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Mineral and Geochemistry Study of Lower Kutai Basin Coal East Kalimantan

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Abstract. This study aims to determine the type of mineral and geochemical character of low rank coal. The coal samples were located at Indominco Mandiri Coal Mine KW 01PB0435 in East Kutai District, East Kalimantan. This area of research is entered into the Lower Kutai Basin, where in this basin there are two formations containing coal, namely Pulaubalang and Balikpapan Formation. The methods used are X-Ray Diffraction (XRD), proximate, and ultimate coal analysis. The results of this study based on X-Ray Diffraction (XRD) analysis of coal contents are clays minerals (kaolinite, illite), quartz, carbonates (calcite and dolomite), sulphides (pyrite and chalcopyrite) and oxides (rutile and goethite). While geochemically coal has a calorific value of 6052.6 cal./gr. (Subbitumionus A Coal), moisture 13.3% (adb), ash 4.0% (adb), volatile matter 41.5% (adb), fixed carbon 41.2% (adb), and sulfur content 1.77% (adb).

1. Introduction

Coal is an organic sedimentary rock that contains varying amounts of carbon, hydrogen, nitrogen, oxygen, and sulfur as well as trace amounts of other elements, including mineral matter [1].

Mineral or mineral matter in coal can be defined as minerals and other inorganic materials associated with coal [2-5]. Mineral matter in coal can be derived from inorganic elements in coal-forming plants or called inherent minerals and minerals derived from outside swamps or deposits and then transported into the deposition basin of coal through water or wind which is called extraneous or adventitious mineral matter [6,7]. Based on its abundance, the minerals in coal can be distinguished over: major minerals, minor minerals and trace minerals [8-10]. Generally, those belong to the main mineral group are clay and quartz minerals while the common minerals group are carbonates, sulphides and sulphates minerals.

Proximate and ultimate analysis were chosen to analyze the coal quality chemically [1]. Proximate analysis is used to determine the rank of coal, a geochemical analysis of coal to determine the moisture content (water in the coal), ash (residual of the inorganic elements of combustion), volatile matter (gas and vapour exiting during pyrolysis), and fixed carbon (coal non-volatile fraction). While the ultimate analysis is a simple analysis used to determine the constituent of coal-forming with only attention to the important chemical content (carbon, hydrogen, sulphur, nitrogen, oxygen and ash) and ignore the existence of complex compounds that exist in coal [11].

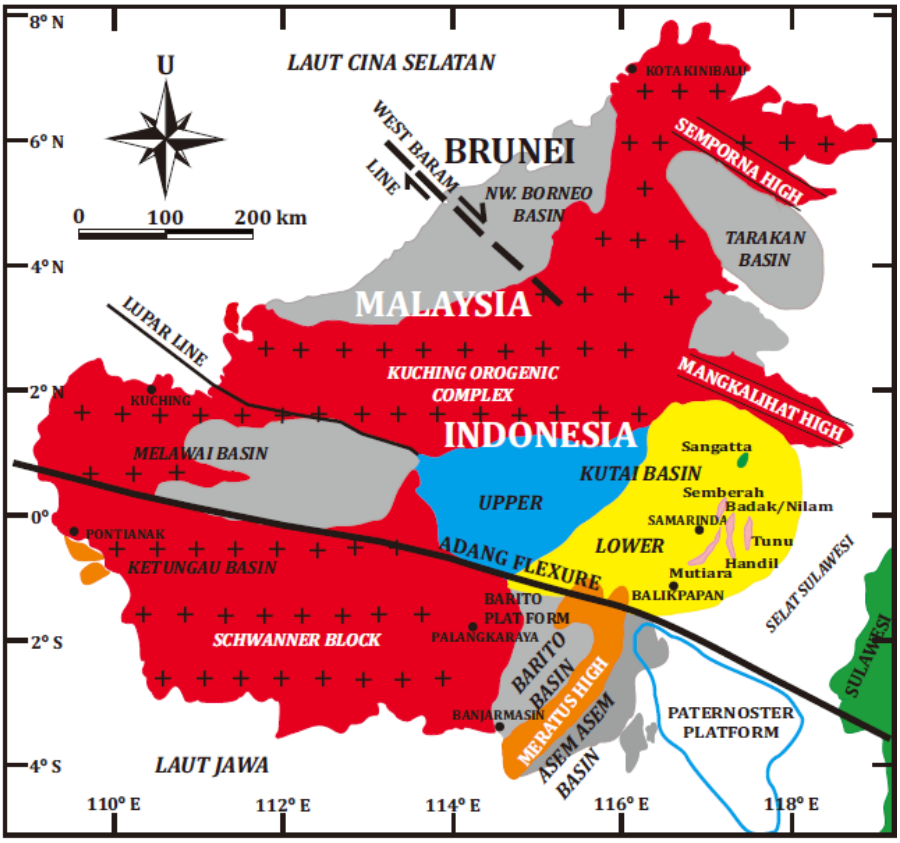
Coal samples were collected at Indominco Mandiri Coal Mine KW 01PB0435 lies on Lower Kutai Basin. Thus, the purpose of this study is to determine the mineral content and quality of low rank coal especially in Formation Pulaubalang and Balikpapan in Lower Kutai Basin.

2. Geological Setting

2.1. A subsection

The first The study area is located in the Kutai Basin, where this basin is one of the largest Tertiary basins in Indonesia, covering an area of 165,000 km2 and a depth of approximately 14,000 m. The Kutai Basin (Fig. 1) is located at the northern part by a area of the bedrock that occurs in the Oligocene, that are Mangkalihat High and Sangkulirang Fault which separates it with the Tarakan Basin. In the eastern part of this basin area, there is the Mahakam Delta which opens to the Makassar Strait. In the western part, the basin is bounded by the Cretaceous Kuching Orogenic Complex (Central Kalimantan Ranges). In the southeastern part of this basin, there is a Paternoster Platform separated by a cluster of Meratus Mountains. In the southern part of this basin, Barito Basin is found separated by Adang Fault [12-16].

Figure 1. Tectonic Setting Kalimantan Island (modified from [16])



2.2. Geological Sturcture

The Kutai Basin may divided into two (sub-) basins;a western Inner or Upper Kutai (sub-) Basin, and an eastern Outer or Lower Kutai (sub-) Basin. Today the Upper Kutai Basin is an area of major tectonic uplift as a result of Lower Miocene inversion of Paleogene depocentres and the effects of subsequent erosion, while the Lower Kutai Basin as we know it today was defined only during the Neogene, and overlies and encompasses many of the Palaeogene depocentres of the Upper Kutai Basin. The boundaries of the present day Kutai Basin, or its Neogene equivalent, do not correspond to the margins of any single Palaeogene depocentres. Many of the Palaeogene rifts were inverted and deeply eroded in the Neogene, further masking their true extent [14].

Fig. 2 shows the orientation of the folds in the Kutai Basin. The Tertiary sediments of the Kutai Basin contain open folds with a general NE-SW trend, except near to the northern margin the basin where the trend is N-NNE. Immediately to the north of the Meratus Mountains, folds within the Tertiary are oriented ENE-WSW. Within the central region of the Lower Kutai Basin, referred to as the Samarinda anticlinorium, folds trend NNE-SSW and form continuous anticlinal ridges for over 100 km [14].

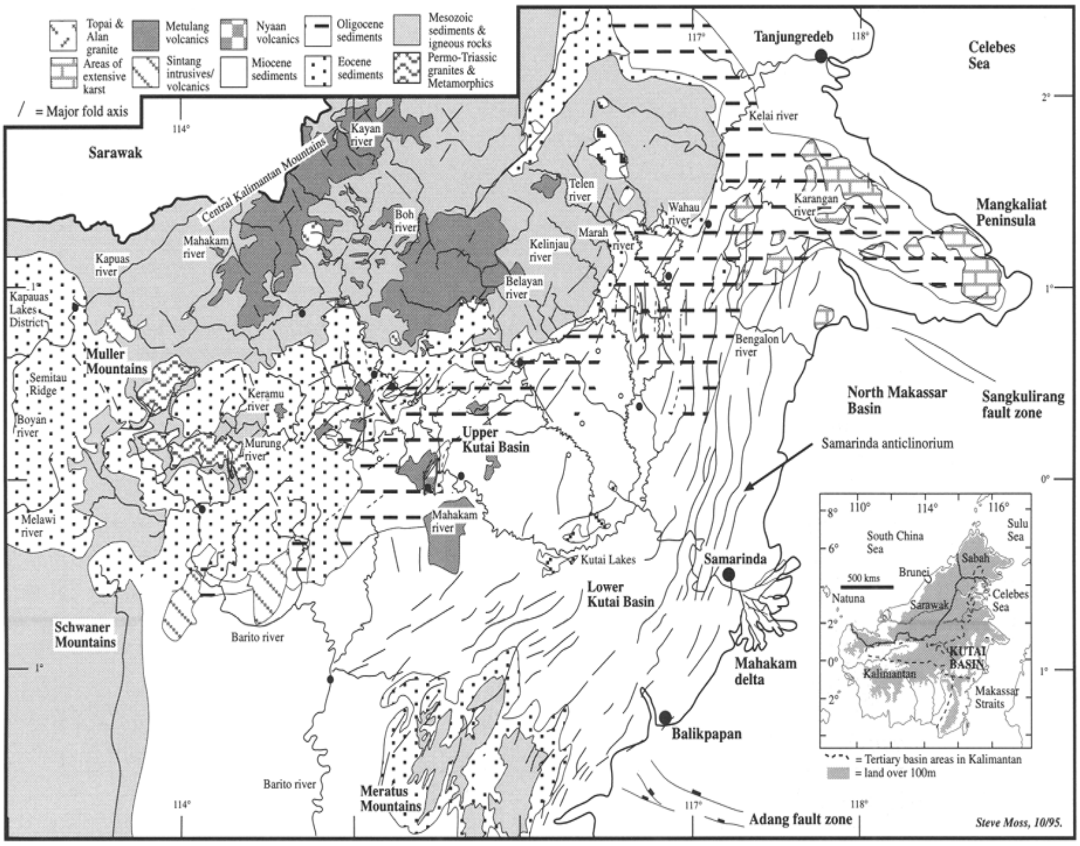


Figure 2. Geological map of Kutai Basin and East Kalimantan. The approximate basement-Tertiary contact, Eocene, Oligocene, and Miocene positions are shown [14]

2.3. *Coal Geology*

Kutai Basin is a basin that has high economic value, because in this area found many sediment of Tertiary coal. This tectonic basin is a delta basin that is progradation with its coal deposition environment, in general is a fluvio-deltaic environment up to marine. Tectonically the process of coal formation in the Kutai Basin is influenced by the process sea of puddle, regression, and transgression affecting the material of coal-forming sediments. The regression sequence in the Kutai Basin includes a delta clastic to paralic layer containing many seams of coal and lignite [17].

The major coal seam formations in the Kutai Basin are the Early Miocene Pulaubalang Formation, the Late Miocene Balikpapan Formation and the and the Kampungbaru Pliocene Formation (Fig.3). Rank of coal in the Kutai Basin are low to moderate, from lignite to high-volatile bituminous [18].

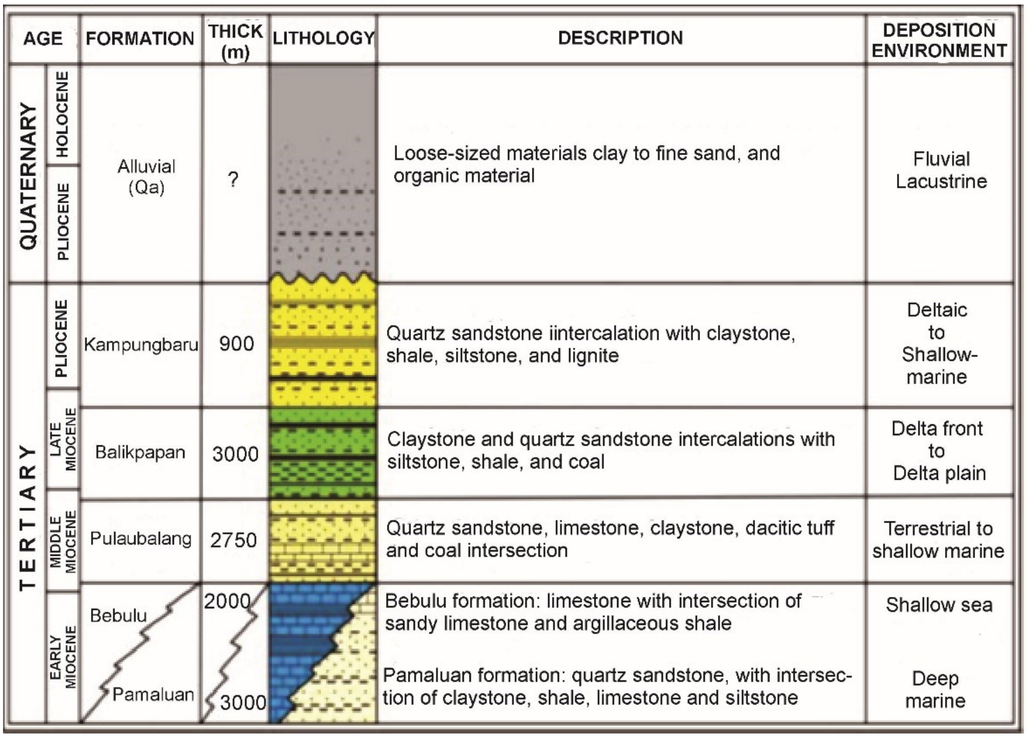


Figure 3. Stratigraphy of the Lower Kutai Basin (modified from [15, 19]).

The coal quality of Pulaubalang Formation is relatively moderate with the rank of lignite-bituminous [20], due to relatively young rock formations (Middle Miocene) and the sedimentary environment influenced by fluvial and tidal systems, so surely the influx of sediment deposit is still dominant. Generally the appearance of black coal, with the general condition looks quite fresh but in some places experiencing weathering is quite intensive. Cleats are quite intensive generally filled by clay material, silt, oxide and sulfide. Coal shine varies from bright, dull – semi bright, with semi-bright dominance. Subconchoidal cleavage, rather hard and non-banded. The main compositions are carbon and impurities in the form of sulfides and oxides [21].

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The rank of the Balikpapan Coal formation includes a lignite-subbituminous [20,22,23]. The coal produced is dominated by ombrotrophic and autochthonous, indicating that the coal is formed in peat bogs during Middle Miocene [20,23]. In the western part of Kutai Basin, [24] suggests coal formation of Balikpapan Formation contained in sandstone and siltstone. The coal in the Balikpapan Formation sandstone is black - dull, waxy, soft-medium, some brittle, blackish brown scratches, wooden structures, diagonal and vertical cleats tightly-medium, often found resin nodules. Solid coal deposits are sometimes conchoidal, lighter shades.

While in siltstone, coal has the characteristics of brownish black, dull, waxy, soft-moderately brittle, partially cleavage subconchoidal, blackish brownish scratches, wooden structures often encountered, cleats tightly and partially filled with resin. The rank of coal in this area is brown coal, with a delta front-delta plain deposition environment.

3. Research Methods

3.1. Field Work

The samples were taken at Indominco Mandiri Coal Mine KW 01PB0435, which is administratively located in East Kutai District, East Kalimantan Province. Area Indominco Mandiri Coal Mine is located in 2 blocks, namely West Block of 18,100 ha and East Block of 7,021 ha. Geographically this area is located in the coordinates 117o12'50"- 117o23'30" BT and 00o02'20 "- 00o13'00" LU (Fig. 4) [25].

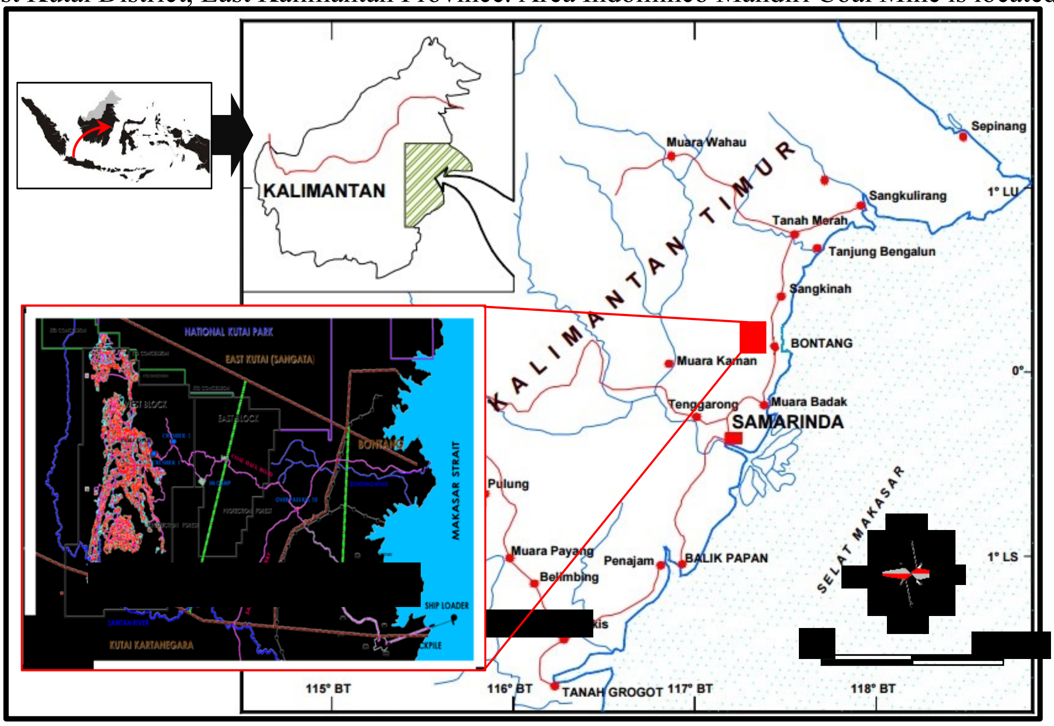


Figure 4. Location of research area (modified from [25]).

The coal samples used in this study were taken from the Lower Kutai Basin which have potential of coal spesifically in Pulaubalang Formation (Tmpb) and Balikpapan Formation (Tmbp). Channel sampling method was proposed for the coal sampling, which involves the process of collecting sample by channel ply sampling / ply by ply. The method of channel ply sampling / ply by ply is the best method for sampling in coal seams because the coarse coal layer is homogenous throughout its thickness [7,26]. Sampling method by channel ply sampling / ply by ply is done from the roof to the floor by dividing the layer into several sub-sections (Fig. 5). The minimum distance of samples taken is 0.25 m from the roof and 0.25 m from the coal floor with a thickness of each ply of at least 0.1 m and a maximum of 1.0 m, if there is a layer other than coal (parting) with a thickness> 0.25 m then the layer is not taken. Each weight of this ply is at least 2.0 kg.

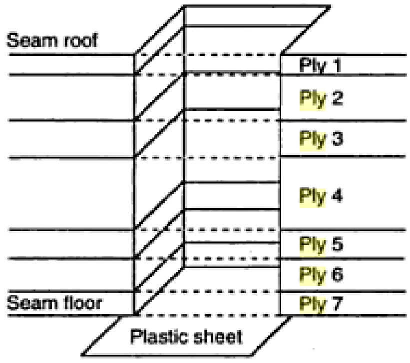


Figure 5. Channel sampling procedure with channel ply sampling / ply by ply [26].

3.2. Laboratory Analysis

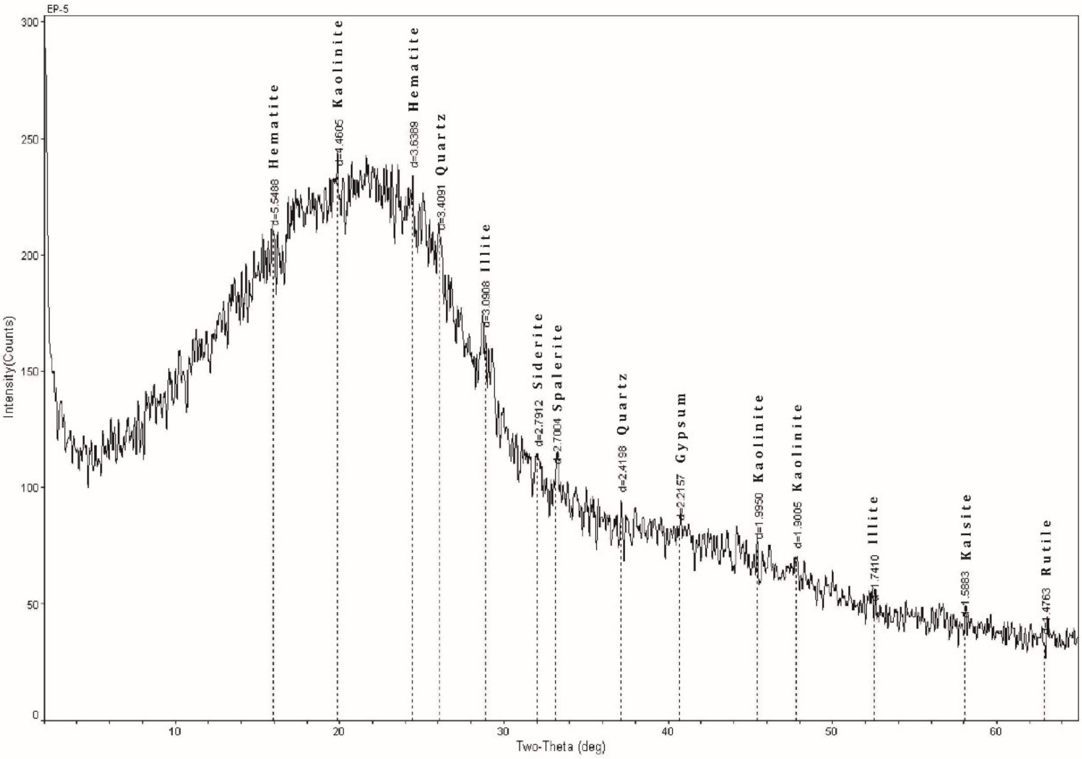
The X Ray Diffraction (XRD) method has been used extensively in identifying minerals in coal [3-5, 8-10,27-31]. To obtain optimum results, coal samples were prepared to fine size of -250 mesh. Organic components (maceral) and inorganic (mineral) can be separated by heating at low temperature (low temperature ashing). The organic compound will oxidize so that its minerals component and residue are then analyzed by using a diffractometer. The resulting diaphragogram is interpreted using Hanawalt and X-ray powder data file (PDF). The implementation of XRD analysis was carried out on samples of ash ash from Low Temperature Ashing (LTA) at 370 ° C for 24 hours [3]. The ash sample is printed on a glass sample holder, before it is analyzed.

Coal proximate and ultimate analyzes were conducted on coal samples aimed at finding out the parameters of coal quality. Proximate analyzes include: inherent moisture-IM (ISO 11722: 2003), ash content (ISO 1171: 2010), volatile matter-VM (ISO 562: 2010), fixed carbon, total sulfur (ISO 19579: 2006), and calorific value (ISO 1928: 2009), while the ultimate analysis includes elements of coal such as carbon (C) , hydrogen (H), and nitrogen (N) (ASTM D.5373: 2002), sulfur (S) (ASTM D.4329: 2012), and oxygen (O) (ASTM D.3176: 1990) is 100 minus percentage of carbon, hydrogen, nitrogen, sulfur, and ash content (% oxygen = 100 - (% C +% H +% N +% S +% ash)) [11].

4. Result and Discussion

4.1. Coal Mineral

Based on the results of XRD analysis, the formation of Pulaubalang consists of clay mineral group (kaolinite and illite), quartz, carbonate (calcite and siderite), sulfide (sphalerite), oxide (rutile and hematite), and sulphate (gypsum) (Fig. 6). While Balikpapan Formation consists of clay mineral group (kaolinite and illite), quartz, oxide (rutile and goethite) (Fig. 7). Mineralogy of sample indicate that the type of minerals formed is mineral matter syngenetic that is mineral matter carried by water or wind into the coal layer where the coal layer is being formed (coalification process) [8]. Kaolinite is commonly present in coal seams syngenetically concentrated in the plating and illite usually found in coal with seabed sedimentary rock layers [2]. Quartz is a syngenetic mineral and rarely found as epigentic [32]. Other minerals such as calcite and siderite can also be well formed in the final syngenetic phase [33]. Siderite formed in a reduction condition can be considered as primary carbonate, while calcite can form both in freshwater and marine environments [32]. Usually mineral sulphate (gypsum) is formed from



the oxidation of sulfide mineral (pyrite) in coal, especially when associated with external air for a long time [2,3]. Presence of rutile in some coal or coal partings is because it was were detrital material of terrigenous origin [34]. Crystalline kaolinite, sometimes containing inclusions of a euhedral TiO2 mineral (possibly rutile). The euhedral inclusions in this case appear to have crystallized out from the infilling solutions before the kaolinite itself.

Figure 6. *X-Ray Diffractogram* (XRD) Pulaubalang Formation

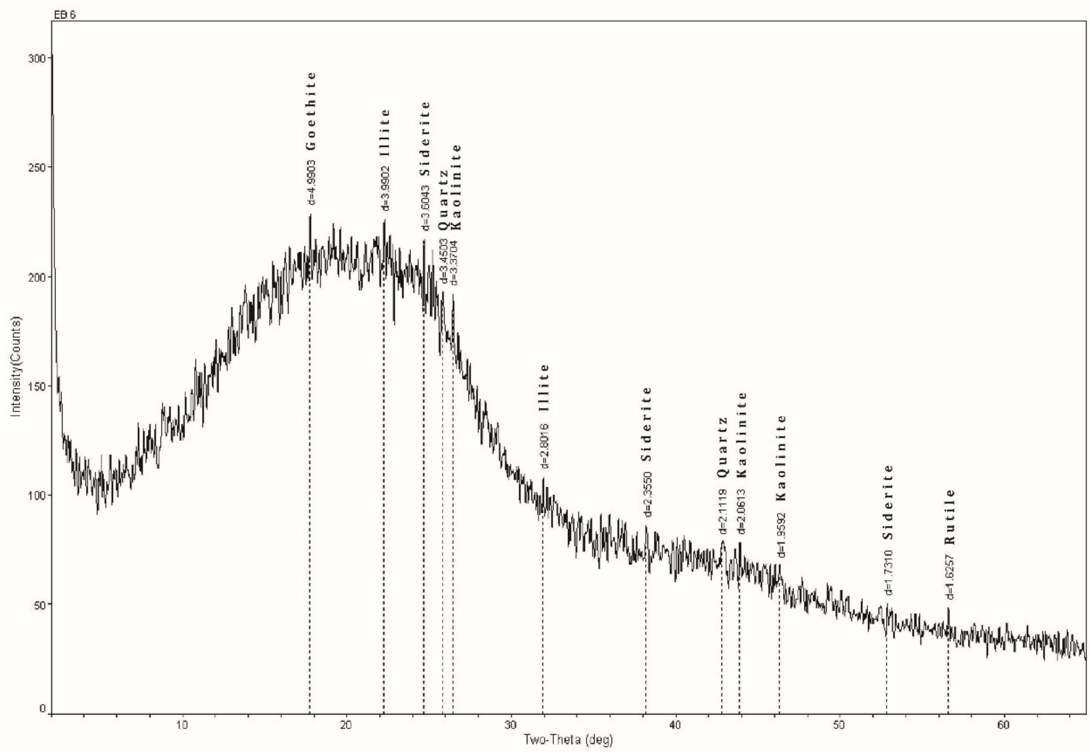


Figure 7. X-Ray Diffractogram (XRD) Balikpapan Formation

4.2. Geochemistry of Organic and Inorganic Coal

Pulaubalang Formation coal has a calorific value of 6099.9 cal./gram which is classified as subbituminous coal A. Followed by fixed carbon by 41.0% adb, volatile matter of 41.8% adb and moisture content of 12.7% adb (see Table 1). Percentage of carbon content reached 64.28% adb, hydrogen 6.13% adb and oxygen 22.11% adb with H/C ratio of 0.10 (see Table 2). Inorganic geochemical composition consists of ash content of 4.6% adb and sulphur of 1.63% adb.

Balikpapan Formation coal has a calorific value of 6005.3 cal./gram which is classified as subbituminous coal A. Followed by fixed carbon by 41.2% adb, volatile matter 41.5% adb and moisture of 13.9% adb (see Table 2). Percentage of carbon content reached 62.63% adb, hydrogen 6.03% adb and oxygen of 24.32% adb with a H/C ratio of 0.10 (see Table 2). The inorganic geochemical composition consists of ash content of 4.0% adb and sulphur of 1.91% adb. Deposition environments affected by marine sediments will produce high sulfur coals [36].

Table 1. Proximate Analysis of Coal

No.	Sample	Formation	Moisture	Ash	Volatile Matter	Fixed Carbon	Calorific Value	Rank
			%, adb	%, adb	%, adb	%, adb	cal./gr.	
1	EP1	Pulaubalang	13,0	1,9	42,2	42,9	6292	SUBBIT A
2	EP5	Pulaubalang	12,0	4,8	41,2	42,0	6137	SUBBIT A

3	EP9	Pulaubalang	12,5	3,7	41,3	42,5	6111	SUBBIT A
4	WP1	Pulaubalang	14,6	4,9	43,5	37,0	5995	SUBBIT A
5	WP5	Pulaubalang	11,4	7,5	40,7	40,4	5965	SUBBIT A
Average			12,7	4,6	41,8	41,0	6099,9	SUBBIT A
6	EB2	Balikpapan	13,7	4,7	41,3	40,3	5942	SUBBIT A
7	EB5	Balikpapan	14,4	2,6	41,2	41,7	5970	SUBBIT A
8	EB6	Balikpapan	13,8	3,1	41,2	41,9	6045	SUBBIT A
9	EB9	Balikpapan	13,8	4,9	41,1	40,2	5870	SUBBIT A
10	EB11	Balikpapan	13,5	1,5	41,5	43,5	6200	SUBBIT A
Average			13,9	3,4	41,3	41,5	6005,3	SUBBIT A
Average total			13,3	4,0	41,5	41,2	6052,6	SUBBIT A

Table 2. Ultimate Analysis of Coal

No	Sample	Formation	Carbon	Hydrogen	Nitrogen	Sulphur	Oxygen	H/C	O/C
			%adb	%, adb	%, adb	%, adb	%, adb		
1	EP1	Pulaubalang	65,80	6,11	1,39	1,93	22,83	0,09	0,35
2	EP5	Pulaubalang	61,25	5,64	1,07	5,59	21,66	0,09	0,35
3	EP9	Pulaubalang	66,13	6,38	1,28	0,31	22,21	0,10	0,34
4	WP1	Pulaubalang	64,00	6,46	1,23	0,15	23,22	0,10	0,36
5	WP5	Pulaubalang	64,23	6,06	1,38	0,15	20,63	0,09	0,32
Average			64,28	6,13	1,27	1,63	22,11	0,10	0,34
6	EB2	Balikpapan	59,57	5,93	1,33	1,93	26,54	0,10	0,45
7	EB5	Balikpapan	58,82	5,62	1,30	0,40	31,22	0,10	0,53
8	EB6	Balikpapan	63,05	6,01	1,23	1,81	24,79	0,10	0,39
9	EB9	Balikpapan	58,67	5,96	1,35	2,28	26,84	0,10	0,46
10	EB11	Balikpapan	64,79	6,11	1,18	3,12	23,29	0,09	0,36
Average			60,98	5,93	1,28	1,91	26,54	0,10	0,44
Average total			62,63	6,03	1,27	1,77	24,32	0,10	0,39

24.32% adb with a H/C ratio of 0.10 (see Table 2). The inorganic geochemical composition consists of ash content of 4.0% adb and sulphur of 1.91% adb. Deposition environments affected by marine sediments will produce high sulfur coals [36].

5. Conclusions

Coal at Kutai Basin (Pulaubalang and Balikpapan Formation) consists of a group of clay minerals (kaolinite and illite), quartz, carbonate (calcite and siderite), sulfide (sphalerite), oxide (rutile, hematite, and goethite), and sulphate (gypsum) and shows that the type of mineral which is formed is a mineral matter syngenetic. While the geochemistry of coal has a calorific value of 6052.6 cal./gram

(Subbitumionus A Coal), moisture content of 13.3% (adb), ash content of 4.0% (adb), volatile matter 41.5% (adb), fixed carbon 41.2% (adb), and a sulphur content of 1.77% (adb).

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