polishing incision is placed on a glass plate with an evening candlestick and then leveled.

Observation of polished incision is done by using reflectant microscope both qualitatively and quantitatively to determine the mineral and mineral's content in coal.

Microscopic research using reflected rays with 200 times magnification with 500 points of observation.

The analysis process was conducted at Petrography Coal Laboratory, Puslitbang TEKMIRA, Bandung. Coal Minerals Classification uses Australian standard (US 2856, 1986) and the microscope used is Microscope Spectrophotometer Polarization with Fluorescence, type: MPM 100, brand: Zeiss.

3. Results

Based on the results of porosity measurements, permeability, specific gravity, vitrinite reflectance, and composition can be seen in table 1.

Table 1. Experimental data of coal petrography and porosity.

No.	Seam	RV	Volume % of coals			% min	Density	Porosity	Permeability	
			Vitrinite %	Inertinite %	Liptinite %		(gr/cc)	(%)	Darcy	mD
1	B11 (Top)	0.29	76	14	3	12.4	1.18	2.35	0.171	170.971
2	B11 (Bottom)	0.32	85	3	1.6	9	1.2	2.71	0.251	251.942
3	A10 (Top)	0.34	73.4	13.6	2	11	1.13	3.05	0.285	282.557
4	A10 (Body)	0.35	64.8	25.8	0	10	1.17	3.83	0.249	249.642
5	A10 (Bottom)	0.36	59.6	26.4	1	13	1.2	3.99	0.224	224.985

Based on vitrinite reflectance (R_V) showed coal in the study area including lignite coal with high vitrinite maceral content, then inertinite, liptinite and low mineral. Although liptinite and mineral deposits have a porosity but very small pedestal. Vitrinite (R_V) reflux strongly influences porosity change, while vitrinite and inertinite have a considerable effect on porosity. In vitrinite consists of submaceral detrovitrinite and telovitrinite, The result of coal microscopic analysis of Warukin Formation, Idamanggala Region, all samples were taken from coal outcrop data on the wall of coal mine [6]. Average percentage of group-maceral vitrinite Warukin formation 78%, average Rv (random) = 0.45% (rank: sub-bituminus). The formation of Methane Gas from Warukin Formation, Idamanggala, South Kalimantan is still in the Biogenic Gas Stage, meaning that the gas is the result of bacterial activity in CO_2, where methanolens metabolism uses H_2 and CO_2 to convert acetate to methane (CH_4) . Maceral vitrinite of the Warukin formation is divided into the Vitrinite, Liptinite and Inertinite maceral groups (Table 2); (Figure 3).

Table 2. Results of Microscopic Analysis (Maceral) Idamanggala Coal [6]

No. Sampel	Total Vitrinite (% vol)	Total Liptinite (% vol)	Total Inertinite (% vol)	Total Mineral Matter (% vol)	Reflektan Vitrinite (Rv) %
1	74,0	1,2	22,8	2,0	0,34
2	74,8	7,6	16,2	1,4	0,58
3	73,0	9,4	16,2	1,4	0,45
4	80,2	1,6	15,8	2,4	0,56

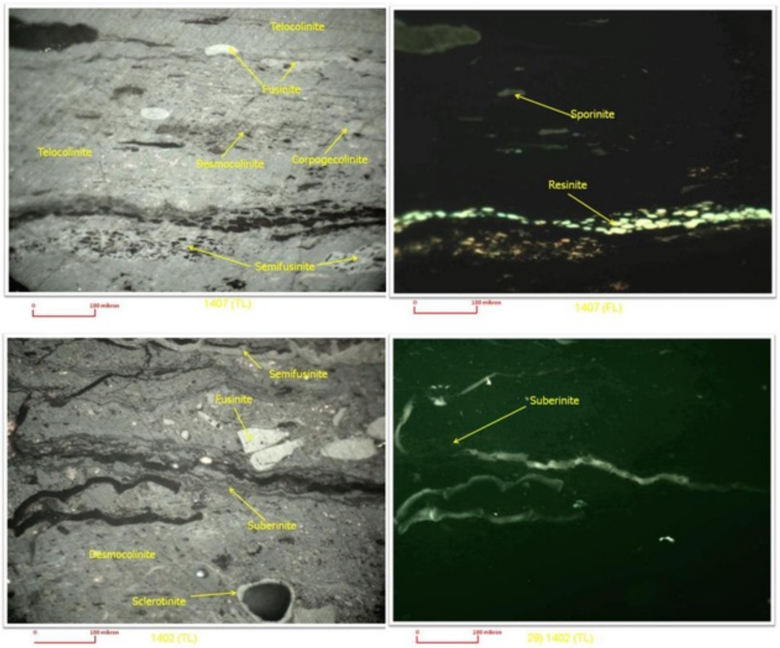

Figure 3. The Microscopic Appearance of Idamanggala Coal, South Kalimantan (Basuki Rahmad, et al., 2017)

The vitrinite maceral group consists of subgroups:

a. Telovitrinite for Warungin Formation of Idamanggala Region. Maceral Telovitrinite consists of telocolinite. Telocolinite under a microscope shows gray to dark gray, forming bright layers.

b. Detrovitrinite (Warukin Formation), consisting of maceral densinite and desmocolinite. Desmocolinite in the form of fragments that are besieged in inertinite, liptinite or can in other mineral materials.

Maceral densinite is the result of gelinalization of maceral attrinite with a low level of gelification. The detrovitrinite maceral group is a component formed by the detrital (detrital) of the vitrinite maceral (Stach, 1982).

Maceral detrovitrinite can serve as a gas storage which the component formed from fragments (detrital) from maceral vitrinite derived from shrubs or from woody plants with high bacterial activity. Shrub plants easily decomposed during the humification stage so that it will form a detrital component. High bacterial activity will be able to change wood plant cells to detrital maceral. This detrital component has more cell fragments and large porosity so that the absorbed gas in the internal maceral coal will increase as the percentage of maceral comes from this shrub [8].

Gelovitrinite for Warukin Formation, consisting of maceral corpogelinite. Microscopically maceral corpogelinite appears to be homogeneous, round to oval, usually often isolated in desmocolinite.

Coal as a representation of plant type components from coal-forming determines the characteristics of coal, especially the quality of coal. The composition of coal microscopy in particular coal coal component indicates the basic material of coal constituents. Each coal coal group has different physical properties and chemical composition (Figure 3). Vitrinite is the result of the process of dissolving humic material derived from cellulose ($C_6H_{10}O_5$) and lignin plant cell walls containing wood fibers such as stems, roots, leaves, and roots. The vitrinite mineral group is largely derived from the humic acid fraction of the humic core, a dark-colored compound of a complex composition. The compound contains elements of carbon, oxygen, hydrogen and nitrogen. Vitrinite has a variety of heavy and soluble molecules, has an aromatic nucleus and contains functional groups of hydroxyl (-

OH) and carboxyl (-COOH). These compounds are formed during peatification and mouldering, even partially within the brown coal stage, especially from plant cell walls in the form of lignin and cellulose. In addition to the original material, the formation and characteristics of humic acid are dependent on the environmental conditions associated with redox potential values (eH) and pH.

The basic nucleus of plants is more easily hydrolyzed, such as disaccharides, starch, cellulose, hemicellulose, pentosanes, pectins and decomposed proteins without any difficulty by bacteria and fungi, partially producing Methane (CH_4) and solution (carbon dioxide, ammonia, methane (CH_4) and water), which will come out and remain to produce solid material (especially humic substances), which participate in the formation of coal. Relatively stable lignin structures are better preserved and concentrated in peat than with lignin-rich woody remains, examples are cellulose-rich tissue in herbaceous plants. Physical properties of the maceral group, such as vitrinite which has an average gravity of 1.27 and high oxygen content and a volatile matter content of about 42.74% can produce methane gas (CH_4) or prone gas. The relatively high vitrinite content of Warukin coal is included in kerogen type III as the characteristic of humic organic matter derived from high-grade plant tissue (angiosperm). The vitrinite is a high methane gas forming metall (gas prone).

The average percentage of Liptinite-class group for Warungin Formation of Idamanggala Region is 4.95%, consisting of macerals: sporinite, resinite, cutinite, alginite and suberinite. The liptinite group comes from plant organs (algae, spore, spore box, outer skin (cuticle), plant resin and pollen). The liptinite group is rich in aliphatic bonds and has the greatest hydrogen content and the least carbon content when compared to other maceral groups (Figure 4). Liptinite has a density of 1.0 - 1.3 and the highest hydrogen content compared to other minerals, while the volatile matter content is about 66%. Liptinite will produce oil (oil prone).

The mean percentage of inertinite maceral groups for Warungin Formation of Idamanggala Region is 17.75%, consisting of subgroup-maceral: fusinite, semifusinite, sclerotinite and inertodetrinite. The inertinite maceral group is a relatively carbon rich (C) protein, with the highest reflectivity and low flouresense, has strong aromatics due to several causes: charring and plant fiber oxidation. So inertinite is an oxidized component due to the reduced moisture of peat. Inertinite groups are thought to originate from burnt plants (charcoal) and some are thought to be due to oxidation of other meteral or decarboxylation processes caused by fungi or bacteria (biochemical processes). In the presence of such process the inertinite group has relatively high oxygen content, low hydrogen content, and O / C ratio higher than in vitrinite and liptinite groups.

Inertinite is derived from the word "inert" containing non-reactive principal elements and contributes to the blending of coking coal such as maceral fusinite, semifusinite and sclerotinite. Inertinite is derived from cellulose and lignin from plant cell walls. The essential elements undergo fusinitization during the cultivation [7]. The characteristic of inertinite is high reflectivity, little or no fluoresense, high carbon content and little hydrogen content, arrogantly strong for several causes, such as charring, molding and destruction by fungi, biochemical gelation and plant fiber oxidation. In inertinite consist of submaceral sclelerotinite and semifusinite (Figure 3).

3.1 . The Relationship of Maceral and Porosity

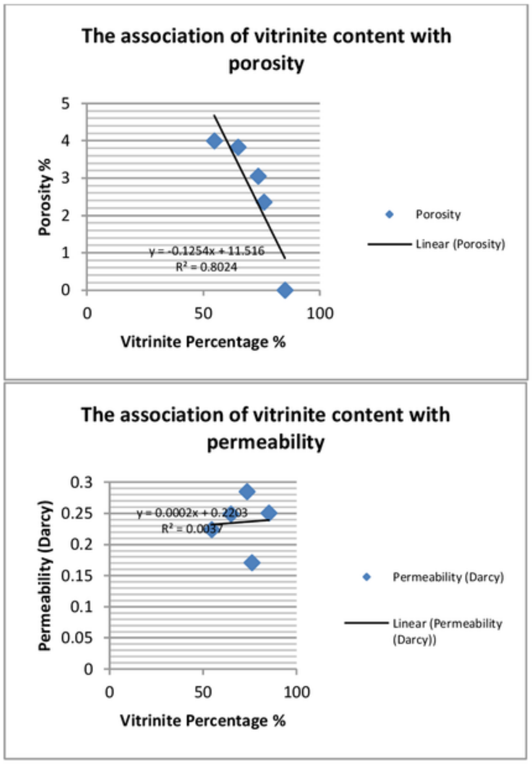

Figure 4. The relationship between vitrinite content with porosity and permeability

The results of the relationship between maceral and lignite rank coal porosity are shown in Figs. 4 and 5. In Fig. 4 it shows clearly that there is a close relationship between vitrinite and porosity, the higher the vitrinite content will increase porosity. The correlation rate between vitrinite and porosity of 64% shows the porosity of lignite rank coal in the fracture porosity of vitrinite maceral. The linkage between vitrinite content and permeability showed no relationship, because r2 = 0.0037.

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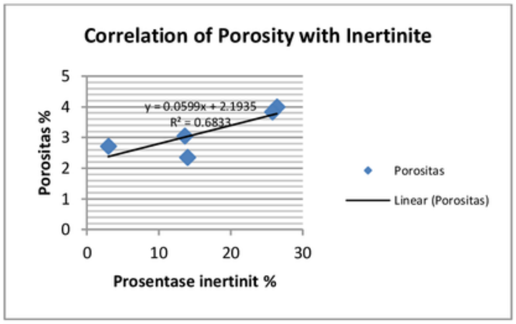

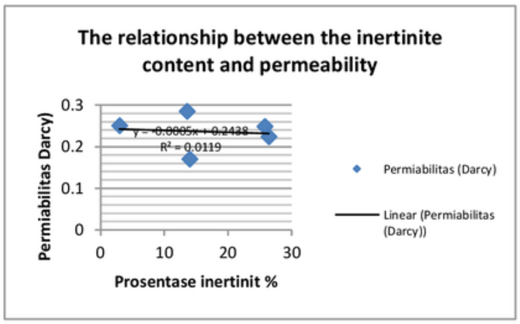

Figure 5. The relationship between inertinite content with porosity and permeability

Figure 5 shows a relationship between the inertinite content and this porosity is shown by the correlation value (r2) = 0.6833. The amount of inertinite content will increase porosity, while the relationship between inertinite and permiablity has no relationship.

3.2. The relationship between submaceral and porosity

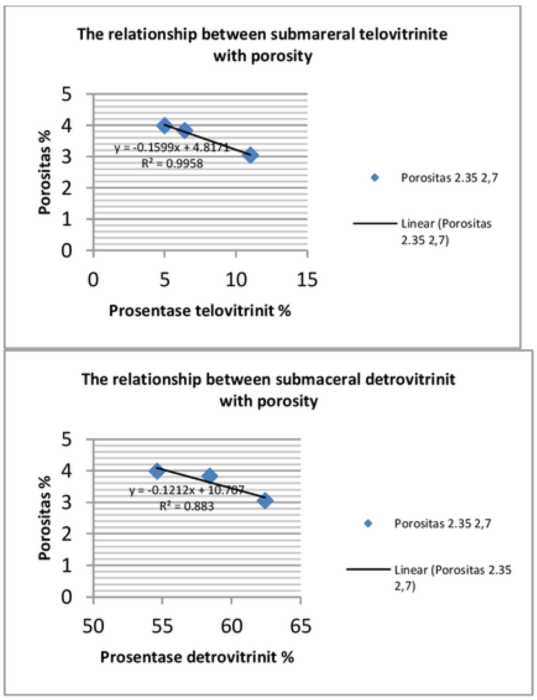

Figure 6. The relationship between submaceral vitrinite and porosity

Submaceral vitrinite that presents in the study area consisted of telovitrinite and detrovitrinite, in our study making the relationship between submaceral vitrinite and porosity can be seen in figure 3. In Figure 6 above shows that the negative correlation between telovitrinite with porosity with coefficient coefficient value of 0.999, that the greater the percentage of telovitrinite the smaller the porosity value. The relationship between detrovitrinite and porosity shows a negative correlation with the correlation coefficient value of 0.883, it also shows the greater the percentage of detrovitrinit will be smaller porosity.

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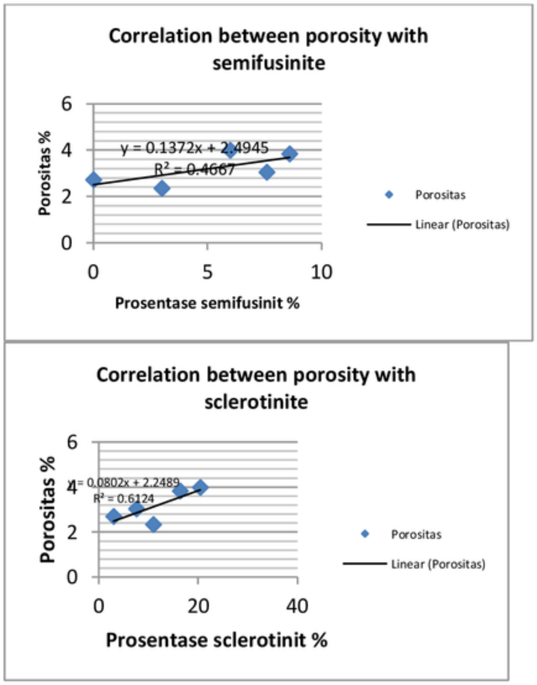

Figure 7. Relationship between inertinite submaceral and porosity

Inertinite submaceral in the study area consisted of fusinite and sclerotinite, in our study made the relationship between suberteral inertinite and porosity can be seen in figure 7. In Figure 7 above shows that the positive correlation between semifusinite with porosity with coefficient correlation of 0.4667, large percentage of semifusinite will have greater porosity value. The relationship between sclerotinite and porosity shows a positive correlation with the correlation coefficient value 0.6124, it also shows that the greater percentage of sclerotinite will have greater porosity.

3.3. The relationship between vitrinite reflectance (RV) with porosity

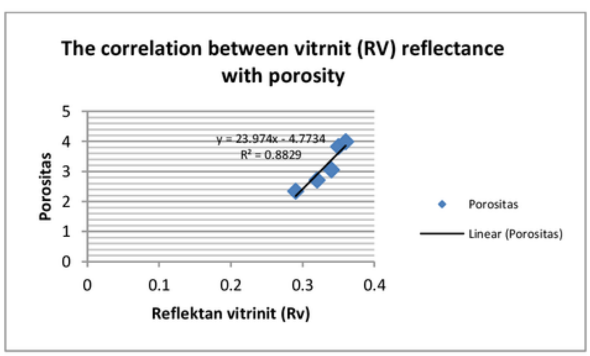

Figure 8. Relationship between vitrinite Reflectant with porosity

Reflectant vitrinite (RV) in the study area has a relationship with porosity can be seen in figure 8. In the picture 8 above shows that there is a positive correlation between vitrinite reflectance with porosity with correlation coefficient value of 0.882, this shows that the greater percentage of vitrinite reflectant will have greater porosity value.

4. Discussion

Maceral changes in coal affect porosity changes in coal as reservoir rocks [1], upper seam (seam 11) and bottom (seam 10) changes in percentage of mass volume, this results in a change in porosity. The influential maceral content of vitrinite and inertinite [9], vitrinite submaceral include telovitrinite and detrovitrinite, while inertinite submaceral is semifusinite and sclerotinite. Detrovitrinite is characterized by the destruction of plant tissue. In brown coal, the detrovitrinite subgroup forms tiny granules of 0.02mm, telovitrinite is a component that still has a good cellular network structure. Semifusinite that are round, oval, or elongated sometimes filled with clay minerals, carbonate or pyrite, oval or circular sclerotinite, has high reflectivity [7].

The change in percentage content of submaceral vitrinite from the young layer (seam 11) to the older layer (seam 10) shows a negative correlation relationship. The magnitude of the relationship between submaceral telovitrinite with porosity of 81% and submaceral detrovitrinite with porosity 65%. The change in the percentage of vitrinite volume from the top to the bottom shows changes in the volume of the micro pores and surface area greater than the inertinite [10]. Research Teng, 2017 shows that the greater the percentage of vitrinite content that develops are micro pores and meso pores [11]. The relationship between porosity with inertinite submaceral has a positive correlation, for the semifusinite submaceral the correlation value is 17% while the sclerotinite correlation value is 36%. This indicates that the micro pores and mesopores are not much in the coal which that contains a lot of inertinite.

Porosity in coal with a lot of inertinite content of pores will be greater than coal rich in vitrinite content. The increasing presence of inertinite submacerals from the coal seam to the old coal causes an increasing amount of pore volume which will increase the percentage of coal porosity. The micro-pore and meso pore changes from the young coal layer to the old coal seams result in the pore size changing. The upper coal layer has a smaller pore size compared to the older or deeper coatings.

The reflectance value of vitrinite (Rv) has a positive correlation with porosity, the higher the Rv the higher the porosity value. Rv value has a negative correlation with percentage of vitrinite volume but positive correlation with percentage of inertinite volume. This indicates that the larger Rv sub-inertinite subtotal is also getting bigger which means the amount of pore micro volume and meso pore will be greater.

The percentage value of vitrinite content of less than 82% mesoporous especially inertinite and micropore is present in vitrinite [5], of the five existing coal samples generally having vitrinite content of less than 82% means that the developing is mesoporous and slightly micro pore.

5. Conclusion

Trough this research, we conclude that the percentage of vitrinite volume from the young to the old shows changes in the volume of the micro pores and surface area greater than the inertinite. The pores that develop in the young coal are the fracture pores.

Porosity in coal with a lot of inertinite content of pores will be greater than coal rich in vitrinite content so it is excellent coal reservoir to produce coal bed methane.

The reflectance value of vitrinite (Rv) has a positive correlation with porosity, the higher the Rv the higher the porosity value so the higher the value of the vitrinite reflectant the more coal reservoir will be gas.

6. Acknowledgments

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