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Methane Adsorption Characteristics of Coals from Sambaliung area, Berau, East Kalimantan and Sawahlunto area, West Sumatra, Indonesia

Karakteristik Penyerapan Metana pada Batubara daerah Sambaliung, Berau, Kalimantan Timur dan daerah Sawahlunto, Sumatra Barat, Indonesia

Komang Anggayana*, Denny Reza Kamarullah**, Asep Suryana***, and Agus Haris Widayat*

* Research Group of Earth Resources Exploration, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Jln. Ganesha 10, Bandung, 40132, Indonesia
** Mining Engineering Study Program, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Jln. Ganesha 10, Bandung, 40132, Indonesia
*** Center for Geological Resources, Geological Agency, Ministry of Energy and Mineral Resources, Jln. Soekarno-Hatta 444, Bandung, 40254, Indonesia
E-mail : haris@daad-alumni.de

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Abstract - There have been limited numbers of studies dealing with coalbed methane of Indonesian coal. This study is an effort to characterize parameters related to the occurrence of coalbed methane of two Indonesian coals, especially on the methane adsorption capacity property. The focused research is taken from the Sambaliung, Berau, East Kalimantan (Latih Formation) and Sawahlunto, West Sumatra (Lower Ombilin Formation) coals. The study involves some analyses including methane sorption isotherm, petrography, and chemistry. Adsorption isotherm analysis reveals storage capacity of Sambaliung and Sawahlunto coals about 113 to 269 scf/ton (daf) and from 486 to 561 scf/ton (daf), respectively. The variance resulted adsorption capacity value of the two region coals is considered to be related with formation pressure reflected either by its depth and coal rank. The resulted low coal rank of Sambaliung area is obtained by the lower vitrinite reflectance (Rr about 0.38%) and higher total moisture (TM about 31%, ar). Moreover, the higher resulted coal rank of Sawahlunto area is confirmed by higher Rr (about 0.72%) and lower TM (about 6%, ar).

Keyword : coalbed methane, methane adsorption, coal, Sawahlunto, Berau

Abstrak - *Studi dengan topik metana batubara di Indonesia masih cukup sedikit. Studi ini merupakan salah satu usaha untuk melakukan karakterisasi keterdapatan metana dalam batubara Indonesia, terutama untuk mengetahui kapasitas serap metana batubara. Studi kapasitas serap (adsorpsi) metana ini dilakukan pada batubara Formasi Latih di daerah Sambaliung, Berau, Kalimantan Timur dan Formasi Ombilin Bawah di daerah Sawahlunto, Sumatera Barat. Pengukuran laboratorium yang dilakukan adalah kapasitas serap metana (adsorption isotherm), petrografi batubara, dan analisis kimia. Hasil analisis adsorpsi isotermik menunjukkan kapasitas serap batubara Sambaliung sekitar 113 sampai 269 scf/ton (daf) dan batubara Sawahlunto sekitar 486 sampai 561 scf/ton (daf). Perbedaan kapasitas serap kedua batubara tersebut diduga disebabkan oleh perbedaan tekanan formasi sebagai faktor dominan yang direpresentasikan oleh kedalaman batubara dari permukaan dan peringkat batubara sebagai faktor penting yang signifikan. Batubara Sawahlunto (Rr 0,72%; kandungan air total sekitar 6% ar) mempunyai peringkat yang lebih tinggi daripada batubara Sambaliung (Rr 0,38%; kandungan air total sekitar 31% ar).*

Kata Kunci: *Gas metana batubara, kapasitas serap metana, batubara, Sawahlunto, Berau*

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INTRODUCTION

In the past decades, Indonesia has an abundance of fossil fuels reserves including oil, gas, and coal. Crude oil has been produced extensively, peaking at about 1.59 million barrel/day in the 1990's decade. However, oil production has been drastically decreased until about 0.83 million barrel/day in the recent years due to declined oil reserves (EIA, 2017). On the other hand, Indonesian coal production has increased dramatically for about 46, 188, and 518 million tons in the mid of 1990's, 2000's, and 2014, respectively (EIA, 2017). The high rates of coal production could decrease coal reserves by conventional open pit mining. These situations could threat the domestic energy supply in the next decades. A policy has been made by the Indonesian government to secure the energy supply. Energy diversification programs have been targeted, including discovery of unconventional fossil resources. With respect to this policy, some early studies on coalbed methane (CBM) potency in Indonesia have been carried out since last decade (Sosrowidjojo and Saghafi, 2009; CGR, 2010, 2012).

Adsorption capacity is a fundamental coal property for CBM prospection. It represents maximum methane amount which could be adsorbed onto coal surfaces in the respective coal depth. Many factors control the quantity of methane adsorbed onto the matrix surfaces such as formation pressure, maceral composition, ash content, coal rank, and moisture content (Crosdale *et al*., 2008; Mastalerz *et al*., 2008; Moore, 2012; Flores, 2013). The objective of this research is to investigate the adsorption characteristics of two Indonesian coals from East Kalimantan and West Sumatra. Adsorption isotherm, maceral, and proximate analyses for coal samples were performed.

GEOLOGICAL BACKGROUND

The study areas are located at Sambaliung, Berau sub-basin which then considered in Tarakan basin and Sawahlunto in Ombilin basin. Tarakan basin is a deltaic basin developed since Eocene in the northeastern part of Kalimantan island (Satyana *et al*., 1999). The investigated coal bearing strata is taken from the Latih Formation (Figure 1). It was deposited during Early-Middle Miocene. The formation consists of sandy shale and limestone in the lower part and sandstone, claystone, and coal seams in the upper part (Situmorang and Burhan, 1995). The coal seams thicknesses in the formation vary between 0.2 m and 5.5 m.

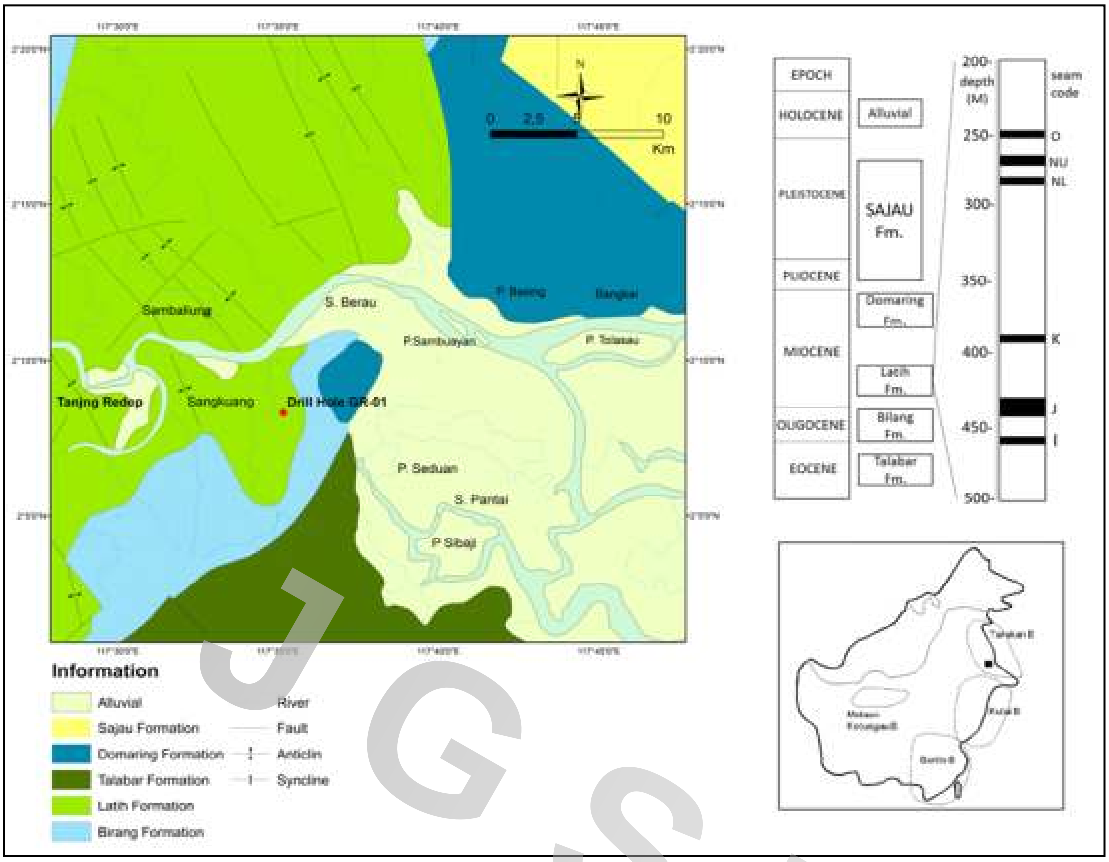
The Ombilin basin is a pull-apart intramontane basin resulted from Early Tertiary tensional tectonics related to strike-slip movement along the Sumatra Fault Zone (Koning, 1985). It is located in the Barisan Mountain, central part of Sumatra Island, Indonesia. The coal investigated in this study is a part of Late Oligocene Lower Ombilin Formation, obtained from Sawahlunto area as shown in Figure 2. The formation comprises a sequence of brownish shales, silty shales, coal seams, and siltstones (Koesoemadinata and Matasak, 1981). The coal seams thicknesses in the area vary from 0.9 m to 5.5 m.

SAMPLES AND METHODS

Nine samples were collected from 500 m and 452 m drill cores of Sambaliung coal in 2013 (7 samples) and Sawahlunto coal in 2009 (2 samples), respectively. The drilling activities were parts of annual CBM prospection programs organized by the Centre for Geological Resources (CGR), Bandung, Indonesia. The sampling points in the two drill cores are marked with dots in the Figures 1 and 2. Coal samples from Sambaliung area occurred in the upper part of Middle Miocene Latih Formation, Tarakan Basin, while those from Sawahlunto area in Lower Ombilin Formations the Late Oligocene, Ombilin basin.

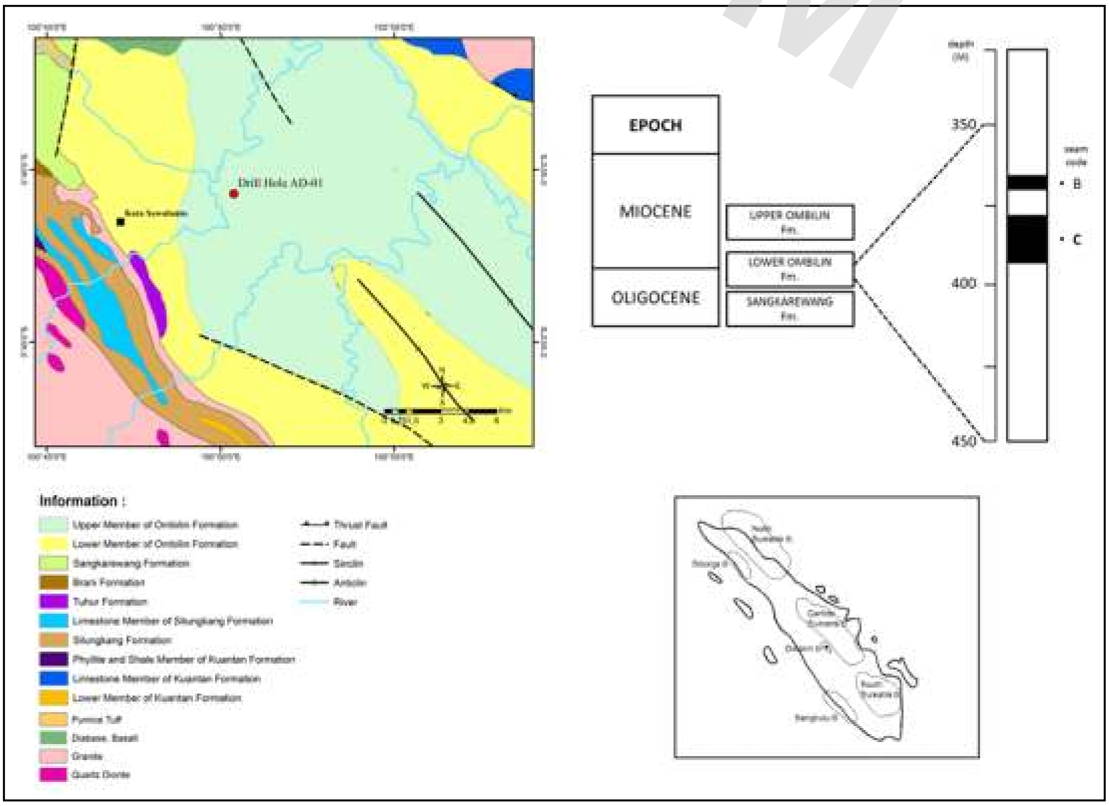
Petrographic analysis was conducted by the CGR to determine maceral composition and vitrinite reflectance. Prior to analyzing, the coal samples were prepared following the method described by Taylor *et al*. (1998). After preparation, microscopic analysis was performed in a reflected-light microscope to identify and quantify coal macerals.

Proximate analysis was conducted by the CGR, following the procedures: ASTM D.2013-03 for free moisture content, ASTM D.3302/D.3302 M-10 for total moisture, ASTM D.3174-11 for ash content, ASTM D.3175-11 for volatile matter, and ASTM D.3172.07a for fixed carbon. Calorific value measurement follows the method ASTM D.5865-10a. Adsorption isotherm analysis was conducted in CBM Analysis Laboratory, Lemigas, Jakarta to measure the maximum methane adsorption capacity of the coal samples, following the volumetric method described by CSIRO (Commonwealth Scientific and Industrial Research Organization). The relation between adsorbed methane and pressure is expressed as Langmuir equation $G_a = \frac{V_L P}{P_L + P} \cdot \frac{1}{(1-a-m)}$ where G_a : adsorbed gas (daf, scf/ton), V_L: Langmuir volume constant (scf/ton), P: pressure (psi), PL: Langmuir pressure constant (psi), a: ash content (ar), and m: moisture content (ar) (Seidle, 2011).



Source : adapted from Situmorang and Burhan (1995).

Figure 1. Location and geological map of the studied area and drill core sampling points.



Source : adapted from Silitonga and Kastowo, (1995).

Figure 2. Location and geological map of Sawahlunto area and sampling points in the drill core.

RESULTS

Results of the analyses are listed in Table 1. Some of analysis parameters are plotted against depth to show their vertical variations along the drill core profile, and presented in Figure 3. The proximate analysis shows a significant difference between the Sambaliung and Sawahlunto coals. The Sambaliung coal has typically much higher total moisture content than that of Sawahlunto, ranging from 25.97 to 35.41% and from 5.14 to 6.77%, respectively. The inherent moisture and volatile matter of the Sambaliung coal show higher value than those of Sawahlunto coal as shown in Table 1. An opposite relation is observed between the two coals for fixed carbon. This compositional difference suggests that the Sawahlunto coal is higher in rank compared to Sambaliung coal. The coals contain low amounts of ash, typically below 5% (adb).

The vitrinite reflectance measurements of the Sambaliung and Sawahlunto coals result different values, vary from 0.33 to 0.42% and from 0.66 to 0.80%, respectively. The calorific values of the coal show similar variation as well, ranging from 5988 to 6311 cal/gr (adb) and 7434 to 7646 cal/gr (adb) for the Sambaliung and Sawahlunto coals, respectively. Based on Taylor *et al*. (1998), referring to North America classification, the coal ranks are sub-bituminous C for Sambaliung coal and high volatile bituminous B for Sawahlunto coal.

Maceral composition of the coals is dominated by vitrinite group, typically more than 95%. Inertinite accounts only a minor amount (<3%), while liptinite account in a very minor amount (<1%). Mineral is present generally in low abundance (<3%).

Adsorption analysis for the Sambaliung and Sawahlunto coals was conducted under the same temperatures where the samples were obtained at depths, and the storage capacity of the coal samples is calculated at the respective depths. Two representative adsorption isotherm curves from the two coal fields are presented in Figure 4. The storage capacity for the Sambaliung and Sawahlunto coal samples vary from 113 to 269 scf/ton and from 486 to 561 scf/ton, respectively. Coal samples from Sawahlunto typically adsorb more methane than those from Sambaliung at similar conditions. The complete Langmuir isotherm parameters of all 9 coal samples are listed in Table 1.

Table 1. Result of chemical, petrographic, and adsorption isotherm analyses.

Location	*Seam*	Sample Code	Depth (m)	Chemical Analysis Result TM (%, ar)	IM	VM	FC	Ash	CV (Cal/gr, adb)	Petrographical Analysis Result Rr %	Vit	Inert	Lip	MM	Adsorption Isotherm Analysis Result V_L (scf/t)	P_L (psi)	Hydro. Pressure (psi)	Storage Capacity (Scf/t, daf)
					%, adb						% vol							
Sambaliung	O	GRC-12	249	34.49	8.79	45.93	41.76	3.52	6008	0.35	97.6	0.2	0.1	2.1	529	1965	367	114
	NU	GRC-13	274	35.41	9.72	46.63	40.61	3.54	5988	0.42	97.2	0.6	0.1	2.1	385	1474	402	113
	NL	GRC-71	286	35.21	8.88	46.63	40.61	3.54	5988	0.33	90.9	0.8	0.1	8.2	1164	4775	421	127
	K	GRC-49	393	31.69	9.12	44.87	41.83	4.18	6050	0.33	95.5	2.3	0.1	2.1	1640	4107	577	269
	J	GRC-56	438	29.14	8.40	47.32	40.81	3.47	6311	0.37	96.3	1.3	0.3	2.1	1007	2511	644	268
	J	GRC-69	443	31.69	9.12	44.87	41.83	4.18	6156	0.39	97.7	0.1	0.1	2.1	1140	3411	651	236
	I	GRC-39	458	25.97	8.71	45.26	42.99	3.04	6085	0.39	95.2	2.1	0.2	2.5	1209	3608	673	246
Sawah-lunto	B	B	371	6.77	2.54	35.18	55.10	7.18	7434	0.66	96.0	1.4	0.7	1.9	742	1005	545	486
	C	C	393	5.14	2.21	40.36	53.42	4.02	7646	0.80	95.2	2.1	0.2	2.5	2154	1987	577	561

TM: total moisture, IM: inherent moisture, VM: volatile matter, FC: fixed carbon, CV: calorific value, Rr: random reflectance vitrinite, Vit : vitrinite, Inert: inertinite, Lip: liptinite, MM: mineral matter, VL : Langmuir volume constant, PL : Langmuir pressure constant.

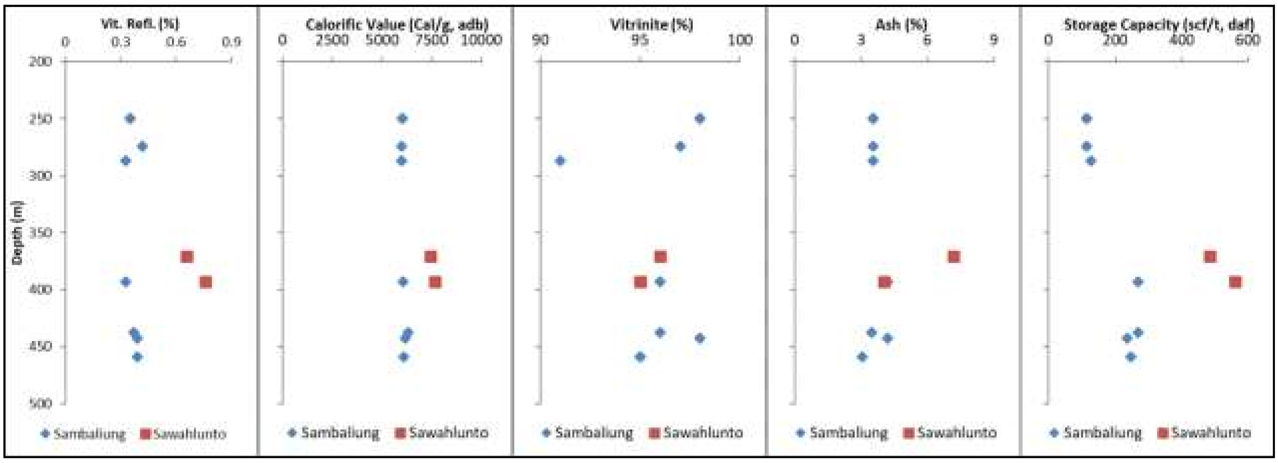


Figure 3. Vertical profiles versus depth of some analysis results.

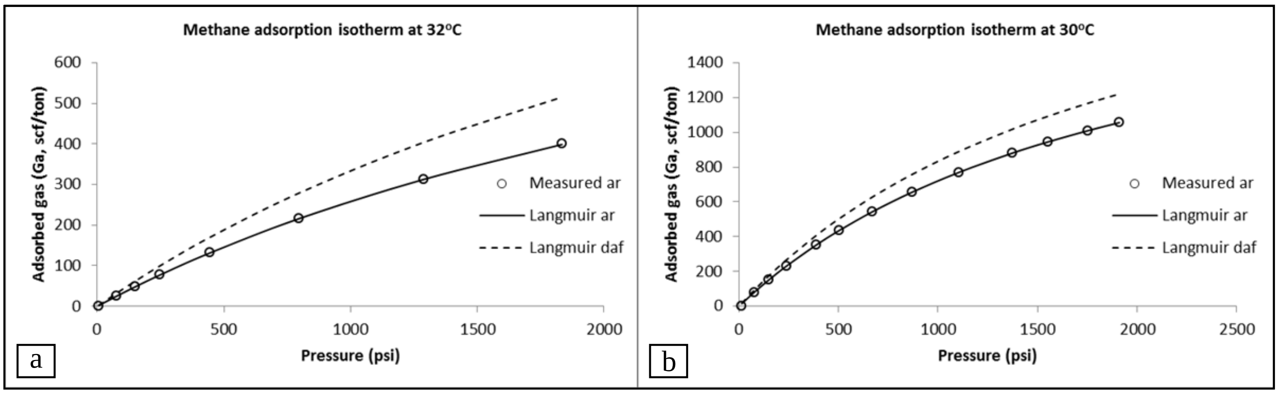


Figure 4. Adsorption isotherm of GRC-69 Sambaliung coal sample (a) and B Sawahlunto coal sample (b).

DISCUSSIONS

The coal ranks of the Sambaliung and Sawahlunto are distinctly different based on the proximate and vitrinite reflectance analyses. The different ranks could be related with geological history of the Tarakan and Ombilin basins. Although sedimentary basins in Indonesia were developed in similar tectonostratigraphy during Tertiary, there are two periods affect the deposition of those coal bearing strata (Doust and Noble, 2008; Koesoemadinata, 2002; Koesoemadinata *et al.*, 1978). The first period occurred in Paleogene when coal bearing strata were typically deposited in the stage of basin development. The coal layers deposited in this period are generally in bituminous rank, as these underwent in more advanced coalification. The second period is Neogene when more widespread coals were developed in Indonesian basins. The rank of coal layers deposited in this period is typically sub-bituminous (Koesoemadinata *et al*., 1978; Koesoemadinata, 2002). The different coal development periods are thus thought to contribute to the different rank observed in the Sambaliung and Sawahlunto coals. Another significant factor which may take a role on the different rank is that Sawahlunto area is the orogenic region of Barisan Mountain. The Barisan Mountain underwent orogenesis during Tertiary. Therefore the Mid-Miocene to Plio-Pleistocene orogenic activities took place in the Barisan Mountain (Koesoemadinata, 2002; Crow, 2005) might increase the Sawahlunto coal rank.

Along the drill core profile (Figure 3), the vitrinite reflectance, calorific values, and ash content of the Sambaliung coal samples generally do not exhibit major variation. The profile resulted from a relatively short section of the Latih Formation, which makes the rank parameters such as vitrinite reflectance has a similar range value. Vitrinite composition does not show any dramatical variation along the vertical profile (Figure 3). The rapid vertical variation is seen for storage capacity which generally exhibits decreasing upwards variation. For comparison, some analysis results of the Sawahlunto coal samples are also presented in the respective profiles.

The vitrinite reflectan and calorific values of Sambaliung coal samples do not vary in the profile due to the well depth scope is relatively narrow from 249 m to 458 m which leads all the samples belong to the same coal bearing strata. Total moisture content is likely controlled by depth. As the depth increase, the compaction would also increase. The greater compaction in the deeper layers promotes to a more intensive dehydration process of the coal seam material. On the other hand, vitrinite composition and ash content do not correlate to any coalification or compaction process. These parameters are influenced by the facies and depositional environments (Taylor *et al.*, 1998). In addition, their vertical profiles are shown to compare with other parameters especially storage capacity.

Methane storage capacity of coals is determined by some major factors. Depth is the most important factor, as this is in most cases directly related to formation pressure. During a high formation pressure condition, the methane gas will adsorbed onto the coal matrix surfaces and vice versa (Moore, 2012). The vertical profile of Sambaliung coal shown in Figure 3 clarifying that the storage capacity is clearly related with formation pressure represented by the depth. Plot between storage capacity versus depth resulted a coefficient correlation of R=0.94, a relatively high result, indicating that formation pressure takes important role for methane adsorption onto the coal surfaces.

Maceral composition also determines the storage capacity. Vitrinite maceral group is typically more porous and has larger matrix surfaces than the other maceral group.

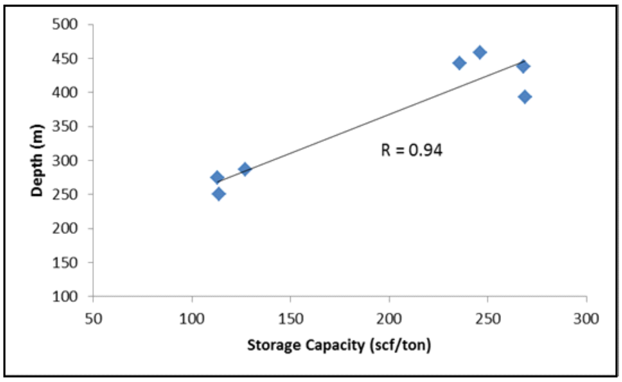


Figure 5. Plot of storage capacity versus depth of Sambaliung coal showing good correlation.

The larger surface will lead to a more favorable for methane adsorption. Therefore, if the vitrinite composition was abundat than the storage capacity would be high (Mastalerz *et al*., 2008; Moore, 2012; Flores, 2013). But in the present study, such relation is not observed in the Sambaliung coal samples due to no major variation of vitrinite composition along the profile which corresponds to that of storage capacity (Figure 5). Plot of the storage capacity versus vitrinite composition (not shown) results a weak coefficient correlation (R=-0.12). By this evidence, the variation of maceral composition of Sambaliung coal likely does not significantly contribute to the variation of storage capacity.

Other important aspects for methane storage capacity are ash content and rank. The former research presents the abundance of mineral matter in coal. Compared to the organic matter, mineral matter is less occurred on the surface area because of its more massive mineral texture. This indicates that the coal with more mineral matter content would adsorb less methane (Moore, 2012; Flores, 2013). In the Sambaliung coal profile, there is no dramatic variations of ash content which corresponds to storage capacity (Figure 5). The vitrinite reflectance and calorific value profiles do not show a significant variation as the profiles span only from a relatively short drill core. The profiles variation is develop differently compared with that of storage capacity. These suggest that ash content and rank do not significantly contribute to the variation of storage capacity.

From the discussion above, the main factor controlling storage capacity of coal in a formation is the formation denoted by depth. Increase of depth will promote more methane adsorption and in contrary lowering total moisture content. Additionally, less moisture content would also promote methane adsorption in coal surfaces. However, depth is not the only main factor, considering the resulted storage capacity measurement for the Sawahlunto coal. Compared at the similar depth range, about 371-393 m, the storage capacity of Sawahlunto coal is about twice of that the Sambaliung coal (Table 1). In this case, the coal rank is interpreted to be the resulting product of the storage capacity difference. The Sawahlunto coal rank is higher than that of Sambaliung coal. When the coal has experiences a more the intensive coalification, the micropores would increase its number (Levine, 1996; Flores, 2013). More abundant of the micropores would lead to a coal surfaces addition and likewise to the methane adsorption.

CONCLUSIONS

The former coal clearly shows that the increase of formation pressure represented by depth plays a significant role to control the adsorption capacity. Comparing the coals of Sambaliung and Sawahlunto at the similar depth range, the depth itself is not the only important factor. Coal rank is also thought as the significant role on the methane adsorption in the coals.

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