DE GRUYTER
OPEN

Arch. Min. Sci., Vol. 59 (2014), No 2, p. 509–516

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI 10.2478/amsc-2014-0037

ANDRZEJ OLAJOSSY*

THE INFLUENCES OF THE RANK OF COAL ON METHANE SORPTION CAPACITY IN COALS

WPŁYW RZĘDU WĘGLA NA POJEMNOŚĆ SORPCYJNĄ METANU W WĘGLACH

Methane sorption capacity is of significance in the issues of coalbed methane (CBM) and depends on various parameters, including mainly, on rank of coal and the maceral content in coals. However, in some of the World coals basins the influences of those parameters on methane sorption capacity is various and sometimes complicated. Usually the rank of coal is expressed by its vitrinite reflectance R_o. Moreover, in coals for which there is a high correlation between vitrinite reflectance and volatile matter V^{daf} the rank of coal may also be represented by V^{daf}. The influence of the rank of coal on methane sorption capacity for Polish coals is not well understood, hence the examination in the presented paper was undertaken. For the purpose of analysis there were chosen fourteen samples of hard coal originating from the Upper Silesian Basin and Lower Silesian Basin. The scope of the sorption capacity is: 15-42 cm^3/g and the scope of vitrinite reflectance: 0,6-2,2%. Majority of those coals were of low rank, high volatile matter (HV), some were of middle rank, middle volatile matter (MV) and among them there was a small number of high rank, low volatile matter (LV) coals.

The analysis was conducted on the basis of available from the literature results of research of petrographic composition and methane sorption isotherms. Some of those samples were in the form (shape) of grains and others – as cut out plates of coal. The high pressure isotherms previously obtained in the cited studies were analyzed here for the purpose of establishing their sorption capacity on the basis of Langmuire equation.

As a result of this paper, it turned out that for low rank, HV coals the Langmuire volume V_L slightly decreases with the increase of rank, reaching its minimum for the middle rank (MV) coal and then increases with the rise of the rank (LV). From the graphic illustrations presented with respect to this relation follows the similarity to the Indian coals and partially to the Australian coals.

Keywords: methane, rank of coal, sorption capacity

Metanowa pojemność sorpcyjna węgla ma istotne znaczenie w zagadnieniach metanu pokładów węgla (CBM) i zależy od różnych parametrów, w tym głównie od rzędu węgla i zawartości mecerałów w węglu. Jednakże zależność ta w wielu zagłębiach węglowych na świecie jest różnorodna i na ogół skomplikowana. Zazwyczaj rząd węgla jest wyrażany przez jego refleksyjność witrynitową R_o. Ponadto

* AGH UNIVERSITY OF SCIENCES AND TECHNOLOGY, FACULTY OF MINING AND GEOENGENEERING, AL. A. MICKIEWICZA 30, 30-059 KRAKOW, POLAND.

w węglach, w których występuje wysoka korelacja między rzędem , a zawartością częsci lotnych V^{daf}, wówczas rząd węgla może być reprezentowany również przez V^{daf}. Wpływ rzędu na metanową pojemność sorpcyjną dla polskich węgli nie jest dobrze rozpoznany, dlatego w tej pracy podjęto próbę zbadania tego zagadnienia. Do przeprowadzenia analizy wybrano czternaście prób suchego węgla kamiennego pochodzącego z zagłębia górnośloskiego oraz dolnośląskiego. W tych węglach metanowa pojemnośc sorpcyjna mieściła się w zakresie 15-42 cm^3/g, a refleksyjność witrynitowa była w zakresie 0,6-2.2%. Większość z tych węgli była niskiego rzędu, o wysokiej zawartości części lotnych (HV), kilka było średniego rzędu, o średniej zawartości częśc lotnych (MV) oraz wśród nich była mała liczba węgli wysokiego rzędu, o niskiej zawartości części lotnych (LV).

Przeprowadzono analizę opartą o wyniki wcześniejszych badań spotykanych w literaturze, dotyczących wysokociśnieniowych izoterm sorpcji metanu oraz składu petrograficznego tych węgli. Niektóre z tych prób były w kształcie ziaren, a inne były płytkami wyciętymi z wegla. Wysokociśnieniowe izotermy sorpcji metanu uzyskane wcześniej w cytowanych pracach były analizowane w celu określenia pojemności sorpcyjnej na podstawie równania Langmuire. W efekcie tej pracy okazało się, że dla niskiego rzędu (HV) metanowa pojemność sorpcyjna węgla V_L nieznacznie maleje ze wzrostem rzędu, osiągając minimum dla średniego rzędu (MV), a następnie wzrasta ze wzrostem rzędu (LV). Z prezentowanych ilustracji graficznych odnośnie do tej zależności widać podobieństwo do węgli z basenu indyjskiego oraz częściowo do węgli z basenu australisjkiego.

Słowa kluczowe: metan, rząd węgla, pojemność sorpcyjna węgla

1. Introduction

Poland possesses significant deposits of coalbed methane (CBM) as an economic resource. Thus far the attempts to obtain this methane from hard coal mines were difficult. Methane is often strongly bound with microporous (submicroporous) coal matrix. Moreover methane is absorbed as dissolved gas in coal matrix. In certain types of coal the internal surface area in micropores is large. CBM reservoir characterization is complex due to high degree heterogeneity and variation in petrographic composition of coals.

An important parameter in the CBM issues is the methane sorption capacity of coals. The coal type is described by the maceral content, including mainly the vitrinite and inertinite content. In addition, the methane sorption capacity of coal is also influenced by such factors, as: mineral matter content and moisture content.

In research on the influence of the petrographic composition on the methane sorption capacity of hard coal it was found that there are differences between bright and dull coals (Levine et al., 1993). Bright – vitrinite rich coals have a higher sorption capacity than dull inertinite rich coals of the same rank (Bustin & Clarkson, 1998). In a work (Laxminarayana & Crosdale, 1999) on the Australian coals a rather complicated nature of this relation was observed. Whereas, from the result of a work (Laxminarayana & Crosdale, 2002) on the Indian coals it follows, that methane sorption capacity and vitrinite content are unrelated with each other. A similar result can be reached under the conclusions of the work (Olajossy, 2013), which determines a weak relation between those two parameters with respect to low and middle rank Polish coals.

Coal rank may be determined by physical and chemical properties, which are influenced by coal type. To minimize the effect of the coal type, in the cited study the use of the vitrinite reflectance R_o as the rank parameter was chosen. For such types of coal, for which there is a high correlation between volatile matter V^{daf} and vitrinite reflectance, also the volatile matter can express the rank of coal. The lack of this correlation means that V^{daf} content is strongly influenced by coal type variations and the presence of carbonates.

A relationship between increasing sorption capacity and increasing rank of coal has been previously established (Yee et al., 1993), (Laxminarayana & Crosdale, 1999). However other study (Levy et al., 1997) reports a wide spread of data with almost no change in sorption capacity up to semianthracite rank followed by a sharp increase in adsorbed gas.

The relation of Polish coal rank to methane sorption capacity is not fully understood. In order to determine this relation, samples of hard coal from Upper Silesian Basin and Lower Silesian Basin were chosen. Their maceral contents and high pressure sorption isotherms were established previously in studies: (Ceglarska-Stefańska, 2000) and (Nodzeński, 2000). On the basis of the available from literature results of those works and also studies of few other authors (cited in the references of the present paper) the required analysis and discussion of their results were conducted. The obtained results may be compared with the conclusion of the research on the relation of methane sorption capacity from the rank of coal regarding the samples of other coals in the World.

2. Effect of the rank of coal on the sorption capacity of coals originating from number of different coal basins in the World

The methane sorption capacity is usually expressed by the Langmuire volume V_L (cm^3/g), which depends on the rank of coal presented by the vitrinite reflectance R_o (%) of the dry coal. There were chosen three known from the literature types of those influences with respect to three coal basins in order to better present the differences indicated in the previous point.

The first analysis concerns dry coal samples from the lower Permian Barkan/Harabari Formation in India (Laxminarayana & Crosdale, 2002). These samples of dry, ash free hard coals are characterized by their high sorption capacity: 25-40 cm^3/g, relatively low and middle rank: $0,6 < R_o < 1,5\%$. Mineral matter in Indian coals appears not to be significantly contributing to their methane sorption characteristics. However, there was observed a clear relation of sorption capacity with the moisture of those coals.

Vitrinite reflectance R_o has been used as an indicator of rank of coals in preference to the volatile matter V^{daf}, which is strongly influenced by coal type variations. Fig. 1 presented a decrease in the Langmuire's volume V_L with increasing rank as R_o for dry coals, India (Laxminarayana & Crosdale, 2002).

It is worth to mention, that in those samples of coals there were no high rank coals and anthracites. Certain differences between the bright and dull coals can be observed with respect to the examined relation.

The second analysis concerns the results obtained on the samples of dry coals from Bowen Basin, Australia (Laxminarayana & Crosdale, 1999). Those coals are characterized by high sorption capacity, within 35-50 cm^3/g and a broad scope of changes of rank: $0,5 < R_o < 3\%$ and lack of the content of liptinite. In those coals volatile matter V^{daf} is strongly correlated to vitrinite reflectance R_o, thus both of those parameters can represent the rank of coal. Trends in Langmuire sorption capacity V_L in relation to coal rank (R_o) are presented on Fig. 2 (Laxminarayana & Crosdale, 1999).

This result indicates that V_L for bright and dull coal types follows discrete, second – order polynomial trends, with increasing rank. This no-monotonically function has a minimum V_L beside some value R_o for bright, low volatile coal and has other minimum V_L at some value R_o for dull, medium volatile coal. For high ranks of coal however the sorption capacity of both of

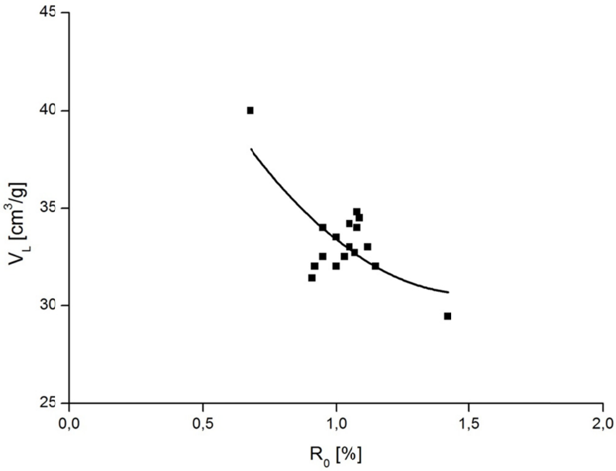

Fig. 1. The relation between methane sorption capacity and rank coal (India)

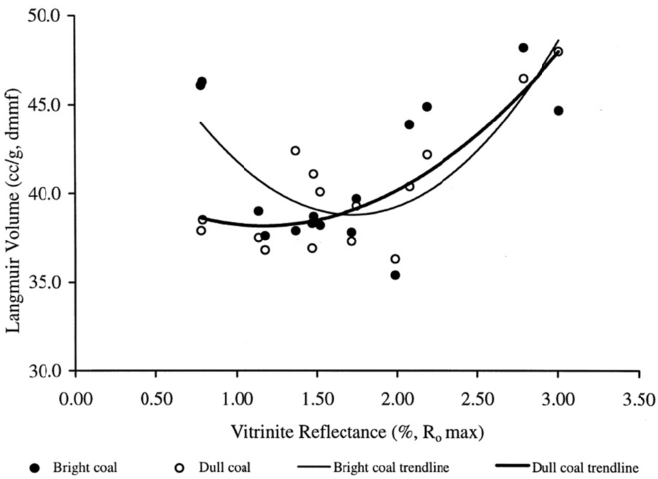

Fig. 2. Rank effects on adsoprtion capacity of dry coal (Australia)

those types of coals increases rapidly with the rise of R_o in a similar manner, thus the differences between bright and dull coals disappear. This conclusion is interesting.

The third analysis concerns the results of the research of dry hard coal samples from location within North America (Chalmers & Bustin, 2007). The coals have the values of methane sorption capacity in scope of changes: 5-25 cm^3/g with scope of change of rank: $0,6 < R_o < 4\%$. The presence of mineral matter in the researched coals did not turn out to be significant. In those studies the presence of liptinite in the composition of macerals was separately considered.

Fig. 3 presents the relation between the methane sorption capacity (for chosen value of pressure 6 MPa) and a coal rank (Chalmers & Bustin, 2007).

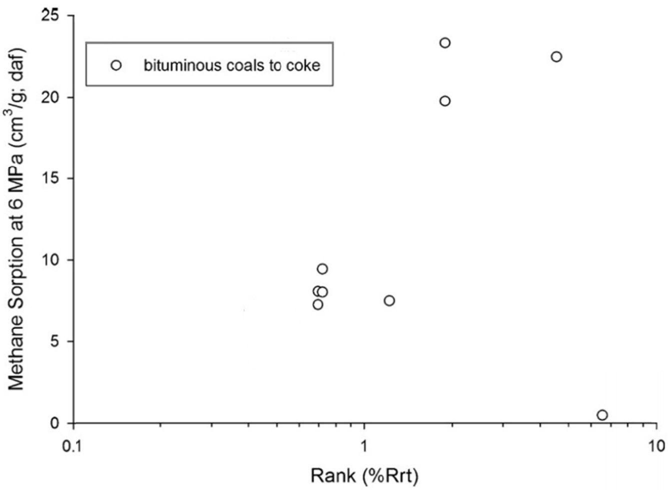

Fig. 3. Relationship between the methane sorption capacity and rank coal (North America)

The examined samples were divided in two groups: bituminous coals with low rank and higher rank groups, although not numerous, in order to show a positive relation between the methane sorption capacity and the rank of coal.

From the analyzed results of the cited papers there follows a varied character of relation V_L (R_o). Therefore it is only natural to attempt to research this relation with regard to Polish coals.

3. The rank of coal and methane sorption capacity of dry coal (Poland)

For examination of the relation V_L (R_o) and making of appropriate comparisons there were chosen fourteen samples of hard coals, including nine obtained from the Upper Silesian Basin and five from the Lower Silesian Basin. Some properties of those coals were presented in the study (Olajossy, 2013). Most of them are low rank, high volatile (HV) coals, some are middle rank, middle volatile (MV), whereas only few are high rank, low volatile (LV) and anthracite. The results of the research of isotherm of methane sorption on those coals and the results of the petrographic analysis of those coals obtained previously by various authors, mainly (Ceglarska-Stefańska, 2000; Nodzeński, 2000) were used.

Moreover the results of other works were used (Ceglarska-Stefańska & Brzóska, 1995), (Ceglarska-Stefańska & Zarębska, 2006; Nodzeński, 1998). On this basis, an analysis of methane sorption capacity was conducted (Olajossy, 2013) in which the Langmuire equation was used:

$$V = \frac{PV_L}{P_L + P}$$

or the linear form:

$$\frac{P}{V} = \frac{P_L}{V_L} + \frac{P}{V_L}$$

where V is the volume of adsorption gas at the pressure P, V_L is Langmuire volume, P_L is Langmuire pressure. Some of the values of V_L were obtained within the scope of high pressures up to 8 MPa and others up to 4,5 MPa.

The relation between the rank of coal of these coals and their volatile matter is presented on Fig. 4. High correlation $r^2 = 0{,}98$ can be presented with the assistance of the linear approximate:

$$V^{daf} = -21{,}32\ R_o + 51{,}62$$

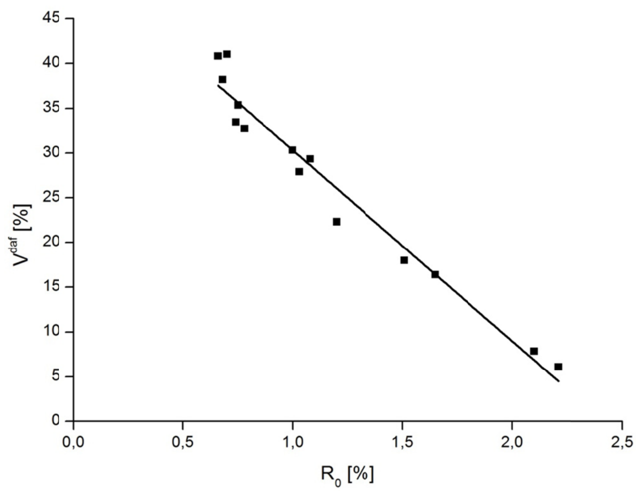

Fig. 4. Relation between volatile matter content V^{daf} and vitrinite effectance R_o (Poland)

Therefore, the rank of coal can be also expressed by the volatile matter. A similar result of linear equation (3) regards also Australian coals (Laxminarayana & Crosdale, 1999) in the scope of $0{,}6 < R_o < 2{,}0\%$.

The content of ash (A_o) in coals evidences the amount of the mineral matter in this coal. Fig. 5 presents the relation between the Langmuire volume V_L and the ash content A_o.

In the examined samples of coals the volume of mineral matters was on the level of about 5%, which may be both of more or less significance.

The relation between methane sorption capacity and the rank of coal, which is material for the present paper, is presented on the Fig. 6.

Regardless of the volume of vitrinite and inertinite (bright coal or dull coal) for the low rank (HV) the Langmuire volume V_L decreases with increase of R_o and passes through minimum for middle rank coal (MV), R_o – 1,20. Subsequently, V_L rises with the increase of R_o for the higher rank coal to semianthracite and anthracite (while sorption capacity semianthracite is lower than the expected – perhaps due to the low content of vitrinite).

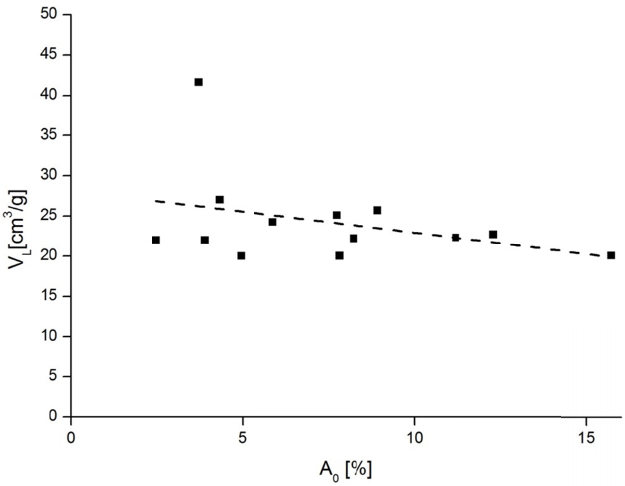

Fig. 5. Relation between sorption capacity V_L and ash content A_o in coals (Poland)

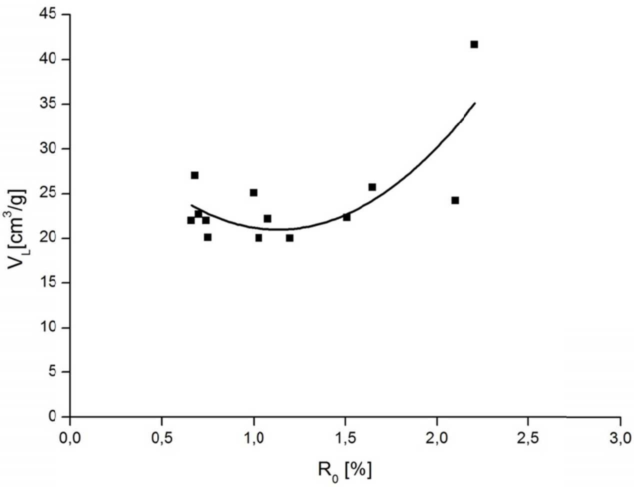

Fig. 6. Rank effects on methane sorption capacity of coals (Poland)

This relation can be presented with assistance of second – order polynomial trends:

$$V_L = 3{,}48\ R_o^2 - 0{,}59\ R_o + 21{,}02$$

as nonlinear approximation with weak correlation, $r^2 = 0{,}60$.

By comparison one can observe here the similarity to the Indian coals (for low rank) and Australian coal (for middle and high rank coal). There is however no broad source basis for the comparative purposes due to a small number of Polish coal samples that were possible to be gathered for the analysis.

4. Summary

With respect to the relation of rank of Polish coal and the methane sorption capacity one should rather focus on the trend, not on a particular strict relationship. The opinion that with the increase of the rank of coal rises also the sorption capacity is untrue. This can be only the case for the high rank coal along with anthracites. Methane sorption capacity, expressed by Langmuire volume decreases for low rank (HV) and reaches minimum for values of R_o corresponding with the medium rank (MV). In the scopes of changes R_o: 0,6-2,2% and the sorption capacity 15-42 cm^3/g the correlation between methane sorption capacity and rank of coal is weak. While for low rank (HV) a similarity to Indian coals was observed as well as for the high rank and middle rank a partial similarity to Australian coals.

References

Bustin R.M., Clarkson C.R., 1998. *Geological controls on coalbed methane reservoir capacity and gas content*. International Journal Coal Geology, vol. 38, p. 3-26.

Ceglarska-Stefańska G., 2000. Monography untitled: *Układ węgiel kamienny – metan w aspekcie desorpcji i odzyskiwania metanu z gazów kopalnianych*. Ed. M. Żyła, Kraków, AGH, UWND, p. 179-200.

Ceglarska-Stefańska G., Brzóska K., 1995. *A contribution to the relationship between the methane sorption capacity of the coal and gas pressure.* Arch. Min. Sci., Vol. 40, No 2, p. 211-219.

Ceglarska-Stefańska G., Zarębska K., 2006. *Sorpcja CO_2 i CH_4 na niskowęglowych węglach z KWK Brzeszcze*. Karbo nr 1, p. 31-35.

Chalmers-Gareth R.I., Bustin R.M., 2007. *On the effects of petrographic composition on coalbed methane sorption.* Coal Geology, vol. 69, p. 288-304.

Laxminarayana Ch., Crosdale P.I., 1999. *Role of coal type and rank on methane sorption characteristics of Bowen Basin, Australia coals.* International Journal of Coal Geology, vol. 40, p. 309-325.

Laxminarayana Ch., Crosdale P.I., 2002. *Controls on methane sorption capacity of Indian coals.* AAPG Bulletin, vol. 86, no. 2, p. 201-212.

Levine J.R., Johnson P.W., Beanish B.B., 1993. *High pressure microbalance sorption studies.* Coalbed Methane Symposium, The University of Alabama, vol. 1, p. 187-196.

Levy J.H., Day S.J., Killingley J.S., 1997. *Methane capacities of Bowen Basin coals related to coal properties.* Fuel, vol. 76, p. 813-819.

Nadzeński A., Hołda S., 2000. Monography untitled: *Układ węgiel kamienny – metan w aspekcie desorpcji i odzyskiwania metanu z gazów kopalnianych.* Ed. M. Żyła, Kraków, AGH, UWND, p. 153-178.

Nodzeński A., 1998. *Sorption and desorption of gases (CH_4, CO_2) on hard coal and active carbon at elevated pressure.* Fuel, vol. 78, no. 11, p. 1243-1246.

Olajossy A., 2013. *On the effects of maceral content on methane sorption capacity in coals.* Arch. Min. Sci., Vol. 58, No 4, p. 1221-1228.

Yee D., Seidle J.P., Hanson W.B., 1993. *Gas sorption on coal and measurement of gas content in hydrocarbons from coal.* AAPG Studies in Geology, vol. 38, p. 203-218.

Received: 06 September 2013