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PETROGRAPHIC STUDY ON GENESIS OF SELECTED INERTINITE-RICH COALS FROM JAMBI SUBBASIN

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ABSTRACT

Genesis of the coal macerals in the studied area depends particularly on the tectonic and geologic setting. The coals formed in the Jambi Subbasin, which is the back-arc basin associated with the fluvial to deltaic environment results in both rich in vitrinite and inertinite contents. The vitrinite content is associated with the bright lithotype deposited in the wet-swampy area; whereas the inertinite is associated with the dull lithotype deposited in the dry-swampy area. The presence of mineral matter causes the dull lithotype as well. The presence of the liptinite maceral cannot be correlated with the lithotypes. This maceral composition is the extreme phenomenon, because most of the Sumateran coals contain very low inertinite content (<5%) with very high vitrinite content (>80%). The coals contain low ash and low (0.1-0.4%) to medium sulphur (1.3-1.6%) contents. The above evidence is the answer of the extreme evidence, and this is the objective of presenting this paper.

Methods applied in this study include in-situ coal sampling for microscopic analyses, which are petrographic determination and reflectance examination. The samples were also analysed for their proximate according to ASTM (2002).

Keywords: coal, inertinite, Jambi Subbasin, petrographic analysis

INTRODUCTION

According to Teichmüller (1990), the genesis of various inertinites probably become an increasingly important subject of research from the view point of coal geology. Moreover, the origin of various coal facies in terms of maceral association is considered in relation to the palaeogeographically depositional environments in terms of peat-forming vegetation, palaeoclimate, marine influence and so forth. Vegetation, water and oxygen supply are the most important factor for the formation of coal facies.

Based on the above statements, the coals from the back-arc Tertiary Jambi Subbasin were selected for this study, because they produced various maceral compositions, particularly the presence of the relatively high inertinite and vitrinite contents over liptinite and mineral matter.

Most Sumateran coals are absolutely low in inertinite content. The Bukit Asam (South Sumatera) and Ombilin (West Sumatera) coals contain less than 5% of inertinite content (Santoso and Daulay, 2007; Daulay and Santoso, 2008; Belkin *et al.*, 2009). Interestingly, Heryanto (2006) stated that the coal deposits in the Jambi Subbasin were formed under a variety of depositional environments. This suggests further investigation in terms of petrographic studies to prove the evidence.

The objectives of this study include as follows:
- Making of maceral analyses in terms of vitrinite, inertinite, liptinite and mineral matter.
- Examination of relation of maceral composition to geologic setting (particularly the depositional environment).
- Contribution of the data of maceral composition to the coal references.

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In order to achieve those objectives, analyses of coalfield in Tebo-Jambi are included in this study.

METHODOLOGY

Six (6) samples studied were obtained from the Jambi Subbasin. The sampling was based on the procedure of the ASTM D 2797-99 (Annual Book of ASTM Standards, 2002). The core samples were collected through the entire thickness of the outcrop of the seams. They were taken to examine reflectance and petrographic determination of the coals showing distinctive compositional features.

The method of preparation of polished particulate coals for microscopic analysis was carried out through crushing, embedding, grinding and polishing. All the samples examined were conducted in the coal laboratory of R and D Centre for Mineral and Coal Technology.

All samples were examined in both reflected white light and reflected ultraviolet light excitation. Maceral analyses were determined in oil immersion in reflected plane polarised light at a magnification of x200. Polarised light was essential for the examination of thermally altered samples. The liptinite group of macerals was studied using ultraviolet light excitation at a magnification of x200. Fluorescence examination was carried out using a Carl Zeiss microscope photometer. This system provides a combination of acceptable intensities, adequate colour separation of components and ease of switching from reflected white light to fluorescence mode (Cook, 1980). An microscope photometer fitted with a camera was used for all photography.

Reflectance measurements were carried out using a Carl Zeiss microscope fitted with a Carl Zeiss MPV 21 microscope photometer. The microphotometer was calibrated against synthetic garnet standards of 0.917% and 1.726% reflectance and a synthetic spinel of 0.413% reflectance. A galvanometer was set to provide a reading of one half the reflectance multiplied by 100. Reflectance measurements were made using incident light of 546 nm wavelength and oil immersion of refractive index 1.518 at room temperature of 23°±1°C (Cook, 1982).

The samples were also analyzed for proximate (moisture, ash, volatile matter and fixed carbon), calorific value and sulfur content. Moisture is determined by establishing the loss in weight of the sample when heated in drying oven under 104 to 110°C for 1 hour. Ash is determined by weighing the residue remaining after burning the coal in the electric muffle furnace under 700 to 750°C for 4 hour. Volatile matter is determined by establishing the loss in weight resulting from heating a coal at a temperature of 950 ± 20°C. After heating for a total of exactly 7 minutes, the crucible from the furnace was removed without disturbing the cover, allow it to cool. Coke should be cooled in a desiccator, and weigh as soon as cold. The percentage loss of weight minus the percentage moisture equals the volatile matter. The measured weight loss, corrected for moisture content. The fixed carbon is the resultant of the summation of percentage moisture, ash and volatile matter subtracted from 100. All percentages shall be on the same moisture reference base. Fixed carbon (%) = 100 – (moisture, % + ash,% + volatile matter,%) (ASTM D 3173-75).

Total sulphur was determined by burning a weighed sample in a tube furnace at a minimum operating temperature of 1,350°C in a stream oxygen. During combustion, all sulphur contained in the sample is oxidized to gaseous oxides of sulphur. These products are then absorbed into a solution of hydrogen peroxide (H_2O_2) forming dilute solutions of sulphuric H_2SO_4 and hydrochloric acid (HCl). The quantities of both acids produced are dependent upon the amounts of sulphur present in the coal sample (ASTM D 4139-02). Gross calorific value of coal (ASTM D 5865-02) is the heat produced by complete combustion of a substance at constant volume with all water formed condensed to a liquid. It is determined by burning a specified mass of benzoic acid in oxygen. A comparable amount of the analyses sample is burned under the same conditions in the calorimeter. The calorific value of the analyses sample is computed by multiplying the corrected temperature rise, adjusted for extraneous heat effects, by the heat capacity and dividing by the mass of the sample.

GEOLOGY

The Jambi Subbasin is a part of the South Sumatera Basin, a Tertiary back-arc basin formed by the collision between the Sundaland and Indian Plate (Halik and Wu, 1994; Darman and Sidi, 2000), as illustrated in Figure 1. The subbasin is situated to the east of the Barisan Mountains and extends into the offshore areas to the northeast. It was formed during east-west extension at the end of the pre-Tertiary to the beginning of the Tertiary age (Daly *et al.,* 1991). The coals were significantly formed in the Talangakar Formation, which was deposited in the unstable and moveable subbasin and was formed by block faulting resulting in horst and graben (Heryanto, 2006).

Stratigraphic sequence of the subbasin (Figure 2) is commenced by the Eocene-Oligocene Lahat Formation consisting of sandstone, siltstone, claystone and conglomerate, which are unconformably laid on the pre-Tertiary rock with fluvio-lacustrine environment. This formation is covered unconformably by the Talangakar Formation comprising sandstone and claystone

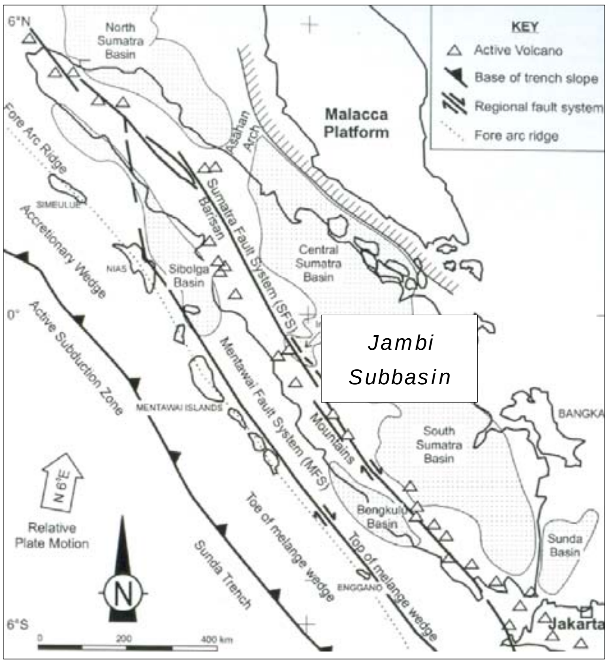

Figure 1. Locality map of the studied area in the Jambi Subbasin (modified from Darman and Sidi, 2000)

AGE			FORMATION
TERTIARY	Pliocene		Kansai
	Miocene	Late	Muaraenim
		Middle	Air Benakat
		Early	Gumai
	Oligocene		Talangakar
	Eocene		Lahat

Figure 2. Stratigraphy of the Jambi Subbasin (modified from Pertamina 1992; Heryanto 2006)

interbedded conglomerate and coal, which is deposited in fluvial-shallow marine environment in Oligo-Miocene age. Then, this formation is conformably covered by the Early-Middle Miocene Gumai Formation including claystone and shale with interbeds of glauconitic sandstone and limestone, which are deposited in shallow-deep marine that is the peak of transgressive process. Regressive process took place in the area with the deposition of the Airbenakat Formation consisting of claystone with interbed of glauconitic sandstone. This formation is conformably deposited over the Gumai Formation in shallow marine environment in Middle-Late Miocene. Next, the Muaraenim Formation including sandstone, sandy claystone and claystone inbedded with coal covers conformably the Air Benakat Formation that is deposited in shallow marine-fluvial environment in Late Miocene-Pliocene age. The Plio-Pleistocene Kasai Formation consisting of tuff and tuffaceous is conformably formed over the Muaraenim Formation in terrestrial environment (Heryanto, 2006).

In the studied area, coal deposits are found in the Talangakar Formation. Megascopically, the coals are dull to bright lithotypes with various thicknesses from 25 cm to 100 cm (Figure 3). These coals are frequently found as interbeds within carbonaceous claystone.

Figure 3. Outcrop of coal seam of 1 m thick in the studied area showing bright and dull lithotypes

RESULT

Six coal samples were obtained from the studied area and analysed in the coal laboratory of R&D Centre for Mineral and Coal Technology-Bandung. The results are presented in Tables 1 and 2.

Megascopically, the coals consist of intercalation between bright and dull lithotypes with various thicknesses from 5 cm to 30 cm. Most of the coals are underlied by carbonaceous claystone and claystone, and are covered by claystone and sandstone. Table 1 shows microscopic results in which the coals are dominant in vitrinite (56.6-77.2%) content, followed by inertinite (17.2-36.0%) with minor mineral matter (0.4-8.8%) contents, as shown in Figures 4, 5, 6, 7 and 8. The vitrinite content indicates dominance of telocollinite, telovitrinite, desmocollinite and detrovitrinite over densinite, corpogelinite and gelovitrinite. The inertinite content is dominated by semifusinite and sclerotinite, followed by inertodetrinite and minor fusinite. Resinite is the dominant maceral in the coals. Cutinite, liptodetrinite and alginate are present in low amount. Mineral matter content is dominated by pyrite and clay mineral with minor carbonate.

Vitrinite reflectance (Rvmax%) values of the coals vary from 0.45-0.47%. This indicates that the rank of the coals is subbituminous according to the Australian classification, or subbituminous B of the ASTM classification.

Table 2 indicates that the coals contain free moisture of 27.4-40.6% ar, total moisture of 46.1-55.3% ar, moisture in air-dried sample of 19.6-26.0% adb, ash of 1.2-7.6% adb, volatile matter 37.6-40.5% adb, fixed carbon of 32.5-38.2% adb, calorific value of 4,980-5,279 cal/g adb and total sulphur of 0.1-1.6% adb. The sulphur content of <1% is categorised as low, whilst of >1% to <3% is medium, and of >3% is high (Chou, 1990). Therefore, the sulphur in the coals is categorised as low to medium.

Table 1. Maceral analysis of the coals

Sample	Vitrinite (%)	Inertinite (%)	Liptinite (%)	Mineral Matter (%)	Rv_{max} (%)
1	62.4	21.4	7.4	8.8	0.47
2	56.6	36	3.8	3.6	0.46
3	67.6	20	7.4	5	0.45
4	76.4	17.2	2.4	4	0.46
5	77.2	21	1.4	0.4	0.46
6	74.4	18.2	1	6.4	0.46

Table 2. Total analysis of the coals

Sample	Free Moisture (% ar)	Total Moisture (% ar)	Moisture in Air Dride Sample (% adb)	Ash (% adb)	Volatile Matter (% adb)	Fixed Carbon (% adb)	Calorific Value (Cal/gr, adb)	Total Sulphur (% adb)
1	36	49.1	20.5	2.4	40.5	36.6	5,138	1.6
2	33.2	46.3	19.6	2.6	39.6	38.2	5,279	1.3
3	27.4	46.1	25.7	1.2	38.8	34.3	4,938	0.2
4	32.5	48.9	24.4	5.2	37.9	32.5	4,611	0.4
5	39.7	55.3	26	2	37.6	34.4	4,713	0.1
6	40.6	53.4	21.5	7.6	38.1	32.8	4,283	0.3

Notes: ar-as received; adb-air dried basis

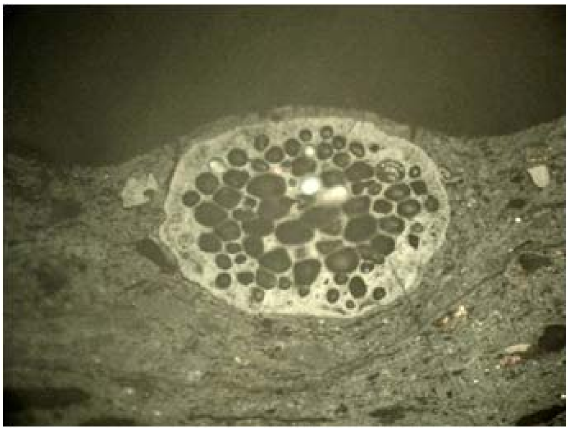

Figure 4. Vitrinite (grey) and inertinite (white). Rvmax: 0.46%, field width: , subbituminous, reflected-white light

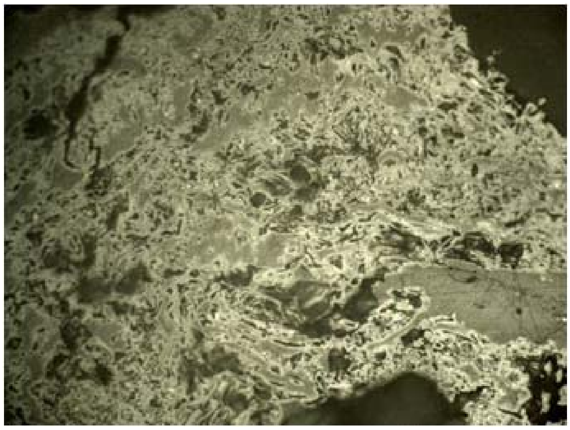

Figure 5. Semifusinite (white) and vitrinite (grey)

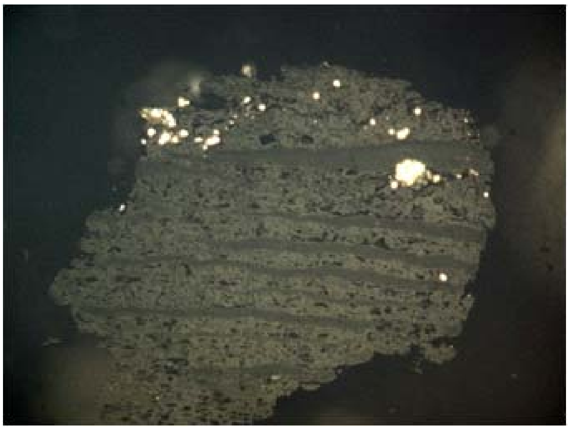

Figure 6. Intercalation between inertinite (white) and vitrinite (grey) with pyrite (yellow)

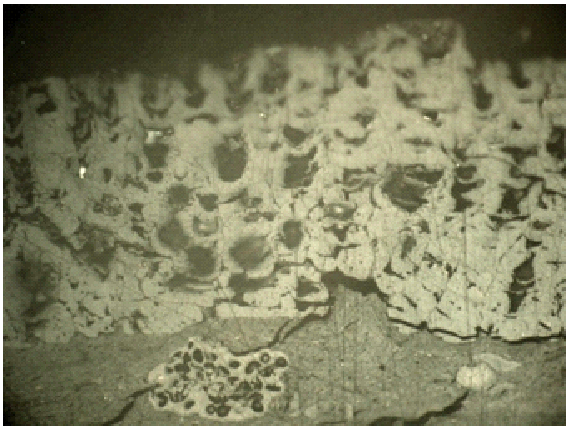

Figure 7. Inertinite (white) and vitrinite (grey)

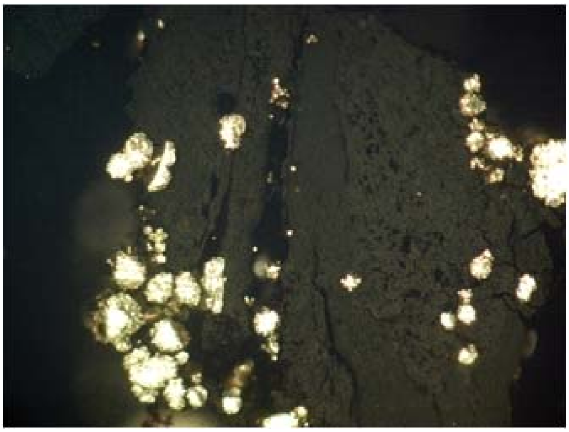

Figure 8. Framboidal pyrite (yellow) embedded in inetinite

DISCUSSION

The coals of the Talangakar Formation were formed in a Tertiary back-arc Jambi Subbasin in fluvial to deltaic environment (Heryanto, 2006). This coal-bearing formation was deposited during Late Oligocene-Middle Miocene. This formation is dominated by very coarse-grained sediments that characterise channel deposit at the lower part of this sequence. Mudstone with parallel lamination indicates flood plain condition. Coal deposits are also found and this suggests that they were deposited in peat swamp. At the middle part of the sequence, the environment changed to be a flood plain associated with swampy area. This is indicated by the presence of claystone with coal interbeds. At the upper part, the environment changed to be delta that is dominated by conglomeratic sandstone and claystone with parallel lamination.

It is presumed that tectonically and geologically, the back-arc basin results in thicker coal deposits rather than the fore-arc basin (Santoso and Daulay, 2007). The coals of the back-arc basin show the intercalation between the brighter and duller lithotypes due to the influence of the change of water table condition, which causes wet (bright lithotype) and dry (dull lithotype) swamp environments. Otherwise, the coals of the fore-arc basin are mainly dominated by wet swamp environment. Megascopically, the coals show intercalation between bright and dull lithotype. Microscopically, maceral of the coals is dominated by vitrinite and inertinite with low liptinite and mineral matter. The fluvial environment dominated by coarse-grained sediment in association with the dry-swamp condition results in the coals with duller lithotypes that are rich in inertinite content (Diessel, 1992). In addition, the presence of mineral matter is also associated with those duller lithotypes. On the other hand, the deltaic environment dominated fine-grained sediments in association with the wet-swamp condition is characterised by the brighter lithotypes that are rich in vitrinite content. The liptinite maceral has no correlation with the lithotypes. However, this maceral indicates dryer condition of the peat swamp during its deposition, and this resulted in duller lithotype. The minor carbonate found in the coals support the lack of influence of marine intrusion. This is in association with dryer condition of the peat swamp. This is indicated by the presence of the dominant low-sulphur coals that are associated with the parent plant material.

CONCLUSION

The coals from the back-arc Tertiary Jambi Subbasin accumulated in a variety of environments, ranging from fluvial (braided to meandering streams) to deltaic environments. These environments represent fluctuation of water table, which influences lithotypes and maceral composition of the coals. The dry water table resulted in duller lithotype and inertinite macerals; whilst the wet water table resulted in brighter lithotype.

A variety of inertinite macerals can be observed from semifusinite, sclerotinite, inertodetrinite and fusinite. Their optical characteristics and associations with determined depositional environments suggest a range of depositional conditions. The inertinite macerals are considered as a result from atmospheric oxidation. Various vitrinite macerals can also be observed from telocollinite, telovitrinite, desmocollinite, detrovitrinite, densinite, corpogelinite and gelovitrinite. The presence of these macerals indicate anaerobic condition. Trace alginite suggests that the coals were formed under dryer condition.

Their chemical properties show that coal is good characteristic as feedstock for coke making and coal liquefaction. In the coke making, the ash and sulphur content are of particular importance because if they increase in the coke, the productivity in the blast furnace declines. Sulphur has a serious effect on the quality of iron. Coal liquefaction process is a conversion of coal into liquid or gas by adding hydrogen to the coal. The conversion of coal is highly dependent on rank and composition of the feed coal. In general, the conversion increases with the increase in reactive (vitrinite and inertinite) macerals. Ash content has a serious effect on the product conversion; on the other hand sulphur contents used as catalyst in the coal liquefaction.

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