GEOLOGICAL INFLUENCE ON QUALITY OF SELECTED TERTIARY BARITO COAL

BINARKO SANTOSO AND BUKIN DAULAY
R & D Centre for Mineral and Coal Technology
Jalan Jenderal Sudirman 623 Bandung 40211
Ph. (022) 6030483-5, Fax. (022) 6003373, e-mail: binarkos@tekmira.esdm.go.id

ABSTRACT

Type and rank variation within Tertiary Barito coals of Tanjung Formation were analyzed by petrographic examination of ten coal samples. Vitrinite, common liptinite and rare inertinite and mi-neral matter dominate all the coals. Vitrinite macerals are dominated by detrovitrinite and telovitrinite. Resinite, cutinite and sporinite are the dominant liptinite macerals in the coals. Inertinite macerals in the coals comprise semifusinite, sclerotinite and inertodetrinite. Mineral matter consists mainly of clay and pyrite. Liptinite and inertinite contents within coals are systematically related to vitrinite content. The liptinite and inertinite contents decrease with increase of vitrinite content. The liptinite content is not related to the inertinite content. Vitrinite reflectance of Palaeogene coals ranges from 0.53% to 0.64% or sub-bituminous to high-volatile bituminous ranks, respectively, as classified by the Australian standards, and of the Neogene ones varies between 0.30% and 0.47%, classified as brown coal and sub-bituminous ranks, respectively. The slight change in vitrinite reflectance from the top to the base of the sequence is due to the thicker cover/overburden on the high rank coals. Similarities and differences in the type and rank of the coals reflect their geological setting.

Key words : type, rank, maceral, coal.

1. INTRODUCTION

Coal deposits are widely present within Barito Basin of South Kalimantan. Most coals have been mined since the Dutch colonialism (Sigit, 1980). Its resources are estimated around 2.7 billion tonnes (Arifin *et al.,* 2003). Coal petrology, in terms of type and rank, can contribute to an understanding of coal nature and helps determine its utilization potential. Unfortunately, there is no petrographic composition data of the Barito coals. Data of coal chemistry are limited and have been published (Roeslan, 1984). The chemistry data are useful to determine coals rank, because there is a good correlation between the proximate analyses and the rank.

The study is aimed to understand the aspects as follows: a. to determine type and rank characteristics of the coals by conducting maceral analyses and vitrinite reflectance measurements; and b. to examine the relation of type and rank to geological setting. To achieve the aims, analyses of major coalfields from South Kalimantan are included in the present study.

2. ANALYTICAL METHOD

Coal samples for this study were obtained from South Kalimantan coalfield. The procedures, preparation, terminology and technique used for the study are referald to the Australian Standards: AS CK5 code of recommended practice for taking samples from coal seams in situ; AS K 149 glossary of terms for coal and coke; AS 2061 code of practice for preparation of hard coal samples for microscopical examination by reflected light; AS 2486 microscopical determination of the reflectance of coal macerals; AS 2617 guide for taking of samples from hard coal seams insitu and AS 2856 coal maceral analysis. Ten coal samples from the area were prepared for petrographic examination according to the techniques developed in the coal petrographic laboratory at the Research and Development Centre for Mineral and Coal Technology, Bandung.

Microscopic examination of polished sections was undertaken using reflected light Leitz Orthoplan microscope fitted with a fluorescence mode. The microscope was fitted with oil immersion objectives of x32 and x50, and x10 eyepieces, connected to Swift Automatic Point counter for quantitative work. Using the same microscope with the aid of a mercury lamp and ultraviolet excitation, fluorescence mode examination was undertaken in conjunction with reflected light. Photomicrographs of macerals and mineral matter in the Barito coals were obtained using a Wild Leitz MPS 46 photo-automat camera fitted to the microscope.

Maceral analysis is based on counting of 500 points using the counter attached to the microscope. The maceral data are calculated as:

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

Measurements on vitrinite reflectance were carried out based on the Australian Standard AS 2486. A hundred measurement was obtained on each sample from which the mean random reflectance (Rvrnd) and the standard deviation were calculated. Additionally, a total of 30 measurements were taken on each sample from which the mean maximum reflectance (Rvmax) and the deviation were also calculated. In the present study, Rvmax was calculated from the mean of the 30 measurements of maximum reflectance on vitrinite of the coal samples.

3. GEOLOGY

Barito Basin is located along the Southeas- tern margin of the Sunda Shield in South Kalimantan (Satyana and Silitonga, 1993), (Figure 1). The basin is defined by the Meratus Mountains to the east, separated from Kutai Basin to the north. The basin has a narrow opening to the south towards the Java Sea. It is an asymmetric basin, forming a foredeep in the eastern part and a platform approaching the Schwaner or West Kalimantan Shield towards the west (Figure 2). The basin developed initially in the Late Cretaceous, following

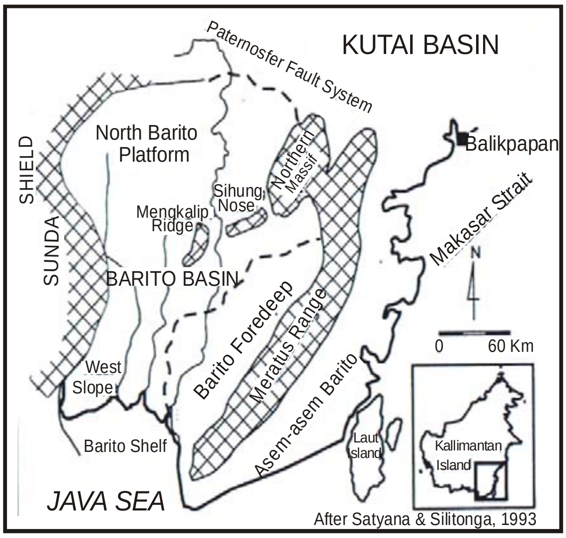

Figure 1. Tectonic framework of Barito Basin (Satyana and Silitonga, 1993)

a microcontinental collision between the Paternoster and Southwest Kalimantan microcontinents (Metcalfe, 1996; Satyana, 1996). Early Tertiary extensional deformation occurred as the tectonic consequence of the oblique convergence. It produced a series of northwest-southeast trending rifts that became accommodation space for alluvial fan and lacustrine sediments of the Lower Tanjung Formation.

In the earliest Middle Eocene, as the result of a marine transgression, the rift sediments became more fluviodeltaic and eventually marine. The transgression subsequently submerged the rifts in Late Eocene-earliest Oligocene, resulting in the deposition of marine shales of the Upper Tanjung Formation. The Late Oligocene is characterized by carbonates of Berai Formation, continued until Early Miocene. Clastic input resulted in the deposition of deltaic sediments of the Warukin Formation.

In the Late Miocene, the Meratus Range reemerged, followed by the subsidence of the basin. Sediments uplift was deposited in the subsiding basin, resulting in the deposition of thousands of metres of the Warukin Formation. The uplift of the range continued into the Pleistocene and resulted deltaic sediments of the Pliocene Dahor Formation. The structural and depositional regime still exists today. The western and southern parts of the basin were centrally tectonised and show

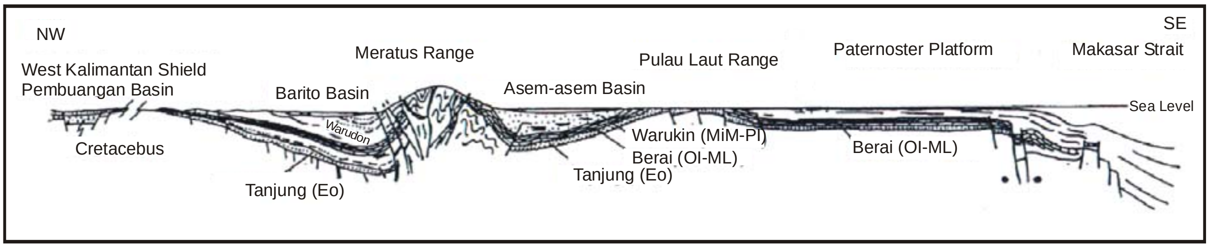

Figure 2. Barito Basin-Makassar Strait section (Satyana and Silitonga, 1993)

no deformation structure. The basin gives the best example of the effects of tectonic interaction on hydrocarbon habitat. Extensional tectonics in the Early Tertiary formed a rifted basin in which coals were deposited in graben areas.

Eocene Tanjung Formation, the oldest Tertiary sedimentary section in the Barito Basin (Figure 3), comprises sandstones, shales, conglomerates and coal seams. This formation was laid down in

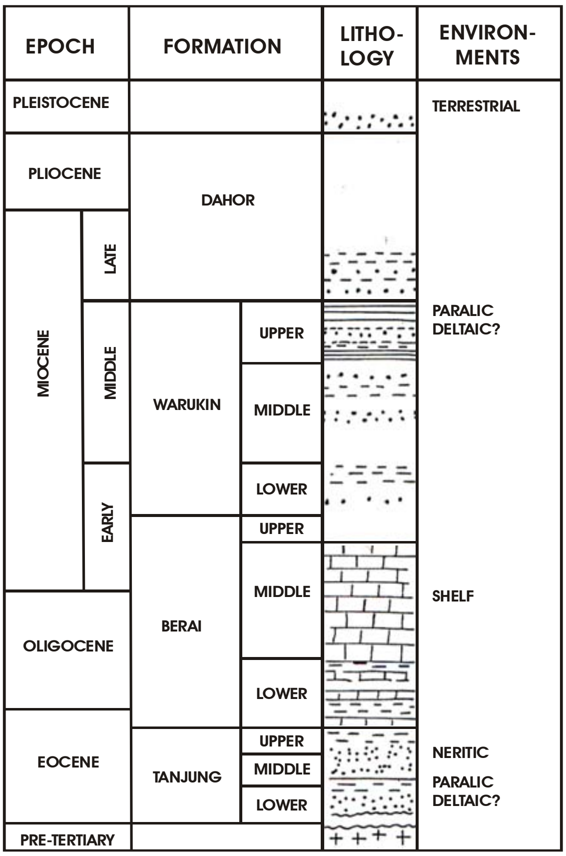

Figure 3. Stratigraphic column of Barito Basin (Siregar and Sunaryo, 1980)

fresh to brackish water and deltaic environments, with increasing marine influence in the younger sediments. Five coal seams are present and their average dip direction is 50° west of north, ranging from 15° to 70° west of north (Siregar and Sunaryo, 1980).

4. RESULTS

4.1 Coal type

Macroscopically, most of the Barito coals can be characterized as bright and bright-banded lithotypes. Analyses of macerals were carried out for 10 (ten) Tertiary (Palaeogene and Neogene) coal samples in selected South Kalimantan coalfields (Table 1). The coals are mainly dominated by vitrinite (Figure 4) with minor liptinite (Figure 5) and rare inertinite (Figure 6). The contents of vitrinite and inertinite slightly decrease from Neogene to Palaeogene coals. On the other hand, the contents of liptinite increase slightly from Neogene to Palaeogene coals. In the Palaeogene coals, liptinites fluoresce from yellow to orange, whereas the Neogene coals fluoresce from green to yellow. Sporinite is dominant in the Palaeogene coals, but is rare in the Neogene coals. In addition, exsudatinite and sporangia are present in some Palaeogene coals.

4.1.1 Palaeogene

Vitrinite is the main constituent within Palaeogene coals in South Kalimantan. The vitrinite content ranges between 72 and 94% with average of 83%. Liptinite constitutes from 3 to 19% with average of 12% and has yellow to orange fluorescence. Inertinite is rare, with a sample containing 6%. Mineral matter consisting of clay and pyrite is common, over 2%, in some samples.

Telovitrinite is present as thin isolated bands in

Table 1. Maceral composition of Barito coals maceral

Sample Number	Age	Vitrinite (%)			Inertinite (%)				Exinite (%)					Mineral Matter (%)
		TV	DV	GV	SF	Fus	Scl	Inert	Res	Cut	Sub	Spo	Lipt	
1	Neogene	29	50	8	tr	-	1	1	4	1	1	1	-	2
2		32	50	8	1	-	1	2	2	tr	2	1	-	1
3		26	52	10	2	1	1	1	1	3	tr	1	-	1
4	Palaeogene	41	42	7	tr	-	1	1	1	3	tr	1	tr	1
5		54	33	7	-	-	1	tr	1	1	tr	1	tr	2
6		28	49	9	tr	tr	tr	-	4	4	1	2	-	2
7		27	42	7	-	-	1	1	6	6	1	6	tr	3
8		28	46	10	1	-	1	1	2	5	2	1	tr	3
9		16	48	8	2	-	2	2	7	2	2	7	1	3
10		22	51	7	tr	-	2	1	4	5	1	2	tr	5

Note: TV: telovitrinite, DV: detrovitrinite, GV: gelovitrinite
SF : semifusinite, Fus : fusinite, Scl : sclerotinite, Inert : inertinite
Res : resinite, Cut : cutinite, Sub : suberinite, Spo : sporinite, Lipt : liptodetrinite
tr : trace

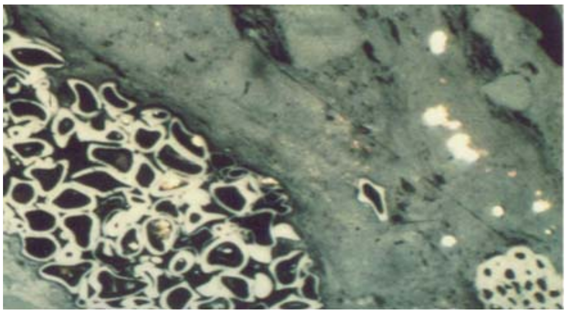

Figure 4. Telovitrinite (grey), sclerotinite (white) and pyrite (bright white), Rvmax: 0.47%, field width: 0.34 mm, reflected white light

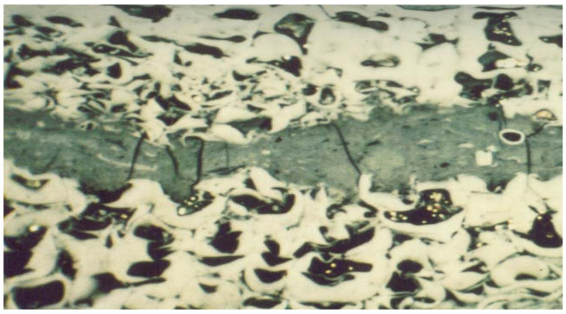

Figure 6. Semifusinite-rich coal (white) in association with detrovitrinite (grey), Rvmax: 0.46%, field width: 0.44 mm, reflected white light

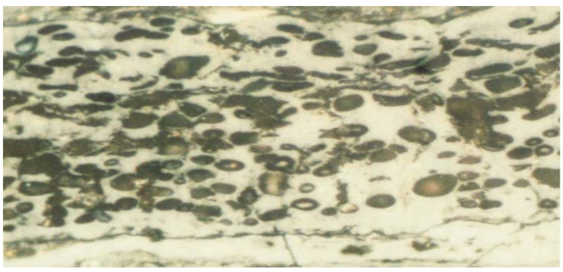

Figure 5. Resinite (black) infilling cell lumens in distinct layer with telovitrinite (grey), Rvmax: 0.46%, field width: 0.28 mm, reflected white light

thicker layers with a detrovitrinite matrix. Gelovitrinite that is mainly corpovitrinite and porigelinite is scattered throughout the coals. It is mostly associated with suberinite.

Liptinite of the Palaeogene coals is dominated by cutinite, sporinite and resinite, although suberinite and liptodetrinite are dominant in some occurrences. Exsudatinite and sporangia take place in some samples. Resinite constitutes over 7% and commonly occurs as rodlets and infilling cell lumens. It has yellow to orange fluorescence. Cutinite, weak yellow to orange fluorescence, constitutes up to 5% of some samples. It is present as thin cuticle. Sporinite is significantly high, up to 6%. It typically occurs evenly disseminated throughout the coals, although some sporinite rich lenses occur locally. It has yellow to orange fluorescence. Suberinite is present in most of the samples, but its content is less than 2%. It typically has weak yellow to orange fluorescence, but in some cases it does not fluoresce.

Semifusinite, sclerotinite and inertodetrinite are the dominant inertinite macerals, whilst fusinite and micrinite are only present in some samples. Sclerotinite constitutes from 1 to 2% and is mostly disseminated throughout the coals. Semifusinite usually forms thin layers in a detrovitrinite matrix. Inertodetrinite content ranges from a trace to 2%. It is evenly disseminated throughout the coals. Fusinite takes place as isolated lenses.

Mineral matter comprising clay and pyrite is significantly common in the Palaeogene coals. Its content ranges from 1 to 5%, with average of 3%. This mostly forms as pods disseminated throughout the coals.

In summary, the liptinite and inertinite contents of the Barito coals are systematically related to the vitrinite content. Their contents decrease with increases in vitrinite content. The liptinite content is not related to the inertinite content.

4.1.2 Neogene

Petrological study on the coal samples from the Barito Basin reveals that all samples have a high vitrinite content, common liptinite and rare inertinite. Mineral matter that is mainly clay and pyrite is present.

Vitrinite of the Neogene coals ranges from 87 to 90%, with average of 88%. It mostly occurs as thick layers with a detrovitrinite matrix interbedded with thin bands of telovitrinite. Thick massive telovitrinite is present with the detrovitrinite-dominated coal in some cases. Gelovitrinite consisting of corpovitrinite and porigelinite takes place as small discrete masses throughout the coals.

Liptinite of the coals varies between 5 and 7%, with average of 6%. Resinite, cutinite and suberinite are the dominant liptinite macerals, and sporinite, liptodetrinite and fluorinite are rare. Exsudatinite occurs in trace amounts in a few samples. Resinite content varies between 1 and 4%, with average of 2%. It mostly occurs as discrete small bodies that are less than 0.06 mm throughout the coals. Some resinite infilling cell lumens, occurs as distinct layers. The resinite has low reflectance and fluoresces greenish yellow to yellow. Cutinite comprising thick and thin-walled cuticles, constitutes between a trace to 3%. The cutinite has strong yellow to orange fluorescence. Suberinite that has weak yellow fluorescence, constitutes a trace to 2%. It is mostly associated with corpovitrinite. Sporinite is common in the coals (4%). It mostly takes place as dark lenses that show internal reflections. This has strong greenish yellow fluorescence.

Inertinite in the Neogene coals is rare, with few samples containing up to 5%. Inertodetrinite is the dominant inertinite maceral containing up to 2%. Semifusinite content varies from a trace to 2%, and it mostly occurs as thin layers or lenses isolated in detrovitrinite matrix. The semifusinite also occurs as thin to thick layers interbedded with thin bands of telovitrinite. Sclerotinite constitutes a trace to 1% and is usually scattered throughout the coals. Fusinite is trace.

To summarize, liptinite and inertinite contents are systematically related to vitrinite content. Both liptinite and inertinite contents decrease with the increase of the vitrinite content. The liptinite content is not related to inertinite content.

4.2 Coal rank

Vitrinite reflectance was conducted to 10 (ten) Palaeogene and Neogene Barito coals. In general, the coals ranks depends largely on the geological age, namely Palaeogene and Neogene. The Palaeogene coals are sub-bituminous to high-volatile bituminous rank, whereas the Neogene coals are brown coal to sub-bituminous rank. Generally, the lower rank of the Neogene is a major difference between Neogene and Palaeogene coals. Vitrinite reflectance increases from the top to the base of the Barito Basin sequence (Figure 7).

Proximate analyses of Kalimantan Palaeogene and Neogene coals reported by many authors (Bemmelen, 1970; Hardjono and Syarifuddin, 1983; Roeslan, 1984) indicate that with increasing age, the specific energy of the carbon content become higher, and the total moisture decreases (Table 2).

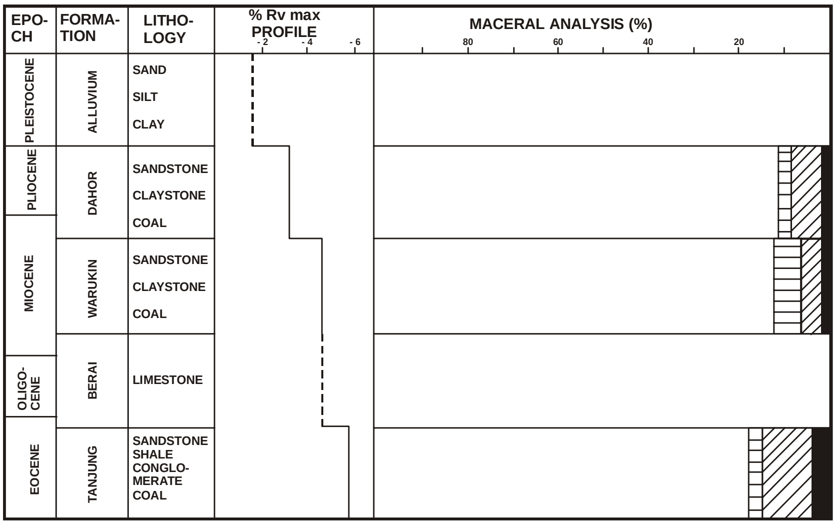

Figure 7. Stratigraphic column of Barito Basin showing rank and type of coals

Table 2. Relationship between vitrinite reflectance and proximate analyses of Kalimantan coals

Age	Specific Energy (kcal/kg)	Total Moisture (%)	Carbon (%)	Rvmax (%)
Neogene Palaeogene	5,000-6,000 6,400-7,000	8 - 20 3 - 7	69.4 79.7	0.30-0.57 0.53-0.67

4.2.1 Palaeogene

Results of vitrinite reflectance measurements are presented in Table 3. Vitrinite reflectance ranges from 0.53 to 0.64% or sub-bituminous to high-volatile bituminous ranks, respectively, as classified by the Australian standards. Four coal seams in Tanjung Formation are present in the basin. Vitrinite reflectance of these seams shows an increase from seam 1 (at the top) to seam 4 (at the base), as indicated in Table 4. The slight change in vitrinite reflectance from the top to the base of

Table 3. Rank of Barito coals

Sample Number	Age	Vitrinite Reflectance ($R_v$max %)	Rank (Australian Standard)
1		0.3	Brown coal
2	Neogene	0.34	Brown coal
3		0.47	Sub-bituminou
4		0.64	High volatile bituminous
5		0.64	High volatile bituminous
6	Palaeogene	0.58	Sub-bituminous
7		0.56	Sub-bituminous
8		0.6	High volatile bituminous
9		0.53	Sub-bituminous
10		0.55	Sub-bituminous

Table 4. Coal seams of Tanjung Formation showing vitrinite reflectance variations

Seam	Rvmax (%)
E1	0.55
E2	0.53
E3	0.56-0.60
E4	0.58-0.64

the sequence is due to the thicker cover/overburden on the high rank coals. The third seam of the formation, for instance, has a vitrinite reflectance of 0.56% at the top and 0.60% at the bottom.

4.2.2 Neogene

Results of vitrinite reflectance measurements of the Neogene coals are presented in Table 3. Vitrinite reflectance varies between 0.30 and 0.47%, classified as brown coal and sub-bituminous ranks, respectively, according to the Australian standards. Vitrinite reflectance slightly increases from the top to the base of the sequence, and it shows the same trend as the Palaeogene coals. This increase is also caused by the greater thickness of cover over the seams.

5. DISCUSSION

Maceral compositions of the Barito Tertiary coal samples are slightly different from each other, and this is caused by the age factor. The coals contain high proportion of vitrinite ranging from 72 to 94%, dominated by detrovitrinite, followed by telovitrinite and minor gelovitrinite. Liptinite maceral is common in the coals with some samples containing up to 19%. Resinite, sporinite and cutinite are prominent in some of the coals and occur in association with vitrinite. The coals contain rare inertinite with some samples containing up to 6%. In some cases, coals with a high inertinite content have a relatively high amount of mineral matter. Cook and Johnson (1975) have suggested that this may be the result of peat ablation in relatively oxidising environments providing an unfavourable balance between the rate of accumulation of organic material and mineral matter.

The obvious trend for the coals is the increase in the proportion of liptinite and decrease in the proportion of vitrinite from Neogene to Palaeogene. Vitrinite in the coals consists of 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.

The dominance of vitrinite in the Barito coals is indicative of forest type vegetation in humid tropical zone, without significant dry events throughout. Vitrinite-rich coal in some cases has a high content of mineral matter. A number of authors, among others, Cook (1975), Shibaoka and Smyth (1975), 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. Resinite, sporinite and cutinite in the coal are usually associated with wood-derived vitrinite. Therefore, they are preserved in forest moor and thus an indicator of the depositional environment (Diessel, 1982 and 1986; Lamberson *et al.*, 1991; Hunt, Brakel and Smyth, 1986). The presence of inertinite in the coals indicates partial oxidation during the peat stage, and is commonly interpreted as indicating dry condition. Semifusinite, inertodetrinite and sclerotinite in the coals were formed under dry and oxidising conditions or terrestrial forest moor. The inertodetrinite, although initially formed in a relatively dry forest moor, is more likely to be the result of transportation and redeposition in a sub-aqueous environment.

In spite of its short geological history, the Barito Tertiary coals exhibit variable vitrinite reflectances, apparently due to age factor (Palaeogene and Neogene) or stratigraphic significance. The coals had a maximum cover of about 2,500 metres (Bemmelen, 1970). Increased depth of burial and increased temperatures and pressures 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, as stated by Hood *et al.* (1975), Cook (1980) and Kantsler *et al.* (1984). Schwartz *et al.* (1973) reported low geothermal gradient for the Barito Basin. They found that the geothermal gradient at the area is approximately 20ºC/km and occurs in a mobile belt and in the stable Sunda Shelf. In general, the low geothermal gradient produces a profile with lower vitrinite reflectance gradient or less additional coalification per depth unit. The Neogene coals have vitrinite reflectances ranging from 0.30% to 0.47% and vitrinite contents varying between 87% and 90%. As noted, most of the Indonesian coals belong to this category. The Palaeogene coals have vitrinite reflectances ranging from 0.53% to 0.64% and vitrinite contents varying between 76% and 94%. Relationship between vitrinite reflectance, carbon content and specific energy is evident in both Palaeogene and Neogene coals. According to Bemmelen (1970), Strauss *et al.* (1976) and Roeslan (1984), carbon content and specific energy of Palaeogene coals are generaly higher than those of Neogene coals (see Table 2).

6. CONCLUSIONS

An establishment of the quality of the Tertiary Barito coals in terms of type and rank characteristics, indicates the influence of geological setting on their characteristics. The type differences between the Palaeogene and Neogene coals reflect the influence of peat environment and climate. The rank variation characteristics result from burial of overburden and palaeotemperature histories.

Megascopically, the Barito coals are characterized by bright and bright-banded lithotypes. Microscopically, the coals are dominated by vitrinite over liptinite and inertinite. The vitrinite mostly contains detrovitrinite and telovitrinite with minor gelovitrinite. Liptinite is common in the coals containing up to 19%. Resinite is the dominant liptinite maceral in the coals. However, cutinite and sporinite are dominant in some occurrences. Liptodetrinite and suberinite are common and fluorinite is rare in the coals. Some of the coals contain more than 5% including sclerotinite, inertodetrinite and semifusinite. Mineral matter consisting mainly of clay and pyrite, is rare in the coals (trace to 5%). High proportion of vitrinite in the Barito coals indicates that the original plant material consisting essentially woody plant tissue and peatification occurred under relatively wet reducing conditions.

The Barito Neogene coals are typically much lower in rank compared to the Palaeogene coals. The Palaeogene coals have vitrinite reflectances between 0.53% and 0.64%, whilst the Neogene coals range from 0.30% to 0.47%. Vitrinite reflectance of the Barito coals show significant increases with depth. Some seams exhibit an increase in vitrinite reflectance from seam top to the bottom. In the geologic viewpoint, it is caused by age factor or stratigraphic position. Increased depth of burial and increased temperature and pressure over a period of time, consequently result in higher rank.

REFERENCES

Arifin., M., Suhendar, Sudradjat, A., Sujono, Miswanto, A., Rustendi, T. dan Supriatna, E., 2003. Ringkasan mineral dan batubara Indonesia 2003. *Litbang tek*MIRA *no. 28.2003.* Puslibang Teknologi Mineral dan Batubara. Bandung.

Bemmelen, R.W.van, 1970. *The geology of Indonesia, vol.II, economic geology.* Martinus Nijhoff, The Hague.

Cook, A.C., 1975. The spatial and temporal variation of the type and rank of Australian coals. In: Cook, A.C. (editor), *Australian black coal-its occurrence, mining, preparation and use,* Wollongong.

Cook, A.C. and Johnson, R.D., 1975. Seam thickness, quality and structure variations in the Bulli coal, Sydney Basin, NSW. *Australasian Institute of Metallurgy Conference.* Adelaide.

Cook, A.C., 1980. Optical techniques for the examination of organic matter in oil shales. In: Cook, A.C. and Kantsler, A.J. (editors), *Oil shale petrology workshop,* Wollongong.

Diessel, C.F.K., 1982. An appraisal of coal facies based on maceral characteristics. *Australian Coal Geology, 4(2).*

Diessel, C.F.K., 1986. On the correlation between coal facies and depositional environments. *Proceedings of the 20th Sydney basin Symposium.* Department of Geology, University of Newcastle, NSW. Newcastle.

Hardjono and Syarifuddin, I.I., 1983. Explanatory notes on coal resources map of Indonesia. *Special Publication of the Directorate of Mineral Resources, Khusus 1.* Bandung.

Hood, A., Gutjahr, C.C.M. and Heacock, R.L., 1975. Organic metamorphism and the generation of petroleum. *American Association of Petroleum Geology Bulletin, 59.*

Hunt, J.W., Brakel, A.T. and Smyth, M., 1986. Origin and distribution of the Bayswater Seam and correlatives in the Permian Sydney and Gunnedah Basins, Australia. *Australian Coal geology, 6.*

Kantsler, A.J., Prudence, T.J.C. and Cook, A.C., 1984. Hydrocarbon habitat of the Cooper/ Eromanga Basin, Australia. *American Association of Petroleum Geology, Memoir 35.*

Lamberson, M.N., Bustin, R.M. and Kalkreuth, W., 1991. Lithotype (maceral) composition and variation as correlated with palaeo-wetland environments, Gates Formation, northeastern British Columbia, Canada. *International Journal of Coal geology, 18*.

Metcalfe, I., 1996. Pre-Cretaceous evolution of SE Asia terranes. In: Hall, R. and Blundell, P.J. (editors), *Tectonic evolution of SE Asia,* Geological Society Special Publication 106.

Roeslan, K., 1984. The coal resources of Indonesia and Southeast Asia. *Paper presented to AGID-ILP Workshop, 7th AGC,* Sydney.

Satyana, A.H., 1996. Adang-Lupar Fault, Kalimantan: Controversies and new observations on the Trans-Kalimantan megashear. *Proceedings of Indonesian Association of Geologists, 25thannual convention.* Bandung.

Satyana, A.H. and Silitonga, P.D., 1993. Thin skinned tectonics and fault propagation folds: new insights to the tectonic origin of Barito folds, South Kalimantan. *Proceedings of Indonesian Association of Geologists, 22thannual convention.* Bandung.

Schwartz, C.M., Laughbaum, Jr.G.H., Samsu, B.S. and Armstrong, J.D., 1973. Geology of the Attaka Oilfield East Kalimantan, Indonesia. *Proceedings of Indonesian Petroleum Association, 2ndAnnual Convention.* Jakarta.

Shibaoka, M. and Smyth, M., 1975. Coal petrology and the formation of coal seams in some Australian sedimentary basins. *Economic Geology 70.*

Sigit, S., 1980. Coal development in Indonesia, past performance and future prospects. In: Mangunwidjaja, A.S. and Hasan, O. (editors), *Coal Technology.* Proceedings of Seminar on Coal technology and the Indonesian needs. Jakarta.

Siregar, M.S. and Sunaryo, R., 1980. Depositional environment and hydrocarbon prospects, Tanjung Formation, Barito Basin, Kalimantan. *Proceedings of Indonesian Petroleum Association, 9thAnnual Convention.* Jakarta.

Standards Association of Australia, 1964. Australian standard code of recommended practice for taking samples from coal seams in situ, *AS CK 5.*

Standards Association of Australia, 1966. Glossary of terms for coal and coke. *AS K 149.*

Standards Association of Australia, 1977. Code of practice for preparation of hard coal samples for microscopical examination by reflected light. *AS 2061.*

Standards Association of Australia, 1981. Microscopical determination of the reflectance of coal macerals. *AS 2486.*

Standards Association of Australia, 1983. Guide for the taking of samples from hard coal seams insitu. *AS 2617.*

Standards Association of Australia, 1986. Coal maceral analysis. *AS 2856.*

Strauss, P.G., Russell, N.J., Bennett, A.J.R. and Atkinson, C.M., 1976. Coal petrography as an exploration aid in the West Circum-Pacific. In: Muir, W.L.G. (editor), *Coal exploration.* Miller Freeman Publication.