CHARACTERISTICS OF SELECTED MANGKALIHAT COALS ACCORDING TO PETROGRAPHIC AND PROXIMATE ANALYSES

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ABSTRACT

A carbonate complex in the Mangkalihat area, East Kalimantan, has been selected for this study, because this area has some coal deposits associated with dominant limestone intercalated by thin claystone and sandstone. Commonly, most Indonesian coals were formed in fluvial and deltaic depositional environment. Accordingly, this study is interesting due to the depositional environment of the coals in association with a marine condition. This environment mostly results in relatively high mineral matter and sulphur contents, particularly pyrite in this study; brighter lithotype and dominant vitrinite content over liptinite and inertinite. The geologic factors have clearly proven a good correlation among the results of megascopic, microscopic and proximate analyses. The coals with brighter lithotype, high vitrinite and moisture contents were formed under a wetter marsh environment. On the other hand, the duller lithotypes with the presence of inertinite and mineral matter were deposited in a dryer marsh environment. The presence of high pyrite and sulphur contents strongly indicates a marine incursion during the coal forming in this area.

Keywords: type, rank, coal characteristic, depositional environment

INTRODUCTION

Generally, most of Indonesian coals (particularly in Sumatera and Kalimantan) occurred in Tertiary sedimentary basins (Thomas, 2002; Miller, 2005; Geological Agency, 2009; Sukhyar, 2009; Belkin *et.al.*, 2009), where coal-bearing strata are very commonly observed without the presence of carbonate rock (limestone). In this study, coal deposits do not relate to the occurrence, because they are found in Tertiary carbonate complex situating in the Mangkalihat High, East Kalimantan, in which this area is located between two prospective coal-producing basins that are the Tarakan Basin in the north and the Kutai Basin in the south formed under fluvio-deltaic depositional environment (Santoso and Daulay, 2005a, 2005b; Belkin *et.al.*, 2009). Therefore, it is very interesting to study the deposits in terms particularly of type and rank of the coals and proximate analysis, in which the coals were deposited in a shallow marine (Djamal *et.al*., 1995). According to Diessel (1992; 2010) and Ward (2002), coal formed in this depositional environment is rich in pyrite content. The aims of the study are:

a. To examine coal type and rank variations;
b. To determine mineral matter;
c. To interpret relationship between coal type and rank variations and geological setting; and
d. To carry out proximate analysis.

To achieve the above objectives, petrographic and proximate analyses of the coals were included in this study.

METHODOLOGY

Ten coal samples from the Mangkalihat area were analysed for the study. The sampling was in accordance with the ASTM (2009). The samples were prepared as polished particulate coal mounts and analysed using incident white light and fluorescence mode microscopy. Meanwhile, the coal petrographic terms and the classification used follow the ASTM (2009) as well.

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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 ASTM (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 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.

Those coal samples were also analysed for proximate (moisture, ash, volatile matter and fixed carbon), calorific value and sulphur content (ASTM, 2009). Total sulphur was determined by burning a weighed sample in a tube furnace at a minimum operating temperature of 1,350°C in stream oxygen (ASTM, 2002). Gross calorific value of coal (ASTM, 2009) is the heat produced by complete combustion of a substance at constant volume with all water formed condensed to liquid. It was determined by burning a specified mass of benzoic acid in oxygen. A comparable amount of the analyses sample was burned under the same conditions in the calorimeter. The calorific value of the analyses sample was computed by multiplying the corrected temperature rise, adjusted for extraneous heat effects, by the heat capacity and dividing by the mass of the sample.

GEOLOGIC SETTING

The studied area is located in the Mangkalihat High, East Kalimantan Province, which is bounded to the north by the Tarakan Basin; to the south by the Kutai Basin; to the west by the turbiditic sediments; and to the east by the North Makassar Strait Basin (Figure 1; Djamal *et.al.*, 1995; Darman and Sidi, 2000; Geological Agency, 2009).

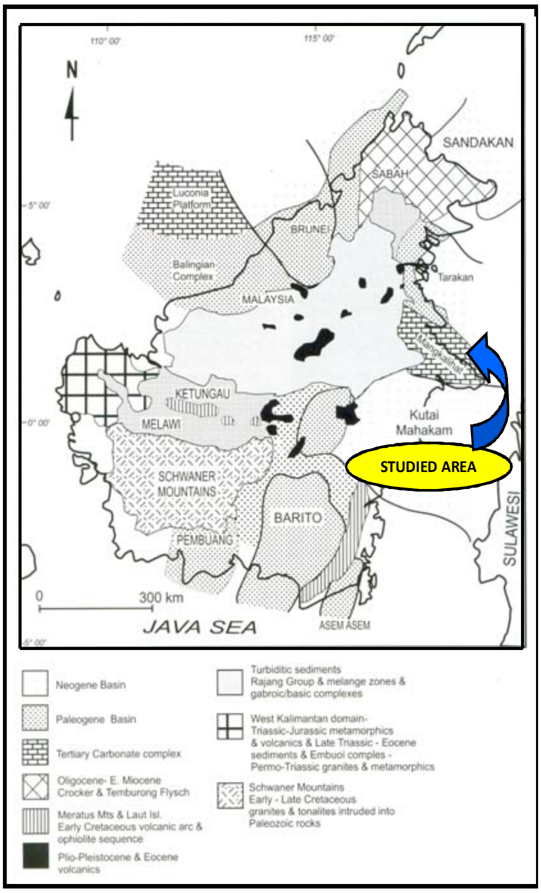


Figure 1. Tectonic setting of Kalimantan (Djamal *et. al*, 1995; Darman and Sidi, 2000; Geological Agency, 2009)

The oldest rock in the Mangkalihat area is represented by the Cretaceous sandy-limestone. This rock is unconformably covered by the Eocene Kuaro Formation, which consists of shale, sandstone, conglomerate, mudstone, breccia, marl and limestone intercalated by coal seams. This formation was formed under a shallow marine environment, with a thickness of 600 m (Djamal *et.al.,* 1995). Then, this formation was conformably underlain by the Oligocene Tabalar Formation that was mainly dominated by limestone and was deposited in a marine environment. The formation has a thickness of 2,000 m (Figure 2).

The coal deposits of the Kuaro Formation comprise 3 seams, namely seam A (1.5 m, upper part), seam B (4.0 m, middle part) and seam C (1.5 m, lower part). These coal seams are illustrated in Figures 3a, 3b and 3c.

AGE	FORMATION	LITHOLOGY	DEPOSITIONAL ENVIRONMENT
Oligocene	Tabalar	Limestone	Shallow marine
Eocene	Kuaro	Shale, sandstone, conglomerate, mudstone, breccia, marl and limestone with intercalation of **3 coal seams: A** (upper)**, B** (middle) and **C** (lower part)	Shallow marine
Cretaceous	Pre-Tertiary Sediment	Sandy-limestone	-

Figure 2. Stratigraphy of the studied area (simplified from Djamal *et.al.*, 1995)

Figure 3. The coal deposits in the studied area, mostly dominated by the bright coal
a. Seam A (1.5 m), dipping 23° to northeast
b. Seam B (4.0 m), dipping 28º to northeast
c. Seam C (1.5 m), dipping 25° to northeast

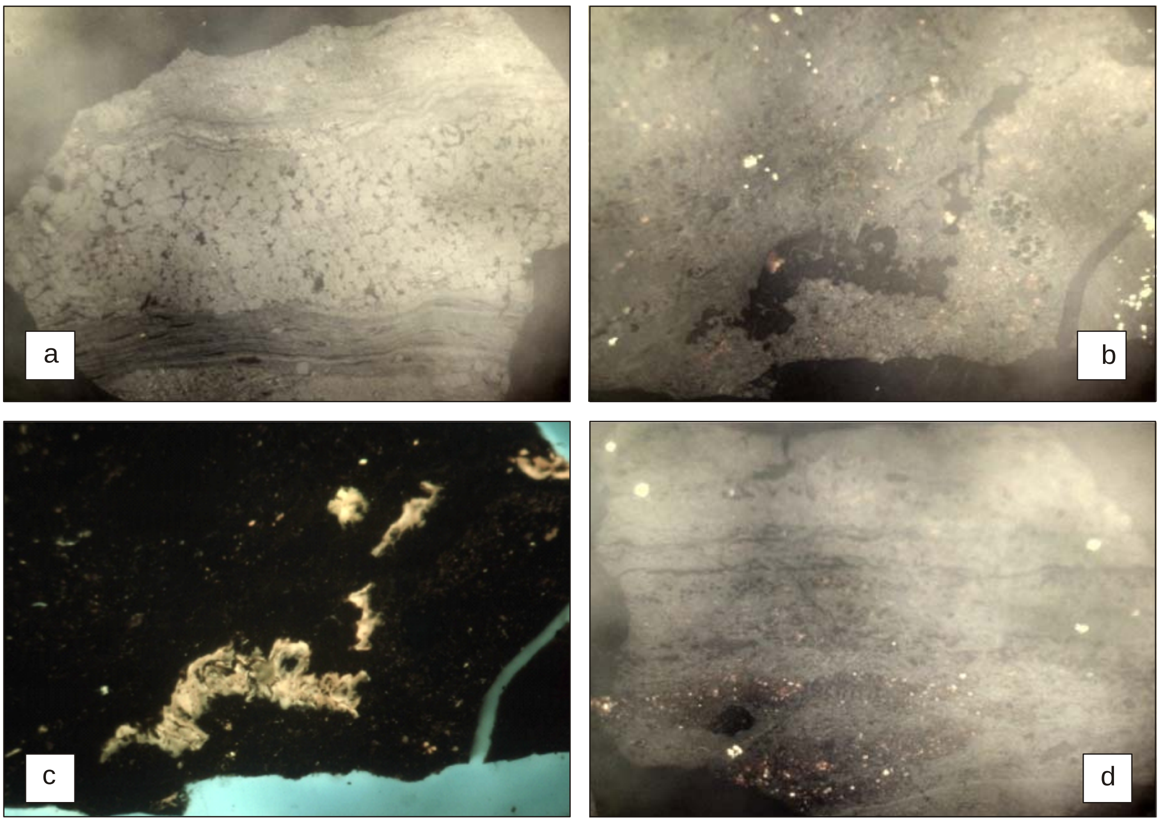
RESULTS AND DISCUSSION

According to the field observation in the studied area, the coal seams are found and they distribute from southeast to northwest. Seam A locates at the upper part of the stratigraphic sequence, followed by seam B, and seam C at the lower part. Megascopically, lithotype of all the coals is mainly dominated by bright banded-bright coal with minor dull coal. Maceral analysis and vitrinite reflectance of the coals is presented in Table 1. It shows that the vitrinite maceral group (71.0-87.6%) is absolutely dominant in the Mangkalihat coals, followed by minor liptinite (3.6-9.0%), inertinite (3.0-8.2%) and mineral matter (2.2-16.2%) as shown in Figure 4.

Table 1. Maceral analysis and vitrinite reflectance [RV_{max}(%)] of the coals

SAMPLES	VITRINITE (%)				INERTINITE (%)				LIPTINITE (%)				MINERAL MATTER (%)				Rv_{max} (%)	RANK (ASTM, 2009)
	telo	detro	gelo	total	sf	sc	int	total	spo	cut	res	total	q	py	cl	total		
1	21	58.6	4.4	84	1.8	6	0.4	8.2	0	3.4	1.4	4.8	0	2.6	0.4	3	0.46	Sub.bit. B
2	9.6	69	2	80.6	0	3	0	3	0.4	3	3.4	6.8	0	8	1	9	0.46	Sub.bit. B
3	28.4	59	0	87.4	0	3.8	0	3.8	0.4	1.2	2	3.6	0	4.6	0.6	5.2	0.48	Sub.bit. A
4	25.8	44	1.2	71	0	3.6	0.4	4	1.6	0.6	6.6	8.8	0	4.6	11.6	16.2	0.46	Sub.bit. B
5	22.8	59	0.2	82	0	4.6	0.2	4.8	1.6	2	3	6.6	0	5.2	1.4	6.6	0.46	Sub.bit. B
6	23.2	60.6	0.8	84.6	0	3	0.8	3.8	0.6	2	2.6	5.2	0	4.8	1.4	6.2	0.46	Sub.bit. B
7	14	71	2.6	87.6	0.2	2.8	0	3	0	4	1.6	5.6	0	2.8	1	3.8	0.46	Sub.bit. B
8	8.2	73.8	0.8	82.8	0.4	5	0.6	6	1.8	1.6	5.6	9	0	1.6	0.6	2.2	0.46	Sub.bit. B
9	18.8	61.8	1	81.6	0.4	3.4	0.4	4.2	2	1.8	3.8	7.6	1.8	3.2	1.2	6.2	0.49	Sub.bit. A
10	12.4	70	3	85.4	1	2	0.4	3.4	0	3.4	4	7.4	0	3.8	0	3.8	0.48	Sub.bit. A

Notes : telo: telovitrinite; detro: detrovitrinite; gelo: gelovitrinite; sf: semifusinite; sc: sclerotinite; int: inertodetrinite; spo: sporinite; cut: cutinite; res: resinite; q: quartz; py: pyrite; cl: clay; Sub.bit.: subbituminous.



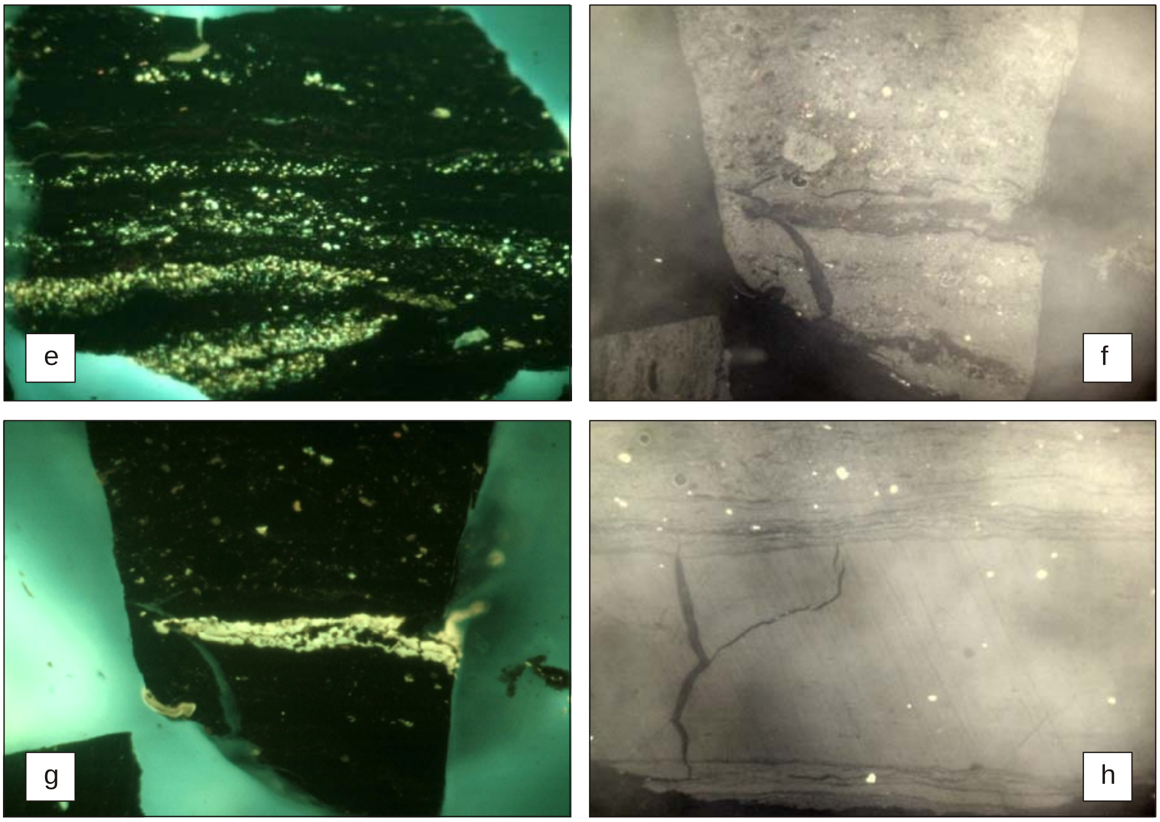


Figure 4. Macerals and mineral matter of the coals

a. Gelovitrinite (rounded) in association with detrovitrinite (reflected light, oil immersion, x200)
b. Detrovitrinite (grey), suberinite (black), sclerotinite (rounded, white) and pyrite (yellow) (reflected light, oil immersion, x200)
c. Same section after blue-light excitation, suberinite displays yellowish fluorescence colour.
d. Detrovitrinite (grey) associated with resinite and liptodetrinite (dark grey) as well as pyrite (yellow) (reflected light, oil immersion, x200)
e. Same section after blue-light excitation, suberinite (rounded) and liptodetrinite (fragmented) display yellowish fluorescence colour
f. Detrovitrinite (grey), suberinite (dark grey), sporinite (blackish grey) and inertodetrinite (white) (reflected light, oil immersion, x200)
g. Same section after blue-light excitation, suberinite and sporinite display yellowish and brownish-yellow fluorescence colours, respectively
h. Telovitrinite (below), detrovitrinite (above) and pyrite (yellow) (reflected light, oil immersion, x200)
i. Detrovitrinite (grey), resinite (blackish-grey) and pyrite (yellow) (reflected light, oil immersion, x200)
j. Same section after blue-light excitation, resinite display yellowish fluorescence colour
k. Pyrite (yellow) in detrovitrinite (blackish-grey) (reflected light, oil immersion, x200)
l. Detrovitrinite (grey), semifusinite (white) and pyrite (yellow) (reflected light, oil immersion, x200)

Total analyses of the coals are shown in Table 2. The coals have moisture content of 15.8-18.6% (adb), ash of 2.1-6.3% (adb), volatile matter of 38.4-44.0% (adb), fixed carbon of 35.0-39.0% (adb), total sulphur of 1.0-2.6% (adb) and calorific value of 4,980-5,553 cal/gr (adb). According to ASTM (2009), the coals are classified as subbituminous B and A. This is in accordance with the rank of the coals based on reflectance of vitrinite (ASTM, 2009).

According to the lithotype of the coals, it can be interpreted that the coals were formed in a wet and reducing condition. On the other hand, the dull coal was deposited under a dry and oxidised condition. These phenomena support Diessel's (1992; 2010) statement for the coal in the same environment. Djamal *et.al.* (1995) mentioned that the sedimentary rocks (mostly limestone with minor claystone, shale, fine-grained sandstone and coals) in the Mangkalihat area were deposited in a shallow marine. The thin minor sedimentary rocks are interpreted to be present as a result of paralic environment; the claystone and the shale derived from marine, whilst the sandstone was from shoreline. In addition, these sediments resulted from slowly subsiding and uplifting conditions. The coals were also deposited and influenced by a marine incursion. The presence of abundant pyrite in the coals also strengthens this evidence due to the marine depositional environment that entered the coal-forming marsh during its deposition (Diessel, 1992; Ward, 2002). Additionally, all the coals are intercalated by very thin claystone and sandstone (about 2 mm thick). This means that during the coal forming, a tidal activity took place and inundated the coal-producing marsh. When the ebb-tide occurred, the coal forming took place again. From this statement, it can be seen that there is a correlation between the depositional environment and the lithotype, where the marine incursion inundated and firmly united with the wet coal-forming marsh. It can also be stated that the wet condition due to subsidence and marine incursion resulted in the bright coal lithotype; otherwise, the dry condition due to uplifting yielded the dull coal lithotype. The presence of high mineral matter content (9% and 16.2%) in the coals also resulted in the dull lithotype content (Diessel, 1992; Ward, 2002).

According to Diessel (1992; 2010) and Thomas (2009), the vitrinite and liptinite groups with minor mineral matter were formed in a wet marsh environment. Otherwise, the inertinite group was deposited under a dry marsh condition. Therefore, it is very clear that all the coals were deposited beneath the marsh water table that underwent fluctuation condition with the dominant tide rather than the ebb condition. The presence of high pyrite and high sulphur content in the coals (as shown in the proximate analysis in Table 2) also provides a significant meaning in interpreting the depositional environment, that is the marine influence entering the coal-forming marsh. Therefore, this can also be stated that there is a good correlation among the marsh condition, lithotype and maceral content. The wet marsh condition resulted in the bright lithotype with high vitrinite and liptinite contents. On the other hand, the dry marsh condition produced the dull lithotype with high inertinite content. Regarding the rank of the coals, there is no relationship with the lithotype and the maceral content. All the coals are subbituminous A and B according to the ASTM classification (ASTM, 2009).

Based on the above phenomena, the Mangkalihat coals can be determined according to relationship among lithotype, maceral and proximate analysis follows:

All the coals are commonly dominated by the bright lithotype with the vitrinite content of >80%, mineral matter content (mostly pyrite) of >1%, sulphur content of >1% (adb) and the moisture content of >15% (adb). This indicates that the coals were formed under a wet marsh environment. This also illustrates that there is a good relationship among the lithotype, maceral and moisture content, in which the higher the bright lithotype and the vitrinite content, the higher the moisture content of the coals. In addition, the coals with the presence of a few dull lithotype contain vitrinite content of <80%. This indicates that they were formed in a fluctuating wet and dry marsh condition.

Table 2. Total analyses of the coals

SAM PLES	MOISTURE IN AIR DRIED SAMPLE %, adb	ASH %, adb	VOLATILE MATTER %, adb	FIXED CARBON %, adb	TOTAL SULPHUR %, adb	CALORIFIC VALUE cal/gr, adb
1	17.4	2.8	40.8	39	2.1	5,322
2	15.8	5.1	42.2	36.9	1.4	5,432
3	16.2	2.1	44	37.7	1.9	5,522
4	18.6	6.3	38.4	36.8	2.6	4,980
5	18.7	6.1	40.1	35	1.8	5,232
6	17.8	5.8	39.8	36.6	3.5	5,185
7	18.1	6.2	41.6	34.1	1.4	5,241
8	16.1	5.8	41.7	36.4	1	5,421
9	15.8	4.3	43.5	36.4	1.6	5,553
10	16.9	3.9	43	36.2	1.4	5,521

The coals are associated with claystone and sandstone. This shows that they were formed under a fluctuating water condition. The coals having high mineral matter (mostly pyrite) and sulphur contents indicate that they were formed and influenced by the marine incursion (Diessel, 1992; 2010).

CONCLUSIONS

The coals in the studied area was observed and investigated in terms of lithotype, petrographic and proximate analyses. The results of the study indicate that most of the coals are mainly dominated by bright lithotype with minor dull lithotype; dominant vitrinite content (71.0-87.6%) over liptinite (3.6-9.0%) and inertinite (3.0-8.2%) contents, relatively high mineral matter (2.2-16.2%) content (particularly pyrite); subbituminous A and B (ASTM, 2009). The proximate analysis shows relatively high moisture (15.8-18.7%, adb), ash (2.1-6.3%, adb) and sulphur (1.0-3.5%, adb) contents and relatively low calorific value (4,980-5,553 cal/gr, adb). Interestingly, there is a good correlation among the marsh condition, the contents of lithotype, maceral and moisture. The relatively wet marsh condition resulted in the coals with bright lithotype, which contains relatively high vitrinite (87.6%) and high moisture (18.1%, adb) contents. Otherwise, the relatively dry marsh environment is associated with the dull lithotype showing relatively low vitrinite (80.6%) and moisture (15.8%, adb) contents. Regarding the rank of the coals, there is no relationship between the lithotype and the maceral contents. The coals are subbituminous A and B according to the ASTM (2009).

The carbonate complex in Indonesia proves that this depositional environment can result in coals with specific phenomena such as the presence of the high vitrinite content associated with the bright lithotype; the low vitrinite content in association with the dull lithotype.

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