Canadian Journal of Pure and Applied Sciences
Vol. 9, No. 2, pp. 3461-3465, June 2015
Online ISSN: 1920-3853; Print ISSN: 1715-9997
Available online at www.cjpas.net

CHARACTERISTICS OF PORES AND ITS EFFECT ON PROBABLE OCCURRENCE OF COALBED METHANE IN THAR COALFIELD OF PAKISTAN: A PRELIMINARY PETROGRAPHIC STUDY

Imdadullah Siddiqui
Center for Pure and Applied Geology, University of Sindh, Jamshoro, Pakistan

ABSTRACT

The Thar Coalfield is located in the Sindh Province of South East Pakistan some 400km east of Karachi. It is world's largest coalfield which is now being studied from Coalbed Methane resources point of view. Thar coal was deposited in Domain to Mountain/Bara Formation of Paleocene to early Eocene age. The pore diameter in coal helps tounderstand the formation Coalbed Methane. The studies conducted for Thar coalfield shows that coal has dual porosity, as some coal seams have nearly micropores or meso-pores, while other seams possess meso pore, on the basis of pore micropore, pore volume is also determined that shows that the samples from Thar coalfield pore volume vary between 0.06 and 2.36 cc/g. For the determination of adsorption capacity of methane, surface area of pores in coal is also calculated which shows that investigated coal has low values of surface area in coal. The investigation shows that, the Thar coal has smaller size of pore, therefore metane will diffuse in these pores, and based on surface area results it shows that the Thar coal has low adsorption capacity.

Keywords: Bara formation, micropore, mesopores, adsorption.

INTRODUCTION

Coal is complex hydrogenous mixture of organic and inorganic components. It has network of cleats and pore structure, which play a very important role in absorbility and flowability of coalbed methane (CBM). Thar coalfield is the seventh largest coalfield of Pakistan; presently it has divided into twelve blocks, out of these twelve blocks one coal block has leased out to a research group for probable occurrence of CBM, but in this regard, research on pore characteristics, i.e. pore diameter, pore volume and surface area of the coal must be conducted. As pore structure of coal is closely related to the absorbability and flowability of coalbed methane (Siddiqui *et al*., 2010). The entire Thar coalfield is located between latitudes 24°15' *N* and 25 ° 45' N and longitudes 69° 45' E and 70° 45' E (Survey of Pakistan topographic sheet Nos. 40 L/2, 5 and 6) situated in District Tharparkar of south-eastern Pakistan (Fig. 1). It is the world's seventh largest coalfield of Pakistan having an area of about 9100 square kilometres (Ghaznvi, 2012). It has north-south length of 140 km and east-west width of 65 km. The resource potential of this single coalfield is about 175 billion tonnes (Jaleel *et al*., 2002). In Thar coalfield about sixteen coal seams of various thickness and depth are found (Fig. 2). Geologically, these blocks have covered with sand dunes. The age of the coal bearing Formation is Domain to Mountain/Bara Formation of Paleocene to early Eocene age.

Thar coal lie at the depth between 130 and 250 meters. There are number of coal seams of varying thickness ranging from 3 meters to 21 meters at average depth of 170 meters. Bara Formation is overlaid by the sub-recent to recent deposits, comprising interbedded carbonaceous sandstone, siltstone, and claystone upto 65 meters thick, at the depth of of 52-125 meters. The recent deposits are overlain by Sub-Recent deposits consists of some 50 meters thick Sand Dunes, of fine to medium grained, containing sub-rounded and moderately sorted grains of ferromagnesian minerals (Akhtar *et al*., 2003).

The cumulative thickness of coal varies between 7.5 to 36 meters and maximum thickness of coal seam in Thar coalfield is 23 meters. The Domain/Bara Formation is some 95 meters thick consisting of sandy/silty claystone and sandstone Formation, overlying at the depth of 100 to 220 meters (Table 1).

The basement rock is light grey, weathered, medium compact granite containing fine to coarse quartz grain (Rizvi, 2011). The overlying Bara Formation consists of layers of light grey to brown colored carbonaceous clay stone, sandy clay stone, and silty clay stone, the clay

Corresponding author e-mail: siddiqui57@gmail.com

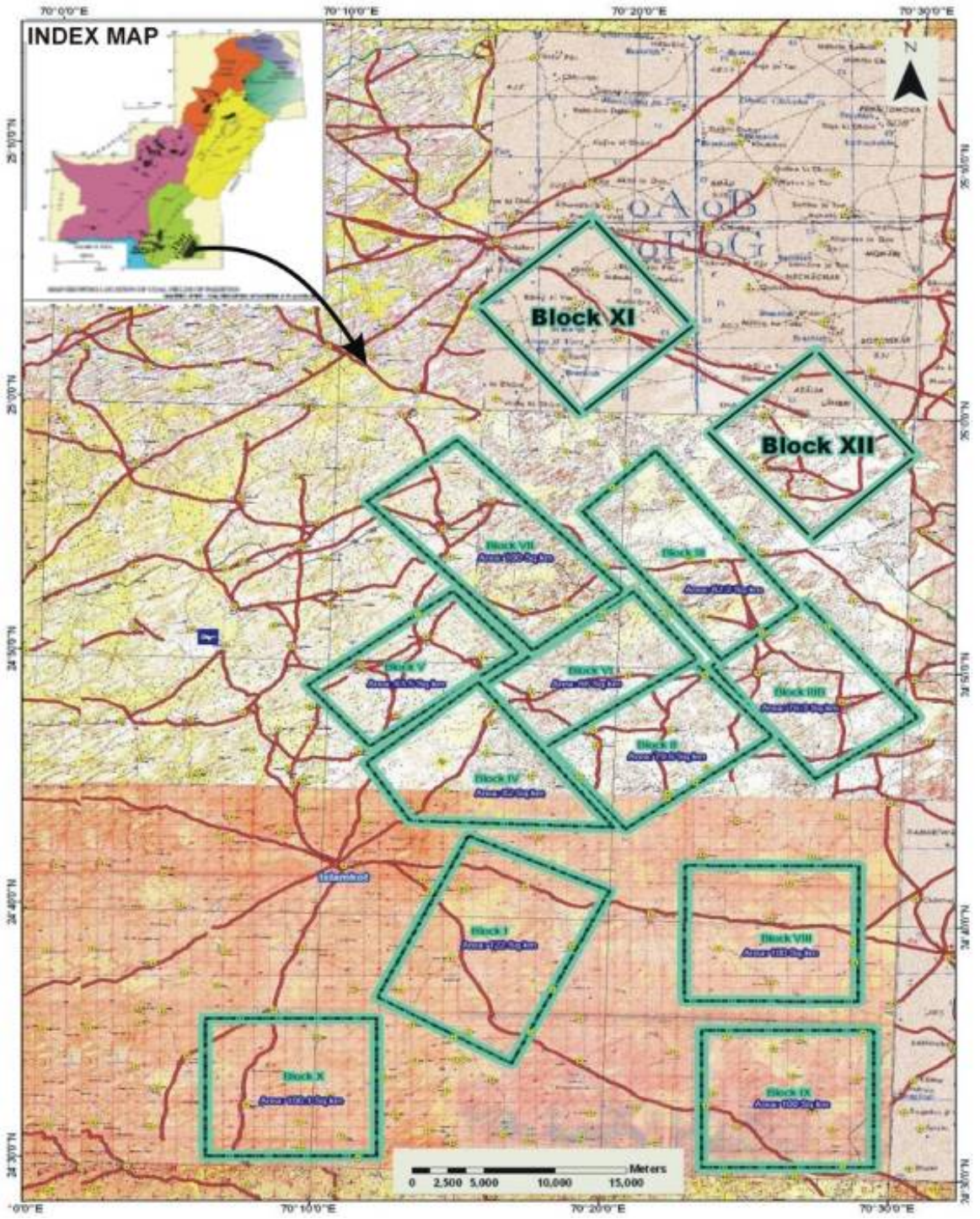

Fig. 1. Map showing location of Thar coalfield, Pakistan.

stone is olive grey to dark grey in color, containing pyritic resin globules and petrified coal roots (Masood and Khan, 1999; Fauzia *et al*., 1997). The chemical analyses of the coal in investigated blocks-VII, VIII and X is displayed in table 2 (Govt. of Sindh, 2013).

MATERIALS AND METHODS

Area of study

The investigated block-VII, known as Dhaklo block is located between Latitude 24° 38' 33'' N and 24° 50' 38'' N, longitude 70°11'11''E and 70° 20'11'' E in the survey of

Pakistan topographic sheet Nos. 40 L/1 and L/5. In this block dune sand was thinnest in, reaching upto the depth of 54.76 m. The total estimated coal reserves are 2175.78 million tones. The block-VIII called as Khario Ghulam Shah block, is approximately located Latitude $24^{o}\,37^{'}\,00^{''}$ N and $24^{o}\,42^{'}\,23^{''}$ N, longitude $70^{o}\,22^{'}\,30^{''}$ E and $70^{o}\,28^{'}\,30^{''}$ E in toposheet No. 40 L/6. The sand dunes in this block are longitudinal ranging in relief from tens of meters to the hundreds of meter. The total estimated coal reserves are 2947.8 million tones. The block-X, known as Mithrio Soomro, is located between Latitude $24^{o}\,30^{'}\,00^{''}$ N and $24^{o}\,36^{'}\,00^{''}$ N, longitudes $70^{o}06^{'}\,00^{''}$E and $70^{o}\,13^{'}\,00^{''}$ E in Survey of Pakistan toposheet No. 40 L/6. The total estimated coal reserves in this block are 2871million tones.

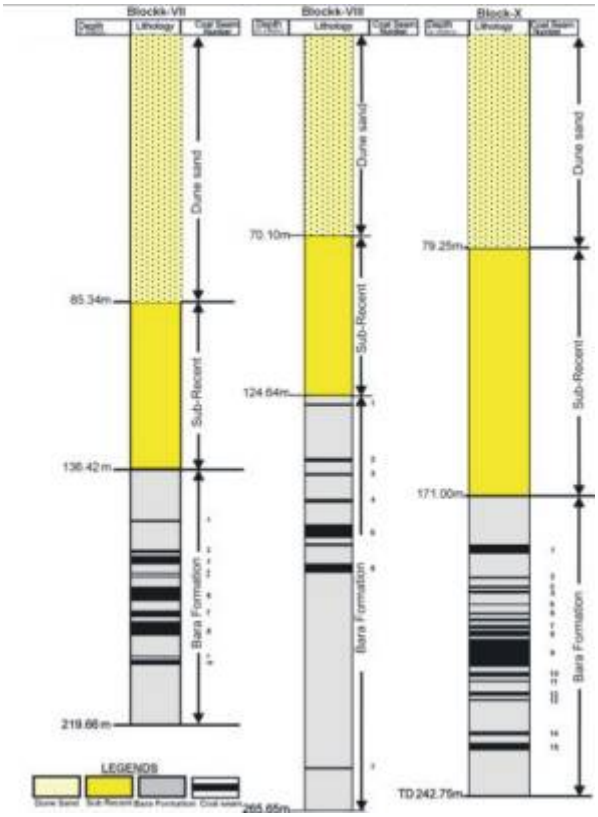

Fig. 2. Showing well logs of investigated coal blocks and their coal seam number.

Methodology

A total six core drill samples were obtained from the drilling site and field core library of Sindh coal authority, Government of Sindh. The samples were dried in oven at 105^{o}C for 24 hours for removing surface moisture and grinded. Barret-Joyner *et al*. (1951) method was applied for the determination of total pore volume, by using nitrogen adsorption/desorption method at 77.4 k. Quntachrome Nova 2200e surface area analyzer instrument with NOVAWin PC based program was used for the operation of instrument as method described by Yao and Liu (2002) and Singh *et al*. (1985). The sample was out gassed at 100^{o}C for 2 hours; the adsorption and isotherm at 77.4 k were measured over relative pressure intervals from 0.100/0.100. The surface area and micropore volume were calculated using Dubinin and Radushkevich (1947) method.

RESULTS AND DISCUSSION

In coal nitrogen, methane and carbon dioxide gasses occur as either in free state, or in a physically absorbed phase, within the highly porous adsorptive peat matrix as macro, meso and micropores. Methane (CH_4) is generated in coal as primary or secondary biogenic gas, which is generated and entrapped within coal macromolecules (SanFilipo *et al*., 2000). The absorbability and flowability of coalbed methane in coal depends upon the pore diameter, pore volume and pore surface area, as case of methane adsorption, it is assumed that little gas may store in adsorbed state in coals with meso and macropores (Clarkson and Bustin, 1999). In coal pores having diameter < 20 Å is known as micro-pore, pores ranging between 20 Å - 500 Å diameter are termed as meso-pore and macro-pores are those having >500 Å diameter (IUPAC, 1982). Table 3 shows that coal in Thar coalfield has dual porosity, the seam two and three of block-X has nearly micropores or meso-pores of 72.29Å and 34.81Å diameter, while in seam six of block VII, VIII and seam one of block-X has the pore of diameter 118.15Å, 116.39Å and 120.39Å, respectively (Fig. 3). In it is assumed that little CH_4 may had been stored in adsorbed state, and seams having coal that possess meso- and macropores may serve as transport pathways.

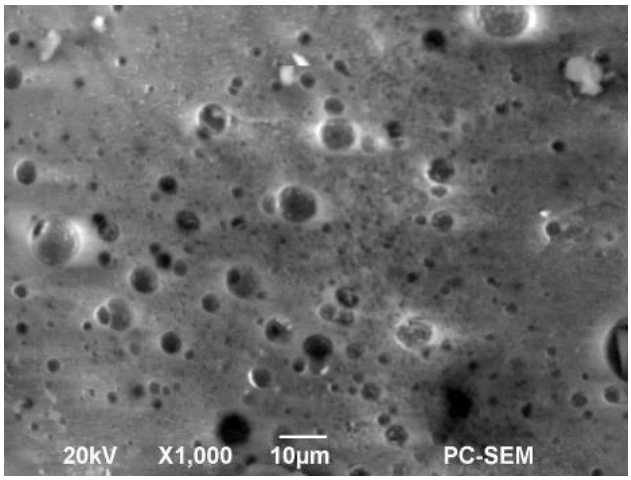

Fig. 3. SEM image showing micropores in Thar coal.

The desorption, diffusion and seepage of methane depends upon the mutual interaction among gas, water and coal matrix or cleat porosity (Siddiqui *et al*., 2014). Whereas, the flow velocity of CBM be influenced by the combined action of diffusion. Table 3 displays that coal from Thar have pore diameter, smaller than the average

Table 1. General stratigraphic sequence of Thar coalfield.

Formation	Age	Thickness	Lithology
Dune Sand	Recent	14m to 93m	Sand, Silt and Clay
……	……Unconformity	…….	……
Alluvial Deposits	Sub Recent	11m to 209m (variable)	Sandstone, Siltstone, Clay stone, mottled
……	……Unconformity	…….	……
Bara Formation	Palaeocene to Early Eocene	+52m (variable)	Claystone, shale, sandstone, coal, carbonaceous clay stone
……..	…..... Unconformity	……..	……
Basement Complex	Pre-Cambrian	----	Granite, quartz and diorite

Table 2. Chemical analyses of investigated blocks of Thar coalfield.

Weighted Average chemical analyses As Received values %	Block VII	Block VIII	Block XI
Moisture	48.27	49.57	48.99
Ash	8.03	7.78	6.35
Sulphur	1.16	1.44	1.17
Fixed carbon	19.56	18.10	14.0
Voaltile matter	25.30	24.32	30.60
Heating value MJ/kg	5.74	5.59	5.11

Table 3. Porosity in Thar coal.

Block/Seam No.	BJH Pore size distribution Adsorption		
	Pore diameter Å	Pore volume cc/g	Surface area m^2/g
VII / 6	118.15	2.36	789.75
VIII / 6	116.39	2.29	785.51
X / 1	120.39	1.18	394.84
X / 2	72.29	0.13	84.48
X / 3	34.81	0.06	44.65

free path of methan molecule, i.e. 530 Å therefore diffusion of methane might take place (Zucrow and Hoffman, 1976). Coal from coal seam 2 and 3 of block-X of Thar coalfield has pore diameter 72.29 Å and 34.81 Å, whereas, molecular diameter of methane is 3.25 Å, this indicates that in this case Knudsen or surface or solid diffusion may occur (Do, 1998).

FU *et al.* (2005) has classified as pores on the basis of diffusion characteristic, and seeping of CBM, as seeping pore and diffusion pores, if the pores are >950 Å. As per classification proposed by FU *et al*. (2005) the pore diameter data displayed in table 3 shows that all pores of Thar coal fall in the category of diffusion pores. These diffusion pores are further, classified as micropore, if the diameter of pore is smaller than 80Å, and the pore diameter ranging between 80 Å and 200 Å, are termed as transitional pores and minipores are those having diameter between 200Å and 650Å. The micropores are dominated by surface diffusion, while minipores are mainly Knudsert diffusion. The figures of block VII (seam 6), VIII (seam 6) and X (seam-1), indicated that mixed diffusion or surface diffusion and Knudsen diffusion may take place.

Because of microporosity in coal, methane is supposed to be stored in adsorbed form, and micrpore volume has the primary control upon high-pressure gas adsorption (Clarkson and Bustin, 1999). In seam three and two of Block-X the pore volume is 0.06 and 0.13 cc/g, whereas the pore volume increases from 1.18 cc/g to 2.36 cc/g, in seam one of block-X and in seam six of block VII and VIII (Table 3). The mechanism of micropore volume, primarily depends upon the gas retention in coal as well as adsorption on internal surface area.

The surface area is principally, linked to the pore size distribution in coal (Siddiqui *et al*., 2011). In general, surface area gradually increases with decline of pore size. The retention capacity of methane depends upon the adsorption of methane molecule on large surface area, which also depends upon the development of cleats

matrix porosity. For the determination of surface area, D-R equation is applied. The surface area in coal samples from Thar coalfield vary from 44.65 m^2/g to 789.75 m^2/g (Table 3).

CONCLUSION

The pore diameter in coal is the foundation for the study of Coalbed Methane. The pore, diameter study shows that Thar coalfield has dual porosity, the samples from seam two and three of block-X has nearly micropores or meso-pores of 72.29Å and 34.81Å diameter, while in seam six of block VII, VIII and seam one of block-X has the pore of diameter 118.15Å, 116.39Å and 120.39Å correspondingly. This reveals that because of smaller size of pore, diffusion of methane molecule will take place. The result also shows that the Thar coal has meso-pores of 34.81Å and 72.29Å, and these pores will work as transitional pore. Pore volume is related to the micropores. Based on pore volume study in coals of Thar coalfield, it is concluded that in Thar coal pore volume vary between 0.06 and 2.36 cc/g. The surface area can control adsorption capacity of methane, the low values of surface area in coal samples of Thar coalfield, reveals that this coal has low adsorption capacity.

REFERENCES

Akhtar, T., Muhammad, AT., Khurram, Y. and Khan, MS. 2003. Preliminary sedimentological study of Dune Sand of Sorah area, Khairpur District, Quadrangle 40A/16 in comparison to Dune Sand of Bhitro and Saleh jo Tar area, Tharparkar district, Quadrangle 40L/5, Sind, Pakistan. Geol. Surv. Information Release No. 785.

Barrett, EP., Joyner, LG. and Halenda, PPJ. 1951. The determination of pore volume and area distributions in porous substances. I. Computations from nitrogen isotherms. American Chemical Society. 75:373-380.

Clarkson, CR. and Bustin. 1999. The effect of pore structure ans gas pressure upon the transport properties of coal: A laboratory and modeling study. 1. Isotherm and pore volume distribution. Fuel. 78:1333-1344.

Dubinin, MM. and Radushkevitch, LV. 1947. Equation of the Characteristics Curve of Activated Charcoal. In: Proceedings of the Academy of Sciences, Physical Chemistry Section. USSR. 55:331-333.

Do, DD. 1998. Adsorption Analysis: Equilibria and Kinetics, Imperial College Press, London, England. pp 892.

Fauzia, H., Masood, KR. and Khan, J. 1997. Palynological analysis of the drill hole core from Sinnhar Vikia Varvi Block, Thar Coal Field, Sindh, Pakistan. Abst. Third Geol. Congress.

FU, X., Qin, Y., Zhang, W., Wei, C. and Zhou, R. 2005. Fractal classification and natural classification of coal pore structure based on migration of coalbed methane. Chinese Sci. Bull. 50:66-71.

Ghaznvi, MI. 2012. An overview of coal resources of Pakistan. Geol. Surv. of Pakistan, Record volume No. 114:167.

Government of Sindh. 2013. Thar Coal Energy Board, Government of Sindh: Thar coalfield. Available at: http://www.sindhcoal.gos.pk/coal-fields/thar-coalfield/ (Accessed: 2015).

International Union of Pure and Applied Chemistry. 1982. Manual of symbols and terminology. (Appendix 2: Part1). Colloidal and Surface Chemistry. Pure and Appl. Chem. 52:2201.

Jaleel, A., Alam, GS. and Hassan, MT. 2002. Coal Resources of Four Blocks in Thar coalfield, Sindh, Pakistan. Geol. Surv. Record Volume No. 115.

Masood, KR. and Iqbal, F. 1999. Subsurface palynology of Tertiary Sediments, Tharparkar Coal Field, Sindh, Pakistan. Part-I Well Nos. 10, 11, 12, STP series. Bull. Geobiol. 1(1):52-62.

Rizvi, Y. 2011. Preliminary Petrological Studies of Basement Rocks, Thar Coal Basin, Tharparkar District, Sindh, Pakistan. Iranian J of Earth Sci. 3:34-46.

San Filipo, JR., Barker, CE., Stanton, RW., Warwick, PD. and Morris, LE. 2000. A shallow coal-bed methane show in the Gulf Coast of Texas, indication of down-dip commercial potential. American Association of Petroleum Geologists Official Program. 9:A130.

Siddiqui, I., Sarfraz, H., Solangi. and Samoon, MK. 2010. Preliminary studies of Cleat fractures and Matrix porosity in Lakhra and Thar coals, Sindh, Pakistan. J. of Himalayan Earth Sciences. 44(2):25-32.

Siddiqui, I., Sarfraz, HS., Aftab, AS., Mashooque, AW., Muhammad, KS. and Suhail, A. 2014. Application of X-ray computed tomography for analyzing cleats and pores for coalbed methane in coals from Thar coalfield. Canadian Journal of Pure and Applied Sciences. 8(1):2743-2749.

Singh, KSW., Everett, DH., Haul, RAW., Moscou, L., Pierotti, RA., Rouque'rol, J. and Siemieniewoska, T. 1985. Reporting physisorption data for gas/dolid systems with special reference to the determination of Surface Area and Porosity. J. of Pure and Applied Chemistry. 57:603-619.

Yao, Y. and Liu, D. 2002. Pore system characteristics of coal reservoirs and their influence on recovering of coalbed methane in Henan coalfields. J. of Coal Sc. and Tech. 34:51-86.

Zucrow, MJ. and Hoffman, J. 1976. Gas dynamics. (vol. I and II). John Wiley, New York, USA.

Received: Jan 21, 2015; Accepted: March 2, 2015