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PETROGRAPHIC PROPERTIES OF PALAEOGENE SOUTHERN BANTEN COAL SEAMS WITH REGARD TO GEOLOGIC ASPECTS

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ABSTRACT

The Palaeogene coal deposits occur in three coalfields in the Banten Province, which are distributed in Bayah, Cihideung and Cimandiri. The Bayah coals (Eocene Bayah Formation) mainly comprise vitrinite and subordinate inertinite and are of sub-bituminous A to high volatile bituminous A ranks (0.60-0.79%). The Cihideung coals (Eocene Bayah Formation) are of sub-bituminous A to medium volatile bituminous ranks (0.53-1.23%) and composed mainly of vitrinite. The Cimandiri coals (Oligocene Cijengkol Formation) are composed of variable proportions of vitrinite in the main and inertinite in very minor amounts. The rank of the coals is sub-bituminous A and high volatile bituminous A varying between 0.64% and 0.83% in vitrinite reflectance. Evaluation of these coals indicates that they tend to have similar coal petrographic properties and were formed in a littoral-neritic environment. Some of the coals, especially the Cihideung coals, show the highest vitrinite content and higher rank (0.99-1.23%), which is high A-medium volatile bituminous, due to an intrusive activity. Most of the coals have high contents of mineral matter (pyrite), mainly in the Bayah coals (2-13%), and this indicates that the coals were influenced by marine incursion during their deposition.

Keywords: type, rank, coal, depositional environment

INTRODUCTION

Coal deposits are found particularly in the southern part of the Banten Province, namely Bayah, Cihideung and Cimandiri. According to Sukhyar (2009) and Belkin *et al.,*2009), the coal resources are approximately 2.4 million tonnes (1.2 tons in Bayah and Cihideung, 1.2 tons in Cimandiri), and all the coals have been mined since 1980 (Arifin *et al.,* 2003). Most of the coals have been utilized as direct fuel for the small-scale industries around the region; and some have been used by a cement industry in West Java as direct fuel as well.

The Bayah and Cihideung coal deposits are found in the Eocene Bayah Formation; whilst the Cimandiri coals are found in the Oligocene Cijengkol Formation (Sujatmiko and Santosa, 2006). All the coals were deposited in a paralic-neritic environment. During Oligo-Miocene times, the southern Banten was domed up because of the Cihara Granodiorite intrusion. Metamorphic rocks are exposed around this intrusion. The presence of this intrusion and the depositional environment influenced the type and rank of those coals (Thomas, 2002; Ward, 2002; Toprak, 2009; Santoso and Daulay, 2009; Singh *et al*., 2010; Widodo *et al.,* 2010, Sarana and Kar, 2010).

The study is aimed for obtaining an understanding of the aspects as follows:

- to determine the type and rank characteristics of the coals by making maceral analyses and reflectance measurements;
- to establish the patterns of variation of rank and type;
- to examine the implication of the petrographic data.

In order to achieve these aims, analyses of four coalfields from the southern Banten are presented in the study.

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METHODOLOGY

The coal samples for this study were collected from borehole cores and spot samples of the Palaeogene Banten coalfields, namely Bayah, Cihideung and Cimandiri. The procedures, preparation, terminology and techniques used for the study are according to the ASTM (2002).

Twenty-one (21) coal samples (10 samples from Bayah, 6 samples from Cihideung and 5 samples from Cimandiri) were prepared for petrographic examination according to the techniques developed in the Coal Laboratory, Research and Development Centre for Mineral and Coal Technology, Bandung.

The method of preparation of polished particulate coal mounts for microscopic analysis included crushing, embedding, grinding and polishing. The microscopic examination of the polished blocks was undertaken by using a reflected light Leitz Orthoplan microscope fitted with a fluorescence mode.

The maceral analysis was based on counting of 500 points using the Swift Automatic Point Counter attached to the microscope. The maceral data were calculated as follows:

- mineral matter counted: % vitrinite + exinite + inertinite + mineral matter = 100
- mineral matter free basis: % vitrinite + exinite + inertinite = 100

The measurements on vitrinite reflectance were carried out based on 100 points obtained on each sample from which the mean random reflectance (Rvrnd) and the standard deviation (s) were calculated. In addition, a total of 30 measurements were taken on each sample from which the mean maximum reflectance (Rvmax) and deviation (s) were also calculated.

GEOLOGIC SETTING

The Banten and West Java region currently marks the transition between frontal subduction beneath Sumatera to the west. However, the region has been continuously active since rifting in Eocene. The Eocene rifting, as throughout SE Asia, was probably related to the collision between India and Asia, resulted in a significant influx of coarse clastic sediment. The Oligocene-Recent history is more dominated by subduction-related volcanism and limestone deposition (Darman and Sidi, 2000).

The Banten area located in the tectonic province is divided into Seribu Carbonate Platform in the north, Rangkasbitung sedimentary sub-basin and Bayah High in the south (Figure 1). In the west, there are minor low and highs so called Ujung Kulon and Honje Highs; and Ujung Kulon and West Malingping Low (Darman and Sidi, 2000).

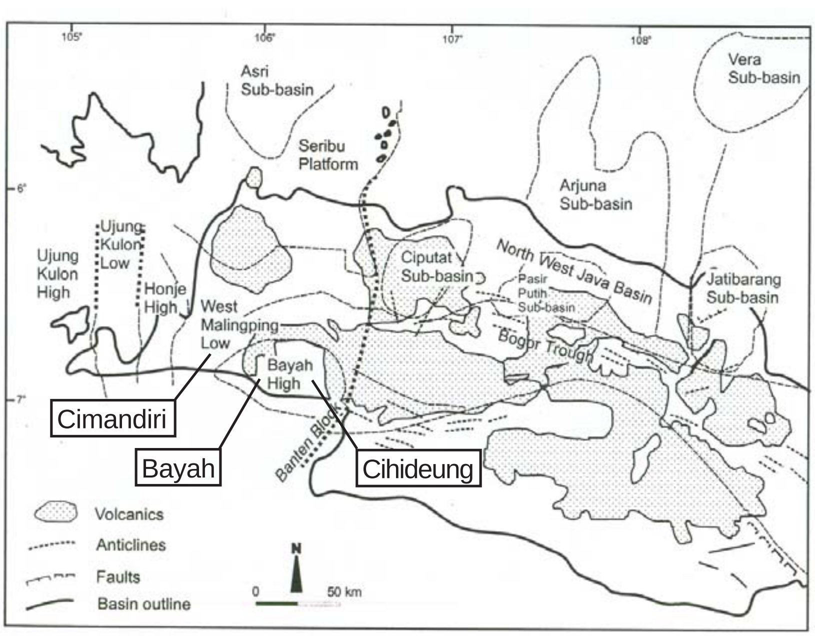

Figure 1. Tectonic map of Banten and West Java showing the studied areas (Darman and Sidi, 2000)

According to Sujatmiko and Santosa (2006), the geologic sequence in southern Banten was commenced in Eocene. Most of this area was a marine basin, in which the Bayah Formation comprises denudation products of the pre-Tertiary rocks. During post-Late Eocene time, a volcanic activity took place and continued until Early Miocene. In Oligocene age, littoral marine basin was formed and the Cijengkol Formation was unconformably deposited to overlie the Bayah Formation. During Oligo-Miocene times, the southern Banten was domed up by the Cihara Granodiorite intrusion. In this period, orogenesis occurred within the Bayah Formation and extended to the Cijengkol Formation resulting in folds and faults. The Palaeogene sediments are strongly folded, especially in the Cimandiri area, where the coal seams have dips of up to 90º. The stratigraphy of the area is presented in Figure 2.

AGE	FORMATION	LITHOLOGY		ENVIRONMENTAL DEPOSITION
		SEDIMENT	IGNEOUS	
Oligocene	Cijengkol	Marl, sandstone, claystone and **coal seams**	Granodiorite Cihara: Granodiorite, porphyry granodiorite, granite, porphyry dacite, gabbro and aplite	Littoral-neritic
Eocene	Bayah	Conglomerate, quartz sandstone, claystone, tuff and **coal seams**		

Figure 2. Stratigraphic sequence of the southern Banten (modified from Sujatmiko and Santosa, 2006)

Tertiary coals are not well developed in Java (Sujatmiko and Santosa, 2006). Terrestrial regressive sedimentation took place in Banten only, particularly in the Bayah area, and resulted in coal deposition. In contrast, sedimentation in Central and East Jawa was associated with a marine transgression that occurred over the pre-Tertiary basement. The Palaeogene coals are found in a monotonous series of quartz-sandstones (partly conglomeratic) and claystones of the Bayah Formation. Several igneous rock intrusions occur in Cimandiri. The coal seams seldom exceed a thickness of one metre, and exceptionally are two metres thick. Up to nine seams occur in some sections and in some localities the coals are highly lenticular. No reliable index-strata are available for correlation of the various coal measures. However, the correlation can be made by applying the coal measures.

RESULTS

The maceral analyses were completed on the southern Banten coal from twenty-one samples. The coal is dominated by vitrinite over liptinite and inertinite is rare. Mineral matter, mainly clay and pyrite, is significantly high. Table 1 shows maceral composition of the coal.

Vitrinite of the southern Banten coals (Figure 3a) ranges from 72% to 96% (average 89%). The vitrinite occurs frequently as thick layers with a detrovitrinite matrix interbedded with thin layers of telovitrinite. Gelovitrinite comprising corpovitrinite and porigelinite is present throughout the coals.

The dominant liptinite maceral in the coal is resinite and cutinite (Figure 3b). In some samples, suberinite, sporinite, liptodetrinite, fluorinite and exsudatinite are present. Resinite of the coals takes place mostly as discrete small bodies of various shapes. The resinite of the coals shows greenish-yellow to yellow fluorescence. Most cutinite occurs as thin cuticles and in some cases forming leaves. The cutinite in the coals has greenish-yellow to yellow fluorescence. Sporinite occurs in trace amounts in the samples and has green-

Table 1. Maceral composition of the coals

AGE	LOCATION	VITRINITE (%)				INERTINITE (%)				EXINITE (%)				MM (%)
		Tv	Dv	Gv	Tot	Sf	Scl	Inert	Tot	Res	Cut	Sub	Tot	
Oligocene	Cimandiri	35	41	15	91	tr	1	-	1	1	tr	-	1	7
		36	44	13	93	tr	1	-	1	1	1	-	2	3
		44	37	9	90	1	1	2	4	2	1	1	4	1
		45	33	11	89	1	1	1	3	3	1	1	5	2
		48	33	9	90	tr	1	1	2	3	1	1	5	2
Eocene	Cihideung	51	26	4	81	3	2	2	7	2	6	tr	8	4
		53	16	2	71	3	2	2	7	2	8	tr	10	10
		66	16	3	85	2	2	2	6	tr	7	tr	7	2
		82	9	1	92	1	-	-	1	-	-	tr	tr	7
		96	tr	-	96	-	-	-	-	-	-	-	-	4
		75	16	1	92	1	1	tr	2	-	-	-	-	6
	Bayah	70	18	5	93	tr	tr	1	1	1	3	-	4	2
		60	22	5	87	1	1	1	3	tr	1	-	1	9
		36	47	5	88	tr	tr	tr	tr	1	2	-	3	8
		37	47	6	90	1	1	1	3	1	1	-	2	4
		39	48	5	92	1	1	1	3	1	1	-	2	3
		37	40	6	83	tr	tr	tr	tr	2	1	-	3	13
		44	36	8	88	-	tr	tr	tr	-	1	1	2	10
		47	33	8	88	2	1	1	4	1	1	-	2	6
		34	55	5	94	-	1	tr	1	1	3	-	4	2
		54	33	6	93	tr	tr	-	tr	1	1	-	2	4

ish-yellow to yellow fluorescence. Suberinite is less common in the coals. Some suberinite in the coals has weak yellow to orange fluorescence. However, in some cases it has no fluorescence. Fluorinite is rare in the coals and has greenish-yellow fluorescence. Liptodetrinite is available in the coals, has greenish-yellow to yellow fluorescence. It is distributed throughout the coals. Exsudatinite is rare in the coals and occurs mostly infilling joints or bedding-plane cracks. It has strong greenish-yellow to yellow fluorescence.

Inertinite content of the Cihideung coals is higher than that of Bayah and Cimandiri coals. This maceral (Figure 3c) comprises semifusinite, sclerotinite and inertodetrinite. The semifusinite content of the coals is up to 3%. Sclerotinite and inertodetrinite of the coals are up to 2%. They are scattered throughout the coals. Some sclerotinite is associated with mineral matter.

Besides the above macerals, the coals contain mineral matter (Figure 3d) that is mainly clay and pyrite. The mineral matter of the coals ranges from 1% to 6% (average 4%), with few samples containing up to 13% mineral matter. The clay and pyrite (consisting of framboidal and massive grain structures) mostly take place as pods disseminated throughout the coals. In some cases, they infill cell lumens.

The vitrinite, liptinite and inertinite contents of the coals are systematically related to one another. Exinite and inertinite contents decrease with increases in vitrinite content. The exinite content tends to increase in inertinite content.

Twenty-one Palaeogene coal samples from the coalfields in southern Banten were examined to determined their vitrinite reflectance and ranks, and the results are provided in Table 2. The Palaeogene coals range from sub-bituminous A to medium volatile bituminous rank (Rvmax ranging between 0.53% and 1.23%), according to the ASTM classification. Vitrinite reflectance of Palaeogene coals in Cihideung area increases locally (Rvmax ranging 0.99-1.23%, high to medium volatile bituminous) due to an igneous intrusion.

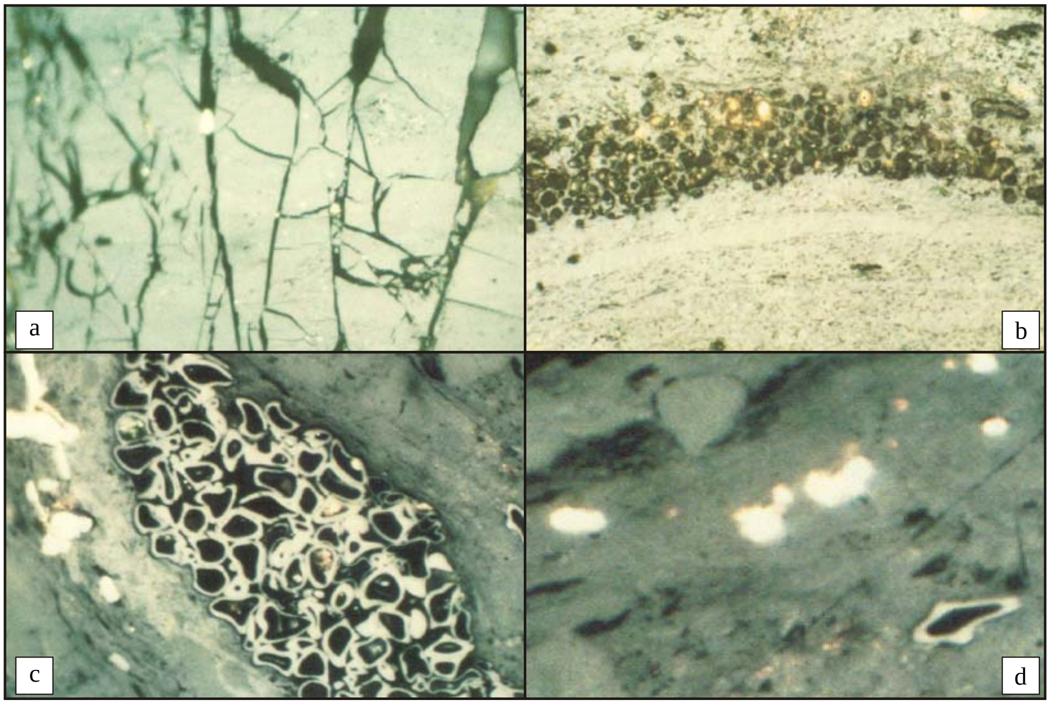

Figure 3. Maceral and mineral matter of the coals

a. Telovitrinite (grey) associated with exsudatinite (black), Rvmax: 0.65%, field width: 0.28 mm, reflected white light. The Cihideung coal.
b. Resinite (black) and telovitrinite (grey), Rvmax: 0.36%, field width: 0.34 mm, reflected white light. The Bayah coal.
c. Sclerotinite (white) associated with telovitrinite (grey), Rvmax: 0.47%, field width: 0.34 mm, reflected white light. The Cihideung coal.
d. Pyrite (white) associated with telovitrinite (grey), Rvmax: 0.47%, field width: 0.34 mm, reflected white light. The Cimandiri coal.

Table 2. Ranks of the coals (ASTM standard)

AGE	LOCATION	Rvmax (%)	RANGE	RANK
Oligocene	Cimandiri	0.83	0.78-0.95	High volatile bituminous A
		0.7	0.63-0.76	High volatile bituminous B
		0.65	0.58-0.72	Sub-bituminous A
		0.65	0.60-0.72	Sub-bituminous A
		0.64	0.57-0.71	Sub-bituminous A
Eocene	Cihideung	0.53	0.46-0.62	Sub-bituminous A
		0.53	0.49-0.61	Sub-bituminous A
		0.53	0.48-0.59	Sub-bituminous A
		0.56	0.48-0.62	Sub-bituminous A
		1.23	**1.18-1.31**	**Medium volatile bituminous**
		0.99	0.90-1.05	High volatile bituminous A
	Bayah	0.63	0.57-0.71	Sub-bituminous A
		0.65	0.59-0.72	Sub-bituminous A
		0.64	0.58-0.72	Sub-bituminous A
		0.6	0.53-0.67	Sub-bituminous A
		0.61	0.56-0.69	Sub-bituminous A
		0.6	0.51-0.65	Sub-bituminous A
		0.63	0.58-0.71	Sub-bituminous A
		0.79	0.73-0.88	High volatile bituminous A
		0.64	0.58-0.73	Sub-bituminous A
		0.65	0.58-0.73	Sub-bituminous A

Vitrinite reflectances vary between the studied area. Rvmax of the Palaeogene coals in Bayah for instance, is higher than that of Palaeogene coals in Cihideung (0.60-0.79% in Bayah and 0.53-0.56% in Cihideung). Vitrinite reflectance also increases in Cimandiri area (0.64-0.83%). The higher vitrinite reflectance in Cimandiri area as compared with Bayah and Cihideung areas is caused by the presence of an igneous (granodioritic) intrusion.

DISCUSSION

The Palaeogene southern Banten coals are discussed in terms of geologic aspects. The most obvious trend for the coals is the decrease in the proportion of exinite and the increase in the proportion of vitrinite. The maceral compositions of the various coal samples are slightly different from each other. Two factors can explain these variations, namely thermal (intrusion) effect and age.

In the thermally affected coals (the granodioritic intrusion), exinite commonly cannot be distinguished from vitrinite (Diessel, 1992; Thomas, 2002; Suarez-Ruiz and Crelling, 2008; Sarana and Kar, 2010). Therefore, it appears to contain high proportions of vitrinite (ranging from 81% to 96%). Exinite maceral is common in coals unaffected by contact alteration with some samples containing up to 10%. In contrast, thermally affected coals have a trace amount of exinite (some of the Cihideung coal). Resinite and cutinite are prominent in the coals and occur in association with vitrinite.

Vitrinite in the coals unaffected by contact alteration comprises thick detrovitrinite matrix (up to 50% in some samples) interbedded with thin bands of telovitrinite. In some cases, thin bands and lenses of telovitrinite are isolated in detrovitrinite matrix. Vitrinite of thermally affected coals is mostly structureless, massive and few pores (see Figure 3a of the Cihideung coal). The dominance of vitrinite in the southern Banten coals is indicative of forest type vegetation in humid tropical zone, without significant dry events throughout. The vitrinite-rich coal in some cases has a high content of mineral matter. A number of authors including Thomas (2002), Diessel (1992) and Suarez-Ruiz and Crelling (2008) have noted that many seams deposited in areas of rapid subsidence have both a high vitrinite content and a high mineral content present as discrete dirt bands.

According to Diessel (1992), the resinite occurs occasionally together with cuticles. This resinite is occasionally abundant and associated with the dull coal and thick layers of vitrinite. This resinite-rich layers can occasionally be used in seam identification. The resinite of the coals fluoresces strongly, from greenish yellow to yellow. With increasing rank, the green colour changes to yellow and finally to orange.

Cutinite appears in the coals as an accessory maceral, but it can also form layers. Selective decomposition usually leads to a concentration of the thin cuticles. However, under certain climatic conditions even the most resistant cuticles can be strongly affected by weathering. This is the frequent case in brown coal (Diessel, 1992).

The thermally affected and unaffected coals contain rare inertinite with some samples containing up to 7%. In some cases, coals with high inertinite content have a relatively high amount of mineral matter. Diessel (1992) and Thomas (2002) suggested that this might be the result of peat deposition in relatively oxidizing environments providing an unfavourable balance between the rate of accumulation of organic material and mineral matter.

In spite of its short geological history, the Palaeogene southern Banten coals exhibit variable vitrinite reflectances, apparently due to variable tectonic and igneous intrusion factors. The thermally affected (some of the Cihideung) coals have vitrinite reflectance of 0.53-1.23% and vitrinite content of 71-93%. In the area, a more rapid and thorough alteration has occurred where bodies of the igneous rock (the Cihara Granodiorite) have intruded the Palaeogene sequences. As a result, coal of lower rank has been metamorphosed to bituminous rank. The extent of rank increase depends primarily on distance from the intrusive rock, but may also be related to size and temperature of the intrusion. The extent of gas or liquid streaming away from the intrusion may also be significant. In addition, the rank of the coal is generally considered to be controlled largely by the level of temperature under confining pressure (burial depth). Increased depth of burial and increased temperature and pressure over a period of time, consequently result in higher rank. For any given amount of burial, rank is therefore firstly a function of the geothermal gradient and secondly a function of the duration of burial (Thomas, 2002; Suarez-Ruiz and Crelling, 2008).

CONCLUSION

The study on petrography of the Palaeogene coals from the southern Banten coalfields, based on 21 samples, indicates the influence of geological setting on their characteristics, particularly thermal (igneous intrusion) effect and age. Type of the coals reflects the influence of peat environment and climate. Vertical and lateral rank variation characteristics result from contrasting burial and palaeotemperature histories. Differences in seam geometry indicate the depositional environment.

In the thermally affected coals (some of the Cihideung coals) due to the granodioritic intrusion, exinite commonly cannot be distinguished from vitrinite. Thus, it appears to contain high proportions of vitrinite. However, the thermally unaffected coals contain less vitrinite. Exinite is common in coals unaffected by contact alteration with some samples containing up to 10%. In contrast, thermally affected coals have trace amounts of exinite (the Cihideung coals). Resinite and cutinite are prominent in the coals and occur in association with vitrinite.

The variable vitrinite reflectances of the coals are apparently due to variable tectonic and igneous intrusion factors. The thermally affected coals have vitrinite reflectance of 0.60-1.23% and vitrinite content of 72-96%. In the area, a more rapid and thorough alteration has occurred where bodies of the igneous rock have intruded the Palaeogene sequences. As a result, coal of lower rank has been metamorphosed to bituminous rank. The extent of rank increase depends primarily on distance from the intrusive rock, but may also be related to size and temperature of the intrusion. The extent of gas or liquid streaming away from the intrusion may also be significant.

The rank of the coals is generally controlled by the level of temperature under confining pressure (burial depth). Increased depth of burial and increased temperature and pressure over a period of time, consequently result in higher rank. For any given amount of burial, rank is therefore firstly a function of the geothermal gradient and secondly a function of the duration of burial.

It is interesting that the above results obviously conclude that the petrographic composition and the rank of the coals are controlled by geologic aspects.

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