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Identifying relationship between Permeability, Overburden Pressure and Gas Content of the coal seams in Raniganj Coalfield.

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Summary

Well log data of density, resistivity and neutron have been used to compute overburden pressure, coal seam porosity and permeability of two coal seams from Raniganj coalfield. Two of the seams are being mainly concentrated upon where each of the following parameters was determined from the above mentioned tools:

1) *Porosity*
2) *Overburden Pressure*
3) *Permeability*
4) *Resistivity.*

Correlations between these parameters were studied as graphical representations and then their significance were interpreted as results.

The curves are compatibly scaled such that the relative deflections indicate the presence of the appropriate coal seams. The Overlays of Density, Porosity (Neutron and Density) and Resistivity are used to study the coal seams at their corresponding depths.

Introduction

Raniganj Coalfield covers an area of about 1530 sq kms spreading over Burdwan, Bankura, Birbhum and Purulia districts of West Bengal and Dhanbad district of Jharkhand. A total coal reserve in West Bengal is estimated to be of 23 billion tones upto a depth of 600m out of which 6 billion tones is proven to be extractable.

Coal Bed Methane reserves in Raniganj Coalfield has a potential of about 40 BCM of Methane gas. Seven coreholes have been drilled by ONGC in the northern sector to asses the CBM potential of the Barakar coal seam Raniganj Coalfield majorly posses bituminous coal, with high moisture content, high volatile, medium fixed Carbon, medium ash, low sulphur and low phosphorous content.

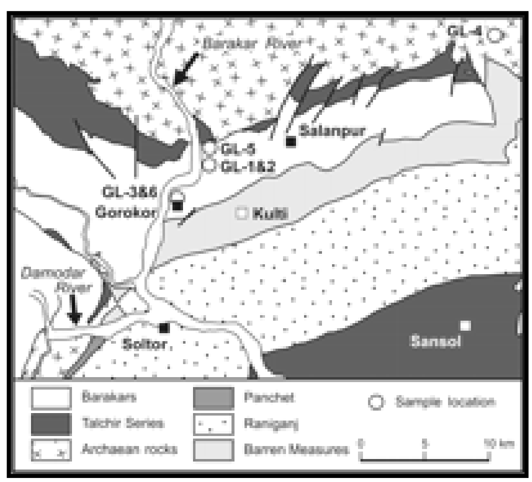

Fig 1: Raniganj Coalfield

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The log data used from a well had tools like Density, Gamma ray, Neutron and Resistivity.

The Gas Content was derived by using the direct method in the laboratory.

The Density measurements are basically related to the electron density of the formation under consideration. But after certain calibrations, this can give a direct idea about the density of the formation. Coal being a low density material is easily visible on the logs. Even impurities like shaly formations cannot deviate this property to much extent. This was used for deriving the Overburden pressure over the successive seams and the porosity ΦD.

In a porous and permeable formation, the Resistivity measurements depend upon the content and the salinity of the fluid filled in the pores. Hence shale, which has water molecules in the fine pores and free water lies between the parting planes, has low resistivity. But coal has a variable range of resistivity response, such as Bituminous usually shows high response whereas Anthracite showing low response. The resistivity response was used as an aid to determine the coal porosity and permeability.

Neutron responds to the hydrogen index of the formation. Shale has some OH content in the mica with some free water, and hence shows high neutron porosity ΦN. Coal reads high for having high hydrogen and carbon content than shale.

The CBM gas content of the coal seams is the sum of Desorbed gas, Residual Gas and Lost Gas determined from the core samples in the laboratory.

METHODOLOGY

As far as clean sand is concerned, the gas reservoirs can be easily encountered by using Neutron and Density Overlay. But the case with coal is very much different. The contrast lies in the form of the gas present. The gas in the sand is found in the pores and in free state but for coal, CBM is in adsorbed state and this is why no such anomaly is found to detect its presence.

ΦD, Density and Resistivity values were used to determine the Coal porosity, Overburden Pressure and the Permeability of the seam.

The given density (g/cc) was converted in Kg/m3. The overburden pressure for the first layer with vertical extent upto depth z1 m would be given by (Serra. O.,1985) :

$$OP= (Den) \times (g) \times (z1).$$

which was in Pascal.

For the resistivity (ρa), the Coal Porosity was determined by using the equation:

$$\text{Coal Porosity}= 100 \times (0.65/\rho a)^n$$

where n=0.6.

And the permeability was calculated by using the equation:

$$\text{Coal Permeability}= 10 \times (\text{Porosity})^n /24$$

where n= 3.

The density tool is basically related to the electron density of the material. The scintillation detectors detect the gamma ray response of the formation. If the detector spacing L is large enough, then the intensity of the gamma rays detected can be expressed as (Serra. O., 1985):

$$I=I_0 \exp(-\mu \rho_e L),$$

where I_0= Intensity of the gamma ray at the source.

ρ_e= Electron density of the formation.

μ= a constant depending upon the tool geometry.

And the bulk density ρ_b is given by (Serra. O.,1985):

$$\rho e= \rho b (Z/A)N.$$

where Z=Atomic Number,

A=Atomic Mass,

N= Avagadro's number (6.02×10^n), n=23.

Now, each of the seams was named as R-X, R-IXA, R-IXA and so on as per their sequence and they will be dealt with, consecutively.

SEAM R-X:

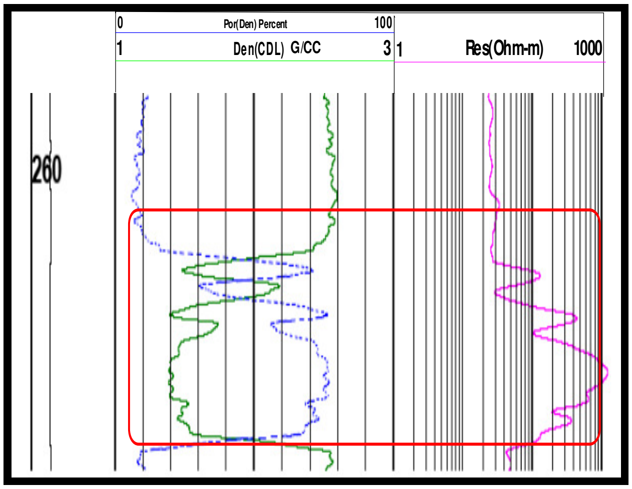

Fig 2: The Porosity (Φ_D), Density and Resistivity response of the coal seam R-X.

The following plots are compared:

PLOT 1:

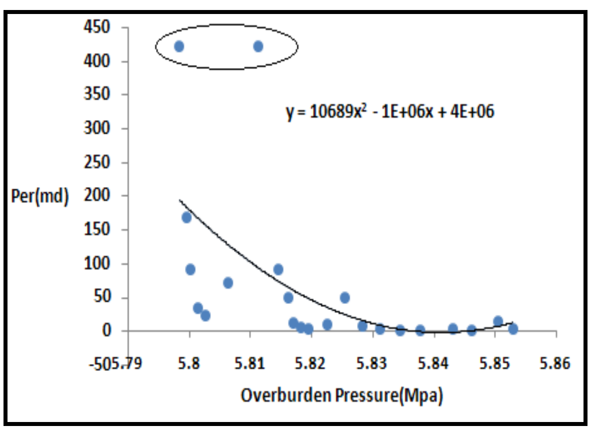

Fig 3: Overburden Pressure and Permeability

Result: Coal being a low porous and permeable rock should show low permeability. Any increment in permeability will be solely due to impurity (any other formation) in the coal seam.

The marked area shows an increment in the permeability which may be due to a thin shaly layer in the seam as per the gamma ray log (as shales have very high connected porosity).

The preceding plot further verifies the view.

The observed values of permeability corresponding to the overburden pressure showed a trend which was best fitted to the curve given by:

$$y = 10869x^2 - 1E{+}06x + 4E{+}06.$$

PLOT 2:

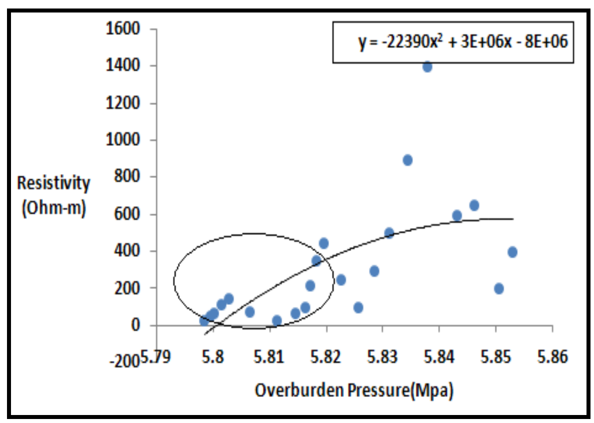

Fig 4: Overburden Pressure and Resistivity.

Result: Bituminous Coal shows high resistivity. But the zone marked, shows relatively much low resistivity, contradicting the presence of coal.

The relation between the observed resistivity values and the overburden pressure in the seam is best represented by the equation :

$y=-22390x^2+3E+06x-8E+06.$

When compared to the last plot, it corresponded to the same depth interval, marked in PLOT 1.

Hence, the high permeability, low density material may be shale which forms a thin layer within the coal seam R-X.

PLOT 3:

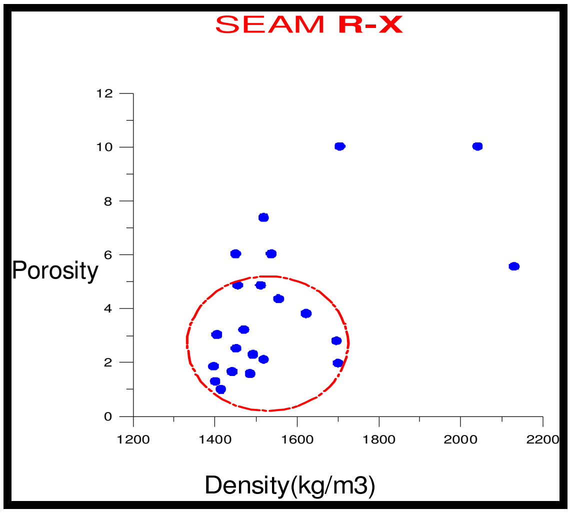

Fig 4: Density and Porosity.

Result: The low density corresponds to the coal matrix and hence should show low porosity (coal being a low porous rock).

In PLOT 3, most of the low density observations are also showing low porosity. And as the density increases, the porosity also increases to signify the high density and high porous impurities. Hence, the inference drawn is also supported by this plot.

PLOT 4:

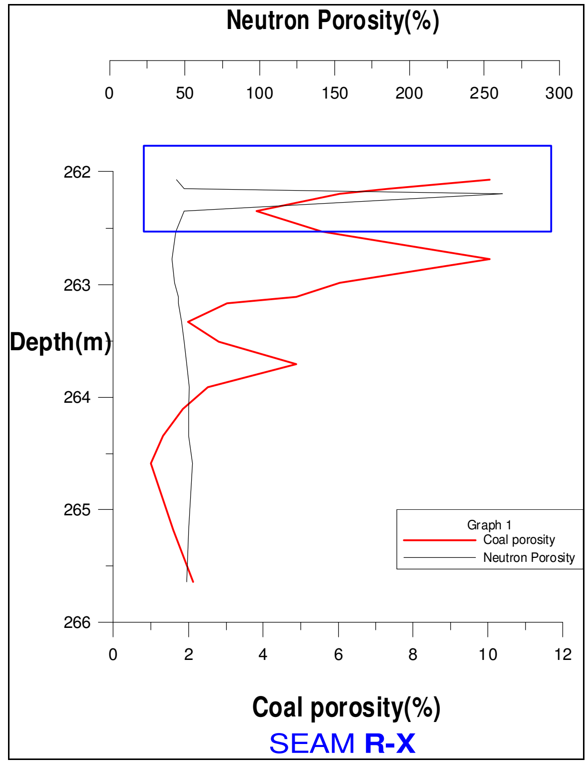

Fig 5: Variation of Coal Porosity and Neutron Porosity with depth.

Result: The Neutron Porosity plot shows a hike at about 262m, which is an indication of non-coaly material. At the same depth, the porosity also increases which further provides an evidence of the above proposal.

Moreover, from the previous plots, it was concluded that the coal seam included a thin shaly layer. And shale has a high porosity than coal (including Φ_N). Hence PLOT 4 also provides an evidence to support the proposal made earlier.

SEAM R-VI:

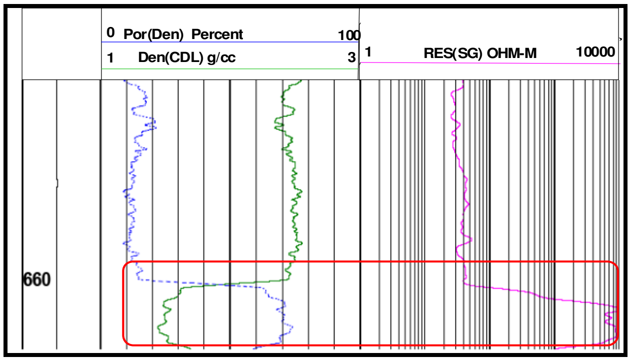

Fig 6: The Porosity (Φ_D), Density and Resistivity responses for the seam R-VI.

The marked area corresponds to the responses for seam R-VI.

PLOT 1:

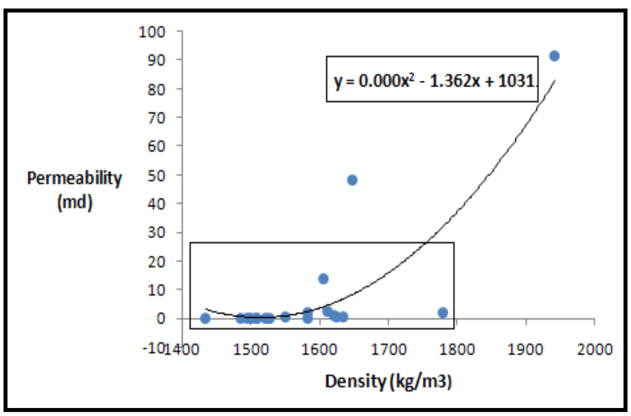

Fig 7: Density and Permeability.

Result: For seam R-VI at a depth of about 661m, the permeability values are too low for the coaly formation with low density, providing no evidence of any non-coaly material, as seen in seam R-X.

The relation between the observed density and permeability in seam R- VI is best represented by the following curve, as shown in fig 7:

$$y= 0.000x^2-1.362x+1031.$$

GAS STORAGE IN COAL:

Typically, coal can store much more gas in adsorbed state, relative to other conventional reservoirs at pressures below 100 psi. The porosity of the cleat system is small and the macro-pores contribute very little to the overall methane content in the coal. Most of the Methane is in adsorbed state in the coal matrix. A sorption isotherm relates the gas storage capacity of the coal to the pressure for a given rank, temperature and the moisture content of the coal. This relation can be used to predict the volume of gas desorbed when the pressure is reduced.

The relation (Aminian. K.,) between the gas storage capacity and the pressure is given by:

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

where G_s is the gas storage capacity.

P is pressure in psi

V_L is Langmuir volume constant in SCF/ ton.

P_L is Langmuir pressure constant in psia.

And Gas Content is given by:

Gas Content= Desorbed Gas + Residual Gas + Lost Gas

Lost Gas: The gas lost during the time of pull out of the core sample till the sample is feeded in the Canister. This is determined by extrapolating the desorbed volume curve with time.

Residual gas: Even after days of observation, the complete volume of gas is not recovered through desorption. Hence, the core sample is being crushed and then the Residual gas is determined.

COMPARISON OF THE GAS CONTENT WITH:

a) PERMEABILITIES.

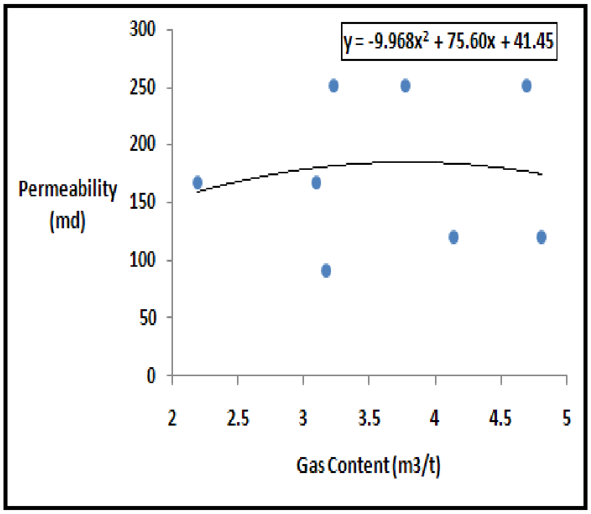

Fig 8: Gas Content and Permeability.

Result: The increase in permeability hardly affects the gas content. As already discussed, the gas present in the macro-pores of the coal seam contributes very little to the overall gas content, and the permeability determined here is mainly due to the those macro-porosities and fractures.

b) OVERBURDEN PRESSURE.

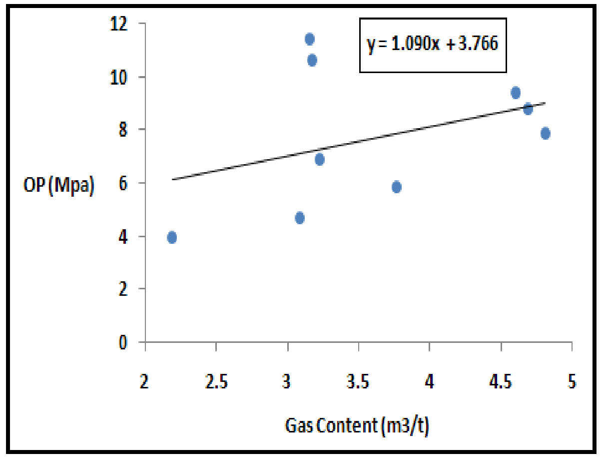

Fig 9: Overburden Pressure and Gas Content.

Result: The Overburden Pressure increases with depth. This increase in Overburden Pressure will result in more absorption of gas. Hence, the gas content is directly dependent upon the Overburden Pressure.

In Fig 9, Gas content increases almost linearly with the Overburden Pressure. The following linear equation best fits the relation between them:

$$y= 1.090x+3.766$$

Further, the Overburden Pressure increases with depth. So from both the relation it implies that the Gas Content is also directly related to the depth of the coal seam.

Conclusion:

After studying all the tool responses and comparing the calculated parameters, it is concluded that:

1) Coal is a low porous, low density and low permeable formation and any increment in the porosity is due to some non-coaly formation.
2) The density of the bituminous coal is low, but any increment is due to an impurity, such as shale.
3) The neutron as well as density porosity shows low response in coal but the presence of shale may affect the property.

4) The gas content is hardly affected by the permeability which is completely independent of the micro-porosity..
5) The gas content increases linearly with the overburden pressure and hence with the depth of the coal seam.

References:

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Bateman, Richard. M., 1985, Methods of gathering formation evaluation data, D. Reidel Publishing company, Boston.

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