# COALBED METHANE POTENTIAL AND COAL CHARACTERISTICS IN MUARA LAKITAN AREA, SOUTH SUMATRA

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Abstract

A research on Coal Bed Methane (CBM) of the Muaraenim Formation has been conducted in the Muara Lakitan area. Megascopically, the coal lithotype varies from dull to bright banded, with black – brownish black and brownish to black streaks, brittle – friable, dull-greasy luster, even-uneven, dirty on fingers, with resin patch and striation, dirt bands (clay/mud layers), pyrite striation, and pore structures. The coal quality, gained from geochemical analysis, indicates that its ash content ranges between 1.22% and 2.47%, total sulphur content is from 0.15% to 0.3 %, and the volatile matter of 38.02% - 40.81%. The coal is dominated by vitrinite (73.6 – 85.8 %), with minor amount of exinite (1.4 – 4.0 %), inertinite (4.2 – 21 % ) and mineral matter (2.4 – 8.2 %). Vitrinite reflectance, varies from 0.44% to 0.45 %, tends to indicate a sub-bituminous to high volatile bituminous-A coal rank. Kaolinite clays are the most prominent mineral matter within all coal samples analyzed, although the clay textures show irregular shapes. Iron oxides are also present in several samples. Microcleats found within the coals are mostly open, and are rarely filled by clay minerals. Based on Barbara/Winter diagram, the methane gas content in the studied area ranges from 0.57 $m^3$/t – 1.70 $m^3$/t = 20.44 scf/t – 60.96 scf/t. The total reserve of gas within six coal seams in the studied area is 15.524,28 scf.

Keywords : Coal Bed Methane (CBM), Muaraenim Formation, Muara Lakitan

*Sari*

*Penelitian gas metana batubara (GMB) Formasi Muaraenim telah dilakukan di daerah Muara Lakitan. Secara megaskopis, batubara mempunyai ciri yang bervariasi dari "dull" sampai "bright banded", cerat hitam-hitam kecoklatan dan hitam – kecoklatan, getas - rapuh, kilap buram-berminyak, pecahan rata - tak rata, mengotori jari, mengandung resin, adanya lapisan lumpur atau lempung, pirit, dan struktur pori. Berdasarkan analisis geokimia, kualitas batubara mengindikasikan bahwa kandungan abu berkisar antara 1,22 dan 2,47%, sulfur total dari 0,15 – 0,3%, dan volatile matter dari 38,02 – 40,81%. Batubara didominasi oleh vitrinit (73,6 – 85,8%), eksinit (1,4 – 4,0%),inertinit (4,2 – 21%) dan bahan mineral (2,4 – 8,2%). Reflektansi vitrinit, dari 0,44% sampai 0,45%, cenderung termasuk dalam tingkat subbituminous sampai high volatile bituminous-A. Kaolinit merupakan mineral lempung yang dominan di semua percontoh batubara, dengan tekstur lempung yang berbentuk tidak beraturan. Oksida besi juga hadir di beberapa percontoh batuan. Mikrokleat ditemukan dalam batubara sebagian besar terbuka, dan jarang yang terisi oleh mineral lempung. Berdasarkan diagram "Barbara/Winter", kandungan gas metana di daerah penelitian berkisar dari 0,57$m^3$/t – 1,70$m^3$/t = 20,44 scf/t – 60,96 scf/t. Total cadangan gas pada enam lapisan batubara di daerah penelitian adalah 15.524,28 scf.*

*Kata kunci : Gas metana batubara (GMB), Formasi Muaraenim, Muara Lakitan*

## Introduction

Administratively, studied area is a part of the Muara Lakitan Subregency, Musi Rawas Regency, South Sumatra Province (Figure 1) that is located approximately 15 km to the northwest of Muara Lakitan. The study has been focused in the Bare Santos coalfields, which is presumed to be potential coalbed methane resources. A research on geological condition and coal characteristics has significantly enhanced the opportunity for profitable exploitation of the CBM resource in the region.

Coal Bed Methane (CBM) is an economic source of gas methane that is generated and stored in coal beds. Methane, both primary biogenic and thermogenic types, in coal is a result of coalification. However, in some cases, a post-coalification biogenic activity occured. Calcification is a process by which peat is transformed into coal during progressive burial, involving the expulsion of volatiles, mainly methane, water, and carbon dioxide.

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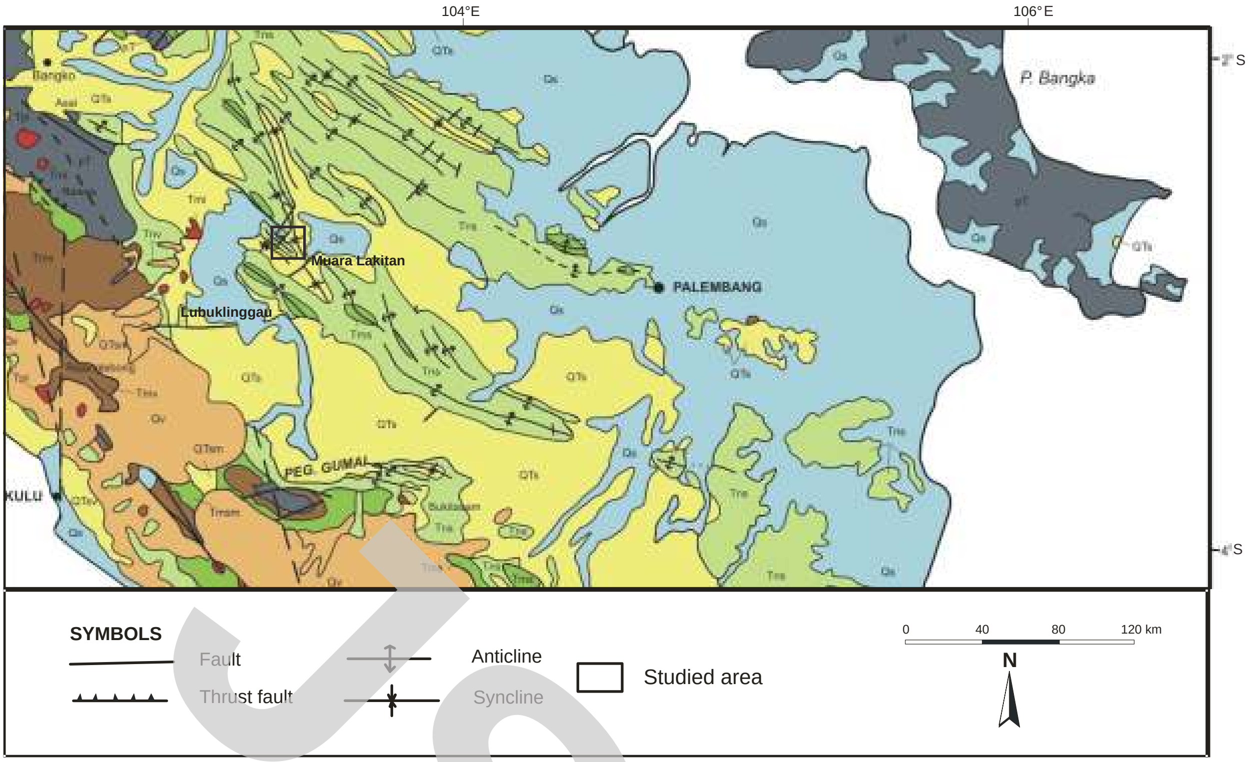



Figure 1. Regional locality map of the CBM study in the Muara Lakitan Area.

Late-stage or secondary biogenic methane is generated by bacterial activities within groundwater systems. Most coals at shallow depth are aquifers, due to the presence of a well-developed cleat (fracture) system. The late-stage biogenic methane is significant and reaching maximum phase at the sub-bituminous level or lower rank coal. As a result, sub-bituminous coals have comprised dominant target of coalbed methane exploration. Thereby, low rank coals, which exist at shallow depths and crop out significantly, may contain mainly late-stage biogenic (secondary biogenic) methane.

The aim of the study is to collect information obtained from coal and its coal measures, both from field and laboratory analysis. The result of the analysis is important for a better understanding on the coal characteristics relating to CBM potential, predominantly, within the Tertiary coal measures. The main objective of the study is to evaluate the CBM potential of low rank Tertiary coals in Muara Lakitan area, in order to define future exploration objectives in regions, that contain rich CBM resources. An overall objectives is to advance our understanding of geological processes in the sedimentary basins in the Muara Lakitan area, in particular with the formation of the Tertiary coalbed methane resources.

Specific objectives are: (a). to determine quantity and quality of CBM generated from the Muaraenim coals, and exploration implications of CBM as a source for new alternative energy, (b). to determine and analyze the coal deposits and their coalification proceses, (c). to evaluate source rock characteristics of the coals and identify the major CBM source area. The results of the study, as the primary objective of the project, could provide information for companies regarding to the occurrence, including quality and quantity of CBM, which will be used as alternative and additional energy resources, and in turn would give contribution in energy sector.

During the fieldwork, the base camp was located at Muara Lakitan, whilst the subcamp was situated inside Pelita Jaya Village (Figure 1). Field activities were concentrated in several areas with suitable geological conditions for the CBM potency. This activity was carried out in 2007 under the Coal Bed Methane Development Project (*Proyek Pengembangan Coal Bed Methane*), a program of the Research and Development Centre For Oil and Gas Technology (*Pusat Penelitian dan Pengembangan Teknologi Minyak dan Gas Bumi* ) "*LEMIGAS*".

Special geologic field investigations and laboratory techniques were conducted, in order to achieve the aims of the study. The fieldwork investigations including detailed determination, observations, and measurement on cleat, lithotype, position, and characteristics of the coals within the measures, were performed in selected areas occupied by the relatively complete coal seams (Figure 2).

## Geological Setting and Stratigraphy

### *Geology*

The studied area is in a small intra-montane basin or presumably the centre of the South Sumatra Basin. In general, morphology of the studied area comprises gentle low hill, rolling country, and rugged mountainous areas.

The geological setting of the South Sumatra Basin was described in several published and unpublished reports. This basin is located in the southern part of Sumatra Island, and de Coster (1974) suggest as a back-arc basin bounded by the Barisan Mountain in the southwest and by the pre-Tertiary of the Sunda Shelf to the northeast. The South Sumatra Basin was formed during east-west extension that took place during pre-Tertiary and early Tertiary times (Daly *et al.*, 1987). The tectonic history and stratigraphy of this basin have been described by de Coster (1974), Darman and Sidi (2000).

### *Regional Stratigraphy*

The oldest rock in the South Sumatra Basin is pre-Tertiary basement, which comprise various igneous and meta sediments. The Eocene–Oligocene Lahat Formation consists of purple green and red brown tuff, tufaceous clay, andesite, brecia and conglomerate, unconformably overlies the basement. The Lahat Formation is unconformably overlain by Oligocene – Miocene Talangakar Formation that compose of medium-to coarse-grained sandstones and coal seams in the lower part; and calcareous grey shale and sandstone with coal seams in the upper part. The thickness of the Talangakar Formation is approximately up to 900 m. Locally, the Talangakar Formation was deposited in a terrestrial to paralic environment, rest unconformably on top of pre-Tertiary Basement. Moreover, the Talangakar Formation is conformably overlain by the shallow marine calcareous shale and limestone of Baturaja Formation. The formation is conformably overlain by or interfingers the Gumai Formation and composes of marl, claystone, shale, and silty shale, with occasionally thin limestone and sandstone. The Gumai Formation was deposited in a deeper open marine environment and underlies comformably litoral to shallow marine Airbenakat Formation, which comprises sandy and marly claystone, numerous sandstones with glauconite, sometimes calcareous. Deposition of the Talangakar and Airbenakat Formations occurred during Oligo-Miocene time.

The Late Miocene-Pliocene Muaraenim Formation, comformably overlying the Airbenakat Formation, is divided into member “a” (interstratified sandstone and brownish claystone with principal coal seams), and member “b” (greenish blue claystone with numerous ligniteous coal seams). Both members were deposited in a brackish environment. The youngest unit is Kasai Formation consisting of gravel, tuffaceous sands and clays, volcanic concretion, pumice, and tuff. The formation comformably overlies the Muaraenim Formation and has Plio-Pleistocene age. The deposition of the Kasai Formation coincided with a volcanic and magmatic activities. This activities formed some igneous intrusions which intruded the coal measures in the Bukit Asam coalfields, particularly in Bukit Kendi, Air Laya, Muara Tiga Besar, and West Bangko areas.

## Coal Characteristics

### *Lithology*

The coal seam horizon occupies the upper portion of the lower part of the coal-bearing measures. These sediments or coal measures are located in a small subbasin. The coal seams distributed in NW – SE direction, and parallel to the Barisan Range. The coal deposits are found in Bara Santosa Coalfields, the Muara Lakitan Regency, South Sumatra Province.

### *Coal seams*

In the field, a potential coal deposit was recognized in the Muara Lakitan area. Its caloric values vary from 4900 to 5100 cal/g. The coal seams in the area occur in the unclear geologic condition; due to fault disturbances taking place within the area are hardly observed. Based on the core samples present, thickness of each subseam is more than 75 cm.

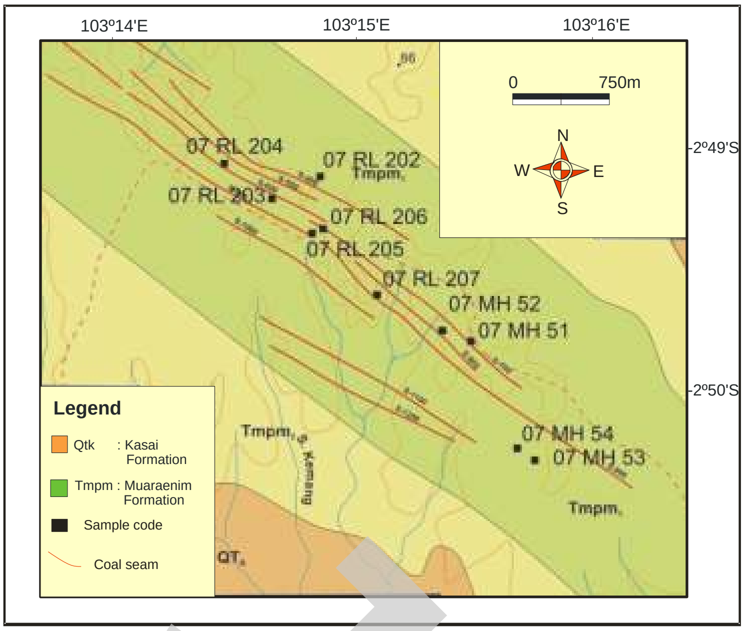



Figure 2. Sample location of the CBM Study in the Muaralakitan area.

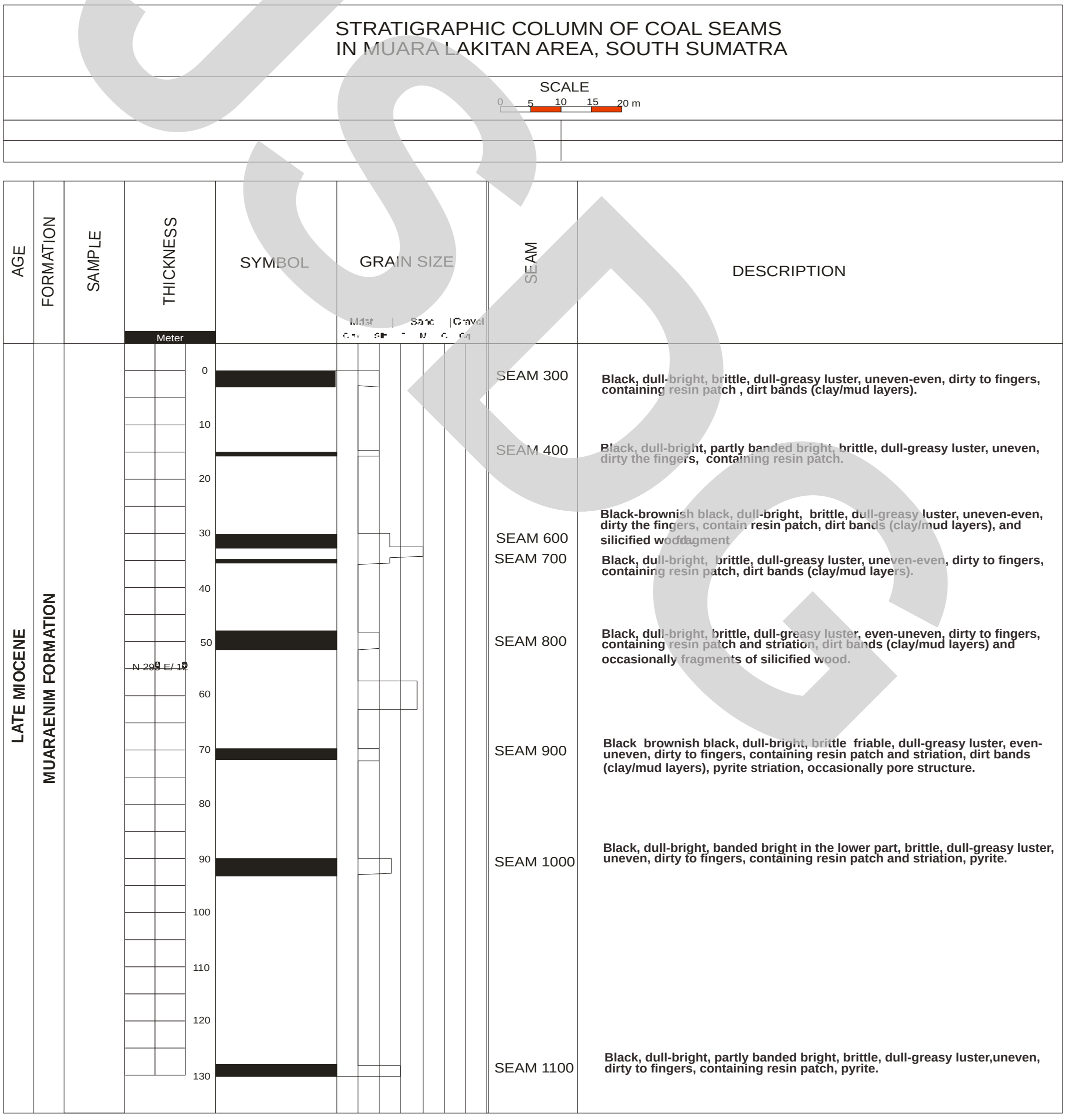



Figure 3. Schematic stratigraphic column of coal seam at Muara Lakitan, South Sumatra.

The coal samples (11samples) from Muaralakitan, South Sumatra analyses have been labeled as 07RL201A, 07RL202, 07RL203, 07RL204A, 07RL205A, 07RL206A, 07RL207A, 07MH51A, 07MH52B, 07MH53B and 07MH54B. All samples are purely coal.

Megascopically, the coal lithotype is dull - bright banded, black – brownish black, brown to black streak, brittle – friable, dull-greasy luster, even-uneven, dirty, containing resin patch and striation, dirt bands (clay/mud layers), pyrite striation, and pore structure (Photo 1).

*Coal Quality*

The coal quality, gained from geochemical analysis, indicates that its ash content is 1.22 – 2.47%, total sulphur content is 0.15 – 0.3 %, and volatile matter is 38.02% - 40.81% (Table 1).

Based on ash and total sulphur contents, the mineral matter contained in the coal is low to high level. Furthermore, organic petrographic analysis shows that the coal is dominated by vitrinite (73.6 – 85.8%), with minor amount of exinite (1.4 – 4.0 %), inertinite (4.2 – 21 %) and mineral matter (2.4 – 8.2%) (Photos 2, 3, 4 and Table 2). Vitrinite reflectance having a value of 0.44 – 0.45%, tends to indicate a subbituminous to high volatile bituminous-A coal rank.

*Coal Cleats and Coalbed Methane Content*

A field study on cleats from coal exposures in the Muara Lakitan area demonstrates that the dip direction of coal face cleats varies from N160°E/80° to N330°E/50°, space ranges between 0.2 cm to 19 cm, aperture of 1 to 8 mm, frequency of 0.239 cm -1 to 1.69 cm -1, and density of 0.0099/cm to 0.21/cm (Photos 5 and 6).

The coal seams having a volatile matter content of 38.02% - 40.81% show that predicted calculated methane content of the coal seam is 0.57 m3/t –1.70 $m^3$/t. It is obtained by plotting the volatile matter contents on Barbara/Winter diagram as shown in Figure 4. This methane content variation indicates that in-situ coal has low to moderate methane or coalbed gas content. The volatile matter characteristic indicates that in-situ coal has low to moderate methane content. However, it is not a pessimistic methane value excepted from the coal, because the coals collected from outcrops.

Photo 1. Field feature of coal seam cropping out at Pagar Gunung, Muara Lakitan, Sumatra Selatan.


Photo 2. Microphotograph of telocollinite associated with semifusinite and sclerotinite within the coal seam in the Muara Lakitan region. Sample: 07 RL 207A.

Photo 3. Microphotograph of semifusinite associated with tellocolinite and pyrite, within a coal sample, from Muara Lakitan region. Sample: 07 MH 52B.

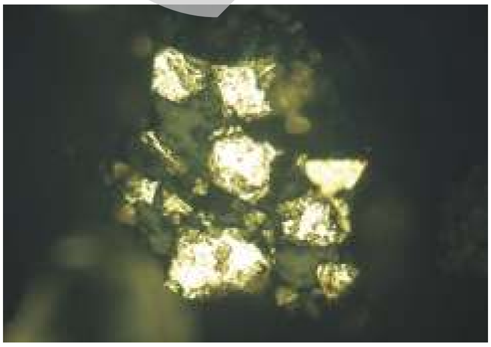


Photo 4. Microphotograph of pyrite recognized in coal of the Muara Lakitan area. Sample: 06 MH 47A.

Photo 5. Coal outcrop showing cleated dull banded lithotype, cropping out at the Pagar Gunung, Muara Lakitan area.

Photo 6. Coal outcrop showing cleated dull banded lithotype, cropping out at the Simpang Kulit, Muara Lakitan area.

Table 1. Proximate Geochemistry of Coal Samples Taken from the Muara Lakitan Area, Sumatra Selatan

| No. | Sample marks | Moister in Air Dried Sample (%, adb) | Ash (%, adb) | Volatile Matter (%, adb) | Fixed Carbon (%, adb) | Calorific Value (Cal/g. Adb) | Total Sulphur (%, adb) |
|---|---|---|---|---|---|---|---|
| 1 | 07 RL 201A | 20.57 | 2.47 | 40.81 | 36.15 | 5151 | 0.23 |
| 2 | 07 RL 204A | 21.49 | 2.08 | 36.54 | 37.89 | 4975 | 0.19 |
| 3 | 07 RL 205B | 23.65 | 1.49 | 38.31 | 36.55 | 5023 | 0.15 |
| 4 | 07 RL 206A | 22.87 | 1.48 | 39.00 | 36.65 | 5187 | 0.30 |
| 5 | 07 RL 207A | 25.47 | 1.22 | 38.02 | 35.29 | 4930 | 0.15 |
| 6 | 07 MH 52B | 21.33 | 1.43 | 39.69 | 37.55 | 5092 | 0.22 |

Table 2. Organic Petrology Analysis of Coal Samples Taken from Muara Lakitan, Musi Rawas

| Maceral | Sample | | | | | |
|---|---|---|---|---|---|---|
| | 07 RL 201A | 07 RL 204A | 07 RL 206B | 07 RL 206A | 07 RL 207A | 07 MH 52B |
| Textinite (TX) | - | - | - | - | - | - |
| Telocollinite (TC) | 30.6 | 32.6 | 41.0 | 7.4 | 40.6 | 31.0 |
| Telovitrinite (TL) | 30.6 | 32.6 | 41.0 | 7.4 | 40.6 | 31.0 |
| Atrinite (At) | - | - | - | - | - | - |
| Densinite (Dns) | 16.6 | 8.0 | 14.8 | 16.0 | 5.0 | 6.0 |
| Desmocolinite (Dsm) | 30.0 | 43.0 | 26.4 | 61.0 | 37.0 | 32.6 |
| Detrovitrinite (DT) | 46.6 | 51.0 | 41.2 | 77.0 | 42.0 | 38.6 |
| Corpogelinite (Crp) | 3.0 | 1.0 | 1.6 | 1.4 | 1.6 | 4.0 |
| Gelovitrinite (GL) | 3.0 | 1.0 | 1.6 | 1.4 | 1.6 | 4.0 |
| Vitrinite (V) | 80.2 | 84.6 | 83.8 | 85.8 | 84.2 | 73.6 |
| Sporinite (Sp) | - | 0.4 | - | - | 1.2 | 0.6 |
| Cutinite (Cu) | 0.6 | 0.8 | 0.4 | 0.8 | 0.4 | - |
| Resinite (Re) | 2.6 | - | 3.0 | 0.6 | - | 1.0 |
| Suberinite (Sb) | - | 1.0 | - | - | 1.0 | - |
| Exudatinite (Exu) | - | - | - | - | - | - |
| Alginite (Alg) | - | 0.4 | - | - | 0.6 | - |
| Liptinite (Lipt) | 0.4 | 0.4 | 0.6 | - | 0.4 | 0.6 |
| Eksinite (EKS) | 3.6 | 3.0 | 4.0 | 1.4 | 3.6 | 2.2 |
| Fusinite (F) | 0.4 | 0.4 | - | - | - | 0.4 |
| Semi fusinite (Sf) | 2.2 | 0.4 | 3.8 | 5.0 | 4.0 | 9.0 |
| Sclerotinite (Sc) | 5.4 | 3.4 | 4.0 | 3.6 | 1.2 | 7.0 |
| Inertodetrinite (Intr) | 3.4 | - | 2.0 | 1.2 | 1.0 | 4.6 |
| Macrinite (Ma) | - | - | - | - | - | - |
| Inertinite (IN) | 11.4 | 4.2 | 9.8 | 9.8 | 6.2 | 21.0 |
| Clay (Cly) | 3.6 | 4.8 | 1.2 | 1.0 | 4.0 | 2.0 |
| Carbonate (Crb) | 0.6 | - | 0.4 | 1.0 | 1.6 | 0.6 |
| Pyrite Framboidal (PyF) | - | - | - | - | - | - |
| Pyrite (Py) | 0.6 | 3.4 | 0.8 | 1.0 | 0.4 | 0.6 |
| Mineral Matter (MM) | 4.8 | 8.2 | 2.4 | 3.0 | 6.0 | 3.2 |
| Rv min | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.44 |
| Rv max | 0.46 | 0.48 | 0.46 | 0.46 | 0.46 | 0.46 |
| Rv mean | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | |

In general, cleat intensity is related to maturity of coal rank, higher coal rank is more developed cleat intensity. Commonly, the coal rank in the studied area is low (Rv < 0.5%), that it is due to cleats intensity. Coals permeability is moderate, although the coals are fairly well cleated, and they have very low porosity. This condition tends to indicate moderate methane desorption capacity. Another substantial factor is desorption rate influenced by both rank and coal. With increasing rank, the effective diffusivity coefficient decreases. In higher rank coal, gas-release rate is slower than it is in lower rank coal.

Additionally, the mineral matter acting as a simple influence to decrease the methane adsorption capacity indicates that the mineral matter content had the strongest effect on the adsorption capacity. The mineral matter content of the coal studied is low to moderate level. Therefore, it is presumed that the adsorption capacity of the coal is relatively moderate. The higher moisture content ranges from 20.57 to 25.47%, indicating that methane adsorption of the coals will be slightly high. On the other hand, methane sorption will be moderate to high. Based on the coal adsorption capacity, coalbed methane content derived from the Muara Lakitan area expected to be at least a moderate level. It is indicated by the presence of bright to bright banded lithotype, maceral composition dominated by vitrinite; low moisture content, moderate to slightly high volatile matter, moderate to high vitrinite reflectance, and low to medium ash content.

## SEM Analysis Results

Each sample of a total 11 (eleven) coal samples from Muara Lakitan area was examined carefully under the SEM method. Summary of the SEM results on microcleat characters and measurements of each coal sample are listed in Table 3. Maceral identified under SEM comprises predominantly telocollinite, followed by desmocollinite. Liptinite maceral are typically sporinite, resinite and exsudatinite. Droplet oil is also visible in some samples (Photo 7). Inertinite consist of semifusinite in one coal sample (07MH51A). Other samples have inertinite maceral.

Kaolinite is the most prominent mineral matter within all coal samples, and it has an irregular shape. Iron oxides are also present in several samples. Detailed observation and examination on microcleat occured within coal samples recorded, including frequency

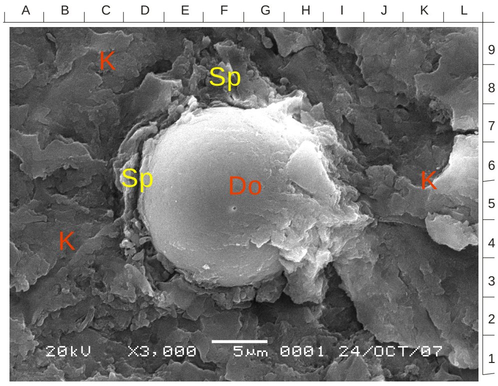



Photo 7. Sample no. 07 RL 204A, Microphotograph SEM, showing droplet oil (Do) surrounded by maceral sporinite (Sp) and clay mineral of kaolinite (K).

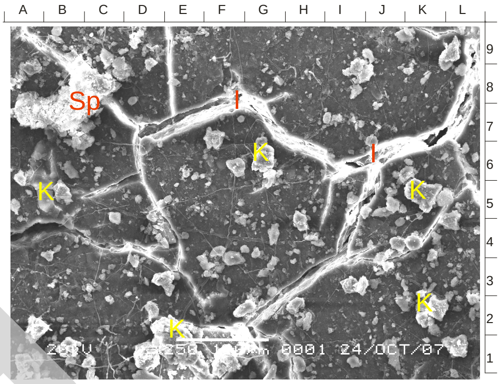



Photo 8. Sample no 07 RL 203, Microphotograph SEM, showing microcleat maceral sporinite 20%(Sp) and clay mineral of kaolinite 50%(K) and illite 30%(I); Magnification 250X.

density, length, aperture and the type of microcleat (face or butts). Butts microcleat appears to be most abundant compared to face microcleat. Microcleats found within the coals are mostly open aperture with very rare filled by clay minerals (Photo 8).

The density of microcleat ranges from 0.02 micron square/freq microcleat to 0.08 micron square/freq microcleat. Three coal samples (07RL202, 07RL203 and 07MH52B) have low-density value of microcleat ranging from 0.02 to 0.05. It means that those three coal samples are categorized as poor for CBM reservoirs. While the other eight samples (07RL201A, 07RL204A, 07RL205A, 07RL206A, 07RL207A, 07MH51A, 07MH53B and 07MH54B) have high-density values (0.06 to 0.08), may be categorized as favorable for CBM reservoir. Many microcleat are connected to each other. Thus, they facilitate for the pathway of gas migration and adsorption.

CBM Potential and Content

This section attempts to evaluate CBM potential in the Muara Lakitan area based on the field works and laboratory data. Physical properties (of type, porosity/ permeability, and rank) and thickness of coal, structural geology, and cleats assessed in the previous section and only the important result will be extracted for the purpose of Muara Lakitan CBM resource assessment. The Muara Lakitan area, located in the Sumatra back - arc region, possesses many favorable and risks for CBM development. Favorable attributes include slightly thick coals in the Mio-Plio Muaraenim Formation, low ash and sulfur content, low to moderate inherent moisture and volatile matter content, low rank coal (sub-bituminous B to A grade), and well-developed cleat. Negative attributes include poor data control, poor sorption isotherm data, structural complexity, probably extremely high CO2 gas content, and relatively narrow prospective area for CBM play.

*Gas In-Place Resources*

Considering the availability of the Muara Lakitan field and laboratory data set required for calculating CBM resources, the calculation of gas in-place potential in the area conducted. Parameters used to calculate the gas in-place potential of the Muara Lakitan consist of theoretical gas content based on Barbara and Winter diagram, and Lost Gas during drilling (Q1) (Figure 4) plus gas desorption during transportation (Q2) and residue gas (Q3). Thereby, the parameter is the theoretical gas content calculation based on the Barbara/Winter diagram. In order to calculate the theoretical gas in-place potential of the Muara Lakitan area, the required important parameter is the volatile matter content of the coal. The gas in-place potential/content of each selected coal seams shown that methane gas content is from 0.57 $m^3/t$ – 1.70 $m^3/t$ = 20.44 scf/t – 60.96 scf/t.

The graphics of Volatile Mater versus Methane content according to Barbara-Winter are shown in Figure 4. The methane content within the coal seam in the Muara Lakitan and its surrounding areas is as follows: According to Barbara-Winter Diagram, the content of methane gas ranges from 20.44 scf/t – 60.96 scf/t. Gas in-place which is supported by the Q1, Q2 and Q3 values, as well as laboratory result has been calculated (Table 4). The calculation follows the formula proposed several studies (Asian Development Bank/Migas, 2003) with some modifications as written below:

Gas in place = (1 - Ash content) x (1 – Moisture Content) x Density x Adsorption

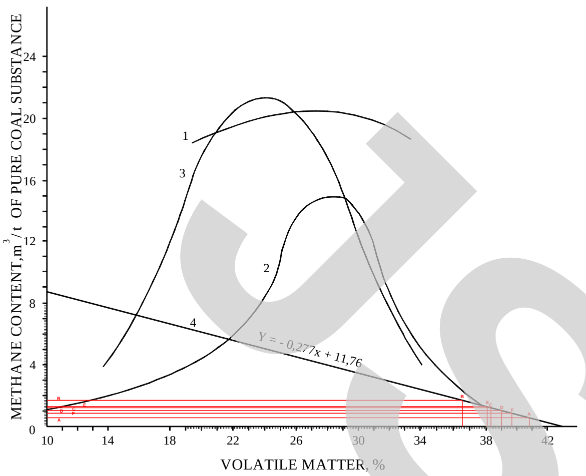
The total reserve of gas in reservoir in the investigated area (six coal seam): 15.524,28 scf.

Table 3. SEM Observation of Micro Cleat Content of the Coal from Muara Lakitan

| No. | Sample No. | Microcleat type | Length (micron) | Width of Aperture (micron) | Density ( 100 micron2/ FreqCleat | Remark |
|---|---|---|---|---|---|---|
| 1 | 07RL201A | Butts (80%) Face (20%); | 110; 20; 40; 50; 30; 40; 20;20 | 0.8; 0.3; 0.3; 0.8; 0.7; 0.7; 0.5; 0.5 | 0.06 | Open aperture (90%); some filled by clays |
| 2 | 07RL202 | Butts (80%) Face (20%); | 250; 200; 220; 150 | 0.4; 0.4; 0.5; 0.5 | 0.02 | Closed aperture (100%) filled by clays. |
| 3 | 07RL203 | Butts (90%); Face (10%) | 750; 400; 200; 600; 600; 500 | 0.9; 0.4; 0.8; 0.7; 0.7; 0.7 | 0.05 | Open aperture (100%) |
| 4 | 07RL204A | Butts (90%); Face (10%) | 300; 250; 1000; 150; 400; 200 | 0.8; 0.8; 0.9; 0.5; 0.7; 0.8 | 0.08 | Open aperture (100%) |
| 5 | 07RL205A | Butts (90%); Face (10%) | 300; 100; 75; 300; 150 | 0.6; 0.6; 0.5; 0.6; 0.5 | 0.06 | Open aperture (100%) |
| 6 | 07RL206A | Face (60%); Butts (40%) | 300; 200; 150; 200; 100; 350; 75 | 0.4; 0.6; 0.4; 0.3; 0.3;0.6; 0.3 | 0.08 | Open aperture (100%) |
| 7 | 07RL207A | Butts (90%); Face (10%) | 400; 100; 500; 150; 100 | 0.7; 0.6; 0.6; 0.5; 0.5 | 0.07 | Open aperture (100%) |
| 8 | 07MH51A | Face (60%); Butts (40%) | 150; 200; 100; 100; 250; 50 | 0.8; 0.7; 0.7; 0.8; 0.7; 0.7 | 0.07 | Open aperture (100%) |
| 9 | 07MH52B | Butts (90%); Face (10%) | 500; 300; 150; | 0.6; 0.6; 0.5 | 0.04 | Open aperture (100%) |
| 10 | 07MH53B | Butts (90%); Face (10%) | 700; 250; 600; 200; 200; 250; 100; 100; | 1.20; 0.8; 1.20; 0.8; 0.8; 0.9; 0.6; 0.6 | 0.08 | Open aperture (100%) |
| 11 | 07MH54B | Butts (90%); Face (10%) | 700; 400; 500; 200; 250; | 0.8; 0.6; 1.0; 1.0; 0.8 | 0.08 | Open aperture (100%) |

Table 4. Gas Content Calculation of the Six Coal Seam Taken from Muara Lakitan area (For sample location see Figure 3)

| No. | No. Sample | Adsorption value | Geochemical content | | | Density | Gas In Place | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 - Ash | 1 - Moisture | 1 - CO2 content | | m2/t | Scf |
| 1 | 07 RL 201 | 82.4059 | 0.9753 | 0.794 | 0.976 | 1.3 | 80.967 | 2903.49 |
| 2 | 07 RL 204 | 74.1285 | 0.9851 | 0.765 | 0.979 | 1.3 | 71.097 | 2549.55 |
| 3 | 07 RL 205B | 67.5145 | 0.9852 | 0.763 | 0.981 | 1.3 | 64.723 | 2320.96 |
| 4 | 07 RL 206 | 65.7020 | 0.9852 | 0.771 | 0.98 | 1.3 | 63.581 | 2280.01 |
| 5 | 07 RL 207A | 73.3795 | 0.9878 | 0.745 | 0.974 | 1.3 | 68.376 | 2451.96 |
| 6 | 07 MH 52B | 84.9056 | 0.9857 | 0.787 | 0.983 | 1.3 | 84.169 | 3018.31 |
| | | | | | | | | 15,524.28 |




LEGEND :
1. ACCORDING TO SCHULZ
2. ACCORDING TO WINTER
3. ACCORDING TO STUFFKEN EXPERIMENTAL MINE
4. ACCORDING TO BARBARA

| Code Samp. | Coal Seam | Volatile Matter | Methane Content | |
|---|---|---|---|---|
| | | | (4) | (2) |
| 07 RL 201A | a | 40,81 | 0,57 | 0 |
| 07 RL 204A | b | 36,54 | 1,70 | 0 |
| 07 RL 205B | c | 38,31 | 1,21 | 0 |
| 07 RL 206A | d | 39,00 | 1,01 | 0 |
| 07 RL 207A | e | 38,02 | 1,29 | 0 |
| 07 MH 52B | f | 39,69 | 0,87 | 0 |

Figure 4. Coalfields consist of theoretical gas content based on Barbara & Winter diagram, and lost gas during drilling (Q1) in Muara Lakitan Area.

## Maceral and Chemical Analysis Relationship

The graph (Figure 5) shows that vitrinite and ash contents have negative relationships. On the other hand, vitrinite and moisture have increase trend (Figure 6) but vitrinite versus volatile matter have a negative style (Figure 7). Inertinite versus ash was decreases or in negative pattern (Figure 8). After that, inertinite versus volatile matter were interpreting positive model (Figure 9). Methane gas content (CH4) versus vitrinite and versus inertinite present that CH4 versus vitrinite have a positive trend (Figure 10) but CH4 versus inertinite is negative correlation (Figure 11).

## Geological Risk Assessment for CBM Potential

Most of parameters for assessing CBM potential in the Muara Lakitan area, including coal thickness, rank, ash content, moisture content, and gas content, have been identified. However, the calculation of CBM resource using theoretical '*gas in-place formula*' will remain a tentative estimation due to the unavailability of accurate in-situ drill hole data. This condition leads to some geological risk as follows :

1. over estimate on the adsorption value of a given coal seam due to limited data.
2. over estimate the density of fracture/cleat within the coal seams, which will create the difficulties in realizing CBM gas molecules from coal micropores.
3. the low CBM content produced is interpreted to be due to unfavorable groundwater condition (both chemically and physically) for microbial development.

## Discussions

Increasing exploration of the coalbed gas type is due to the growing recognition of CBM sources. A notable predictable CBM expectation occurring in the Muara Lakitan coalfields is derived from the coal characteristics of the coal measures studied. The coal characteristics in the areas studied enhance significantly the opportunity for profitable exploitation of the CBM resource. Coal type, rank, porosity/permeability, the presence or absence of seals, stratigraphic or structural traps, local pressure variations, and basin hydrodynamics are factors controlling the distributions of gas contents in coal beds.

Gas content measurement depends on several factors, such as sampling procedures, sample type, coal properties, and analytical methods and qualities. The gas storage capacity of coal beds assumed to correlate with coal rank. There is a relationship between gas content and depth for each rank coal category. Furthermore, sorption capacity increases with progressive coalification.

The investigated coal seams for CBM purpose located in the Muara Lakitan, South Sumatra based on the vitrinite reflectance, categorized as a subbituminous to high volatile bituminous-A coal rank. Furthermore, commonly, the coal seams are characterized by low ash and moderate sulfur contents. Due to the level of vitrinite reflectance values of coal tending to thermally immature (Rv: 0.44 – 0.45%), the expected gas present is suggested to be of biogenic origin. The coalbed gas level category is indicated by the presence of dull to bright banded lithotype; maceral composition dominated by vitrinite with minor content of exinite and inertinite; moderate moisture content; moderate to slightly high volatile matter; low to medium vitrinite reflectance, and low ash content.

The SEM analysis displays that the coal is dominated by vitrinite maceral, with minor exinite and inertinite. The microcleat occurs in rare to medium density, and shows an opened texture.

It can be summarized, that coalbed gas in-place contents derived from the Muara Lakitan area, coal seams expected to be low - moderate level. However, in the Muara Lakitan area, based on Barbara-Winter diagram, the content of methane (CH4) within coalbed gas ranges from 20.44 scf/t – 60.96 scf/t, whilst according the formula, the total reserve of gas in reservoir in the investigated area (six coal seam) is 15.524,28 scf.

## Conclusions

The coal quality, gained from geochemical analysis, indicates that its ash content ranges between 1.22 – 2.47 %, total sulphur content is from 0.15 – 0.3 %, and volatile matter of 38.02% - 40.81%. The dominant maceral is vitrinite (73.6 – 85.8 %), with minor amount of exinite (1.4 – 4.0 %), inertinite (4.2 – 21 %) and mineral matter (2.4 – 8.2 %). Vitrinite reflectance having a value of 0.44 – 0.45 %, tends to indicate a subbituminous to high volatile bituminous-A coal rank. Methane content of the coal seam is 0.57 $m^3$/t – 1.70 $m^3$/t = 20.44 scf/t – 60.96 scf/t.

Coal Cleats of each coal field is as followed: the dip direction of coal face cleat varies from N160°E/80° to N330°E/50°; space ranges between 0.2 cm to 19 cm, averaged cm; aperture of 1 to 8 mm, frequency is 0.239 $cm^{-1}$ to 1.69 $cm^{-1}$, and density of 0.0099 cm to 0.21/cm . Coal bed methane content of the coal seam, based on the Barbara-Winter Diagram, ranges from 0.57 $m^3$/t – 1.70 $m^3$/t = 20.44 scf/t – 60.96 scf/t. This character indicates an in-situ coal have a low to moderate methane content. Gas in-place reserved in six coal seams supported by the Q1; Q2 and Q3 calculations show a calculated varieties value 15.524,28 scf.

The coal bed gas level category is indicated by the presence of dull to bright banded lithotype; maceral composition dominated by vitrinite with minor content of exinite and inertinite; moderate moisture content; moderate to slightly high volatile matter; low to medium vitrinite reflectance, and low ash content.

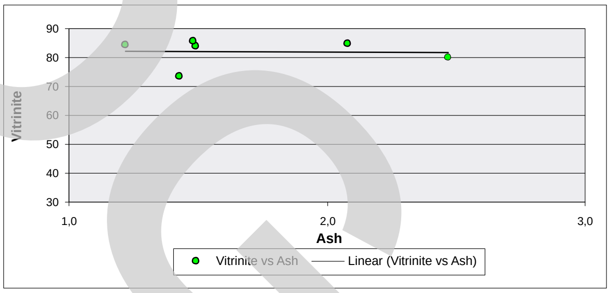



Figure 5. Relationship between percentages vitrinite and ash of coal from Muara Lakitan, Musi Rawas, South Sumatra.

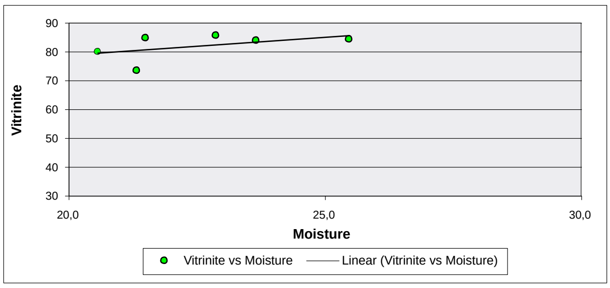



Figure 6. Relationship between percentages vitrinite and moisture of coal from Muara Lakitan, Musi Rawas, South Sumatra.

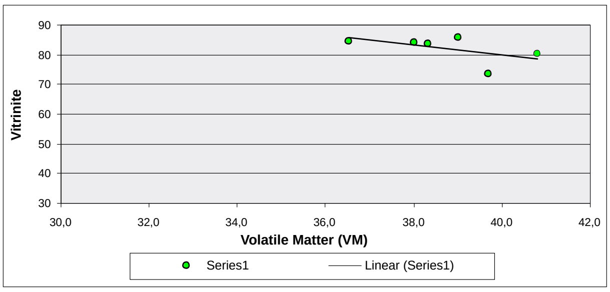



Figure 7. Relationship between percentages vitrinite and volatile matter of coal from Muara Lakitan, Musi Rawas, South Sumatra.

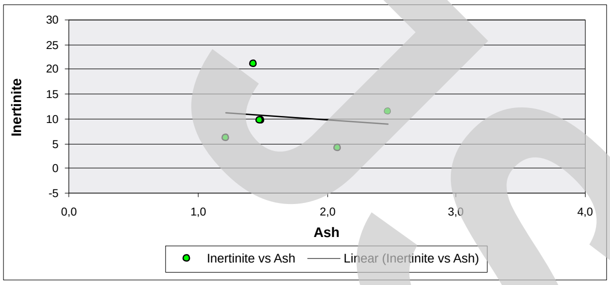



Figure 8. Relationship between percentages inertinite and ash of coal from Muara Lakitan,Musi Rawas, South Sumatra.

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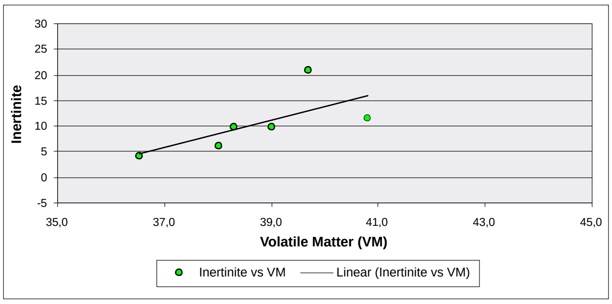


Figure 9. Relationship between percentages inertinite and volatile matter of coal from Muara Lakitan, Musi Rawas, South Sumatra.

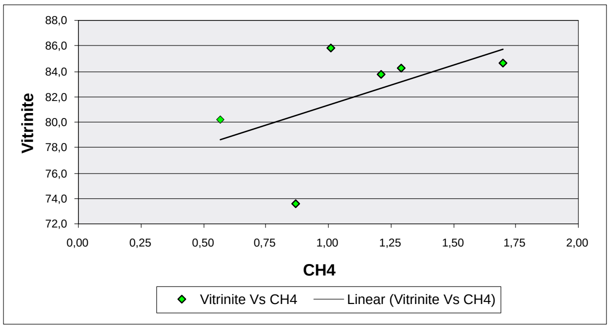


Figure 10. Relationship between percentages vitrinite and CH4 of coal from Muara Lakitan, Musi Rawas, South Sumatra.

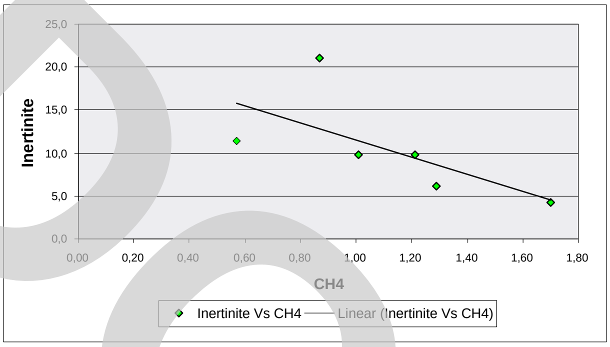


Figure 11. Relationship between percentages inertinite and CH4 of coal from Muara Lakitan, Musi Rawas, South Sumatra.

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