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EXPLORATION AND PRODUCTION OF COALBED METHANE - NORTH SOHAGPUR, WEST COAL FIELD OF MADHYA PRADESH

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Abstract:

The study has been carried out in the North Sohagpur West Coal field in different parts of Umaria and Shahdol district of Madhya Pradesh. Sohagpur coal field occupies an area of 3000 sq. Km. The basin type of area is South Rewa Gondwana basin. The coal bearing unit of study area consists of Brakar Formation of Lower Gondwana. The area is of Lower Permian in age.

The study has been done on the basis of Geological studies, proximate analysis and Vitrinite reflectance studies (VRo%). The main objective of the study is to get acquainted with geological field work by taking reading of Dip and Strike of exposed rocks and sedimentary structures.

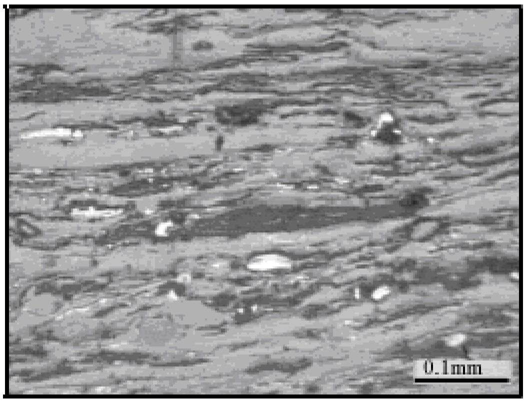
Proximate analysis of coal samples to know the potentiality for coal bed methane content. Vitrinite Reflectance (VRo %) study used to know the maturity / rank of the coal and Coal Bed Methane generation with depth.

Introduction:

The Coal Bed Methane (CBM) associated with coal deposits represents a major resource of clean energy which is increasingly playing a role in supplementing gas supplied from more conventional natural gas accumulations. Methane has been produced from coalmines for many years, originally for mine safety and later for commercial use. The production of gas from CBM reservoirs is unconventional compared to production from sandstone or carbonate reservoirs. This is a function of the dual reservoir storage and flow mechanisms which characterize CBM. Coal seams have a dual porosity system comprising micropores, which exist in the coal matrix, and a system of natural fractures called cleats, which are the macropores. Most of the gas in place is adsorbed onto internal coal surfaces requiring a large pressure drop for the gas to become mobile. With de-watering and pressure drawdown gas molecules desorbs from the coal and diffuse through the matrix to the cleats. Coal seams are often highly variable in terms of their thickness and coal properties. In particular, lateral variations in gas content, gas saturation and permeability lead to difficulties in predictions of production rate. In contrast to conventional gas accumulations, many more wells are necessary to describe the CBM resource because of the relatively more heterogeneous sand extensive nature of CBM reservoir.

Coal bed methane is a new energy source of India, during initial days of mining of coal, CBM release and causes of fire in mining. Now in India and other development country, CBM use as source of energy and safe life and environment .CBM is a natural gas containing virtually 100% methane (CH_4) produced from coal seam reservoirs. CBM is often produced at shallow depths and its often produced with large volumes of water of variable quality. CBM is extracted from coal seams by dewatering of coal seams in undersaturated CBM reservoir but in oversaturated reservoir pressure is high so no need to dewatering of coal seams. Major percentage of mine gas in most hard coal deposits is methane i.e. 90-95%. CBM is a bi product of coalification process.

Coal Petrography:



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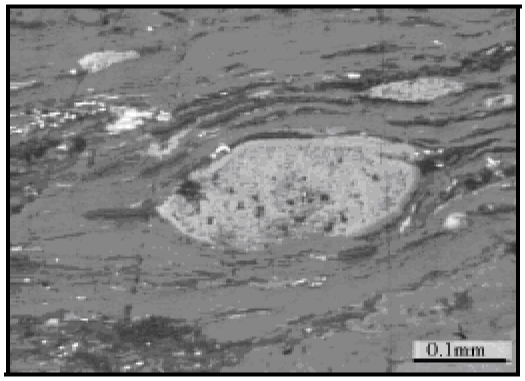

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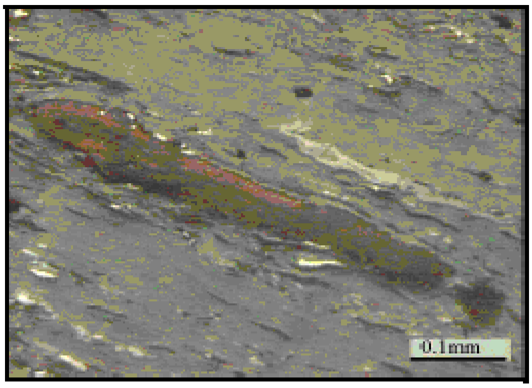

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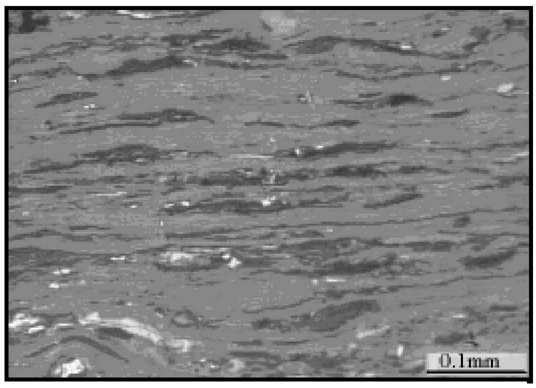

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1. Vitrinite interlayered with Exinite (clarite)

2. Bending of vitrinite & Exinite against large sclerotinite

3. Megaspore with vitrinite

4. Numerous sporinite with vitrinite (clarite)

About 7000 cu. feet of methane is generated for each ton of coal during coalification from lignite to anthracite rank.

CBM is naturally occuring methane (CH_4) with small amount of other hydrocarbon and non hydrocarbon gases contained in coal seams. As a result of physical and chemical processes plant material are converted from peat to coal. After increasing depths, heat and pressure increase which may cause chemical and physical changes to the plant material that transform the peat into coal. Driving water and other volatile constituent expel out of the organic compound and concentrating the carbon into coal. The whole process of conversion is known as maturation.Maturation is measured as vitrinite reflectance. Vitrinite is a common maceral that is abundant in most coal. As vitrinite is subjected to maturation, its carbon content increase, its volatile content decreases, and it becomes harder, its reflectance increase as it matures. The rank of coal is determined from Vitrinite reflectance.As burial and maturation proceeds, organic compound give off water, CO_2, methane and other gases. Physically, the material loses porosity because of compaction and maturational changes. Porosity is measured in the table as moisture-plant debris having over 75% porosity and hard coals having 1% or less. The reduction in porosity happens because of compaction and deformation of coal grains or macerals.

Coal Bed Methane is natural gas or methane (CH_4) that occurs in coal beds and has been generated during the conversion of plant material to coal (the process known as coalification). (Figure 2.1) This can broadly be divided into biochemical and physico-chemical stages of coalification incorporating five successive steps

1. **Peatification** (anaerobic degradation of organic materials in the peat swamp);
2. **Humification** (formation of dark coloured humic substances by anaerobic degradation);
3. **Bituminization** (generation of hydrocarbons with increase in temperature and pressure);
4. **Debituminization** (thermal degradation of matter and generated hydrocarbons); and
5. **Graphitization** (formation of graphite).

The generation of CBM during coal formation occurs in two processes:

(i) Bio-chemical and

(ii) Geo-chemical

The methane gas generated at shallow depth below 50^0C temperature termed as biogenic methane gas (diagenetic methane). Gas generated during this processes is about 10% of the total gas generated by the coalification processes. Most of the gas generated during the early stage of coalfication generally escape into the atmosphere due to low hydrostatic pressure. At above 50^0C thermogenic gas (catagenesis and metagenesis) is generated by thermal cracking of hydrogen- rich substances. Thermogenic methane comprises bulk (90%) of total CBM. Thermal maturation of sub-bituminous / bituminous coal by catagenesis and metagenesis produce thermogenic methane.

Methane generation by above process begins at vitrinite reflectance (Ro%) values of 0.5% and steeply increase reaching a maximum between medium volatile to low volatile bituminous coal stage (Ro:1.1-1.9%, max. at 1.2%) and temperature 120-180^{O}C).

However, further rise in temperature (above 170^{O}C) and reflectance values (above 2.0%) results only in slow and gradual decrease in methane yield.

CBM is often produced at shallow depths and is often produced with large volumes of water. CBM resources represent valuable volumes of natural gas within and outside of areas of conventional oil and gas production.

The prospect for coal bed methane is mainly related to the coal resources of the country. India has two types of coal:

1. Gondwana Group (mainly Permian, 99.5%)
2. Tertiary Group (Eocene and Oligocene)

These coal deposits distributed in several basins located mainly in two region of India:

1. Peninsular region.
2. Extra-peninsular regions.

About 204 billion tons of coal reserves have been established and approximately 200 million tons or so are likely to be added in the near future by further explorations. The main Gondwana coal basins are rifted intra-cratonic grabens having thick sequence of coal seams, and hold considerable prospects for coal bed methane. The major part of Indian Gondwana coals (mostly up to 300 m depth) is of low rank.

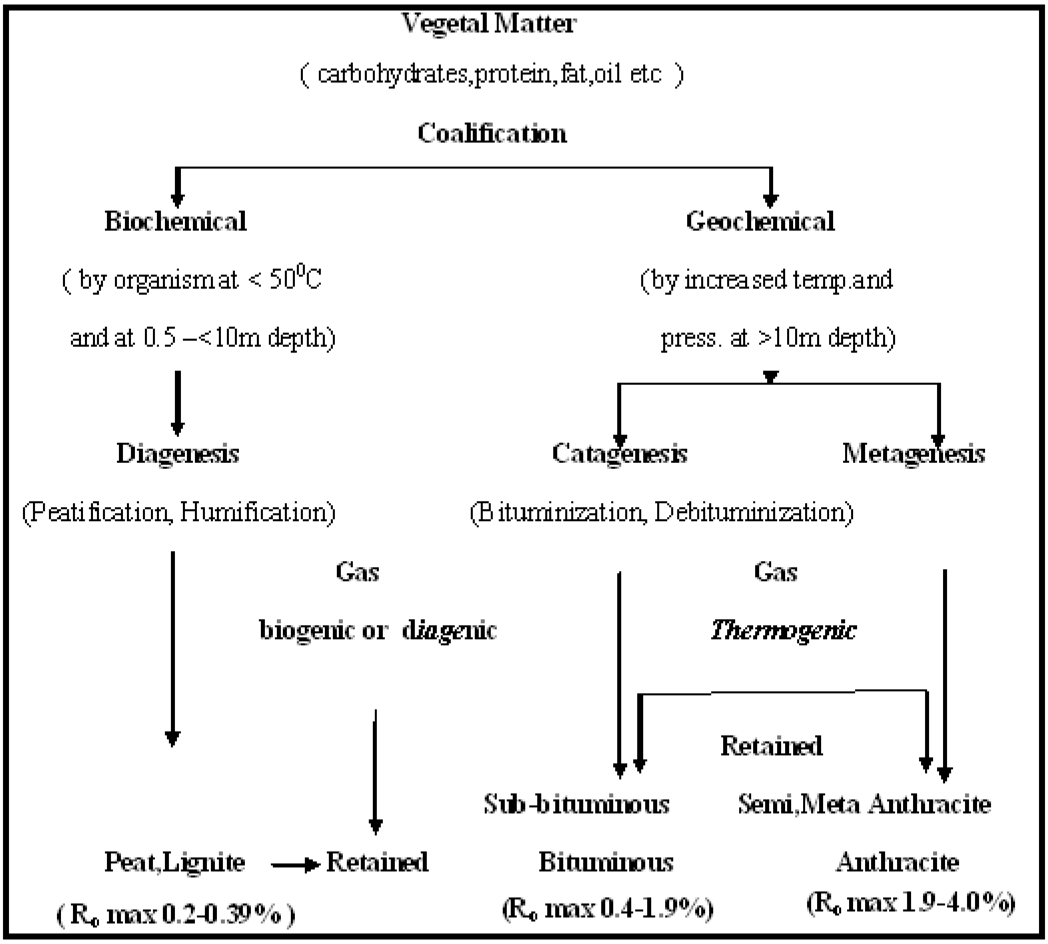

Figure: 2.1 Flow chart of methane gas generation by coalification process

Petrographic Study:

Coal petrography is the study of the organic and inorganic constituents of coal. Coal petrology is applied to the studies of the depositional environments of coals, correlation of coals for geological studies, and the investigation of coals for their industrial utilization. Significance of coal petrology has been demonstrated in coalbed methane exploration and in potential CO_2 sequestration into the coal seams. Techniques developed in the study of coal are also used in the investigation of organic-rich rocks to evaluate source rocks in petroleum and natural gas exploration. The organic constituents in coal and non-coal organic-rich rocks are termed macerals. Macerals are the microscopically identifiable constituents in coal, somewhat analogous to minerals in an inorganic rock (Stopes, 1935). These are generally divided into the vitrinite (or huminite in lower rank coals), inertinite, and liptinite groups.

Vitrinite macerals are derived from humic substances, the alteration products of lignin and cellulose (lignite to anthracitic ranks). The distinction with vitrinite (ICCP, 1998) is based on the textural and physical changes associated with gelification.

In contrast to the latter maceral group, the inertinites have been oxidized, with fire thought to be the primary cause of their formation. The macerals fusinite and semifusinite are the products of such oxidation and, in most coals, are the most abundant inertinite macerals.

The liptinite group macerals originate from the bacterial degradation products of carbohydrates, cellulose, proteins and algae.

Inorganic elements can be included in coal in minerals or as elements incorporated in the organic structure of macerals such as Clay minerals, quartz, calcite, siderite, and pyrite/marcasite. Coal petrography is the indicators of the degree of coalification.

Geological and Structural control on Coalbed Methane

Structural and geology of the area effect on the production of water and CBM. Major structural feature of Coalfield are sets of sub parallel strike fault which are E-W trending. The main fault is Bamhani-Chilpa fault which is an enechalon fault running through the central part of the field.

Generally gas is more concentrated in geologically active areas, such as folded and faulted region as well as the surrounding area of fault. The well developed fractures and cracks in the coal seams provides more permeability to coal seams.

The composition and rank of the coal is also influenced the generation of gas and storage capacity of coal seams.

Proximate Analysis:

It includes determination of moisture content, volatile matter, fixed carbon and ash content. This analysis widely used for industrial purpose and also for grading the coals.

1. **Moisture**

Moisture in coal is found in two forms-

A. Free moisture
B. Hydroscopic moisture

When coal comes in contact with water in the seam or in washery it carries free moisture. For the determination of inherent moisture 1 gm of air dried coal is taken in a silica dish and heated to a temperature of $108^0 \pm 2^0$ C in an oven. The loss in weight before and after the heating is taken as moisture. Moisture determination method varies and depends upon temperature and relative humidity in the laboratory. It means moisture varies with the variation of temperature and relative humidity of the air in the laboratory.

A relation exists between the moisture content and the rank or maturity of coal. Generally, the moisture content of low rank coal (lignite) is greater than 20% whereas in the anthracite moisture content is generally 1-2%. Strongly coking coals also contain less than 2% moisture.

2. Volatile Matter

For measuring volatile matter 1 gm of air dried coal is heated under controlled conditions in a standard crucible with a lid. To obtain the percentage of volatile matter, the moisture content should also be determined at the same time. The moisture content value is deducted from the total percentage of volatile matter obtained in volatile matter determination.

For example:

Sample taken for V.M determination is 1gm. After heating to 900 ± 10^0 C for seven minutes the weight of the residue is 0.75 gm. Therefore, loss in weight due to escape of moisture + volatile matter = 0.025 gm

% loss due to V.M. + moisture = 25%

Moisture as determined = 2%

Therefore, V.M. = 25% - 2% = 23%

After heating for 7 minutes to 900 ± 10^0C it is to be noted whether the residue is forming a coherent agglutinating or not.

3. Ash Content

Ash is obtained by the complete combustion of the inorganic mineral matter of coal. Mineral matter of coal may be of two types-

a. Inherent mineral matter –which is intimately associated with coal.

b. Adventitious or epigenetic mineral matter-this is deposited subsequent to the formation of coal in its cracks, fissures, cleavage or cleats through percolating water.

For determination of ash 1 gm of air dried coal ground to pass through 212 micron IS sieve is taken in a silica dish. The temperature is raised to 500^0C 30 minutes and to 815 ± 10^0 C in another 30 to 60 minutes. The temperature is maintained for another 60 minutes. The dish is then taken out and cooled in a desicator and weighed. The difference in weight before and after the heating gives the weight of ash, which can be expressed in percentage of amount of original coal taken for experiment.

4. Fixed Carbon Content

Fixed carbon is the weight loss upon combustion of a devolatalized coal sample. Fixed carbon is not determined. It is estimated by deducting the sum total of moisture %, volatile matter % and ash % from 100. In other words:

$$\textbf{F.C.} = \textbf{100} - (\textbf{M} + \textbf{V.M.} + \textbf{A})$$

The fixed carbon in a coal is not the same as the total carbon content of a coal.

5. Dry ash-free basis or dry mineral matter free basis calculation:

For comparison of the result of proximate analysis of different coals, the result as obtained on air dried coal is calculated on dry ash free or dry mineral matter free basis or generally known as **pure coal** basis.

Suppose 1 gm of air dried coal contained 0.1 gm moisture + 0.2 gm Ash + 0.3 gm V.M. In this case 1 gm of air dried coal contained 1 gm–(0.1 gm moisture + 0.2 gm Ash) = 0.7 gm of pure coal. So in effect in 0.7 gm of pure coal 0.3 gm of V.M. was present. Therefore, it is necessary to calculate how much V.M. was present in 100% pure coal.

In 0.7 gm pure coal 0.3 gm V.M. present

Therefore in 100 gm pure coal

$0.3 \times 100/0.7 = 42.85\%$ V.M. present.

Therefore for dry ash free basis calculation the formula is as follows:

$$\textbf{V.M.} = \textbf{V.M.(air dried)} \times 100/\ 100-(M+A)$$

Where M = Moisture % on air dried coal

A = Ash % on air dried coal

V.M. = Volatile matter in air dried coal.

Ash = Mineral Matter – Water of hydration

Therefore, Ash % when multiplied by 1.08 or 1.1 gives the amount of total mineral matter.

In this case mineral matter free calculation becomes as follows:

$$\textbf{V.M. (dry mineral matter free or d.m.f. basis)} = \textbf{V.M.(air dried)} \times 100/\ 100-(M+1.1A)$$

Where M = Moisture % on air dried coal

A = Ash % on air dried coal

V.M. = Volatile matter % on air dried coal.

Estimation of Coal Bed Methane:

To estimation of Coal Bed Methane in the coal seams direct and indirect methods are generally use. In the direct method, we estimated loss gas, desorbed gas and residual gas. Total gas content is estimated by the, desorbed and residual gas whereas calculation of loss gas by the extrapolation of graph which has been plotted earlier for determination of desorbed gas.

According to Yee et al (1993), Coal Bed Methane is stored in four ways in coal seams. To calculate the volume of gas in place, it is important to first define the component parts of a rock sample's gas contents and to know to accurately determine these values. Generally gas content is subdivided into three parts, loss, desorbed and residual gas. Different procedures are being used to yield the total gas content of sample.

The lost gas is that portion of the total gas that escape from sample during its collection and retrieval of core. Lost gas cannot be directly measure. It can measure with the help of lost gas times. Most estimation methods are based on the assumption that the lost gas is desorbed gas and all the measured gas volume used in extrapolation are also desorbed gas.

After the collection of coal sample, the desorbing gas accumulates and can be measured directly at atmosphere pressure at the exploratory well site. The desorbed gas is the quantity of gas released per gram of coal at STP. Desorbed gas is measured based on periodically measuring differentials in the desorption canister as gas is released over time, and calculating the desorbed gas. The measurements will continue till released gas amount less than $0.1 cm^3$/gram/day for several days.

The volume of gas desorbing from a coal sample gradually declines with time. Generally, at the point when desorption rate reaches the established termination point, some volume of gas still remains in the sample. Traditionally, this residual gas has been thought of as gas that is "trapped" within the coal structure due to slow diffusion rates. The residual gas volume can be determined by crushing the sample in an airtight container and measuring the volume of gas released by the same method as that used for the desorbed gas.

The total gas content by the in direct methods is based on the empirical formula given by Meinser and Kim. The quantity of gas is determined by Meisner and Kim formula with using the moisture content, volatile content, volume of gas adsorbed on wet coal, fixed carbon, thickness of coal and temperature.

Meinser (1984) observed that the amount of methane gas (V_{CH4}) is related to volatile matter (daf).

$$\mathbf{V_{CH4} = -325.6 \times \log (V.M/37.8)}$$

Estimation of in-situ gas content of the coal will be evaluated by using Kim's (Kim 1977) equation

$$\mathbf{V = (100 - M - A) /100 \times [V_w / V_d] \; [K(P) \; N - (b \times T)]}$$

Where,

V = Volume of methane gas adsorbed (cc/g)

M = Moisture content (%)

A = Ash content(%).

$V_w/V_d = 1/(0.25 \times M + 1)$

V_w = Volume of gas adsorbed on wet coal (cc/g)

V_d = Volume of gas adsorbed on dry coal (cc/g)ss

K = 0.8 (F.C /V.M) + 5.6

Conclusions:

The study has been done in the area by taking reading of dip and strike at different places. In general dip of the area varies from 3^0 to 7^0 and strike is ranging in EW direction. Sedimentary feature such as cross bedding of Raniganj Formation indicate deltaic to fluvial depositional environment. The major rocks exposed in the block are Sandstone, Shale and Igneous Intrusive. This area is not much more affected by tectonic activities. The general trend of igneous rocks is in E-W direction. The lithology of well no. A consist alternate succession of sandstone and shale. Coal is present at 28 m to 130 m depth and thickness is varies from 1-3 m. Three Seams namely Seam V, VI and VII present in the bore hole-A at depth of 97.07 m, 71.85 m and 47.05 respectively. Vitrinite reflectance show the rank of the coal is bituminous (med-vol bituminous). Proximate analysis of Coal Seams are as follows:

- By

Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)
5.7 to 8.0	13.1 to 24.7	25.5 to 30	43.0 to 50.9

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