Characterization And Reconstruction Of Deposit Facies Of Mallawa Coal Formation Of South Sulawesi Based On Proximate And Petrography Analysis

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Abstract. This study has purpose to analysis the characteristic of Mallawa coal Formation, reconstruct facies deposit, and determine the rank of Mallawa coal Formation based on maseral content and reflectance of vitrinite.The data were collected from the field survey and were analysed by means of proximate measure and petrography analysis in the laboratory. The proximate analysis reveals that Doi-Doi and Massenrengpulu coals have higher calorie values (4900.47 kal/gram-6700.75kal/gram) but also possessing higher sulfur content (0.9%-4.63%). The petrography analysis of both areas indicates uniform contents of maceral consisting of vitrinite (57.4%-83.2%), inertinite (2.8%-17.8%), and liptinite (0.8%-3.0%). In addition, there are also other minerals such us pyrite (3.8%-15.4%) and clay (3.8%-18.4%). Reflectance value of Doi-Doi coal vitrinite is 0.31%-0.44% (peat sub bituminous C), and reflectance value of Massenrengpulu coal vitrinite is 0.38%-0.56% (lignite sub-bituminous B). Plotting result of TPI and GI values at Diessel diagram along with GWI and VI at Calder diagram indicates that coals of Doi-Doi and Massenrengpulu were deposited at back barrier in area condition of limnic-marsh. Environment facies of the coals in both areas were expansion from peat swamp with low moor in eutrophy condition to high moor in mesotrophy-oligotrophy condition when the top of coal seam was formed.

Keywords : Maceral, vitrinite, petrography, proximate.

1. Introduction

Coal at Mallawa Formation in South Sulawesi spreads over Maros, Pangkep, Barru, Soppeng and Bone Municipalities. The coal is encountered as a form of insertion and lens-shaped with thickness based on measured stratigaphy is 1 - 80 cm which is formed in the sedimentation environment of swamp-marsh (Peera, 2007). Coal on the Mallawa Formation generally has a high calorific value and is eligible for fuel. However, it is not optimally utilized due tothe high sulfur content, which is above two percent (Widodo, 2003). If coal with high sulfur content is utilized, it will cause environmental pollution. In addition, the tools used will quickly experience corrosion (Ulum, et al, 1997).

Other parameters used to determine the utilization or quality of coal are from the ash content, moisture content, volatile matter, fixed carbon, and calorific value (Sukanddarrumidi, 2009). These parameters relate to the maceral composition and mineral content as well as the environmental conditions of the coal formation. Proximate analysis was conducted to determine the character of the coal parameters. While to interpret the depositional environment can be determined from the maceral composition (Heryanto, 2009). Coal maceral composition can be determined from petrographic analysis. In addition, from petrographic analysis was also determined the rank of coal, based on the value of rerlektance of vitrinite (Amijaya, et al, 2004). The coating character or maceral variation may reflect its genesis, facies, dispositional environment, and maturity level/rank (Bechtel, et.al., 2003).

Research on the coal characteristics and depositional environment has been performed for coal in several rock formations in other parts of Indonesia. For example, based on the study of organic facies of coal in the Mengkarang Formation in Central Sumatra, it is known that coal is deposited in the “wet limnic-telmatic” to “tlmatic wet forest swamp” zone. This concept of organic facies can be applied in the context of basin studies, and is one of the parameters for the interpretation of depositional environments (Suwarna, 2006). The purpose of this research was to analyze the characteristic, maceral content and reflectance of vitrinite of coal petrographically which then can percentage can be performed for analysis in reconstructing facies of sedimentation and coal rank of Mallawa Formation in South Sulawesi.

2. Methodology

The research method performed was multilevel, where the various data obtained during research will be integrated and then interpreted to achieve a synthesis. The research data source was from field data taken directly from Doi-Doi region of Barru Municipality and Massenrengpulu region of Bone Municipality which included in the Mallawa Formation (figure 1). Geological data recording on coal outcrops include: coal megascopi appearance, coal coating position, and coal roof/floor layer data, and coal sampling of 2 kilograms or more. Coal sampling at the research site was based on a certain sampling technique adapted to the coal conditions found in the field, namely channel ply sampling which is a systematic coal sampling technique (bottom, middle and top),perpendicular to the coal outcrop layer. Coal sampling wasperformed by observing the change of lithotype in the seam of coal at the research location. Laboratory analysis method performed in this research was petrography and proximate analysis. Both data analysis results were needed to complement each other of the end result of this research.

Petrographic analysis was aimed to determine the organic content and value of reflectance of vitrinite of coal by using a direct light microscope (Transmitted Ligth Microscope) for coal maceral analysis. The standard used was recommended by The International Committee For Coal Petrography in Falcon and Snyman (2001), ASTM Standards (2009) consisting of coal sample preparation standard, vitrinite reflectance determination standard, and coal maceral composition determination standard. Observation of polished incision on petrographic analysis was done as much as 500 points per sample which the result was stated in percent volume. Petrographic analysis was conducted at Puslitbang tekMIRA laboratory, Bandung. The model for reconstruction of coal sedimentary facies of the Mallawa Formation based on the maceral content and the calculation results and plot of the TPIS (Tissue Preservation Index) and GI (Gelification Index) values in Diessel diagram (1986), and the calculation and plot of GWI (Ground Water Index) and VI (Vegetation Index) on the Calder diagram, et.al. (1991), which are formulated as follows:

$$TPI = \frac{Telovitrinit + Telo\text{-}inertinit}{Detrovitrinit + Gelovitrinit + detro\text{-}inertinit + Gelo\text{-}inertinit}$$

$$GI = \frac{Vitrinite + Telo\text{-}inertinit}{Telo\text{-}inertinit + Detroinertinit}$$

$$GWI = \frac{\text{gelinit + corpohuminit + mineral matter}}{\text{texto – ulminit + (eu)ulminit + attrinit + densinit}}$$

$$VI = \frac{\text{texto-ulminite + (eu)ulminit +fusinit + semifusinit + suberinit+resinit}}{\text{attrinit+densinit+inertodetrinit+alginit+liptodetrinit+sporinit+cutinit}}$$

Proximate analysis aimed to obtain data on the coal characteristics in the form of moisture content, ash content, volatile matter, Fixed carbón and calorific value, sulfur content.

3. Result

The lithology encountered in the research area is carbon-black clay on the bottom, coal and claystone at the top. However, in the Massenrengpulu area, basal intrusion was found (**Figure 2**). General position of coal wasN 296^0 E/6^0 with measured thickness of 170cm in Doi-Doi and 150cm in Massenrengpulu area.

The results of the proximate analysis of the coal of the research area (Table 1) show the value of sulfur content which decreases from the lower layer to the upper layer, the smallest water content is in the center of the layer, the ash content is abundant at the bottom of the coal layer and decreases in the upper layer, the volatile matter tend to be inconsistent in each layer, the highest fixed carbon value is at the center of the layer, and the calorific value also highest in the center of the layer. While the result of analysis of clay sulfur content of top layer (Doi-Doi 1.0% and Massenrengpulu 1,1%) is higher than clay in the bottom layer (Doi-Doi 0,74% and Massenrengpulu 0,88%).

Table 1. Proximate analysis result of the Mallawa coal Formation

NO	PARAMETER ANALYSED	ANALYSIS RESULTS (%)					
		***Ply* D.01**	***Ply* D.02**	***Ply* D.03**	***Ply* M.01**	***Ply* M.02**	***Ply* M.03**
1.	*sulfur content*	2,64	2,22	0,99	4,53	3,10	2,95
2.	*moisture content*	13,95	12,40	7,82	6,68	4,04	7,00
3.	*ash content*	15,66	16,24	6,52	8,53	3,05	3,16
4.	*volatile matter*	38,20	31,72	48,91	37,43	41,25	40,82
5.	*Fixed Carbon*	32,19	39,64	36,75	47,37	51,66	49,02
6.	*Calorific falue*,(kal/gr)	4900,87	5450,18	5225,95	6652,75	6700,25	6670,50

The result of the coal petrography analysis in the research area (Table 2) shows the abundance of vitrinite maceral group dominated by desmocolinit maceral (Figure 3), followed by inertinite maceral group, and the least are by liptinite masculine group.

Table 2. The analysis results of maceral content and vitrinite reflectant of Mallawa coal Formation

Maceral Group	Maceral Sub-group	Maceral	Coal Sample from Doi-Doi			Coal Sample fromMassenrengpulu		
			***Ply* D.01**	***Ply* D.02**	***Ply* D.03**	***Ply* M.01**	***Ply* M.02**	***Ply* M.03**
Vitrinit	Telovitrinit	Telocollinit	4.6	2.2	1.8	2.6	0.6	0.8
	Detrovitrinit	Densinit	0.2	4	12	17.2	7.4	7.2
		Desmocollinit	68.2	49.2	48	61.6	56.8	50.2
	Gelovitrinit	Corpogelinit	4.6	2	6.8	1.8	6	14.4
Total vitrinit/huminit (%)			**77.6**	**57.4**	**68.6**	**83.2**	**70.8**	**72.6**
Liptinit		Sporinit	0	0	0.2	0.6	0.2	0
		Resinit	1.8	0.8	2.8	0.6	2	2.8
		Suberinit	1	0	0	0	0	0
Total liptinit (%)			**2.8**	**0.8**	**3**	**1.2**	**2.2**	**2.8**
Inertinit	Telo-inertinit	Semifusinit	0.4	0	0.8	0	2.2	0
	Detro-inertinit	Sclerotinit	7.2	6.4	9	2.6	9	10.4
		Inertodetrinit	2.2	1.6	3	0.2	6.6	3
Total Inertinit (%)			**9.4**	**8**	**11**	**2.8**	**17.8**	**13.4**
		Lempung	5.6	18.4	7.8	5	5.4	3.8
		Pirit	4.6	15.4	7.8	7.8	3.8	7.4
Total mineral matter (%)			**10.2**	**33.8**	**15.6**	**12.8**	**4**	**11.2**
Measurement Result of VitriniteReflectant			0.31	0.32	0.44	0.56	0.39	0.38

Other than maceral, mineral content is also found on the incision of polished coal in the form of clay minerals, and pyrite minerals that are present in the form of euhedral, subhedral, framboidal and massive pyrite, as indications of singenetik pyrite. Based on the variation of mineral and maceral composition of coal in the research area, it is determined that the coal microlitotype in Mallawa Formation is duroclarite and carbopoliminerite. Duroclarite, is a trimaseralic group of coal microlitotype, where coal contains a greater percentage of vitrinite maceral components than the percentage of liptinite and inertinite maceral content. The coal of research area included in this microlitotype are on ply D.01 (vitrinite 77,6%), ply D.03 (vitrinite 68,6%, ply M.01 (vitrinite 83.2%), ply M.02 (vitrinit 70.8%), and ply M.03 (vitrinit 72.6%) Carbopolyminerite, is a carbominerite group of coal microlitotype where coal contains minerals of clay and pyrite minerals totaling more than 20% .The coal included in this microlitotype is Ply D .02 (total clay mineral content and pyrite 33.8%).

Figure 1. The appearance of basal intrusion (left) and Massenrengpulu coal (right)

The result of the vitrinite reflectance analysis in Table 3 indicates that the Doi-Doi region coal rank is in the peat-sub bituminous C rank with an average vitrinite reflectance value of 0.31% -0.44%, while in Massenrengpulu area it is in the lignite-sub bituminous B rank with an average vitrinite reflectance value of 0.38% -0.56%, according to Teichmuller (1982), in the American Association of Petroleum Geologists (AAPG, 1998).

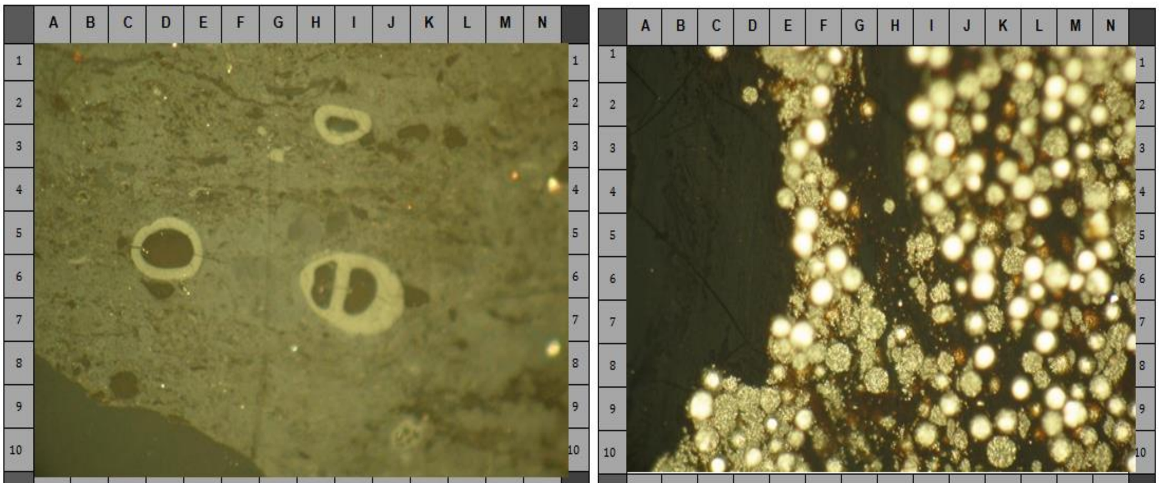

Figure 2. Mikroskopic appearance ofdesmocolinite (9F), sclerotinite (2I), resinite (5D) (left), framboidal pyrite (6J) associated with detrovitrinite (4c) (right), in halogen rays (500x)

4. Discussion

Coal characteristics based on the results of the proximate analysis indicate that the Mallawa Formation coal has a high sulfur content average of 2.0% in Doi-Doi area and 3.5% in Massenrengpulu area. Despite being in one formation, the difference in the analysis results of both areas is made possible by the occurrence of basal intrusion in coal in Massenrengpulu area. Basal intrusion leads to an increase in Massenrengpulu coal maturity rank, followed by increased calorific value and fixed carbon values. The maturity level of coal is caused by temperature, pressure and time or heating duration. One of the influence of temperature can be derived from the intrusion of igneous rocks (Bustin, et al., 1983). The high sulfur content in the coal in the research area is not influenced by the sulfur content of the floor/roof clay but is strongly thought to be derived from the high singenetik pyritis sulfur formed along with the formation of coal closely related to the abundance reactive iron brought by the water stream. It is also reinforced by the petrographic appearance of pyrite morphology present in euhedral, subhedral, framboidal and massive pyrite forms as indications of singenetic pyrite.

Generally, the Doi-Doi and Massenrengpulu coals contain the vitrinite maceral group (57.4% - 83.2%) which indicates that the coal-forming peat is always in a condition with preserved moisture in a wet environment with shrubs as the material origin has a network rich in lignin and cellulose. A small percentage of inertinite maceral content (2.8% -17.8%) gives an indication that peat has a low oxidation rate. The presence of liptinit maceral with a percentage of 0.8% -3% indicates that coal is also composed by low-level plants.

When viewed vertically, there is a slight variation in the proportion of telovitrinite maceral sub-group proportion between upper, middle, and lower coal layer both in the coal of Doi-Doi and Massenrengpulu. The telovitrinite maceral sub-group is dominated by other unobserved telokolinite maceral. The telovitrinite maceral sub-group is a component that still has a good cellular network structure. A low proportion (0.6%-4.6%) of this sub-group indicates that the coal components have been damaged into detrital by bacterial activity or gelified under water condition. The devotrinite maceral sub-groupwhen viewed vertically shows that in Doi-Doi coal, there are variation of detrovinite maceral sub-group proportion namely in the lower and upper layer is relatively larger than the middle layer so that it can be interpreted that the lower and upper coal layer are dominated by shrub plants, while the middle layer is dominated by more varied plants. This indicates that there is peat evolution from eutrophic type with shrubs that then change into mesotrophic-oligotrophic peat type with woody plants. Then the swamp dominated again by shrubs with mesotrophic-oligotrophic condition in which the growth relies only on rain water. Whereas in Massenrengpulu coal, there is a decrease in the proportion from the lower layer to the upper layer which indicates that at the lower part of Massenrengpulu coal is dominated by shrub plants and at the upper part is dominated by various plants. This is also an early indication that peat has evolved from the eutrophic type which mainly formed by water plants to the mesotrophic-oligotrophic type with varied plants and then dominated again by the shrubs in the Doi-Doi coal. This is interpreted as a result of changes in the peat type from low moor which is eutrophic into high moor with mesotrophic-oligotropic conditions. The gelovitrinite maceral sub-group observed under the microscope is only from corpogelinite maceral. The proportion of these maceral sub-group in the Doi-Doi coal layer shows that the largest proportions are in the upper and lower layers and low in the middle layer. This indicates that the gelification process is relatively more intense at the lower and upper than in the middle of the layer. However, in the Massenrengpulu area there is an increase of gelification process from the lower layer to the upper layer.

The inertinite maceral group which consists of semiphucinin, sclerotinite, and inertodetrinit maceral is maceral with the same plant origin with vitrinite maceral but has been oxidized because it was formed in relatively dry conditions. The existence of the maceral group is not too much, namely between 2.8% -17.8% with an average of 10.4%. This indicates that peat during the sedimentation process experiences a low oxidation rate in the lower layer and is relatively elevated in the upper layer under water deprivation. The sclerotinite maceral content in each coal layer in Doi-Doi and Massenrengpulu show an increasingproportion of the lower layer (4.9% average), the middle layer (average 7.7%) and the top layer (average 9.7% %). This indicates the more intensive growth of fungus in the middle and upper layers is because it is in a humid condition (not under water). Based on the content and pattern of inertinite and sclerotinite variations, it can be interpreted that during peating process, the middle and upper parts tend to not submerged by water than at the lower parts. This can occur due to changes in peat type from low moor which is eutrophic to highmoor with mesotrophic-oligotropic conditions. The liptinite maceral group is dominated by the maceral resinite, which is present in all the coal layers of Doi-Doi and Massenrengpulu, and a little sporinite and suberinite maceral with irregular vertical variations.

Based on the analysis of the above maceral content, it is obtaine that there is a uniformity of maceral content in Doi-Doi and Massenrengpulu coal where during the sedimentation process, there is a facies change of formation from peat swamp with low moor type in eutrophic conditions in the lower layer into high moor peat type in mesotrophic-oligotrophic condition in the middle and upper layer with shrubs and wood as the source of the forming material. This is strongly supported by the data results on sclerotinite masceral content and vertical inertinite variation analysiswhich indicating that the upper and middle layers are more dominated by fungal plants grown under humid conditions (not under water). Based on the uniformity of maceral content in coal in Doi-Doi and Massenrengpulu, it is known that both areas are in a position parallel to the edge of the basin. The maceral content will be more varied in the directions parallel to the direction of delta development and will be more uniform in the perpendicular direction (Anggayana dan Widayat, 2007).

The determination of the depositional environment of Doi-Doi and Massenrengpulu coal is based on the calculation and value plot of TPI (Tissue Preservation Index) and GI (Gelification Index) of equations (1) and (2) into Diessel diagram (1986) in Figure 4, and calculation result and value plot of GWI (Ground Water Index) and VI (Vegetation Index) of equations (3) and (4) into Calder diagram, et. al., 1991 in Figure 5. The calculation results of the scalar parameters (Table 3) are supported by organic facies from the results of maceral component analysis, mineral matter characteristics, and proximate analysis results. Based on these, it is obtained that the Doi-Doi and Massenrengpulu coals are formed in the parallel area namely the back-barrier region in limnic-marsh environment conditions that are still influenced by sea tides, under the influence of microbial activity and clastic material input from outside the restricted basin.

Initially, the coal formation environment was a coastal lowland of marsh in the Back Barrier environment. The sea water transgressions occurred causing the supply of fine sediment material enterred the basin, deposited and formed claystone as a floor layer. Then slowly regression occurs so that the swamp environment did not get a direct effect of sea water that allows the development of grasses and shrubs varieties and formed the insitu organic deposits, forming the initial layer of Doi-Doi and Massenrengpulu coal in low moor conditions under the water level so that microbial activity was quite low. Eutrophic conditions causeda relatively high content of clay minerals due to minerals dissolved in water whereas pyrite availability was a result of the abundance of reactive iron carried by the water stream. Regression slowly allowed this condition to continue to form a middle layer above it. At the time of formation of the top layer of coal, the thickness of the peat continued to increase and the water level decreased. This resulted in the change of peat type from low moor type with eutrophic condition to high moor peat type with mesotrophic-oligotropic condition. This condition lead to the growth of mushrooms indicated by the significant increase of sclerotinite maceral content in coal. In this condition, oxidation process increased due to the high concentration of oxygen content in the peat which indicated by the increase of inertinite maceral content of the Mallawa Formation coal.

Subsequently, there was a gradual decrease of the basin followed by the transgression, so that the higher water level caused the plants varietieswhich formed the coal organic deposits cannot survive in such conditions so that the formation of coal layer was ended. This condition continuedwhich cause a fine clastic material input in large quantities which then filled the basin and then formed a clay layer and is the top layer of the seam of the Mallawa Formation coal.

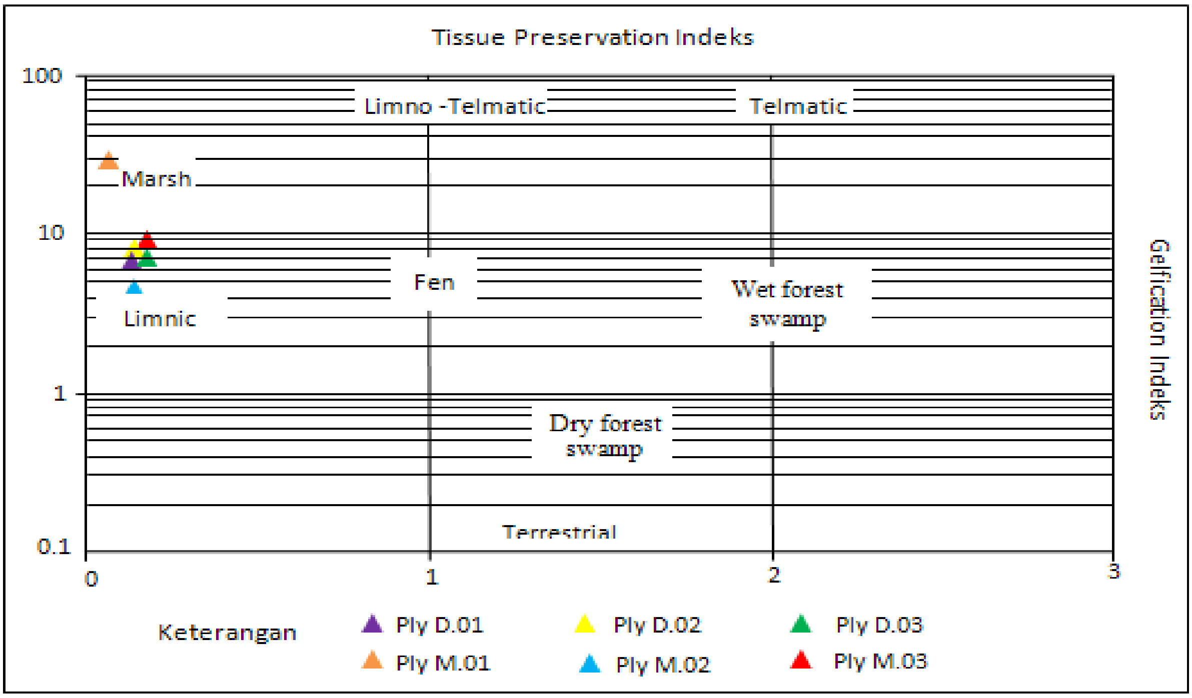

Figure 3. TPI and GI of Mallawa Formation coal in Diessel diagram (1986)

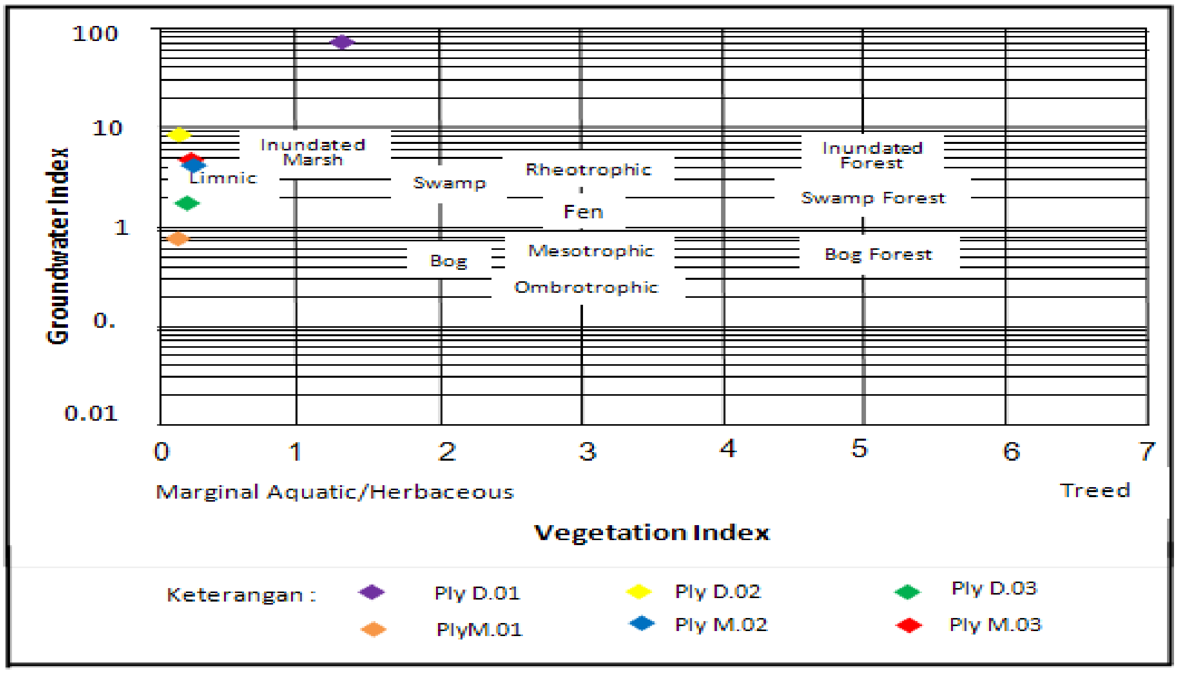

Figure 4. GWI and VI Mallawa coal Formation
in Calder diagram (1991)

Table 3. Scalar parameter of facies indicators

NO	COAL SAMPLES	TPI	GI	GWI	VI
1	*Ply* D.01	0.16	8.7	74	1.33
2	*Ply* D.02	0.15	7.9	8.95	0.14
3	*Ply* D.03	0.16	6.1	1.87	0.24
4	*Ply* M.01	0.06	18.3	0.85	0.03
5	*Ply* M.02	0.15	4.6	1.35	0.29
6	*Ply* M.03	0.15	6.2	3.56	0.27

5. Conclusion

Differences in calorific values, fixed carbon, sulfur content and vitrinite reflectance in Doi-Doi and Massenrengpulu areas are affected by the occurrence of basal intrusion in the Massenrengpulu area. While the high sulfur content (0.99% - 4.63%) in coal is not affected by the sulfur content of rooc/floor clay and is strongly thought to be derived from the singenetikpyritic sulfur. The results of the value plots of TPI, GI, GWI and VI are known that the Doi-doi and Massenrengpulu coals are deposited in the back barrier in the limnic-marsh environment condition, with the development of sedimentation facies from peat swamps of low moor to high moor, in eutrophic to mesotrophic-oligotrophic condition.

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