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Coal Bed Methane Exploration and Possibility for CO_2 Sequestration in Jharia Coalfield, India

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ABSTRACT

Coal proximate parameters, petrography and permeability are key parameters for evaluating the economic production of natural gas from coal seams of Jharia coalfield. Coal quality parameters, including maceral composition, grade and rank, have a significant impact on the source rock and reservoir characteristics of coal. Coal proximate parameters such as ash content, volatile matter and moisture content of these coal seams vary between 17.45% to 33.75%, 15.45% to 25.84% and 0.68% to 1.21% respectively. Coal petrographic analysis, carried out for a selected 16 coal core samples shows that vitrinite reflectance of coal samples varies from 1.21% to 1.75%. Gas content values, calculated from available empirical equation vary from 11.11 cc/gm to 11.91 cc/gm. Considering the actually available experimental data, coals rich in vitrinitemacerals is promising for the exploitation of CBM. The injection of CO_2 into coal beds and simultaneous production of CBM combines gas production (enhanced CBM recovery) with CO_2 sequestration results in cleaner energy production. The present work would be useful for CO_2 sequestration while producing CBM from the Jharia coalfield in near future.

INTRODUCTION

Exploration in coal bed methane (CBM) in Jharia coalfield has been going on vigorously for some 15 years. Methane from coal represents an emerging energy resource that has considerable long-term potential for discovery and development. During the formation and maturation of coal, considerable amount of hydrocarbons, mainly methane, is generated by both biogenic and thermogenic processes which in turn are controlled by burial history, maceral composition, and basin hydrodynamics (Scott and Kaiser, 1996). Coal quality parameters, including maceral composition, grade, and rank, have a significant impact on the source rock and reservoir characteristics of coal (Scott and Kaiser, 1996).

There are several case studies which focus on the relationship of coal quality to gas sorption and to quantify the CO_2 sequestration capacity of CBM reservoirs in USA and Canada (White et al., 2005; Gentzis, 2000). Gas content of the recovered coal samples were determined by carrying out canister desorption tests at reservoir temperature at well sites by using the modified direct method of the United States of Bureau of Mines (USBM) (Diamond and Levine, 1981). The other available techniques of estimating gas content from well log mainly uses the density log for determination of ash content and other proximate parameters for the estimation of gas content.

Coal reservoir parameters such as gas content, coal seam permeability, coal seam thickness, critical desorption pressure, reservoir pressure generally affect the CBM production, among which permeability is the main factor to the migration and flow of gas in CBM reservoir and thus controls CBM production (Paul and Chatterjee, 2011a; Paul and Chatterjee, 2011b). Recent studies of cleat orientation patterns and fracture style in Jharia coalfield yielded insight into coal permeability and CBM production (Paul and Chatterjee, 2011b). Prior information about opening mode fracture/face cleat orientation pattern in a coal field is another requirement to plan well locations or horizontal drilling for any CBM project development including CO_2 sequestration.

To assess the coal seam for its CBM potentiality and for future enhanced CBM recovery, coal properties are to be known. The objectives of this paper are (a) to obtain coal chemical properties from proximate analysis of core samples, (b) estimation of coal bed permeability from well log and (c) to assess the possibility for CO_2 sequestration. Although the focus of this work has been on potentiality of coal beds as CBM reservoir, it will also serve as a basis for future assessments of the coal beds for other use such as sites for sequestration of CO_2 with simultaneous recovery of CBM.

STUDY AREA

The Jharia coal field located in Jharkhand state, India is roughly sickle shaped, its longer axis running northwest-southeast. The dip of the Formation in general is southerly (10°). The stratigraphic units of the Jharia coalfield are marked by the presence of two coal-bearing horizons: the Barakar Formation and the Raniganj Formation. Present study area, consisting of Singra, Kapuria, Barki, Dumarda

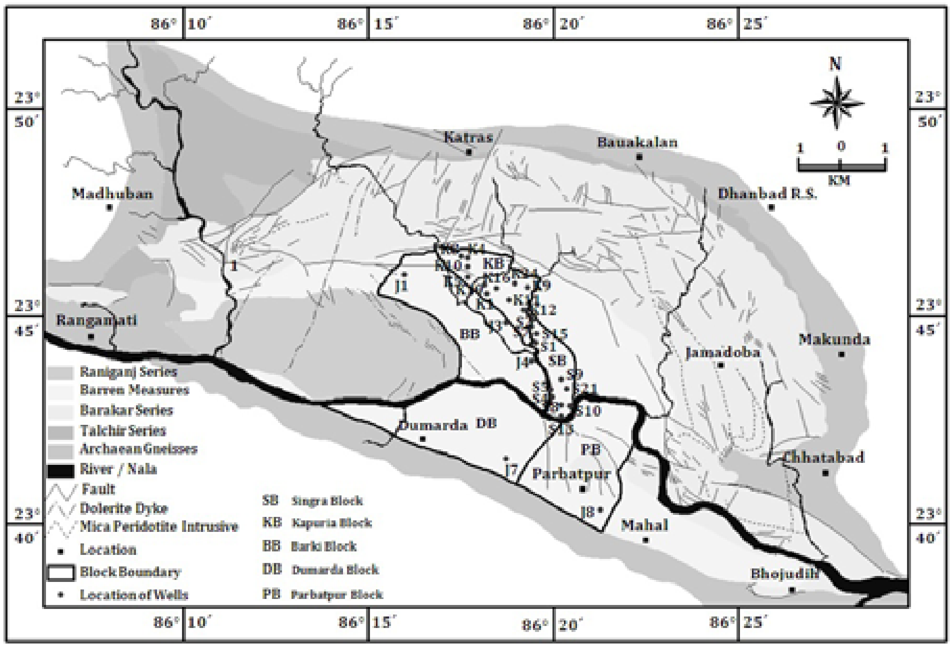

Figure 1. 27 numbers of wells are distributed in Singra, Kapuria, Barki, Dumarda and Parbatpur blocks, Jharia coalfield, India.

and Parbatpurblocks, is located in the central part of Jharia coalfield (Fig. 1).There are 18 major regional coal seams of Barakar Formation of Permian age, which are designated as: A (Bottom seam), B, C, D, E, F, G, H, I, J, K, L, M, N, O P, Q and R (Top seam). Well logs, litho logs and available coal analysis data of 27 exploratory wells have been used for coal seam correlation (Fig. 1). For most of these wells, it was easy to identify the litho-units such as coal, shaly coal, carbonaceous shale, shale, shaly sand and sandstone from the density versus gamma ray cross-plots.

COAL PETROGRAPHY AND PROXIMATE PARAMETERS

Coal petrographic analysis for 16 samples from 5 wells, namely, S15, K10, K16, K19, and K24 were carried out at the Central Institute for Mining and Fuel Research, Dhanbad following the Bureau of Indian Standard (BIS) procedures. From petrographic study, it is found that the volume of vitrinite ranges from 16.10% to 65.50%, semi-vitrinite ranges from 1.10 % to 6.40%, inertinite ranges from 24.40% to 69.70%, mineral matter ranges from 2.30% to 13.10% and vitrinite reflectance (VRo) (check superscript or subscript) ranges from 1.21% to 1.75% in this study area (Table 1).

Seam-wise proximate analysis for about 80 coal samples collected from 10 wells, namely, S4, S5, S9, S15, S21, K9, K10, K16, K19 and K24, were carried out at the Dept. of Fuel and Mineral Engineering, ISM. The moisture content is representative of the inherent moisture of the coal which ranges from 0.68% to 1.21%.All core samples have medium to high volatile matter content ranging from 15.45% to 24.84%.The ash content and fixed carbon content of the core samples of the Singra and Kapuria blocks of Jharia coalfield ranges from 17.45% to 33.75% and from 49.48% to 59.76% respectively (Table 2). It can be inferred from proximate analysis that the moisture and volatile matter contents of coals gradually decrease with the increase of depth, whereas ash content relatively increases with depth (Table 2). The volatile matter on dry ash free basis estimated by Rudra and Hazra (2009) indicates that the Barakar coals of Jharia are high volatile 'A' bituminous to low volatile bituminous in rank (Rudra and Hazra, 2009).

Peters (2000) showed that measured gas content of Barakar coal seams around the study area varies from 7 cc/gm to 17 cc/gm (Peters, 2000) whereas other authors like Sahay (2009) showed that gas content of a few coal seams at the Moonidih block ranges 5 cc/gm to over 10 cc/gm (Sahay, 2009),Bhanja and Srivastava (2008) showed that gas content of a few coal seams at Parbatpur block ranges 12 cc/gm to 15 cc/gm (Bhanja and Srivastava, 2008).

ESTIMATION OF COAL PARAMETERS FROM WELL LOGS

Shallow resistivity logs of the 20 wells namely: S1, S2, S4, S5, S7, S8, S10, S13, K1, K4, K5, K8, K10, K11, K12, J1, J3, J4, J7 and J8 have been considered for computation of permeability of 14 major coal seams namely: C, D, E/F/G, H, I, J, K, L, M, N, O, P, Q and R. Coal seams are typically characterized by high electrical resistivities (725 ohm-m to 1750 ohm-m).It had been observed that the resistivity

Table 1: Showing the results of coal petrography analysis from 5 wells of Jharia coalfield, India

Seam Name	Well Name	Coal Core Recovery Depth Interval (m)	(Volume % as received basis)(why colour)					
			Vitrinite (%)	Semi-vitrinite (%)	Liptinite (%)	Inertinite (%)	Mineral Matter (%)	Mean VRo (%)
R	S15	512.05 - 512.20	60.20	3.40	1.80	25.40	9.20	1.27
Q	K19	477.45 - 477.55	65.50	2.90	1.80	25.10	4.70	1.21
P	S15	834.57 - 834.76	50.50	2.30	1.10	37.60	8.50	1.56
O	K16	729.65 - 729.55	52.30	2.70	0.00	39.70	5.30	1.46
O	K19	696.04 - 696.14	63.40	2.60	0.90	29.60	3.50	1.41
N	S15	964.25 - 964.35	44.40	1.23	1.00	40.60	12.77	1.75
M	K10	624.80 - 624.95	61.60	2.40	1.20	29.80	5.00	1.40
M	K24	663.25 - 663.65	58.80	6.40	1.90	24.40	8.50	1.41
L	K24	737.75 - 737.85	60.70	1.90	0.30	30.70	6.40	1.48
K	K10	712.65 - 712.75	58.90	2.10	0.80	33.80	4.40	1.48
J	K24	790.30 - 790.40	46.30	5.60	0.40	39.50	8.20	1.49
I	K10	747.45 - 747.55	57.50	1.90	0.60	35.80	4.20	1.51
I	K16	886.75 - 886.85	46.30	2.10	0.30	48.20	3.10	1.61
H	K24	822.95 - 823.10	42.10	5.10	0.20	45.40	7.20	1.54
C	K16	1074.55 - 1074.70	44.60	1.10	0.20	51.80	2.30	1.67
B	K10	895.85 - 896.00	16.10	1.10	0.00	69.70	13.10	1.71
VRo = Vitrinite Reflectance (why colour)								

Table 2: Seam-wise proximate analysis results for 5 wells of Jharia coalfield, India

Seam Name	Proximate Analysis Results (weight %)(colour)			
	Moisture (%)	Ash (%)	Volatile Matter (%)	Fixed Carbon (%)
R	1.05 - 1.21	17.86 - 26.38	19.50 - 24.84	50.41 - 55.09
Q	1.03 - 1.13	22.31 - 27.39	18.92 - 24.43	50.51 - 54.40
P	0.80 - 1.18	17.45 - 29.73	17.48 - 23.52	50.77 - 58.91
O	0.78 - 1.15	20.83 - 30.26	17.27 - 23.28	49.52 - 54.82
N	0.75 - 1.13	21.31 - 30.87	17.15 - 22.67	49.96 - 54.95
M	0.82 - 1.09	18.52 - 31.35	16.38 - 22.30	50.01 - 58.31
L	0.72 - 1.01	21.70 - 33.75	15.89 - 21.42	49.48 - 55.93
K	0.75 - 0.98	24.85 - 30.90	15.45 - 20.91	50.42 - 54.10
J	0.84 - 0.94	19.20 - 26.63	18.55 - 20.34	53.30 - 59.56
I	0.79 - 0.90	24.85 - 30.82	18.39 - 20.13	53.24 - 59.76
H	0.81 - 0.86	25.43 - 26.63	18.38 - 19.78	53.45 - 54.62
E/F/G	0.72 - 0.93	25.71 - 27.85	17.87 - 18.74	52.52 - 54.73
D	0.68 - 0.89	25.79 - 29.92	17.18 - 18.69	52.02 - 54.73
C	0.70 - 0.87	26.68 - 31.72	16.77 - 17.61	50.65 - 53.84
B	0.85	27.83	17.28	54.04

measured by shallow resistivity logging tool across the coal seam decreases substantially in wellbores filled with high salinity fluids compared to wells with low salinity fluids (Yang et al., 2006). This indicated that the borehole fluid had replaced pore fluid in the cleats (invasion zone). The cleat volume / porosity of cleated coal is given by the previous authors (Paul and Chatterjee, 2011a) as,

Cleat volume or Porosity (Φ)=100 x (0.65/Resistivity) 0.6 … (1)

Using the matchstick model of cleating, initial porosity and initial permeability of coal in the Jharia Coalfield area can be expressed as a function of cleat spacing and aperture (Harpalani and Chen, 1995).

Porosity (Φ)=2b/s and Permeability (K)=b3/12s …(2)

where, b is cleat aperture and s is cleat spacing.

Cleat spacing of 20 mm as observed previously at the underground mines and opencast mines of Jharia coalfield (Paul and Chatterjee, 2011a; Paul and Chatterjee, 2011b) has been used for computation of permeability. Coal seam permeability value ranges from 0.60 md to 1.25 md. There is a significant variation of permeability within the same seam.

POSSIBILITY FOR CO_2 SEQUESTRATION

The recent technology of CO_2 sequestration offers an approach to redirect CO_2 emissions into sinks (e.g., depleted oil/gas fields with enhanced oil recovery, deep saline aquifers, gas rich shales, salt caverns, oceans, and other geological formations) and stabilize future atmospheric CO_2 levels (Gentzis, 2000; White et al., 2005). Coal seams have the ability to store significant amount of gases by adsorbing them. The CO_2 storing capacity within coal seams is much greater than CH4 storing capacity. The net ratio of injected CO_2 to recovered CH4 varies from 2:1 to as high as 10:1 (Nelson, 2003; Carroll and Pashin, 2003). This storage mechanism occurs naturally and is well documented, suggesting that a gas, particularly CO_2, can be reliably stored in coal seams. Unmineable coal seams are among the types of geological formations that are being considered by industry and government agencies for use as sites for geological CO_2 sequestration (White et al., 2005). Unmineable coal seams at a depth of around 700 m to 1500 m are suitable for CO_2 sequestration. Many of these coal deposits occur at depths greater than 700 m, which renders them uneconomical for recovery by surface mining or underground mining, and, thus, potentially viable targets for CO_2 sequestration. CO_2 sequestration in unmineable coal seams would most likely only be conducted in areas where natural gas recovery would provide a value-added revenue stream to partially offset the cost of the CO_2 capture and sequestration processes (White et al., 2005).

It is not anticipated that all coalbed gas reservoirs are suitable candidates for CO_2 (subscript) sequestration or application of Enhanced Coal Bed Methane (ECBM) technology. Carbon capture, CO_2 sequestration and CO_2 related ECBM have been conducted in several regions of the United States, Canada, Europe, Japan, Austraila, Poland and China (e.g. Nelson, 2000; Carroll and Pashin, 2003, Damen et al., 2005; Yu et al., 2007, Gurba et al., 2009 and Pinetown, 2013). These laboratory research and field projects have been focused on bituminous or sub-bituminous coals, and their results, although relevant, are not entirely applicable to the lignite coals of the Williston Basin. Permeability and gas sorption capacity are two key characteristics of coal that are known to vary significantly according to coal rank. The results of the Colorado, Alberta, and Alabama projects, therefore, have limited applicability to lignite coals. With this in mind, permeability and sorption isotherm tests are needed to be conducted in order to determine if CO_2 injection into a coalbed would be feasible and would enhance CH_4recovery from a coalbed reservoir.

Considering the actually available experimental data, coals rich in vitrinitemacerals (> 50%) are promising for the exploitation of CBM. Production of CBM by injecting CO_2 in coal beds is one of the popular methods of enhanced recovery of CBM (ECBM).The coal seams occurring at a depth of more than 700 m, thickness of more than 1 m and permeability of about 1 md with gas content more than 10 cc/gmmay be considered for planning of any ECBM project. The present work may be useful for CO_2sequestration while producing CBM from the Jharia coalfield in near future. Though it is beyond the scope of the present work, it is suggested to conduct adsorption isotherm study in future before going for CO_2sequestration.

CONCLUSIONS

The Barakar coal seams under the study area, as revealed from the proximate and petrographic analysis, are of medium volatile to high volatile bituminous "A" in rank, ash content ranging from 17.4% to 33.7%, VRo% ranging from 1.21% to 1.75%, reflecting the maturation of coal and prospecting for CBM exploration/exploitation. Permeability of the 14 major coal seams of the study area has been estimated by using well logs. As significant variation of permeability is observed within the same seam, it may be used as a guide to locate potential CBM areas for exploration. Predicted coal seam permeability values ranging 0.65 md to 1.25 md are in good match with the well test permeability data (Peters, 2000; Sahay, 2009) adjacent to the study area. The findings summarized here, are useful for CO_2 sequestration and ECBM studies.

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