IMPORTANCE OF ORGANIC PETROLOGY TO TYPE AND RANK OF MIOCENE ASEM-ASEM COAL-SOUTH KALIMANTAN

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ABSTRACT

The Asem-Asem Basin has cratonic and back-arc settings containing coal deposits that were formed in Tertiary sequences. The coals were deposited in fluvial to deltaic environments.

Megascopically, the coals are dominated by bright-banded and banded lithotypes. Microscopically, vitrinite and liptinite are the dominant macerals in the Miocene coals. Inertinite is a minor component and mineral content is also low in most of the coals. There is significant relationship between megascopic and microscopic observations; the brighter coal is in association with the vitrinite-rich coal, otherwise, the duller coal is in association with the inertinite-rich coal with relatively high mineral content. The differences in the coal type are due to the interaction of tectonic, geologic, palaeoclimate and plant evolutionary factors.

The ranks of the Miocene coals ranging from brown coal to high volatile bituminous indicate a normal regional coalification.

Most of the coals are suitable for feedstocks in combustion that is the most important present day use for coals.

Keywords: organic petrology, type, rank, Asem-Asem coal

1. INTRODUCTION

Coal deposits are mainly widespread in Sumatera and Kalimantan with minor deposits distributed in Sulawesi, Moluccas, Papua and Java. The total of the Indonesian coal resources is 90.45 billion tons with the reserve of 18.71 billion tons (Centre for Geological Resources, 2007; Figure 1). The Sumatera coal has a resource of 58.82 billion tons and a reserve of 13.41 billion tons; while the Kalimantan coal has a resource of 36.22 billion tons and a reserve of 5.3 billion tons, in which the Asem-Asem coal has a resource of approximately 1.4 billion tons. Mining first commenced around 1850, but terminated in 1941 because of lack of demand as a result of the limited number of consumers. It is only recently that mining operation has again become a major industry for Indonesia and this reflects changes in the government policy.

The studied area is located in the Asem-Asem area, a basin situated at the southeastern part of Kalimantan (Figure 2). The laboratory-based study was initiated to collect petrographic data on coals from this area. This study has the potential to make a significant contribution to the knowledge and exploitation of the Asem-Asem coal and should provide a framework for later studies.

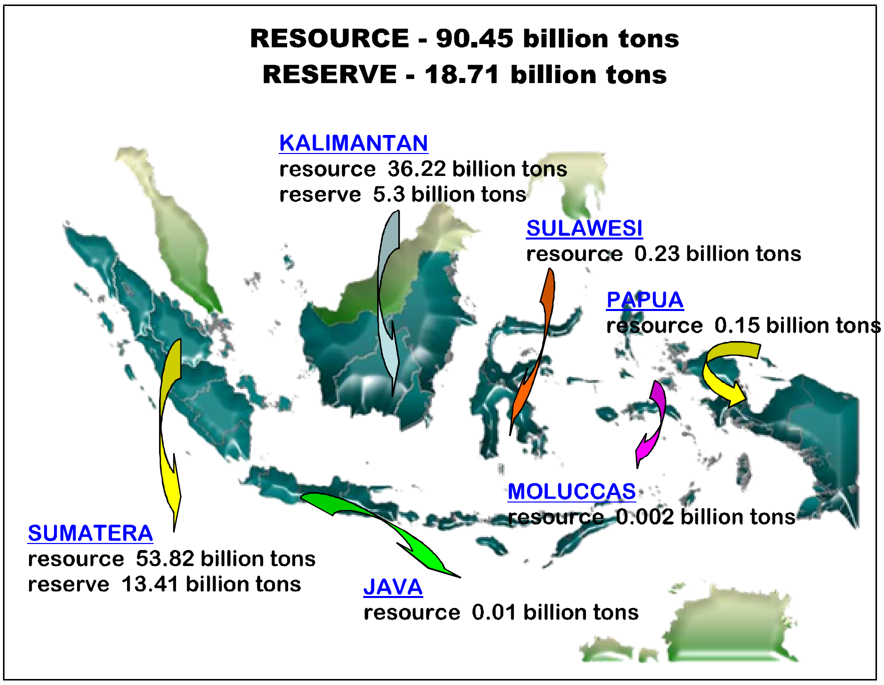

Figure 1. Resource and reserve of the Indonesian coals (Centre for Geological Resources, 2007)

The aims of the study are:

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

2. GEOLOGICAL SETTING

The Kalimantan island currently lies upon the southeastern margin of the Eurasian plate. The island 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 (Darman and Sidi, 2000). Katili (1989) greatly contributed the evolution of the tectonic history of the island. As a result of the tectonic activity, 4 main Tertiary sedimentary basins associated with coal deposits, are recognised along the east coast of the island. From north to south, they are the Tarakan, Kutai, Barito and Asem-Asem Basins, respectively (Figures 2 and 3). All of them 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 Tertiary sequence of the 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 4 (modified from Achmad and Samuel, 1984).

Coal seams of the basin are found in the Eocene Tanjung, Middle Miocene Warukin and Pliocene-Pleistocene Formations (PT. Arutmin Indonesia, 1986). Economic coal deposits occur in the basin. The coals were deposited in Tertiary sequences in depositional environments ranging from fluviatile to delta.

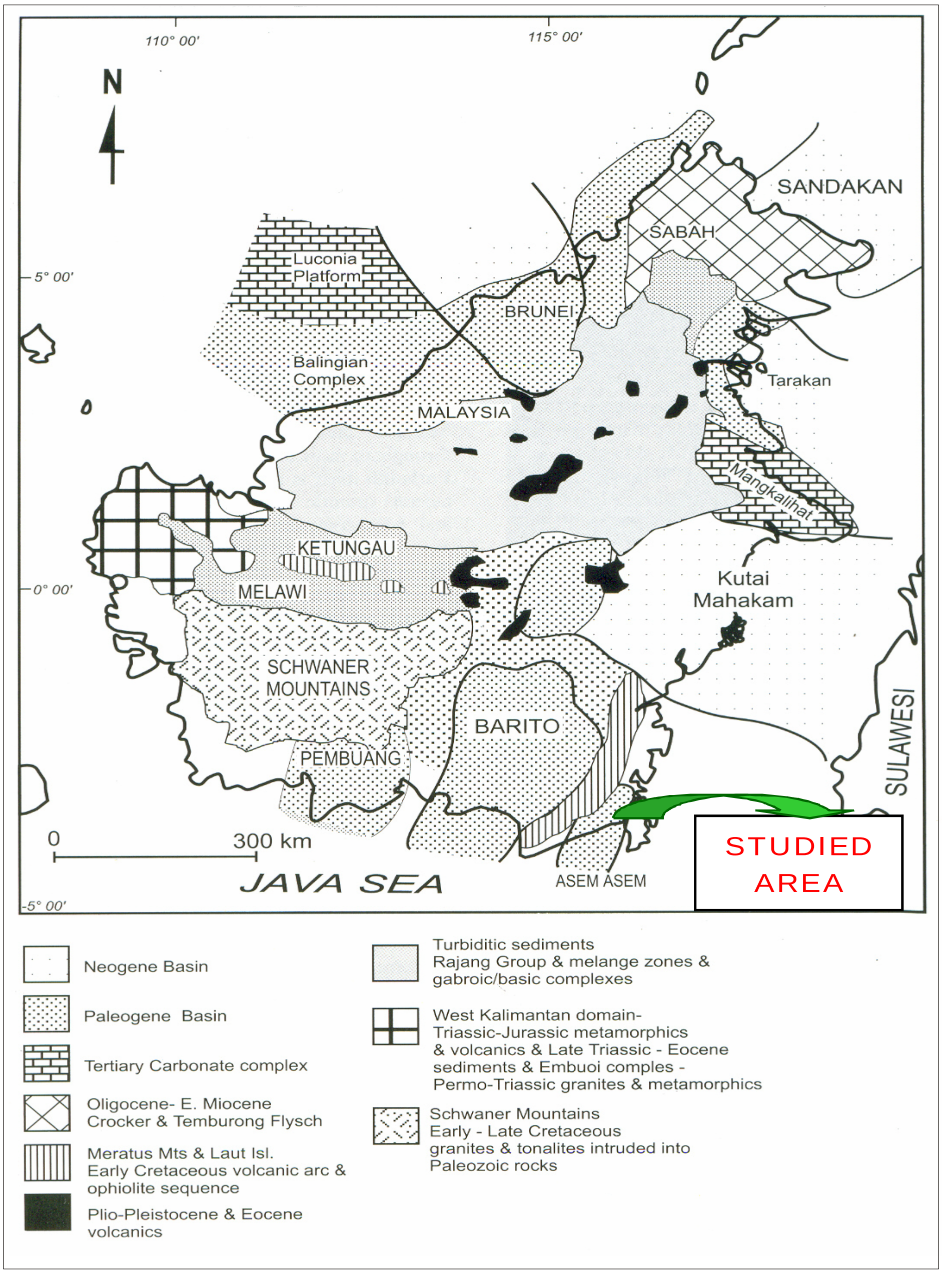

Figure 2. Geological setting of Kalimantan (Darman and Sidi, 2000)

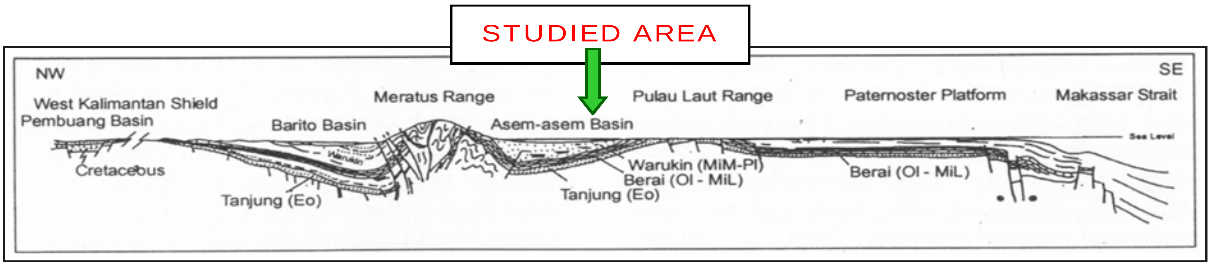

Figure 3. Barito Basin-Makassar Strait section (Satyana and Silitonga, 1993)

AGE		THICKNESS (m)	FORMATION	REMARKS
TERTIARY	Pliocene	50-700	DAHOR	Poorly-consolidated sandstone, minor fine-grained clastic sequences with **coal seams**. Fluvial, deltaic environment.
	Miocene	600-1,700	WARUKIN	Soft, fine-grained clastic rocks with sand stone, siltstone and **coal seams up to 40 metres thick**. Paralic, deltaic, shal low marine environment. **The coal samples for this study were obtained from this formation**.
	Oligocene	200-3,000	BERAI	Limestone, marl and fine-grained clastic strata. Shallow marine, deltaic, shoreline environment.
	Eocene	100-2,500	TANJUNG	**Coal seams** interbedded with laminated sequences of fine-grained sandstone, siltstone and shale. Fluvio-deltaic environment.*unconformity*
PRE-TERTIARY		-	-	Ophiolite complex, metamorphic and vol canic rocks.

Figure 4. Stratigraphy of the Asem-Asem Basin (modified from Achmad and Samuel, 1984)

3. ANALITICAL METHODS

Thirty-four coal samples from the Asem-Asem area were analysed for the study. The sampling was in accordance with the Australian Standard AS 1676 (Standards Association of Australia, 1975).

The samples were prepared as polished particulate coal mounts and analysed using incident white light and fluorescence mode microscopy.

The coal petrographic terms used follow the Standards Association of Australia (1986). The classification is based the maceral nomenclature described by the International Committee for Coal Petrology Handbook modified by Smith (1981).

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 measurement of maximum reflectance of vitrinite follows the Standards Association of Australia (1989). 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 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.

4. ORGANIC PETROLOGY

Petrological variation in coal may be considered in terms of two concepts that are coal type and coal rank. The organic petrology of thirty-four samples from the Asem-Asem area was examined for this study. The coals were obtained from the Miocene Warukin Formation having thickness of up to 40 metres.

4.1. Coal type

Megascopically, examinations of hand specimens indicate that the Asem-Asem coals are composed mainly of bright-banded and bright bands. 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.

Microscopically, all samples contain dominantly vitrinite (63.5-94.2%, average of 82.0%), sparse to major liptinite (0.8-30.9%, average of 10.7%), rare to major inertinite (0.2-9.9%, average of 3.4%) and sparse to major mineral matter (1.1-20.1%, average of 3.9%), as seen in Table 1.

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

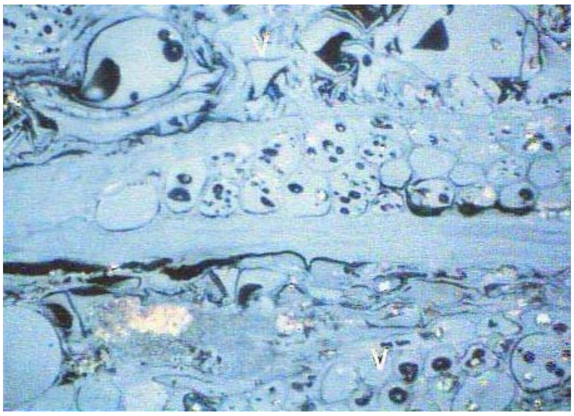

Figure 5. Vitrinite with well-preserved cellular structure. Rvmax=0.36%, brown coal. Field width 0.36 mm, reflected white light

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 forms distinct layers within telovitrinite.

Liptinite consists predominantly of resinite, suberinite, liptodetrinite and cutinite with minor sporinite, fluorinite and exsudatinite. 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 (Figures 6a and 6b).

Figure 6a. Suberinite showing broken-cell structure (yellow), Rvmax=0.37%, brown coal. Field width 0.23 mm, fluorescence mode.

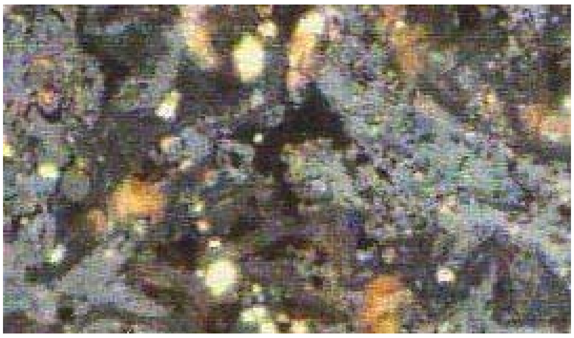

Figure 6b. As Figure 6a, but in reflected white light.

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

Table 1. Petrographic data of the Asem-Asem 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	44.6	33.2	2.9	80.7	0.7	1.1	0.6	2.4	0.6	1.4	3.7	1.1	4.1	1.4	12.3	4.2	0.2	0.2	4.6
2	72.7	11.5	9.9	94.1	0.8	0.2	-	1.6	-	-	0.4	0.2	0.2	-	0.8	3.4	-	0.1	3.5
3	37.3	39.2	1.2	77.7	1.4	0.2	0.2	1.8	0.2	0.9	5.1	0.8	4.1	0.2	11.3	8.6	-	0.6	9.2
4	32.3	57.1	0.5	89.9	1.3	0.8	-	2.1	0.2	0.2	1.6	-	1.6	-	3.6	4.2	0.2	-	4.4
5	30.0	37.1	8.7	75.8	4.4	0.9	1.1	7.0	0.4	-	4.3	0.4	6.2	0.6	11.9	5.3	-	-	5.3
6	40.4	47.6	3.8	91.8	0.4	0.4	0.4	1.2	0.2	0.4	0.9	0.4	1.5	-	3.4	3.6	-	-	3.6
7	38.1	49.8	4.2	92.1	2.9	0.8	0.6	4.9	-	0.4	0.2	-	1.1	0.2	1.9	1.1	-	-	1.1
8	58.2	25.8	6.7	90.7	1.4	-	0.4	2.4	-	0.4	0.8	-	0.6	0.2	2.0	4.3	0.2	0.4	4.9
9	37.9	40.6	3.4	81.9	4.3	2.1	1.7	8.3	-	0.4	1.7	-	4.8	0.6	7.5	2.3	-	-	2.3
10	53.7	24.6	5.1	83.4	0.4	0.2	0.2	0.8	0.7	0.4	1.9	0.7	3.8	2.2	9.7	5.9	-	0.2	6.1
11	40.4	28.6	6.9	75.9	3.4	1.1	1.5	6.6	0.4	0.2	1.8	3.6	9.2	-	15.2	2.3	-	-	2.3
12	50.2	20.6	7.5	78.3	0.2	0.2	0.5	0.9	0.2	0.8	1.8	2.1	9.5	0.4	15.0	5.8	-	-	5.8
13	19.1	19.1	6.7	44.9	1.7	-	1.0	2.7	0.3	-	1.8	0.6	3.1	0.6	6.7	45.7	-	-	45.7
14	55.6	18.8	6.0	80.4	0.5	-	0.2	0.7	0.2	0.3	1.7	1.1	8.0	0.9	12.2	6.7	-	-	6.7
15	42.1	37.0	5.9	85.0	2.3	0.2	0.5	3.2	-	0.5	0.8	0.2	4.3	0.8	7.0	4.8	-	-	4.8
16	33.6	29.6	6.1	69.3	5.6	1.0	2.4	9.9	-	0.6	1.7	2.0	13.0	-	17.3	3.5	-	-	3.5
17	34.7	46.7	1.1	82.5	1.7	0.7	1.3	3.9	-	1.5	1.8	0.5	5.9	1.4	11.1	2.2	0.1	0.2	2.5
18	53.5	25.7	7.5	86.7	2.1	0.2	0.7	3.8	-	-	1.5	0.5	3.5	0.4	6.1	3.4	-	-	3.4
19	33.4	36.9	5.9	76.2	5.7	1.2	2.2	9.5	-	-	2.2	0.4	7.2	-	10.6	3.7	-	-	3.7
20	33.7	24.5	7.3	65.5	2.8	0.5	0.3	4.1	-	-	1.2	0.8	6.8	-	10.3	16.1	-	4.0	20.1
21	47.9	39.9	6.4	94.2	0.9	0.4	0.6	1.9	-	0.4	0.6	-	0.2	-	1.2	2.5	-	0.2	2.7
22	20.6	50.1	4.1	74.8	2.1	0.7	0.7	3.5	1.2	0.4	5.1	3.6	5.6	2.5	19.6	1.6	-	0.5	2.1
23	22.6	50.3	2.6	75.5	1.8	0.3	0.4	2.5	1.1	0.2	5.8	2.9	4.8	2.1	19.3	2.5	-	0.2	2.7
24	62.1	28.7	2.9	93.7	0.9	-	0.4	1.3	-	-	1.9	0.7	0.2	0.4	3.2	1.8	-	-	1.8
25	28.4	55.6	2.4	86.4	0.6	-	0.5	1.5	0.2	0.5	1.3	-	6.5	1.6	10.7	1.4	-	-	1.4
26	40.7	33.7	4.3	78.7	0.6	0.8	-	1.4	0.1	1.1	5.7	0.6	7.4	2.6	17.5	2.2	-	0.2	2.4
27	35.9	44.1	6.3	86.3	1.1	0.2	0.6	1.9	0.5	0.4	3.9	0.2	4.1	0.9	10.4	1.4	-	-	1.4
28	28.8	54.9	1.6	85.3	4.6	1.1	1.3	7.6	0.5	-	1.1	0.6	1.4	0.4	4.2	2.5	0.2	0.2	2.9
29	16.6	40.7	6.2	63.5	1.8	0.9	0.8	3.5	0.6	-	7.5	4.6	8.2	8.8	30.9	1.9	-	0.2	2.1
30	58.8	25.1	8.5	92.4	-	0.2	-	0.2	0.4	-	1.2	0.9	0.6	0.9	4.0	2.8	0.2	0.4	3.4
31	22.9	56.6	5.6	85.1	0.4	0.6	0.6	1.6	0.8	-	3.1	0.2	6.6	0.9	12.2	1.1	-	-	1.1
32	44.6	27.4	4.1	76.1	1.8	0.6	0.8	4.1	0.7	0.2	4.2	1.8	8.2	2.3	17.4	2.2	-	0.2	2.4
33	23.8	47.4	4.1	75.3	1.9	0.6	0.8	4.2	0.8	0.2	4.3	1.9	8.6	1.9	17.7	2.6	-	0.2	2.8
34	24.4	55.1	1.8	81.3	1.4	1.2	0.4	3.2	0.2	-	6.2	0.8	6.1	0.7	14.0	0.8	-	0.7	1.5

fluorescence. Large fragments in some coals are included as liptodetrinite maceral because they cannot be assigned to any other liptinite maceral. 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 7a and 7b). 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.

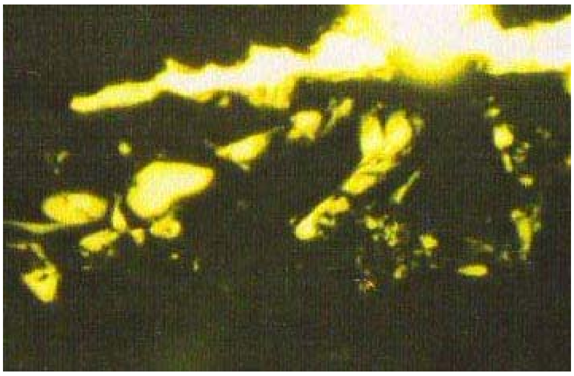

Figure 7a. Exsudatinite (yellow), Rvmax=0.34% (brown coal). Field width 0.42 mm, fluorescence mode.

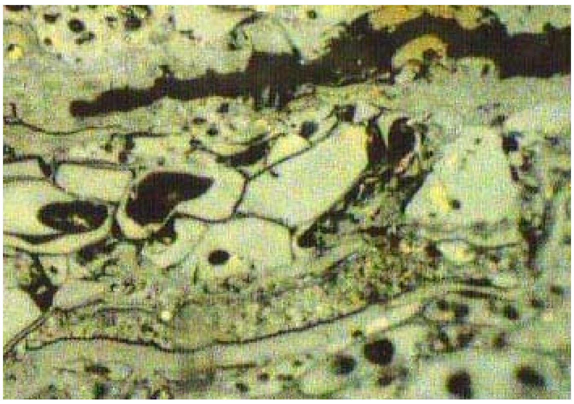

Figure 7b. As Figure 7a, but in reflected white light.

Mineral content in the coals ranges commonly from 1.1% to 9.2% (average of 5.2%) with the exemption of 2 coal samples that contain 20.1% and 45.7%. Clay minerals and quartz are the most common mineral in samples in the Asem-Asem Basin. These minerals usually occur in partings, veins and nodules of different sizes, or are disseminated throughout the coals. Silicate mineral contents for the coals range from 0.8% to 8.6% with average of 4.5% (except for 2 samples, 16.1% and 45.7%). Pyrite is the most abundant sulphide ranging from 0.0% to 4.0% with average of 0.5%. It mostly fills cleavage partings, joints (cleats) and bedding planes. Calcite is the most common carbonate mineral varying from 0.0% to 0.2% with average of 0.1%. It occurs mainly as vein-like fracture fillings and as nodules scattered throughout the coal.

4.2. Coal rank

In this study, vitrinite reflectance measurements were taken from thirty-four samples (Table 2). The vitrinite reflectance data support the rank assessment that varies from brown coal (Rvmax of 0.25-0.40%) to subbituminous (Rvmax of 0.41-0.46%) according to the Australian classification, or lignite to subbituminous B as classified by ASTM. These coal ranks are also supported by calorific value (4,344-4,690 kcal/kg adb) and volatile matter (37.0-37.9% adb) data (Perusahaan Umum Tambang Batubara, 1990).

5. DISCUSSION

Petrographic 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 to the properties of other coals in different parts of the same seams, in different part of the same basin or coals in other basins.

The maceral compositions of the coals are remarkably consistent with those for Tertiary coals from other localities in Indonesia (Santoso and Daulay, 2005a,b; 2006a,b; 2007). Overall, the Asem-Asem 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

Table 2. Vitrinite reflectance data of the Asem-Asem coals

No	TELOVITRINITE (%)	DETROVITRINITE (%)	VITRODETRINITE (%)	RANGE (%)
1	0.33	0.32	0.32	0.28-0.39
2	0.35	0.33	0.35	0.29-0.43
3	0.34	0.32	0.33	0.29-0.40
4	0.35	0.36	0.36	0.31-0.41
5	0.34	0.34	0.34	0.30-0.40
6	0.32	0.33	0.32	0.29-0.36
7	0.38	0.36	0.37	0.30-0.44
8	0.34	0.33	0.33	0.25-0.39
9	0.35	0.33	0.34	0.28-0.45
10	0.37	0.35	0.36	0.31-0.41
11	0.36	0.34	0.35	0.32-0.42
12	0.30	0.29	0.30	0.26-0.35
13	0.37	0.36	0.36	0.31-0.42
14	0.35	0.33	0.34	0.28-0.39
15	0.36	0.36	0.36	0.31-0.41
16	0.37	0.36	0.37	0.30-0.42
17	0.35	0.36	0.36	0.32-0.39
18	0.35	0.35	0.35	0.31-0.39
19	0.36	0.37	0.36	0.31-0.44
20	0.35	0.36	0.35	0.33-0.41
21	0.34	0.33	0.34	0.30-0.39
22	0.35	0.34	0.34	0.30-0.40
23	0.40	0.35	0.35	0.29-0.40
24	0.34	0.32	0.34	0.30-0.40
25	0.40	0.40	0.40	0.35-0.44
26	0.41	0.41	0.41	0.38-0.46
27	0.34	0.34	0.34	0.30-0.38
28	0.37	0.36	0.36	0.31-0.40
29	0.36	0.36	0.36	0.29-0.43
30	0.36	0.37	0.36	0.32-0.42
31	0.40	0.40	0.40	0.32-0.43
32	0.39	0.37	0.38	0.30-0.41
33	0.36	0.37	0.37	0.32-0.40
34	0.40	0.40	0.40	0.34-0.44

all 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; Bustin *et al.,* 1983). Vitrinite-rich coal in some cases has a very low mineral content. Low ash is a characteristic of a many Tertiary coals and has been interpreted as indicating a high-moor origin.

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. 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 Miocene 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 (Cook and

Kantsler, 1982).

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 low mineral matter of the Asem-Asem coals indicates that the rate of subsidence is more rapid than that of accumulation of peat during the Miocene. The coal contain fewer mineral matter, particularly clays, characterises bright lithotype with abundant vitrinite.

Mean maximum vitrinite reflectance values (Rvmax) for the Miocene Asem-Asem coals vary from 0.26-0.46%. These values indicate brown coal to subbituminous rank. These coals have been subjected to normal regional coalification.

From a utilisation viewpoint, the most important feature of the Asem-Asem coals is the relatively low mineral contents (with the exception for few coals), particularly pyrite, suggesting that the coals will have a ready market both for domestic use and export, when the production is increased in the near future.

6. CONCLUDING REMARKS

This paper has completed a significant contribution to the understanding of the importance of organic petrology of the Miocene Asem-Asem coals in terms of type and rank. 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 than were present for the inertinite-rich, duller layers that were probably derived from peat that was exposed to an oxidising atmosphere above the water table.
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 low. This is a function of the environment of deposition of the peat.
d. The rank of the coals shows the range from brown coal to subbituminous. These ranks are subjected to normal regional coalification.
e. Due to the relatively low mineral content (except for few coals) , the coals are appropriate for its utilisation in coal-fired power plant.

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