A STUDY ON WIRELINE LOGGING APPLICATION FOR CBM (COAL BED METHANE) RESERVE ESTIMATION AND SUITABILITY OF CBM EXTRACTION PROJECT IN BANGLADESH COAL FIELDS

Mohammad Islam Miah[1*]

[1]Department of Petroleum and Mining Engineering,
Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh
[*]Corresponding Author: islam.pge20@gmail.com, islam_pge@yahoo.com, islam_pme@yahoo.com

Abstract: *Wireline logging is a continuous recording or measuring tool of the geophysical characteristics of formation at various distances from the bottom in petroleum and mining engineering field. Wireline logs are quite useful and informative. In mining engineering field, their common uses are mineral & coal identification, gas content, coal tonnage, coal reservoir characterization (i.e. stress orientation, natural fracturing, porosity and permeability in coal beds) and volumetric reserve estimation of Coal Bed Methane (CBM). These are crucial parameters to understand early in the lifecycle of the field and throughout the years as the project matures. Five major Gondwana coalfields (Jamalganj, Barapukuria, Khalaspir, Dighipara and Phulbari) have been discovered which bearing about 4744 million ton coal reserve in the Bogra-Dinajpur-Rangpur areas of the tectonically stable Precambrian platform in the northwestern part of Bangladesh. Due to sufficient geological evidence, indication of significant gas content, higher reserve, and the relatively suitable burial greater depth of coal compared to other coal fields, Jamalganj coalfield is more viable for CMB extraction project in a Gondwana coal basin. Bangladesh needs coal utilization as a major alternative energy source to overcome the present critical situation in the power sector. CBM extraction project also can minimize this energy crisis of the country.*

Keywords: Wireline Logging, Gas Content, Reserve Estimation, CBM, Jamalganj Coal Field.

1. INTRODUCTION

Coal is a readily combustible sedimentary rock composed essentially of lithified plant materials. It was the principal commercial energy source of the world till the end of nineteenth century. Natural gas is the prime fuel in the world from 1980 to till now. As the contribution of greenhouse gases to the atmosphere by burning coal and oil became more alarming, natural gas was preferred as clean and environmentally friendly fuel. CBM refers to the methane gas that occurs within coal beds lying underground. Methane is produced during qualification process that transforms plant materials into coal in response to burial. The methane thus produced is stored mostly (about 90%) as adsorbed gas held by molecular attraction on coal particles. It occurs in fewer amounts (about 10%) as free gas in microspores in coal and as dissolved gas in water within pores. Bangladesh (BD) is a young deltaic sedimentary basin and meets the geologic requirements for generation and accumulation of coal and natural gas in the subsurface. The country has a proved coal rich province in the north western part [6]. Five major Gondwana coalfields have been discovered in the northwestern part of Bangladesh by the end of 2004. The location map of Gondwana basin and coal fields of Bangladesh (BD) has been shown in Figure-1.

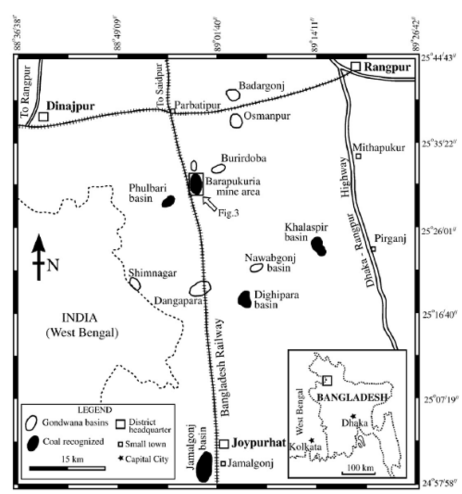

Fig. 1: Location map of Gondwana Coal Fields of Bangladesh (Imam, 2002)

A well log is a continuous record or measurement of the geophysical characteristics of formations during the drilling or production phase of a well [5]. Wireline log is gives the significant sub-surface data which is mostly used to detect coal or hydrocarbon bearing formation, coal or minerals, Formation evaluation (coal, oil or gas), for estimating reserve of CBM and reservoir characterization, etc. The major focus of this article is to explain the application of Wireline logging for volumetric reserve estimation of CBM and its suitability in Bangladesh coal fields.

3. APPLICATION OF WIRELINE LOGGING FOR CBM RESERVE ESTIMATION

Wireline logging measurements are recorded at various distances from the bottom of the logging tool. Gamma Ray (GR) & Spontaneous Potential (SP), Porosity logs (Neutron-Density porosity, Sonic log) and Resistivity logs are commonly used in Well logging application for coal and petroleum formation evaluation. The natural gamma ray tool measures bulk gamma rays emitted from the radioactive minerals in the immediate vicinity of the wellbore. Most of the naturally occurring radioactivity in sedimentary formations comes from three general types of minerals: thorium, potassium, or uranium. Clay minerals generally contain large amounts of naturally occurring radioactive minerals. Uranium, being a more soluble mineral, can be transported by groundwater moving through the formation. Typically, a gamma ray measurement is interpreted as follows: the high readings are shales and the low readings are potential reservoirs. Coals usually have a very low natural gamma ray response because the concentration of clay minerals is low. Occasionally, a coal will have some radioactive material (typically Uranium) that was deposited by groundwater movement, making the gamma ray measurement much higher. Enhanced vertical resolution processing of the natural gamma ray measurement is a recommended practice in CBM applications. This processing mathematically reduces the vertical resolution of the measurement, sharpening the bed boundary to help highlight the detail within the coal and result in a more accurate coal-thickness measurement. It distinguishes between potential hydrocarbon-bearing formations (sands, carbonates) and shale. It is the complementary log of resistivity and porosity logs. The SP measurement is a voltage potential difference created by three phenomena: salinity difference between the borehole fluid and reservoir fluid, streaming potential, and electro chemical invasion. The most common source of this SP is the salinity difference between connate water and borehole fluids. SP is generated by fluids moving from the borehole to the reservoir. The SP is measured as a voltage in reference to the zero baseline value in shale. The shale content of the formation tends to decrease the magnitude of the SP response, as do thin beds, hydrocarbons, and low permeability. The magnitude of the SP deflection times the thickness of the coal is a good qualitative indication of permeability. Resistivity tools come in two general categories, induction or laterolog. The most common resistivity devices run for CBM applications are induction-based tools. While the principles of measurement behind the tools differ, interpreting the resistivity log response in coal is similar. Generally, coal tends to exhibit rather high resistivity measurements. Coal, in its purest form, is a good insulator and has very high resistivity. Impurities in coal such as clays, pyrites, volcanic minerals, and fluid-filled cleating tend to reduce the resistivity in coals. Permeable coal is observed as having a typical invasion profile while the tight coal shows very high resistivity with no invasion [4,5&7].

3.1 Coal Identification

Coal can be identification using Lithology logs as GR log. Generally, GR shows lower value at coal formation (Figure-2). A wet coal (a typical coal that produces water as the mechanism to reduce pressure in the cleat system for gas desorption) is often observed as a stacking of the neutron and density porosity. This observation may vary based upon the minerals present, geographic area and service-company logging tool response. The condition of the borehole in which the wireline log was recorded must be considered when using wireline logs for the identification of coal. Cavings or rugose boreholes can give a false indication of coal. Using multiple coal indicators helps minimize the negative effects of borehole rugosity on coal thickness. All of the preceding cutoffs must to be determined locally but the gross thickness of a particular coal seam is determined by following these general wireline log measurement cutoffs [5, 11, 12&13]:

- Bulk-density measurements: 1-2 g/cc
- Gamma ray measurements less than 60 API
- Neutron porosity measurements >50%
- Sonic transit time greater than 80 µs/ft
- Shear transit time greater than 180 µs/ft and
- Resistivity greater than 50 ohm-m.

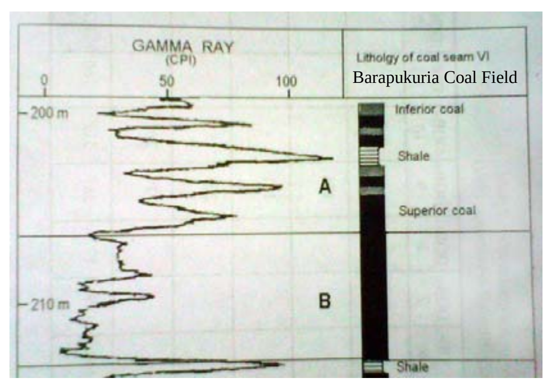

Fig. 2: Gamma Ray log of Coal field (Imam, 2005)

3.2 Volumetric Reserve Estimation of CBM

3.2.1 Coal Tonnage

A suitable measure to evaluate analog CBM projects compares coal tonnage per acre. However, coal tonnage per acre gives a starting place with stimulation treatment design. Determining coal tonnage in the project area is the first step to quantify the available resource. Generally, Coal tonnage [5,12&13] is calculated using Eq. 1:

$CTpA = 1359.7 * h * RHOB$ …………… (1) where

CTpA = coal tonnage per acre,
h = coal thickness (ft) and
RHOB = minimum bulk density in the coal, g/cc.

3.2.2 Gas Content in Coal

Determining gas content in coal is the primary goal of CBM reservoir analysis. It is essential to have representative measurements of the initial gas content in a distribution of coals as well as in the organic-rich shale around the wellbore. This information is used to construct a linear correlation between initial gas content and the wireline log measurement of bulk density. From the basic correlation, initial gas content can be derived for a larger area than just the pilot project. When expanding the gas content algorithm for a more descriptive case, the effects of pore pressure from dewatering the coal need to be taken into consideration. Equation-2 is the characterization of the Langmuir isotherm most commonly used to model the gas content through the lifecycle of the well.

$GC\_L = L_c*[1- M_c+ A_c]/[P_r/(P_r+P_c)]$ …….. (2) where
GC_L = Langmuir desorbed gas content (scf/ton),
L_c = Langmuir constant (scf)
M_c = Moisture content in the coal (%),
A_c = Ash content in the coal (%),
P_c = Langmuir pressure, psi (gas content versus reservoir pressure [5]) and P_r = Reservoir pressure, psi

Comparing the measured gas content at initial reservoir conditions with the calculation Langmuir gas content is another step in CBM reservoir understanding. Coupling the calculated desorbed gas content using wireline log data with the Langmuir isotherm is a powerful tool to help users understand CBM production response. This is especially important through the later stages in the lifecycle of the CBM reservoir when it is time to select infill drilling locations [5, 12&13].

3.2.3 Gas-In-Place Calculations

Total gas-in-place (GIP) calculations [5] are derived by multiplying the project area, coal tonnage and the gas content together using equation-3.

GIP = GC_L * CTpA * A …………….. (3) where
GIP = Gas in place (scf),
GC_L = Langmuir gas content (scf/ton),
CTpA= Coal tonnage per acre and A =Total area in acres.

3.2.4 Recovery Factor

The recovery factor can be estimated using the Langmuir isotherm to obtain gas content at initial and abandonment reservoir pressure, respectively. The recovery factor is estimated as the ratio of the initial gas content and the gas content at abandonment. The gas content at abandonment pressure is not a strict engineering calculation because it falls on the steep portion of the isotherm curve. The actual recovery factor will be a combination of drainage patterns, well interference, production operations, and economic variables. When gas prices are high, projects can be economic longer than with low gas prices. The actual recovery factor determination may be decades in the future, but this method is a good first approximation of the recovery factor. The recovery factor can be estimated [5, 12&13] by Equation-4:

R = GC_A / GC_L ……………… (4) where
R = Recovery factor,
GC_A = Gas content at abandonment pressure from the Langmuir isotherm (scf/ton) and GC_L = Initial desorbed gas content, scf/ton.

4. SUITABILITY OF CBM EXTRACTION IN COAL FIELDS OF BD

There are five major Gondwana coal fields (Jamalganj, Barapukuria, Khalaspir, Dighipara and Phulbari) of Permian age contains 4744 million tons of coal reserve in the north western part of Bangladesh. The depths of coal seams below surface lie in range 118-1158m including 29 coal seams in average coal thickness range of 38-64m [6&9].

4.1 Origin of BD Coal Fields

In the northwestern part of the country, major deposits of coal are high quality bituminous. These are called Gondwana coal as these occur in the rock unit named Gondwana Group formed during Permian period about 250-285 million years before present. During this time, a vast landmass or supercontinent known as Gondwanaland existed in the south. The Gondwana supercontinent consisted of the present day land mass of India plus NW Bangladesh, Australia, Africa, South America and Antarctica, all jointed together. The coal deposits of BD are genetically related with West Bengal and Bihar of India. Climatic condition at that time allowed thick vegetation to grow within river born basins creating suitable setting for peat formation in many years. As a result of qualification process, the vegetations die and were subsequently buried under thick sand and clay layers and gradually turned into coal. Later, these coal deposits were affected by faulting. Then coals preserved in fault bound half graben basins. It has been suggested that individual coal deposits in NW Bangladesh were parts of master coal basin from which large portions were subsequently eroded. Only the parts of coal bearing sediments preserved within the faulted basins are available at present [2].

4.2 General Characters of Bangladesh Coal Fields

Most of the coal fields are located in stable platforms in North-Western part of Bangladesh. General Stratigraphy of the North-western part is shown in Figure-3. Gondwana coal consists of 90% methane, calorific value of 10450-11876 Btu/lb and average estimate in-situ CBM resource is 9.56 m^3/ton of the country. The general characteristics [6&9] of the coal fields are given below:

- The coal found in North West Bangladesh is high volatile bituminous coal. The quality of the coal is very good.
- The coal is Permian in age and occurs within fault bounded Gondwana basins.
- The coal seams occur at depth range from 118m to 500 m at Rangpur saddle but 600m to 1000m at Bogra shelf zone. Thick to very thick multiple coal layers are found in these fields.
- The coal deposits are covered unconformable at the top by 100m to 200m thick loose to poorly consolidated water bearing sand layer. This water aquifer belongs to the Dupitila rock unit of Pliocene age (Figure-2).

- The coal basins are bounded by major normal fault forming half graben.

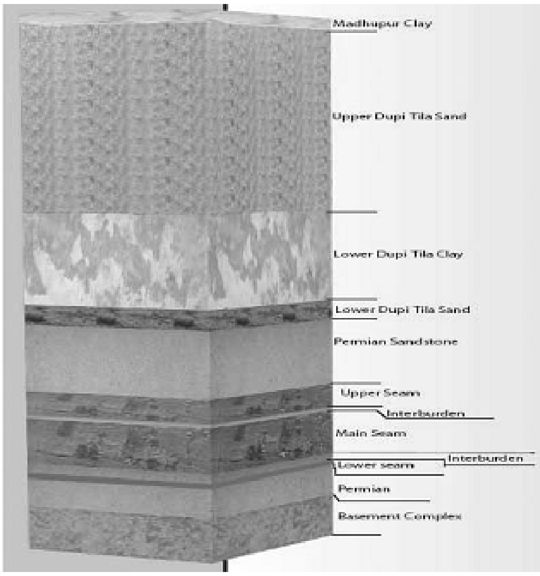

Fig. 3: Stratigraphy of stable platform of BD [9]

4.3 Seam thickness and Reserve of Coal Fields

The coal thickness and reserve of Bangladesh coal fields varies from one field to another field. The depth of coal seam, seam thickness and coal reserve have been shown with respective coal fields of Gondwana basin in the country in Table- 1.

Table-1: Coal Fields and Reserve of BD [6,10,14&16].

Coal fields (District)	Depth of Coal seam, meter	No. of coal seam & thick-ness, (avg.), m	Reserve (million ton)		Status
			Imam, 2005	Mu-ller, 2009	
Jamalganj (Jaipurhat)	640-1158	7 & 64	1053	2513	Mining not feasible economically (Open pit or Underground)
Barapukuria (Dinajpur)	118-506	6 & 51	303	377	Producing by Underground Method
Khlashpir (Rangpur)	257-451	8 & 42	147	828	Undeveloped
Dighipara (Dinajpur)	250	7 & 42	200	600	Undeveloped
Phulbari (Dinajpur)	152-246	1 & 38	380	426	Open pit mine feasibility study undertaken, 2004
Total	-	29 & 237	2003	4744	-

The Barapukuria coal field has minimum reserve about 8% but Jamalganj has highest coal reserve as 53% of total reserve (4744 million ton) of Bangladesh coal fields. These reserves also have been shown graphically by Figure-4.

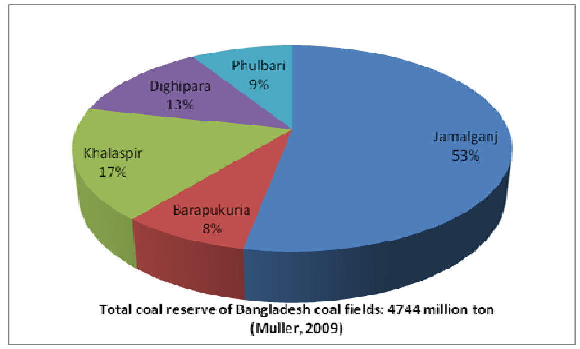

Fig.4: Reserve distribution of Bangladesh coal fields

4.4 CBM Prospect in Bangladesh

There are two types of mining methods (Open-pit and Underground mining) have been considered for the exploration of coal in the worldwide. The recovery factor is 90% (Almost all) and 60% of open pit and underground mining method, respectively. However, a major disadvantage of open pit mining lies in the unfavorable impact of massive surface excavation on the surroundings and environmental impact. On the other hand, Underground mining is more environment friendly method but it has several risk and hazards such as methane gas explosion, spontaneous combustion, roof collapse or subsidence, water flooding pose danger to mine personnel etc [6&8]. These methods are mainly used under the considerations of several factors. Some factors are coal rank and methane content of coal, burial depth and thickness of coal seam, fractures in the coal seam, hydro-geological conditions or hydrodynamic properties, geothermal gradient and economic feasibility. CBM project is another way to recovery of burial depth coal reserve where open pit and underground mining is not economic feasible. In assessing the prospect of CBM development, some important factors have been considered. Generally, burial depth of more than 600 m, gas content of 6-7 m^3/ton, high rank coal with thickness in excess of 30 m, permeability greater than 1.5 md, and an in-situ reserve of more than 1 billion tons of coal is considered reasonably viable for developing CBM prospect in a Gondwana coal basin [3]. The five coal fields of Bangladesh is highly prospective and more suitable for CBM extraction project because these have satisfactory values of terms required and meet with the minimum standard values which listed below in Table-2.

Table-2: Comparison of vital factors for CBM between minimum standard values and Bangladesh coal fields [10&14].

Consideration Factors for CBM	Bangladesh Coal Fields (average)	Minimum Standard
Depth (meter)	283-590	300
Seam thickness (m)	38-64	20
Rank of coal	High to medium volatile bituminous	High volatile bituminous
Porosity (%)	1.6-3.2	> 1.6
Permeability (md)	9.8-137.8	5
Temperature (°C)	32-36	<40°C
CBM content (ft^3/ton)	200-400	70

Among five coal fields, Jamalganj coalfield has largest coal reserve and more burial depth of coal seams (Figure-5) at lower Gondwana formation (Figure-6) of stable platform in the country which 9 bore holes that penetrated the coal seams are spread over an area having a maximum east-west distance of 12.5 km and a north-south distance of 4.8 km [15].

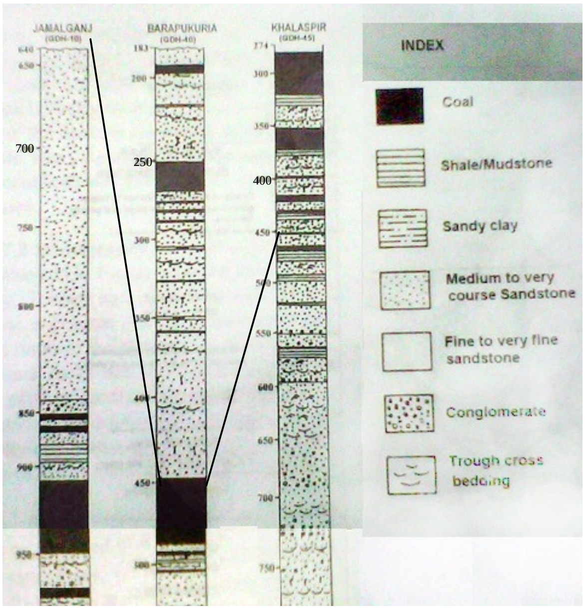

Fig.5: Rock sequence and depth variation of seams at different coal fields in Bangladesh (Imam, 2005)

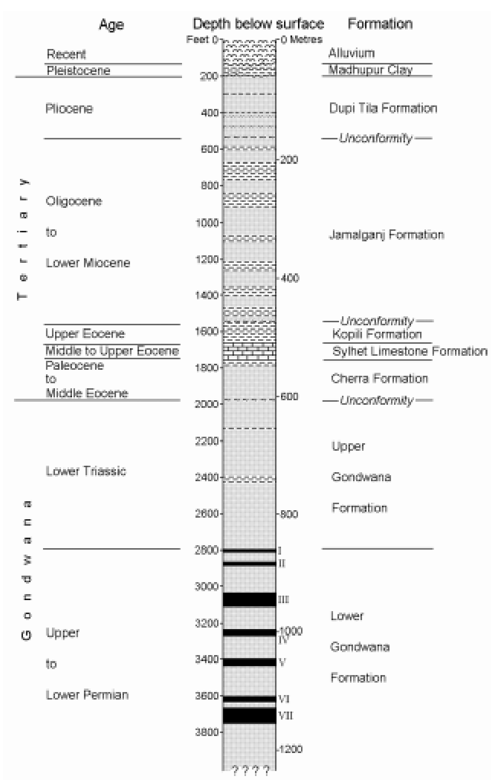

Fig.6: Stratigraphic Succession of Jamalganj Coal field (Imam, 2002)

Some important factors of Jamalganj field [1&6] have been listed below:

- Coal rank and methane gas content: Jamalganj coal is high-volatile to medium-volatile bituminous coal. No direct measurement of the methane gas content of this field. Fried Krupp Rohstaff suggested that the coal will give off large quantities of gas.
- Depth of Coal seam: ranges from 641 to 1126.
- Thickness of coal seam: 64m (46 of Seam III).
- Areal extent of coal and reserve: 30 sq km (2891. 133 acres) and 1053 million tons (Imam, 2005).
- Permeability of coal seam: it is indicated by mud losses during drilling EDH-14.
- Impermeable seal: The sandstone overlying the coal seams are effectively impermeable due to high compaction and cementation, especially because of the presence of kaolinitic cement.

Jamalganj coalfield is the best favoring for CBM project under considering the aforementioned minimum standard and positive factors as large coal reserve, very large thickness of the coal seams, suitable burial depths of coal seam, indication of significant gas content, and also the low permeability of the rocks above and surrounding the coal-bearing layers.

5. DISCUSSIONS AND CONCLUSIONS

The first goal of this article is to show the value and utility of incorporating wireline logs as an integral component of modern CBM project assessment. Wireline logs are a very useful evaluation tool when calibrated with core measurements, not only for gas content or estimating reserve estimation, but for identifying stress orientation, natural fracturing and permeability in coal beds. These are essential parameters to understand early in the lifecycle of the field and throughout the years as the project matures. The average value of ash content & moisture content, fixed carbon, calorific value, gas content and coal thickness (all seams) of coal are 24.2 & 3.58%, 36.7, 11,878 Btu/lb, 4-7 m^3/ton and 210 feet respectively which will be helpful for estimating volumetric reserve of CBM project at Jamalganj coal field. Bangladesh is a developing country. It has very limited natural resources like gas, coal, limestone and pit etc. Like the whole world, Bangladesh is also facing energy problem due to the lack of gas and other natural resources. But electricity is the key element of socio-economic development of the country. Adequate and reliable supply of electricity is an important pre-requisite for attracting both domestic and foreign investment. The Government has given top priority to the development of the sector and has set the goal of providing electricity to all citizens by proper utilization of coal or unconventional gas resource (CBM) and natural gas, etc. Thus, Bangladesh needs coal or CBM unconventional gas resource as a major alternative energy source to overcome the present critical situation in the power sector. CBM project can minimize this energy crisis of the country within half time required for mining. The total CBM potential reserve is 0.8 -1 Tcf in Bangladesh coal fields [10]. According to the BHP-UTAH

Inc. maximum production of 26 bcf (0.026 Tcf) of gas per year may be maintained from 4th year to 15th year before showing a rapid decline of production rate and depletion of the field. As a result, the total gas that could be produced would be about 0.34 Tcf [6]. This is equivalent to as a small size gas field compared to the eastern Bangladesh gas province. Large amount of water will be produced due to production of CBM which contains high amount of total dissolved solids can cause salinity problems of soil, decrease the ground water level as well as affect the environment. Proper treatment and management of process can ensure the safety and risk of CBM project. Government should take necessary actions to utilization these coal reserves as CBM extraction project with Extraction Company by positive negotiation.

6. ACKNOWLEDGEMENT

I am very much grateful to Professor Badrul Iamam, Department of Geology, Dhaka University who wrote a book about "Energy Resources of Bangladesh" to use the necessary information for this article. I am also grateful to Mr. Mijanur Rahman, Deputy General Manager, Geological Division, BAPEX and Md. Abdus Sultan, Deputy General Manager (Geology), RDMD, Petrobangla for their proper guideline about Formation evaluation (Oil/Gas and Coal) by well logging. Thanks to several authors who wrote different articles about Bangladesh coal fields.

7. REFERENCES

[1] Imam, B. and Shaw, H. F., "Coal bed methane prospect of Jamalganj coal field, Bangladesh", The Arabian Journal for science and Engineering, v. 27, pp. 17-27, 2002.

[2] Islam, S. A. and Eickhoff, G., "Hdrocarbon source rock potential of Gondwana sediments in Wertern Bangladesh", Bangladesh Journal of Geology, v. 20, p. 87-98, 2001.

[3] Sharma, D. D., "Review of coal resources in Indian and their exploration strategy", Journal of Geological society of India, v. 61, p.387-402, 2003.

[4] Bassiouni, Z., "Theory, Measurement and Interpretation of Well Logs", First Printing, Henry L. Doherty Memorial Fund of AIME, SPE, Richardson, TX, pp. 372, 1994.

[5] Rogers, R. E. et al "Coalbed Methane: Principles and Practices", Oktibbeha Publishing Company, Halliburton, pp. 495, 2009.

[6] Imam, B., "Energy Resources of Bangladesh", First Edition, University Grants Commission Publication No. 89, Bangladesh, pp. 280, 2005.

[7] Schlumberger, "Log Interpretation Principles/ Applications", 7th printing, Houston, pp. 235, 1998.

[8] Asia Energy Plc, The Phulbari Coal Project, Bangladesh, Presentation to Coaltrans Asia Conference, Bali, Indonesia, June 05, 2006.

[9] Hossain, A. M. and Hasan, M. M., "Underground or Open Pit Mining Method – an Unresolved Debate Delaying Coal Mining in Bangladesh", Proceedings of the Conference on Engineering Research, Innovation and Education (CERIE 2011), Sylhet, Bangladesh, ISBN: 978-984-33-2140-4, pp. 1044-1050, 11-13 January 2011.

[10] Rahman, Tahmilur and Alam, S. M. J., "Coal Bed Methane (CBM) Project, How Far To Minimize the Energy Crisis of Bangladesh", Proceedings of the Conference on Engineering Research, Innovation and Education (CERIE 2011), Sylhet, Bangladesh, ISBN: 978-984-33-2140-4, pp. 959-962, 11-13 January 2011.

[11] "Coalbed Methane Play and Prospect Evaluations Using GeoGraphix Soft- ware," Customer White Paper published on \\http:www.geographix.com, 2003.

[12] Mullen, M. J., "Coalbed Methane Resource Evaluation from Wireline Logs in the Northeastern San Juan Basin: A Case Study" paper SPE 18946 pre- sented at the Rocky Mountain Regional/Low Permeability Reservoirs Sym- posium, Denver, CO, March 6-8 , 1989.

[13] Mullen, M. J., "Log Evaluation in Wells Drilled for Coalbed Methane" RMAG Coal bed Methane San Juan Basin Symposium, 1988.

[14] Muller, M., "It's not only about Coal Mining: Coal-Bed Methane (CBM) and Underground Coal Gasification Potential in Bangladesh", p.38, 2009.

[15] Rahman, M. M. and Zaher, M. A., "Jamalganj coal-its quality and Mineability. Proc. Seminar on Petroleum and Mineral Resources of Bangladesh, Ministery of Petroleum and Mineral Resources, Govt. of Bangladesh, 8-12 Oct. 1980, p. 41-53.

[16] Saleque, K. A., "Coal Mining Challenges in Bangladesh", Part -1, The Energy Bangla, April 26, 2009.

8. NOMENCLATURE

Symbol	Meaning	Unit
A_c	Ash content in the coal	%
API	American Petroleum Institute	-
AEC	Asia Energy Corporation	-
Bcf	Billion cubic feet	
BHP	Broken Hill Propreiter	-
Btu/lb	British thermal unit per found mass	-
CBM	Coal Bed Methane	-
ft	Feet	-
h	Coal thickness	ft
L_c	Langmuir constant	scf
M_c	Moisture content of coal	%
m	Meter	-
md	Milli-darcy	-
m^3/ton	Cubic meter per ton	-
P_c	Langmuir pressure	psi
P_r	Reservoir pressure	psi
psi	Found force per Square inch	-
RHOB	Bulk density	gm/cc
scf	Standard cubic feet	-
Tcf	Trillion cubic feet	-
μs/ft	Micro-second per feet	-