INDONESIAN MINING JOURNAL Vol. 14, No. 2, June 2011 : 63 - 73

GEOLOGIC ASPECTS CONTROLLING MACERAL AND MINERAL MATTER CONTENT OF SATUI COALS-SOUTH KALIMANTAN

BINARKO SANTOSO
R & D Centre for Mineral and Coal Technology
Jalan Jenderal Sudirman 623 Bandung 40211,
Ph. 022 6030483, fax. 022 6003373
e-mail: binarkos@tekmira.esdm.go.id

ABSTRACT

Coal deposits were formed in Tertiary sequences in Satui area of Asem-Asem Basin, South Kalimantan. The coals were deposited in paralic to neritic environments. Lithotype of Satui coals is dominated by bright-banded and banded. Petrographically, vitrinite and liptinite are the dominant macerals in the Eocene coals. Inertinite is a minor component. Mineral content is relatively high in most of the coals. There is a significant relationship between lithotype and petrographic observations; the brighter coal is in association with the vitrinite-rich coal. The differences in the coal type are due to the interaction of geologic factors. There is a good correlation among lithotype, petrographic composition and geologic aspects that clearly influence the characteristics of the coals. The ranks of the Eocene coals ranging from brown coal to high volatile bituminous indicate a normal regional coalification.

Keywords: maceral, mineral matter, coal, geologic aspects

INTRODUCTION

Distribution of coal seams is considerably widespread in Kalimantan with minor deposits stretched in West Kalimantan (Darman and Sidi, 2000; Thomas, 2002; Miller, 2005; Sukhyar, 2009; Belkin *et al*, 2009; Daulay, 2010). The eastern Kalimantan coal has a resource of 37.54 billion tons and a reserve of 5.76 billion tons, in which the Satui coal has a resource of approximately 1.4 billion tons. Mining was first commenced around 1850, but terminated in 1941 because of lack of demand as a result of limited number of consumers (Arifin et al., 2003). Recently, mining operation has become a major industry again for Indonesia and this reflects changes in the government policy. The coal-steamed power of 130 Mega Watts in the Satui area utilizes the coal as the main source of energy (Sukhyar, 2009), in which the coal has a good prospect to fulfil energy demand in the future in this area.

The studied area is located in Satui area, South Kalimantan Province, at the Asem-Asem Basin that is situated at the southeastern part of Kalimantan (Figure 1). The laboratory-based study was initiated to collect petrographic data on coals from this area. This study has a potential to make a significant contribution to the knowledge and exploitation of the Satui coal and can provide a framework for later studies.

The objectives of the study are as follows:

a. to examine variations of type and rank of the coal;
b. to determine types and abundance of mineral matter;
c. to interpret relationship between coal type and rank variations and geological setting.

The objectives have been met by an integrated petrologic study presented in this paper. The author is solely responsible for the preparation of the

Received : 10 March 2011, first revision : 20 May 2011, second revision : 06 June 2011, accepted : June 2011

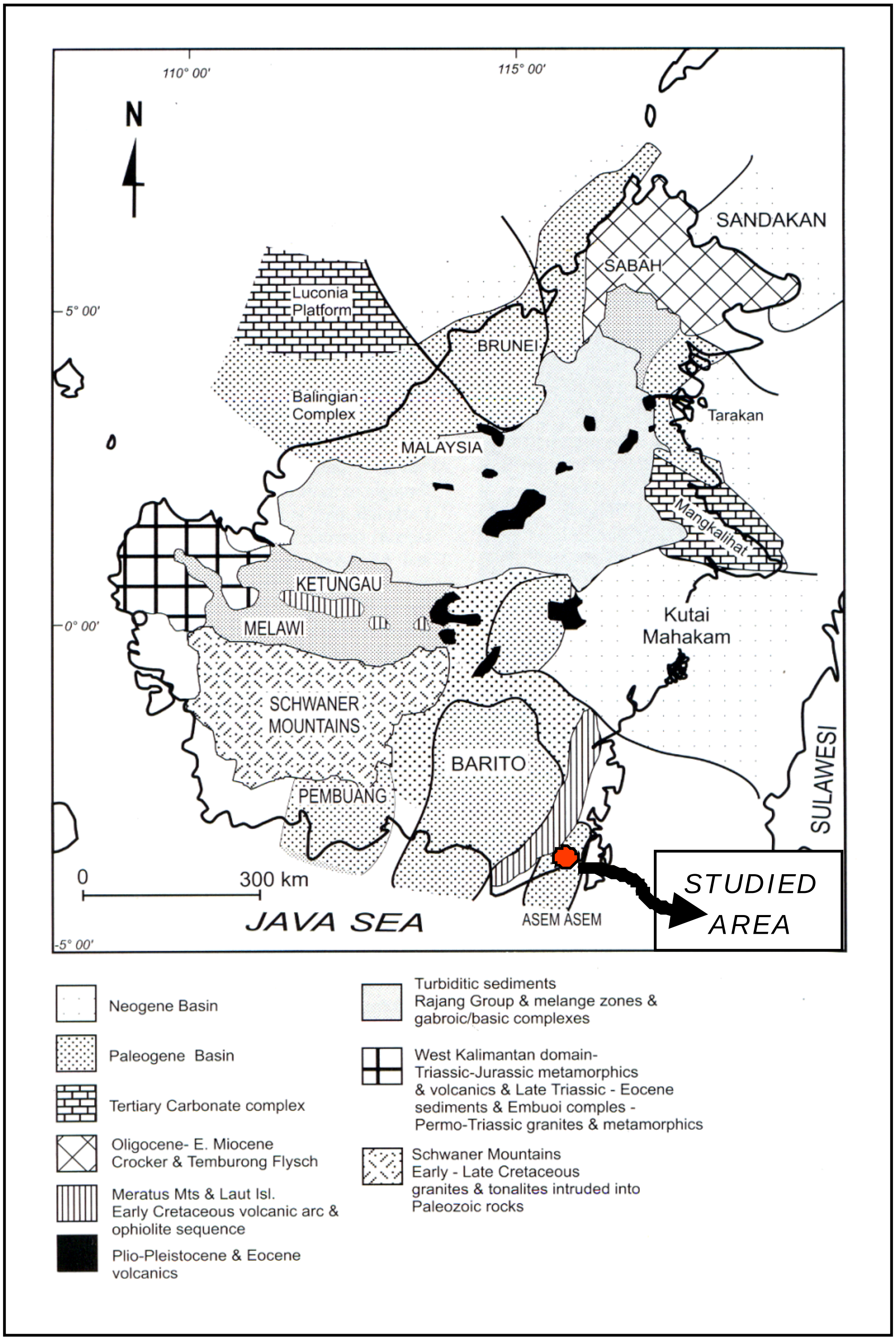

Figure 1. Tectonic setting of Kalimantan (Katili, 1989; Darman and Sidi, 2000)

coal samples and collection of the petrologic data.

GEOLOGICAL SETTING

According to Katili (1989) and Darman and Sidi (2000), Kalimantan, located in the south-eastern margin of the Eurasian plate, is defined to the north by the South China Sea, to the east by the Philippine Mobile Belt and the Philippine Sea Plate and to the south by the Banda and Sunda arc systems. They incredibly contributed the evolution of the tectonic history to the island. As a result, four main Tertiary sedimentary basins, associated with coal deposits, are recognized along the east coast of the island. From north to south, they are the Tarakan, Kutai, Barito and Asem-Asem Basins, respectively (Figure 1). All basins are also applied by the Geological Agency (2009) to the present sedimentary basin map of Indonesia according to gravity and geological data. They are cratonic and back-arc basins associated with the Tertiary southeast directed subduction zone in northwest Kalimantan (that is no longer active) and that developed in the eastern part of the island and the adjacent Makassar Strait. The sedimentation was fairly continuous throughout the Tertiary, and still occurs offshore today as regressive sequences. The Asem-Asem Basin in detail is illustrated in Figure 2.

Sikumbang and Heryanto (2009) stated that the Tertiary sequence of Asem-Asem Basin overlies strongly-deformed Cretaceous rocks comprising an ophiolite complex, metamorphic and volcanic rocks. Marine sedimentary rocks underlie the Tertiary coal deposits and probably form the basement of the Tertiary basins over most of the eastern Kalimantan (Sikumbang, 1986). The basin has a related depositional history ranging in age from Eocene through the Middle Eocene. Stratigraphy of this basin is illustrated in Figure 3 (modified from Sikumbang and Heryanto, 2009).

Coal seams of the Asem-Asem Basin are found in the Eocene Tanjung, Middle Miocene Warukin and Pliocene-Pleistocene Formations (Santoso and Daulay, 2005b). Economic coal deposits occur in the basin, and have been exploited by several companies in order to fulfil the domestic needs (particularly for coal-steamed power) and for export. The coals were deposited in Tertiary sequences in depositional environments ranging from paralic to neritic environments. In this study, only the Eocene Tanjung Formation coals are discussed in this paper.

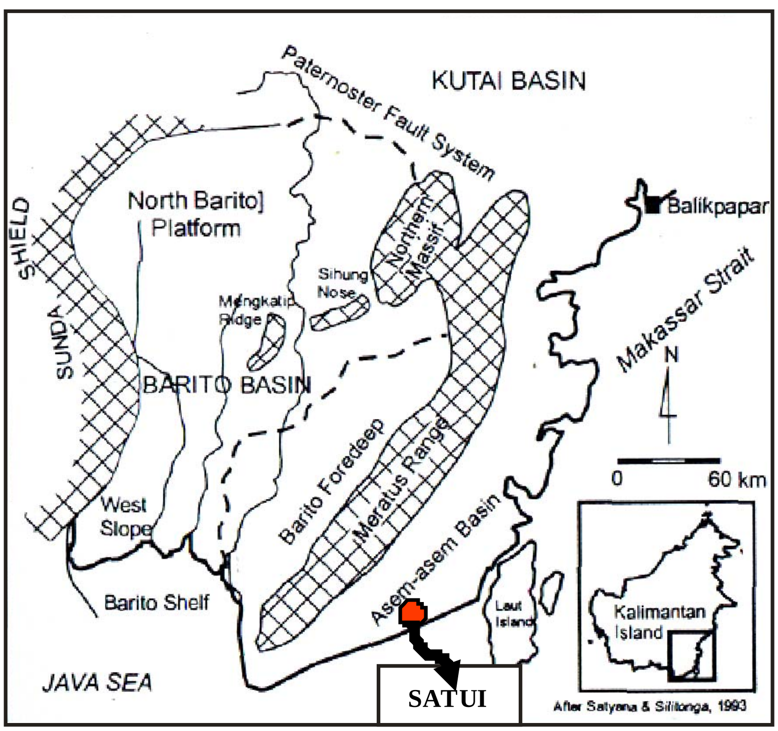

Figure 2. The Satui area in the Asem-Asem Basin (Katili, 1989; Darman and Sidi, 2000)

AGE		THICKNESS (m)	FORMATION	REMARKS
TERTIARY	Oligocene		BERAI	Limestone, white- grey, in places abundant of corals, foraminifera and algae, well-bedded, thickness of beds 20-200 cm; with intercalation of lightgrey marl, well-bedded, containing abundant planktonic foraminifera and grey claystone, shaly in places with thickness of beds 25-75 cm. This formation was deposited in a neritic environment with thickness of about 1,000 m
	Eocene	750	TANJUNG	Quartz-sandstone, fine-coarse grained, the thickness of beds 50-150 cm, parallel lamination and cross-bedding; claystone, grey, shaly in places, present as intercalation in the upper part of the formation with the thickness of beds 30-150 cm; **coal seams**, black, bright-banded, massive, found as intercalation in the lower part of the formation, thickness of the seams 50-150 cm. In places lenses of limestone, brownish-grey, containing fragments of mollusk, echinods and foraminifera indicating Eocene age and was dep osited in paralic to neritic environment. Thickness of this formation is approximately 750 m. *unconformity*
PRE-TERTIARY		-	KINTAP OLISTOLITH, PUDAK FORMATION	Clastic limestone, light- dark grey and yellowish-white, massive to thickly bedded. The lower part contains conglomeratic-limestone, blackish-grey, poorly sorted, angular-subangular grain roundness, compact; clasts consist of basaltic-andesitic fragments and limestone.

Figure 3. Stratigraphy of Satui area (simplified from Sikumbang and Heryanto, 2009)

METHODOLOGY

Twenty coal samples from Satui area-South Kalimantan were analyzed for the study. The sampling was carried out in accordance with the ASTM standard (2009). The samples were prepared as polished particulate coal mounts and analyzed using incident white light and fluorescence mode microscopy in the coal laboratory of R&D Centre for Mineral and Coal Technology, Bandung.

The coal petrographic terms used also follow the ASTM standard (2009). The point-counts of approximately 500 points for each block were obtained. Traverses were made perpendicular to the gravitational settling direction during mounting of the polished blocks. The petrographic (maceral and mineral matter) data are calculated as follows:

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

The measurement of maximum reflectance of vitrinite follows the ASTM standard (2009). The stage of the microscope was rotated to obtain the first maximum reading and then rotated through approximately 180° for the second maximum reading. Each pair of readings was averaged and the mean was calculated to provide mean maximum vitrinite reflectance in oil immersion (Rvmax). The measurements were made on telo-, detro- and gelovitrinite maceral subgroups with number of measurements on each vitrinite subgroup, based on the proportion of each subgroup in the sample as determined by point counting.

RESULTS

Petrological variation in coal is considered in terms of two concepts, which are coal type and coal rank. The organic petrology of thirty-four samples from the Satui area was examined for this study. The coals were obtained from the Eocene Tanjung Formation.

Coal Type

Megascopically, examinations of hand specimens indicate that the Satui coals are composed mainly of bright-banded and bright bands (Figure 4). This statement supports the works of Santoso and Daulay (2005b; 2006a) in which the eastern Kalimantan coals have the same phenomena. Thick bright bands are commonly interbedded with finely-striated bright banded bands.

Figure 4. The bright coals in the studied area

Microscopically, all samples contain dominantly vitrinite (61.9-90.7%, average of 82.0%), sparse to major liptinite (4.8-33.3%, average of 10.7%), rare to major inertinite (0.5-3.9%, average of 3.4%) and sparse to major mineral matter (2.1-12.6%, average of 3.9%), as seen in Table 1.

Vitrinite mostly occurs as telovitrinite and detrovitrinite with gelovitrinite as a minor component (Figure 5). Telovitrinite (Figures 5a and 5b), varying from 0.04-0.2 mm in thickness, is dominant and consists of textinite, texto-ulminite, eu-ulminite and lesser telocollinite. Detrovitrinite (Figures 5c, 5d, 5e and 5f) is commonly associated with liptinite. Attrinite and densinite are the most common detrovitrinite macerals with desmocollinite as a minor component. Sparse gelovitrinite is disseminated throughout the telovitrinite and detrovitrinite with porigelinite occurring as thin bands within telovitrinite.

Inertinite is rare in the coals and comprises predominantly semifusinite, inertodetrinite and sclerotinite. Semifusinite is dominant over other inertinite macerals and commonly occurs as layers (up to 1.0 mm in length), lenses or isolated fragments. Semifusinite is generally associated with vitrinite (mainly telovitrinite). Inertodetrinite is commonly associated with vitrinite and semifusinite. Sclerotinite is generally scattered throughout the coal with local concentrations. Fusinite, micrinite and macrinite are present in several samples, but commonly accounts for <1.0% of the bulk coal. These macerals are commonly disseminated throughout the coals with the exception of some micrinite that form distinct layers within telovitrinite.

Table 1. Petrographic data of the coals

No	VITRINITE (%)				INERTINITE (%)				LIPTINITE (%)							MINERAL MATTER (%)			
	TV	DV	GV	total	SF	SCL	INE	total	SPO	CUT	RES	LIP	SUB	EXS	total	C,Q	CA	PY	total
1	21.4	57.5	2.4	81.3	0.2	-	0.4	0.6	4.6	1.1	6.4	2.8	0.2	0.2	15.3	2.1	-	0.7	2.8
2	21.4	44.9	0.5	66.8	0.8	1.3	0.8	2.9	5.9	0.8	11.6	2.1	3.8	2.9	27.1	2.8	0.2	0.2	3.2
3	46.1	36.9	1.4	84.4	0.7	1.2	0.2	2.1	1.5	0.4	6.6	0.9	0.2	-	9.8	3.7	-	-	3.7
4	48.4	28.1	2.8	79.3	0.8	0.5	0.8	2.1	2.3	2.6	3.9	0.8	0.7	1.6	11.9	6.1	0.4	0.2	6.7
5	28.7	45.4	3.7	77.8	1.3	2.2	0.4	3.9	2.2	1.3	4.9	1.1	2.1	1.4	13.0	5.3	-	-	5.3
6	27.2	47.5	0.4	75.1	0.4	1.5	0.4	2.3	5.9	4.3	6.8	2.2	0.9	0.2	20.5	2.1	-	-	2.1
7	25.8	40.2	4.1	70.1	2.8	1.8	1.1	5.7	2.2	1.2	5.4	1.6	1.1	1.2	12.7	10.7	0.4	0.4	11.5
8	43.5	32.6	3.8	79.9	1.1	0.9	1.6	3.6	1.7	4.1	5.4	1.2	0.8	0.2	13.4	2.4	-	0.7	3.1
9	41.6	29.2	5.9	76.7	-	0.4	1.1	1.5	2.1	3.5	6.1	0.4	1.1	-	13.2	7.8	0.6	0.2	8.6
10	35.8	29.6	1.3	66.7	0.8	0.8	0.8	2.4	5.5	2.2	6.6	1.8	2.3	2.9	22.0	8.5	-	0.4	8.9
11	24.9	39.7	1.1	64.5	1.1	0.9	0.9	2.9	3.1	0.9	14.1	1.2	1.6	4.2	26.0	5.9	0.2	0.5	6.6
12	50.3	30.2	6.8	87.3	0.4	0.4	-	0.8	0.6	3.3	3.9	-	1.2	0.2	9.4	2.5	-	-	2.5
13	58.5	21.9	0.8	81.2	1.2	-	0.2	1.4	1.1	0.4	2.5	-	0.6	0.2	4.8	11.8	0.2	0.6	12.6
14	39.8	35.6	1.7	77.1	0.6	0.6	1.1	2.3	2.4	1.3	10.7	0.9	0.8	1.3	18.5	2.1	-	-	2.1
15	20.4	45.1	0.8	66.3	1.5	1.3	0.6	3.4	6.8	1.7	12.7	3.3	0.4	1.8	27.2	2.7	0.2	0.2	3.1
16	28.5	45.5	0.8	74.8	1.2	1.2	0.8	3.1	5.6	1.2	7.6	2.2	0.8	0.8	18.2	3.7	-	0.2	3.9
17	21.1	38.9	1.9	61.9	0.2	1.6	0.4	2.2	7.5	1.8	15.6	3.8	1.8	2.2	33.3	2.6	-	-	2.6
18	38.9	42.6	7.1	88.6	0.5	0.7	0.3	1.5	1.1	1.1	3.8	0.3	0.3	0.4	7.2	2.5	-	0.2	2.7
19	59.3	30.2	0.9	90.4	0.1	0.3	0.1	0.5	1.1	1.5	3.2	-	0.2	0.2	6.3	2.8	-	-	2.8
20	62.3	28.1	0.3	90.7	0.3	0.4	-	0.7	1.3	0.6	2.6	0.2	0.3	0.9	6.3	2.3	-	-	2.3

Notes: TV : telovitrinite, DV : detrovitrinite, GV : gelovitrinite, SF : semifusinite, SCL : sclerotinite, INE : inertodetrinite, SPO : sporinite, CUT : cutinite, RES : resinite, LIP : liptodetrinite, SUB : suberinite, EXS : exsudatinite, C,Q : clay, quartz, CA : calcite, PY : pyrite

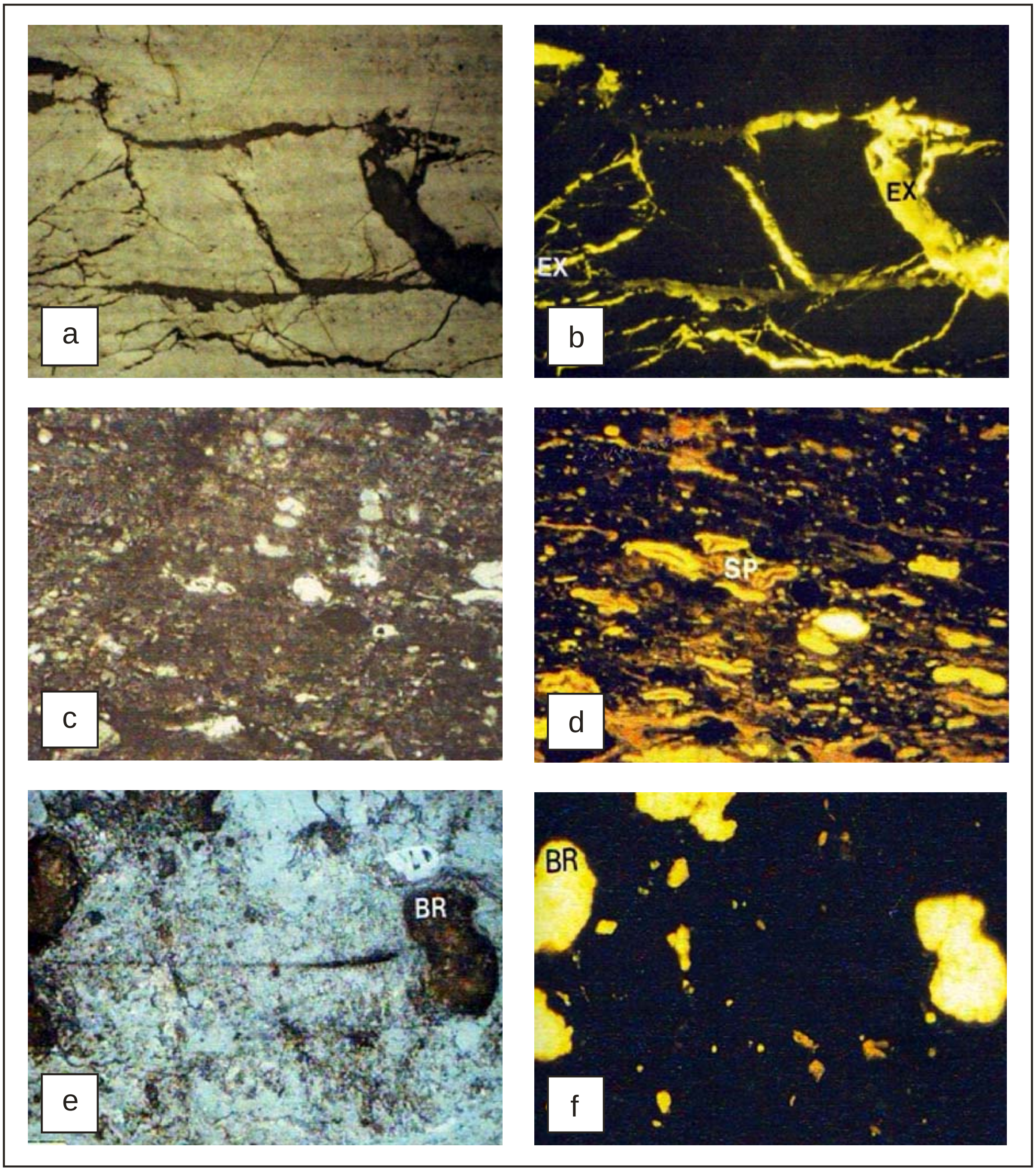

Figure 5. Maceral and mineral matter of the coals

a. Long-thin veins of exsudatinite (EX) infilling fractures in telovitrinite. $R_{v}max$=0.64%. Field width=0.36 mm. Reflected-white light.
b. As for (a), but in fluorescence mode.
c. Sporinite (SP) associated with detrovitrinite and sclerotinite. $R_{v}max$=0.51%. Field width=0.23 mm. Reflected-white light.
d. As for (c), but in fluorescence mode.
e. Botryococcus-related alginite (BR) associated with detrovitrinite. $R_{v}max$=0.51%. Field width=0.36 mm. Reflected-white light.
f. As for (e), but in fluorescence mode.

Liptinite consists predominantly of resinite, suberinite, liptodetrinite and cutinite with minor sporinite (Figures 5c and 5d), fluorinite and exsudatinite (Figures 5a and 5b). Resinite has bright greenish-yellow to dull orange fluorescence. It occurs as discrete bodies and lenses with some occurring as diffuse cell fillings in telovitrinite, semifusinite and sclerotinite. Suberinite commonly occurs as distinct layers with greenish-yellow to orange fluorescence.

It commonly occurs in association with corpogelinite. In some samples, suberinite has broken cell structure that may have occurred during the diagenesis of the peat. Liptodetrinite mainly occurs in vitrinite. It has greenish-yellow to orange fluorescence. Large fragments in some coals are included as liptodetrinite maceral because they cannot be assigned to any other liptinite macerals. Cutinite commonly occurs in association with vitrinite and resinite. It generally has greenish-yellow to orange fluorescence. Sporinite mostly occurs in association with detrovitrinite, resinite and suberinite. It has greenish-yellow to orange fluorescence. Exsudatinite occurs in most coals and commonly has bright greenish-yellow to orange fluorescence (Figures 5a and 5b). It has various shapes and occurrences including infillings in fractures, bedding plane cavities and cell lumens. Fluorinite typically occurs as isolated bodies and lenses with bright green to greenish-yellow fluorescence of very strong intensity.

Mineral content in the coals ranges commonly from 2.1 to 12.6% (average of 5.2%). Clay minerals and quartz are the most common mineral in the coal samples. These minerals usually occur in partings, veins and nodules of different sizes, or are disseminated throughout the coals. Silicate mineral contents of the coals range from 2.1 to 11.8% with average of 4.5%. Pyrite is the most abundant sulphide ranging from 0.2 to 0.7% with average of 0.5%. It mostly fills cleavage partings, joints (cleats) and bedding planes. Calcite is the most common carbonate mineral varying from 0.2 to 0.6% with average of 0.3%. It occurs mainly as vein-like fracture fillings and as nodules scattered throughout the coal.

Coal Rank

In this study, vitrinite reflectance measurements were taken from twenty samples (Table 2). The vitrinite reflectance data support the rank assessment that is subbituminous according to the Australian classification, or subbituminous B to subbituminous A as classified by ASTM.

Table 2. Vitrinite reflectance (Rvmax%) data of the coals

No	TELO (%)	DETRO (%)	VITRO (%)	RANGE-Rvmax (%)	RANK	
					Australian	ASTM
1	0.48	0.48	0.48	0.42-0.53	Subbituminous	Subbituminous B
2	0.49	0.49	0.49	0.43-0.52	Subbituminous	Subbituminous B
3	0.52	0.50	0.51	0.46-0.55	Subbituminous	Subbituminous A
4	0.54	0.53	0.54	0.50-0.61	Subbituminous	Subbituminous A
5	0.52	0.51	0.51	0.47-0.56	Subbituminous	Subbituminous A
6	0.50	0.48	0.49	0.42-0.55	Subbituminous	Subbituminous B
7	0.51	0.50	0.51	0.46-0.56	Subbituminous	Subbituminous A
8	0.49	0.48	0.48	0.42-0.53	Subbituminous	Subbituminous B
9	0.51	0.48	0.50	0.44-0.56	Subbituminous	Subbituminous B
10	0.53	0.51	0.52	0.48-0.56	Subbituminous	Subbituminous A
11	0.49	0.50	0.50	0.46-0.54	Subbituminous	Subbituminous B
12	0.52	0.51	0.52	0.47-0.57	Subbituminous	Subbituminous A
13	0.52	0.51	0.52	0.47-0.57	Subbituminous	Subbituminous A
14	0.44	0.42	0.43	0.36-0.51	Subbituminous	Subbituminous B
15	0.51	0.49	0.50	0.46-0.56	Subbituminous	Subbituminous B
16	0.52	0.51	0.51	0.47-0.55	Subbituminous	Subbituminous A
17	0.48	0.48	0.48	0.38-0.52	Subbituminous	Subbituminous B
18	0.51	0.51	0.51	0.47-0.57	Subbituminous	Subbituminous A
19	0.51	0.51	0.51	0.47-0.55	Subbituminous	Subbituminous A
20	0.52	0.50	0.51	0.47-0.56	Subbituminous	Subbituminous A

Notes: TELO: TELOVITRINITE; DETRO: DETROVITRINITE; VITRO: VITRODETRINITE

DISCUSSION

Megascopically, lithotype of all Satui coals is particularly dominated by bright-banded and bright bands. This can be interpreted that the coals were deposited in a wet and reducing condition; and this phenomenon supports Diessel's (1992; 2010) statement for depositional environment. Of the coal Sikumbang and Heryanto (2009) stated that the coal-bearing strata of the Eocene Tanjung Formation (quartz-sandstone, claystone, shale, coal and limestone) in the Satui area were deposited in a paralic-neritic environment. The thin quartz-sandstone is interpreted as a result of paralic environment, which was formed in shoreline. The claystone and the shale were derived from marine. Additionally, these sediments resulted from slowly subsiding and uplifting conditions. The coals were formed and influenced by a marine incursion as well. The presence of calcite and pyrite in the coals also strengthens the evidence because of the marine depositional environment, which entered the coal-forming marsh during its forming (Diessel, 1992; Ward, 2002). Based on these phenomena, it can be stated that there is a strong correlation between the depositional environment and the lithotype, where the marine incursion inundated and firmly united with the wet coal-forming marsh. This can also be mentioned that the wet condition due to subsidence and marine incursion resulted in the bright coal lithotype.

According to Stach et al. (1982), Thomas (2002) and Suarez-Ruiz and Crelling (2008), maceral and mineral matter composition of the coals is related to palaeoclimate, geological and tectonic setting. The tectonic setting also plays an important role in any subsequent burial metamorphism. As a result of these aspects, spatial and temporal variations in palaeoclimate, geological and tectonic setting cause coal type provincialism. Thus, some coals have properties that are different from other coals in different parts of the same seams, in different part of the same basin or coals in other basins.

The petrographic compositions of the coals are remarkably consistent with those of Tertiary coals from other localities in Indonesia (Santoso and Daulay, 2005a,b; 2006a,b; 2007; Belkin et al., 2009; Daulay, 2010). Overall, the Satui coals are characterised by the dominance of vitrinite with subordinate liptinite and relatively low inertinite. The high vitrinite content of the coals indicates that they have been deposited in areas of rapid subsidence. The dominance of vitrinite in all of the coals is indicative of forest type vegetation in a humid tropical zone that does not have a significant dry season (Stach et al., 1982; Thomas, 2002).

Inertinite comprises predominantly semifusinite, sclerotinite and inertodetrinite with minor fusinite, micrinite and macrinite. It is generally believed that inertinite is derived from strongly oxidised, degraded wood tissue that is indicative of the comparatively dry conditions during peat diagenesis even though the overall climate may have been wet and temperate as it was during the Tertiary in Indonesia (Belkin et al.,2009; Diessel, 2010). Therefore, the higher inertinite content in some of the coals may indicate that the coal deposition occurred in a shallow basin under more aerobic conditions where the peat was frequently exposed to the atmosphere.

Liptinite is relatively abundant in the coals. Slightly different liptinite content in the coals indicates that there may have been different floral assemblages, particularly flowering plant types, at the Eocene age. High suberinite contents are normally found in the samples. This is indicative of rapid coalification that occurs over the range of subbituminous to high volatile bituminous stages (Sarana and Kar, 2011).

The distribution of mineral matter in coal depends on its geological history and the environment of the peat mires. These factors as the surrounding geological setting and the nature of the groundwater are the great influence on the proportion of mineral matter added to peat swamp. The relatively high mineral matter of the Satui coals indicates that the rate of subsidence is slower than that of accumulation of peat during the Eocene.

Mean maximum vitrinite reflectance values (Rvmax) for the Satui coals vary from 0.48-0.54%. These values indicate subbituminous rank (Australian classification) or subbituminous B-A (ASTM classification). These coals have been subjected to normal regional coalification (Belkin et al., 2009; Sarana and Kar, 2011).

Based on the above evidence, the Satui coals can strongly be determined according to the relationship among lithotype, petrographic composition and geologic aspects.

CONCLUSIONS

This paper has completed a significant contribution to the understanding of the importance of organic petrology of the Eocene Satui coals in terms of type and rank in relation with geologic aspects. Characteristic conclusions are listed as follows:

a. the coals are composed dominantly of brighter lithotypes. The vitrinite-rich bright layers were derived from peat that accumulated under water in more reducing conditions;

b. small differences in the coal type can be attributed to the interaction of tectonic, sedimentary, palaeoclimate and plant evolutionary factors;

c. the mineral matter content of the coals is typically high. This is a function of the environment of the peat deposition;

d. the rank of the coals is subbituminous (Australian classification) or subbituminous B-A (ASTM classification), in which the ranks are subjected to normal regional coalification;

e. there is a strong correlation among lithotype, maceral and mineral matter, and geologic aspects.

REFERENCES

Annual Book of American Society for Testing and Material (ASTM) Standards, 2009. *Petroleum products, lubricants and fossil fuels, gaseous fuels; coal and coke,* USA, 650 p.

Arifin, M., Suhendar, Sudrajat, A., Sujono, Miswanto, A., Rustendi, T. and Supriatna, E., 2003. Ringkasan mineral dan batubara Indonesia 2003. *Litbang tek*MIRA *No.28.2003.* Bandung.

Belkin, H.E., Tewalt, S.J., Hower, J.C., Stucker, J.D. and O'Keefe, J.M.K., 2009. Geochemistry and petrology of selected coal samples from Sumatera, Kalimantan, Sulawesi and Papua, Indonesia. *International Journal of Coal Geology 77 (2009),* p.260-268.

Darman, H. and Sidi, F.H., 2000. *An outline of the geology of Indonesia.* Indonesian Association of Geologists, Jakarta, p. 69.

Daulay, B., 2010. Evaluation of Kalimantan coal quality in order to select the appropriate and effective utilization technologies. *Proceedings-Kalimantan coal and mineral resources.* Balikpapan, p. 49-60.

Diessel, C.F.K., 1992. *Coal-bearing depositional systems.* Springer-Verlag, 721 p.

Diessel, C.F.K., 2010. The stratigraphic distribution of inertinite. *International Journal of Coal Geology 81 (2010),* p.251-268.

Geological Agency, 2009. *Sedimentary basin map of Indonesia based on gravity and geological data, scale 1:5,000,000.* Bandung.

Katili, J.A., 1989. Evolution of the Southeast Asian arc complex. *Geology of Indonesia, 12,* p. 113-143.

Miller, B.G., 2005. *Coal energy systems.* Elsevier Academic Press, Amsterdam, 526 p.

Santoso, B. and Daulay, B., 2005a. Vitrinite reflectance of Ombilin coal according to its petrographic analysis. *Indonesian Mining Journal, vol.8 no.1, February 2005,* p. 9-20.

Santoso, B. and Daulay, B., 2005b. Type and rank of selected Tertiary Kalimantan coals. *Indonesian Mining Journal, vol.8 no.2, June 2005,* p. 1-12.

Santoso, B. and Daulay, B., 2006a. Geologic influence on quality of selected Tertiary Barito coals. *Indonesian Mining Journal, vol.9 no.5, June 2006,* p. 14-22.

Santoso, B. and Daulay, B., 2006b. Coalification trend in South Sumatera Basin. *Indonesian Mining Journal, vol.9 no.6, October 2006,* p. 9-21.

Santoso, B. and Daulay, B., 2007. Maceral and mineral analyses of Lebak coals regarding their utilizations. *Indonesian Mining Journal, vol.10 no.8, June 2007,* p. 1-9.

Sarana, S. and Kar, R., 2011. Effect of igneous intrusive on coal microconstituents: study from an Indian Gondwana coalfield. *International Journal of Coal Geology 85 (2011),* p. 161-167.

Sikumbang, N., 1986. Geology and tectonic of pre-Tertiary rocks in the Meratus Mountains, Southeast Kalimantan, Indonesia. *PhD Thesis,* the University of London, 400 p (unpublished).

Sikumbang, N. and Heryanto, R., 2009. *Geological map of the Banjarmasin Quadrangle, Kalimantan.* Geological Survey Institute, Geological Agency, Bandung.

Stach, E., Mackowsky, M.Th., Teichmuller, M., Taylor, G.H., Chandra, D. and Teichmuller, R., 1982. *Stach's textbook of coal petrology,* 3rd edition, Berlin, Stuttgart, 535 p.

Suarez-Ruiz, I. and Crelling, J.C., 2008. *Applied coal petrology-the role of petrology in coal utilization.* Elsevier Ltd., Amsterdam, 388 p.

Sukhyar, R., 2009. Indonesian coal resources and reserves. *Seminar and Workshop, Indonesian Coal Conference*, Geological Agency, Ministry of Energy and Mineral Resources, Jakarta.

Thomas, L., 2002. *Coal geology.* John Wiley&Sons, Ltd., West Sussex, England, 384 p.

Ward, C.R., 2002. Analysis and significance of mineral matter in coal seams. *International Journal of Coal Geology 50 (2002),* p. 135-168.