OPTICAL PROPERTIES OF SOME TERTIARY COALS FROM KUTAI BASIN INDONESIA THEIR DEPOSITIONAL ENVIRONMENTS AND HYDROCARBON POTENTIAL

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Abstract

The present study describes the relationship between macerals constituent, chemical properties and hydrocarbon potential in some Tertiary coals from Lower and Upper Kutai Basin, East Kalimantan, Indonesia. Seven representative coal samples have analyzed from different depositional environments and maturities. They have analyzed by macroscopy, microscopy, chemical properties, total organic carbon (TOC) and Rock-Eval pyrolysis to determine the hydrocarbon potential and depositional environments. Evidence shows that coals have both of gas and oil generation potential. Experiment's result indicate that coals from Upper and Lower Kutai Basin could have contributed to oil or gas accumulation.
Keywords: *Organic petrography, organic geochemistry, Tertiary coals, Kutai Basin, hydrocarbon potential*

1. INTRODUCTION

Many previous investigation in Kutai Basin have described the characteristic, type, morphology, genesis based on macerals constituent to predict the paleoenvironmental conditions during deposition of the coals (Anggayana, 1996; Belkin et al., 2009; Widodo et al., 2009; Dwiantoro et al., 2012). It has been knowing that coals could be also as a source rock both of oil or gases. Many publications gave a thorough review of oil-prone macerals, determination of petroleum potential, oil generation, and expulsion potential of humic coal (Peters and Cassa, 1994; Wilkins and George, 2002). Coals may contain significant quantities of the hydrogen-rich and hydrogen generating maceral group such as liptinite, and when heated coals produce petroleum-like pyrolysis product (Tissot and Welet, 1984; Taylor et al., 1998). Early opinion indicated that the vitrinite source of was gas-prone, liptinite was oil-prone, and inertinite had little or no petroleum generation potential (Tissot and Welte, 1984).

The aim of this study are using organic petrography and geochemistry properties to evaluate their optical properties correspond with the hydrocarbon potential based on some coals from different maturities and depositional environments.

2. GEOLOGICAL SETTING

The Kutai Basin was formed during early Tertiary times and was fill up with clastic sediments progressing from the western to the eastern part of the basin. This basin was subdevided into the Upper Kutai Basin and Lower Kutai Basin.

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Research area covers both of Lower and Upper Kutai Basin that consist of different maturities and depositional environments. The geological setting shows that basin acumulated and inverted in the middle of Miocene and created a great amount of anticline traps, named Samarinda Anticlinorium, that provide the prolific hydrocarbon production in the basin (Clay et al., 2000; Moss and Chamber, 1999).

3. METHODS

3.1 Sampling and Lithotype Analyses

The geology field investigation and petrographic were carried out to achieve the aim of the study. Coal samples were collected from two depositional setting that were from Upper Kutai Basin (KB-1 and KB-2) and Lower Kutai Basin (KB-3, KB-4, KB-5, KB-6, and KB-7). Three coal samples were collected from shallow drill holes activities that were KB-2, KB-6, KB-7 and the others came from four coals outcrop (Figure 1). Each coal samples were determined in lithotype appearances in term of brightness versus dullnes. Lithotypes are macrocopically recognisable band of coals sample. Describing lithotype sequences, 1 cm was chosen as the minimum thickness for the delineation of individual lithotypes. The macroscopic analysis can predict the microscopic constituent of coals. A lithotype log form can also useful basis for sampling and describing vertical variation in seam relative both of macroscopic and microscopic properties. Beside that, it could be a basis for an interpretation of the succesion of mire conditions during the seam formation.

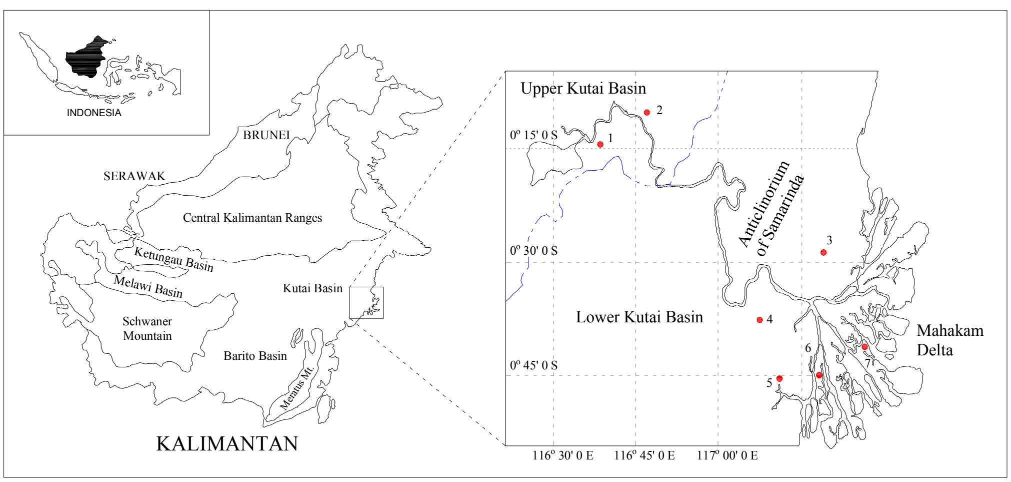

Figure 1. Left side, simplified geological map of Borneo and the red circle show the research area at Upper and Lower Kutai Basin (modified from Clay et al., 2000). Right side, seven coal samples from different location, maturities, and depositional enviornments located within the great amount of anticline traps that called Samarinda Anticlinorium.

3.2 Petrographic Analyses

The samples were crushed under 1 mm grain size and particulate pellets excluding fines were prepared by cold embedding in epoxy resin. Quantitative assesment of macerals, their description and reflectance measurements (Rv) were carried out following ICCP 1994. Vitrinite reflectance measurement is a standard and very accurate to determine the rank of bituminous coals. The determination of reflectance vitrinite were performed at PSDG Bandung (Center for Geological Resources), 50 points for Rv were measured of each polished block. Yttrium-alluminium-garnet with reflectance 0,89% and Spinel with reflectance 0,43% were used for a standard for determination of Rv. Oil immersion objectives 50x/0.85 and 100x/0.25 were used also.

Maceral analyses. The petrographic composition was obtained by macerals under standard condition for maceral analyses (ISO 7404-2009). Point counting was performed on seven polished samples to evaluate the micropetrographic composition. Maceral point counting analyses were perfomed at Mining and Exploration Department-ITB using an Axio Imager A2m reflected light microscope equipped with photometer of white and ultra violet sources (blue light excitation used for recognition and differentiation of liptinite macerals). Also automatic counter "Prior G" was used for the counting of the macerals.

3.3 Paleoenvironmental Analyses.

The lithotype studies combined with micropetrographic analysis have been used to aid in the interpretation of coal depositional environments. The formulas to define the environment deposition are Tissue Preservation Index (TPI) and Gelification Index (GI) according to Diessel (1992) and Kalkreuth et al., (1991). The Kalkreuth's formula to determine the paleoenvironment of the low coal rank stages, whereas the Diessel's formula define the sub bituminous and high volatile bituminous stages.

Kalkreuth's original TPI and GI formula was given as:

$$TPI = \frac{\text{textinite+texto ulminte+ulminite+corpohuminite+fusinite}}{\text{attrinite+densinite+macrinite}}$$

$$GI = \frac{\text{textoulminite+ulminite+corpohuminite+densinite+macrinite}}{\text{textinite+attrinite+fusinite+inertodetrinite}}$$

Diessel's's original TPI and GI formula was given as

$$TPI = \frac{\text{telinite + telocolinite + fusinite + semifusinite}}{\text{desmocolonite + macrinite + inertodetrinite}}$$

$$GI = \frac{\text{vitrinite + macrinite}}{\text{semifusinite + fusinite + inertodetrinite}}$$

Tissue preservation index (TPI) is the ratio of tissue-derived structured maceral versus tissue-derived unstructured maceral is a measure not only of the degree of humification suffered by the maceral precursors but to some extent it also gives an indication of the proportion of wood which has contributed to the peatland and was preserved in it. Maximum TPI indicates a balance ratio of plant growth and peat accumulation versus rise in groundwater table, for example due to basin subsidence. A low TPI suggest either a predominance of herbaceous plants in the mire or large-scale destruction of wood because of extensive humification and mineralisation (Diessel, 1992). While, the Gelification index (GI) is the ratio of intensely gelified versus non gelified macerals. The higher of GI values indicate increased moisture in the mire and higher rate of subsidence and also decreased the oxidation.

3.4 Geochemical Properties

Coal samples were also subjected to chemical properties (proximate and ultimate), and organic geochemical studies comprising the following: (a) TOC determinination to estimate the quantity of organic matter in each samples, and (b) Rock-Eval pyrolysis to determine the hydrocarbon generative potential of the organic matter (S_1, S_2, S_3, T_{max}, and the derivatives HI and OI). The total organic carbon (TOC) and Rock-Eval Pyrolysis were performed at LEMIGAS (research and development center for oil and gas technology) Jakarta-Indonesia. The total organic carbon (TOC) content was measured using a carbon deteminator LECO SC-144 DR. Pyrolysis analyses using a Rock-Eval 6 instrument.

4. RESULT AND DISCUSSION

4.1 Macroscopic Character

Coals from Upper Kutai Basin have special lithotypes profile dominated by dull (KB-1) and banded dull (KB-2). The lithotypes variation indicate the range of wet and dry conditions reflecting subsidence rate with fusain representing durain for dull coal and clarain for banded. The dull coal consist of macerals such as inertinite group (funginite, semifusinite and inertodetrinite) and also mineral matter groundmass. It was conclude that these dull lithotype were performed during period of elevated water and circulation within the mire.

Coals from Lower Kutai Basin are bright lithotype (KB-4) shows the presence of vitrain that consist of high vitrinite macerals (telocolinite dan colinite). While the banded coals (KB-3,KB-5, KB-6, and KB-7) show the clarain that dominated by colodetrinite, vitrodetrinite. These data support general that banded and bright lithotypes are a product of relative wet conditions.

4.2 Microscopic Analyses

Result from reflectance measurements on the vitrinite maceral, the mean maximum reflectance value of the samples ($R_{max,}$ %) reveal that the coals from Kutai Basin attained various maturities (0.24-0.80%). It have reached peat, liginit, and sub bituminous B and C stages. The KB-4 has a higher reflectance value than other coal samples, it was influenced by the pressure of anticline trap surrounding the area. Macerals from Huminite Group are prevailing in the study of coals. The amount of those huminite varies from 53.6-71.6%, inertinite from 5.8-11.2 (%), and liptinite from 11.2-11.8 (%) (Figure 2).

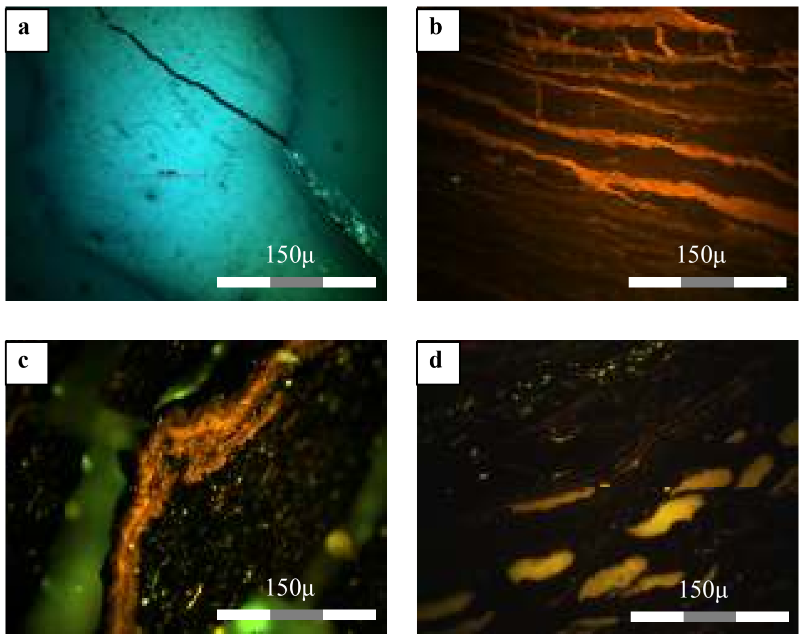

Figure 2. Representative photomicrographs macerals from potential source rock from different environments in Kutai Basin. Scale bar 50 µm. (a) telocolinte as a source of gas-prone, under reflected white light; (b,c,d) cutinite, suberinite, and alginite are source of oil-prone, fluoresence light under ultraviolet excitation.

Macerals from Vitrinite Group have amount of vitrinite varies from 35.6 – 53.6% which dominated by telinite and colotelinite. Macerals from Inertinite Group were low to moderate (5.8-27.6%) value. Semifusinite, inertodetrinite, funginite were the main macerals of the inertinite group recorded. Macerals from Liptinite Group are moderate value (11.2-47.6%). Resinite, suberinite, cutinite, liptodetrinite, alginite were the main macerals of the liptinite group recorded (Table 1 in Appendix 1).

4.3 Paleoenvironmental Analyses.

Examination of lithotype variations and the distribution macerals constituent suggested some Tertiary coals as a limnic (marsh depositional setting) and telmatic (wet and dry forest swamp depositional setting) (Figure.3).

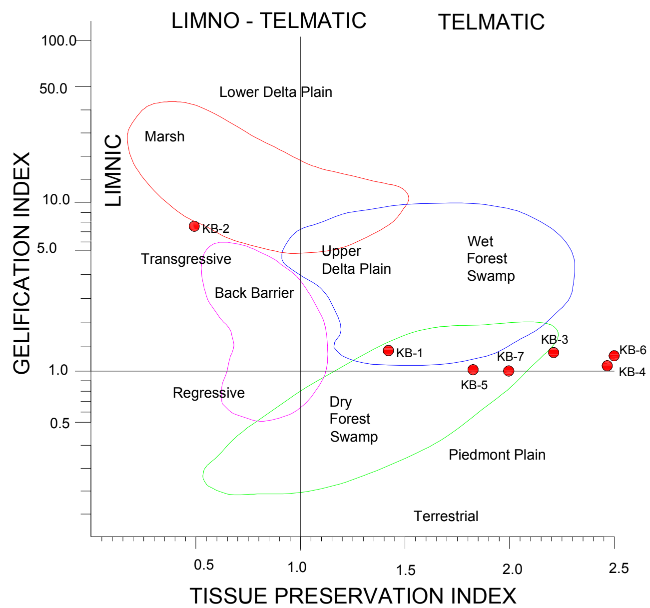

Figure 3. Facies diagram and suggested depositional environment for study areas (after Diessel, 1992).

4.4 Chemical Characteristic

The air dried basis was used to analyze the chemical properties. The Tertiary coals of Kutai Basin shows typical of low rank and sub bituminous coal (Table 2 in Appendix 1). The coals of Upper Kutai Basin KB-1 and KB-2 have total moisture (13.34-33.7%) and ash content (3.75-5.04%). Their volatile matter content (41.27-42.86%). The amount of low sulphur varies from 0.18-0.31% and calorific values (5129-5529 cal/g) were low with relatively low fixed carbon content (42.42-42.77%). The ultimate analysis shows their carbon content varying between 58.17-61.29% and hydrogen content varies from 5.17-5.27. The oxygen content varies from 27.39-31.61%. The coals of Lower Kutai Basin consist of KB-3, KB-4, KB-5, KB-6 and KB-7. There was a coalfield strongly caking that coal from KB-4. It has high calorific value (8308 cal/g), low total moisture content (1.43%), low ash content (1.53%), high content of fixed carbon (58.16%).

The ultimate analyses shows the high carbon (85.18%) content, low sulphur (0.38%) content and both low of hydrogen (5.83%) and oxygen (4.58%) content. The other coals differ distincly by being non-caking in the nature. They have average moderate of total moisture (13.58-20.94%) and ash (1.43-7.21%), and the amount of sulphur of coals are low content (0.17-0.45%). While their volatile matter (41.18-43.95%) and calorific values varying from (5319-6324 cal/g). The ultimate analyses showed the varying values of elements such as carbon (59.29-68.77%), hydrogen (4.96-5.64%) and oxygen (22.35-27.28%).

4.5 Geochemical Organic Characteristic

The Rock-Eval pyrolysis showed the results of coal samples from Upper Kutai Basin (KB-1 and KB-2) and Lower Kutai Basin (KB-3, KB-4, KB-5, KB-6, and KB-7). The TOC content of Upper Kutai Basin ranges from 42.69-57.39%, while the Lower Kutai Basin varying from 61.80-83.12 %. All of the high TOC content of coals indicated the excellent as source of hydrocarbon potential (Figure. 4). The maximum temperatur (T_{max}) data indicates that the coals are characterized by the value from 400-445^{o}C. Moreover based on Hydrogen Index (HI) organic mattter have varying value from 73-260 mgHC/g TOC. Plotting on the T_{max} versus HI (Figure.5) showed that coals contain type III kerogen (KB-4 and KB-7) and type II kerogen (KB-1, KB-2, KB-3, KB-5, and KB-6). For more detail see Table 2 in Appendix 1.

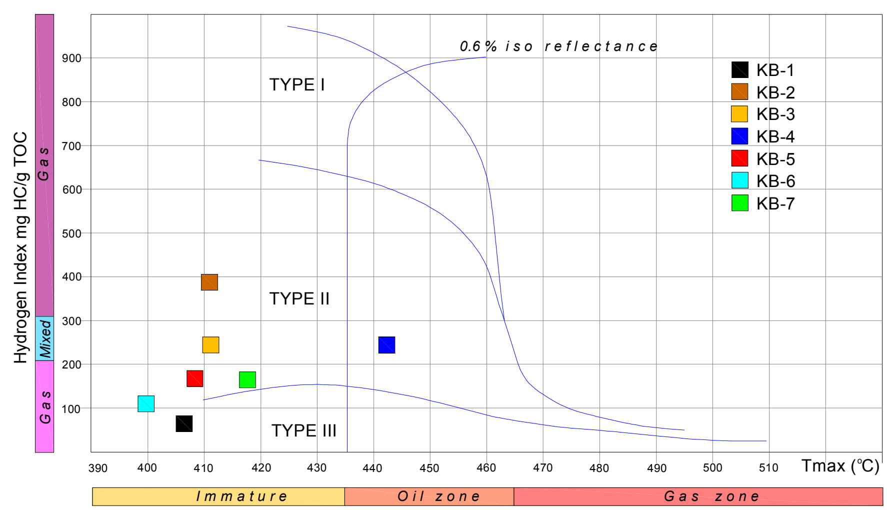

Figure 4. Plotting on the TOC versus Hydrogen Index (HI) diagram, the Upper and Lower Kutai Basin are excellent at gas and oil-gas prone (after Peters and Cassa, 1990)

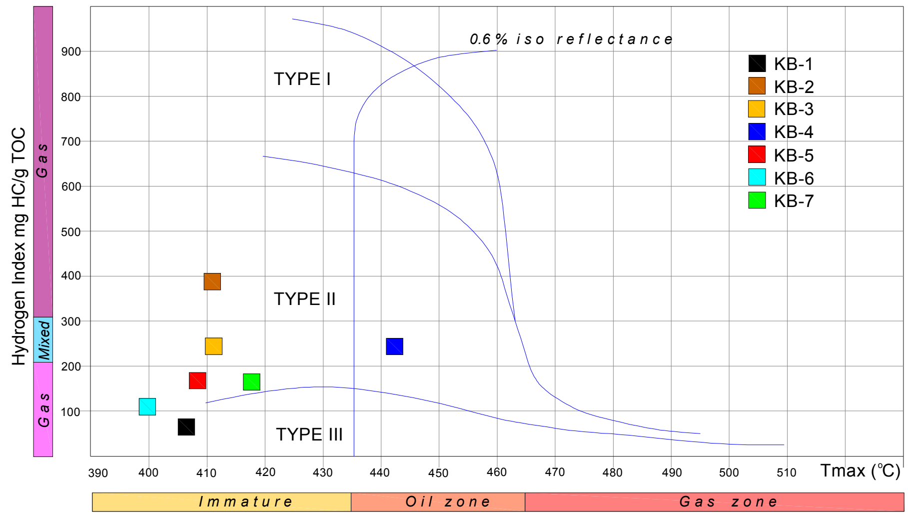

Figure 5. Plotting on the hydrogen index (HI) versus T_{max} diagram, showing kerogen type and maturity level of coal samples from the research areas (after Peters and Cassa, 1990).

5. CONCLUSION

Tertiary coals from Kutai Basin were rich in vitrinite and liptinite. They were the most common macerals in the coals constituting major proportion by volume. The coal rank on the basis of vitrinite reflectance attained various maturities. These coals reached peat, lignite, sub-bituminous B and C stages. The lithotype variation consist of dull, banded, and bright in nature. Examination of lithotype variations and the distribution macerals constituent suggested some Tertiary coals as a limnic (marsh depositional setting) and telmatic (wet and dry forest swamp depositional setting). Based on reflectance measurement and geochemistry analyses in these research area that coals were mainly at an early stage (immature) of oil/gas generation.

References

1. Anggayana K., 1996. Mikroskopische und organisch - geochemische untersuchungen an kohlen aus Indonesia, ein beitrag zur genese und fazies verschiedener kohlenbecken, Dissertation RWTH Aachen, Germany.
2. 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 Sumatra, Kalimantan, Sulawesi, and Papua, Indonesia. International Journal of Coal Geology, vol. 77, pp. 260-268.
3. Diessel C.F.K., 1992. Coal bearing depositional system. Springer-Verlag Berlin Heidelberg.
4. Dwiantoro D., Notosiswoyo S., Anggayana K., and Widayat A.H., 2012. Paleoenivormental interpretation based on lithotype and macerals variations

from Ritan's lignite, Upper Kutai Basin, East Kalimantan, Procedia Earth and Planetary Science, vol. 6, pp. 155-162.

5. Kalkreuth, W.D., Marchioni, D.L., Calder, J.H., Lamberson, M.N., Naylor, R.D., Paul J., 1991. The relationship between coal petrography and depositional environments from selected coal basins in Canada. International Journal of Coal Geology. vol. 19, no.1, pp. 21-76.
6. McClay K., Dooley T., Ferguson A., Poblet J., 2000. Tectonic evolution of the Sanga Sanga block, Mahakam Delta, Kalimantan, Indonesia. AAPG Bulletin vol.84, no.6, pp. 765-786
7. Moss, S.J., and Chamber, J.L.C., 1999. Tertiary facies architecture in the Kutai Basin, Kalimantan, Indonesia. Journal of Asian Earth Sciences, vol.17, pp.157-182.
8. Peters K.E., and Cassa, M.R., 1994. Applied source rock geochemistry, in Magoon, L.B., Dow, W.G. (Eds.), The petroleum system: from source to trap. AAPG Memoir, vol. 60, 93-117.
9. Taylor, G.H., Teichmuller, M., Davis, A. Diessel, C.F.K., Littke, R., Robert, P., 1998. Organic Petrology, 1st ed.,Gebruder Borntraeger, Berlin and Stuttgart.
10. Widodo S., Betchel A., Anggayana K., and Puttman W., 2009. Distribution of sulfur and pyrite in coal seams from Kutai Basin (East Kalimantan, Indonesia): Implication for paleoenvironmental conditions. International Journal of Coal Geology, vol.81, no.3, 151-162.
11. Wilkins, R.W.T. and George, S.C., 2002. Coal as a source rock for oil: a review, International Journal of Coal Geology, vol. 50, pp. 317-361.

Appendix 1.

Table 1. The frequency distribution of various macerals from different maturities and environments from Kutai Basin, East Kalimantan, Indonesia.

No.	Codes	Location	Te	Col	Vtr	Cldt	Tx	Crph	Den	Atr	Crp	Gel	**Vitr**	Fu	Sf	Fg	Ma	Idt	**Inert**	Sp	Cu	Sb	Re	Al	Ltd	**Lipt**	Mm	Py	Σ	Rv (%)	TPI	GI
1	KB-1	Muara Batua	0,0	0,0	0,0	0,0	12,8	2,0	2,8	20,8	15,2	0,0	**53,6**	0,0	4,4	6,0	0,4	0,4	**11,2**	0,4	0,4	0,0	2,8	7,2	0,4	**11,2**	24,0	0,0	100	0,358	1,43	1,88
2	KB-2	Ritan	7,3	0,0	0,0	0,0	4,4	0,2	1,8	47,6	10,3	0,0	**71,6**	0,0	2,1	3,4	0,0	0,3	**5,8**	0,0	3,8	9,2	1,2	1,2	3,4	**18,8**	3,8	0,0	100	0,275	0,49	7,60
3	KB-3	Loa Tebu	16,0	18,4	0,4	14,0	0,0	0,0	0,0	0,0	4,8	0,0	**53,6**	0,0	0,0	4,8	0,4	1,2	**6,4**	3,6	1,6	4,2	3,6	0,0	1,6	**14,6**	19,0	6,4	100	0,564	2,21	1,69
4	KB-4	Ketapang	3,2	28,6	6,0	10,8	0,0	0,0	0,0	0,0	1,6	0,0	**50,2**	0,0	0,0	6,0	1,2	0,8	**8,0**	21,4	10,8	1,6	2,0	0,0	0,0	**35,8**	5,2	0,8	100	0,80	2,48	1,35
5	KB-5	Batuah	6,8	17,2	0,8	15,2	0,0	0,0	0,0	0,0	4,8	0,0	**44,8**	0,4	9,6	14,4	0,8	2,4	**27,6**	6,4	0,0	2,0	9,2	0,0	3,6	**21,2**	6,4	0,0	100	0,484	1,85	1,02
6	KB-6	Loa Janan	10,0	15,8	7,8	9,6	0,0	0,0	0,0	0,0	7,6	0,0	**50,8**	0,0	5,4	2,2	0,4	2,4	**10,4**	12,0	10,8	1,2	8,0	0,0	3,6	**35,6**	3,2	0,0	100	0,473	2,52	1,42
7	KB-7	Sangasanga	10,0	7,2	4,0	8,0	0,0	0,0	0,0	0,0	6,4	0,0	**35,6**	0,0	0,8	6,4	0,8	0,4	**8,4**	8,4	2,4	11,6	17,2	2,0	6,0	**47,6**	7,2	1,2	100	0,467	1,96	0,96

Te: telinite, Tx: textinite, Crp: corpogelinite, Fg: funginite, Sp: sporinite, ltd: liptodetrinite, Col: colotelinite, Crph: corpohuminite, Vitr: amount of vitrinite, Ma: macrinite, Cu: cutinite, Lipt: amount of liptinite, Vtr: vitrodetrinite, Den: densinite, Fu: fusinite, Idt: inertodetrinite, Sb: suberinite, Mm: mineral matter Cldt: colodetrinite, Atr: attrinite, Sf : semifusinite, Inert: amount of inertinite, Re: resinite, Σ: total of macerals, Rv: reflectance vitrinite, GI: gelification index TPI: tissue preservation index

Table 2. Total organic carbon (TOC), Rock-Eval pyrolysis, proximate and ultimate result of representative coal samples from Kutai Basin, East Kalimantan, Indonesia

No.	Sample Code	Location	Coordinate	Formation	TOC	S_1	S_2	S_3	Tmax	PY	HI	OI	TM	Ash	VM	FC	CV	C	H	O	N	S
					(wt %)	mg/g	mg/g	mg/g	(C°)	(S_1+S_2)	mgHC/g	TOC	(%)	(%)	(%)	(%)	(Cal/g)	(%)	(%)	(%)	(%)	(%)
1	KB-1	Muara Batua (UB)	372396E / 3746N	Kampungbaru	42,69	1,58	31,08	35,61	407	32,66	73	83	33,7	3,75	41,27	42,77	5129	58,17	5,27	31,61	0,89	0,31
2	KB-2	Ritan (UB)	387199E / 37142N	Balikpapan	57,39	3,13	83,16	29,23	412	86,29	145	51	13,14	5,04	42,86	42,42	5529	61,29	5,17	27,39	0,93	0,18
3	KB-3	Loa Tebu (LB)	504076E / 9960860S	Balikpapan	71,58	2,16	185,8	3,1	412	187,98	260	4	13,58	1,43	41,39	48,34	6324	68,77	5,48	22,35	1,52	0,45
4	KB-4	Ketapang (LB)	468653E / 9957458S	Pamaluan	83,12	3,41	215,7	2,74	445	219,15	260	3	1,43	1,53	39,29	58,16	8348	85,18	5,83	4,58	2,50	0,38
5	KB-5	Batuah (LB)	505997E / 9924427S	Balikpapan	66,67	1,02	118,5	11,22	419	119,56	178	17	20,94	2,09	43,95	44,1	6015	65,1	5,64	25,65	1,35	0,17
6	KB-6	Loa Janan (LB)	514416E / 9924331S	Balikpapan	61,8	2,85	73,34	36,78	400	76,19	119	60	14,85	7,21	41,18	41,87	5319	59,29	4,96	27,28	1,09	0,17
7	KB-7	Sangasanga (LB)	531571E / 9932656S	Kampungbaru	63,52	2,38	114,3	19,25	409	116,66	180	30	15,26	13,38	9,32	37,95	39,35	62,41	4,87	28,45	1,22	0,42

UB: upper basin, TOC: total organic carbon, S1: amount of free hydrocarbon, S_2: amount of hydrocarbon released from kerogen during pyrolysis, S_3: organic carbon dioxide, Tmax: maximum temperature at top of S_2 peak, PY: potential yield, amount of total hydrocarbon, HI: hydrogen index (S_2/TOC)x100, OI: oxygen index (S3/TOC)x100, TM: total moisture, Ash: ash content, VW: volatile matter, FC: fixed carbon, CV: calorific value, C: carbon, H: hydrogen, O: oxygen, N: nitrogen, S: sulphur.