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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 coal seams in South Western part of Raniganj coalfield. Each of the following parameters was determined from the above mentioned tools:

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

Correlations between these parameters are studied as graphical representations and their significance are interpreted.

The curves are compatibly scaled such that the relative deflections indicate the presence of the appropriate coal seams. The Overlays of Density and Neutron Porosity are used to study a coal seam at its corresponding depth.

The gas content of the coal seams are obtained by using Direct Method, an internationally accepted method and hence quite reliable. The gas content considered here is determined on dry ash free (daf) basis. The gas content is correlated with the overburden pressure which is seen to follow a linear trend.

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.

Several coreholes were drilled by ONGC, Essar and GEECL in North, East and South Blocks of the coalfield respectively to asses the CBM potential of the Barakar coal seams. The South Block constitutes the study area of the present investigation.

Proximate analysis of the coal samples from the study area showed that moisture content in coal varies between 0.62 to 9.44%, ash content between 9.86% to 46.84%, volatile matter between 21.15 to 36.76%, and fixed carbon between 27.32 to 51.9%.

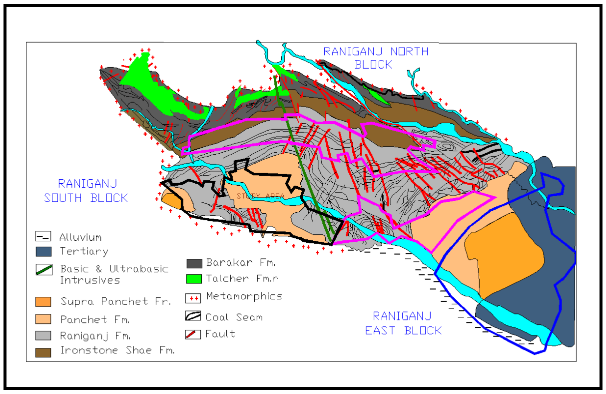

Fig 1: Raniganj Coalfield

Ultimate analysis of the samples showed that coals are rich in Carbon and Hydrogen.

Petrographic analysis showed that vitrinite and inertinite are the major maceral constituents varying between 30.4% to 80.9% and 2.8 to 31.5% respectively. Mean vitrinite reflectance varied between 0.62 to 0.87% suggesting sub-bituminous rank of coal.

The Gas Content was determined by the "Direct method" in the field laboratory. The gas content of the coal seams is the sum of Lost gas, Desorbed gas and Residual Gas volumes. While Desorbed gas and Residual gas were determined from the core samples in the laboratory, the Lost Gas was estimated by extrapolation.

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 log. This was used for deriving the Overburden pressure over the successive seams and the porosity Φ_D.

In a porous 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 between the parting planes, has low resistivity. But coal has a variable range of resistivity response, such as bituminous coal usually shows high response whereas Anthracite exhibits 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.

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 in free state but for coal, methane is in adsorbed state and that 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/m^3. The overburden pressure (in Pascal) for the first layer with vertical extent upto depth z_1 m would be (Serra. O.,1985):

$$OP = Density \times g \times z_1$$

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

$$CoalPorosity = 100\left(\frac{0.65}{\rho_a}\right)^{0.6}$$

The permeability was calculated by using the equation:

$$CoalPermeability = \frac{10 \times Porosity^3}{24}$$

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):

$$\rho_a = \rho_b (\frac{Z}{A}) N$$

where Z=Atomic Number,
A=Atomic Mass,
N= Avagadro's number (6.02×10^{23}),

The coal seams considered for this investigation are R-X, R-IXA, R-IX and so on as per their sequence and they are dealt with, consecutively.

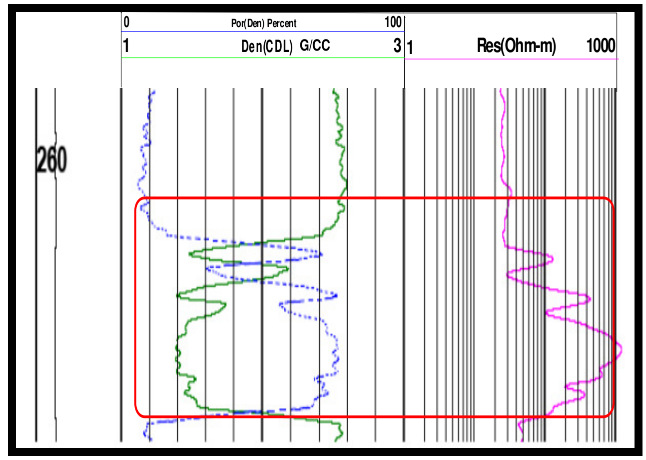

Fig 2: The Porosity (Φ_D), Density and Resistivity response of the coal seam R-X.

Relation between Overburden Pressure and Permeability

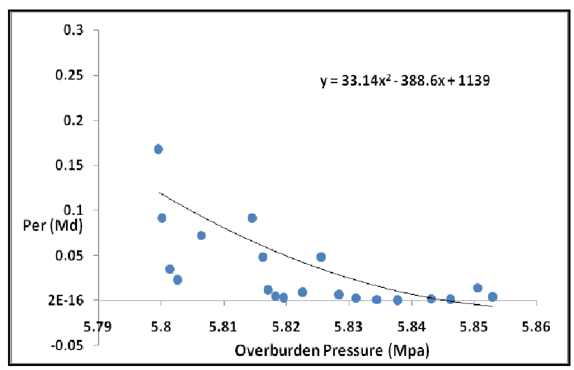

Fig 3: Overburden Pressure and Permeability –Seam RX

Result: As the Overburden Pressure increases, it tends to decrease the permeability of the coal seams The seams subject to lower pressure are showing relatively higher permeability. The following relation best fits the variation between overburden pressure and permeability for seam RX:

$$y=33.14x^2-388.6x+1139.$$

The result can be explained as the increase in overburden pressure increases the compaction and hence reducing the permeability.

A similar behavior is shown by the seams RIX-A, RIX and LOCAL as shown below:

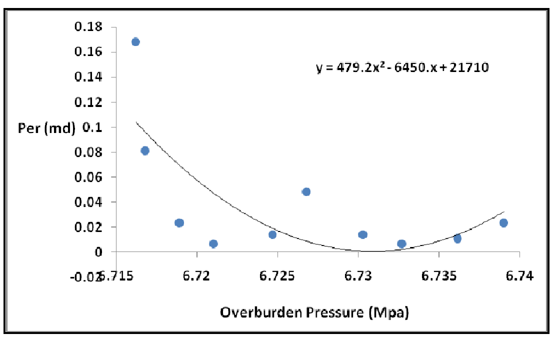

Fig 4: Overburden Pressure and Permeability –Seam RIX-A

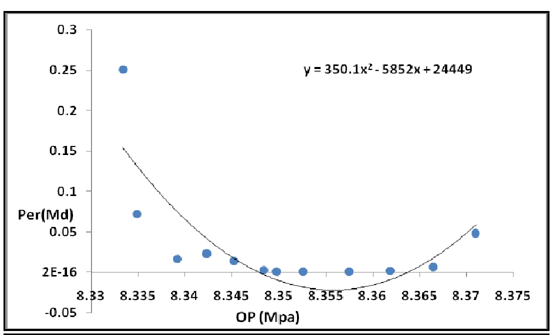

Fig 5: Overburden Pressure and Permeability –Seam RIX

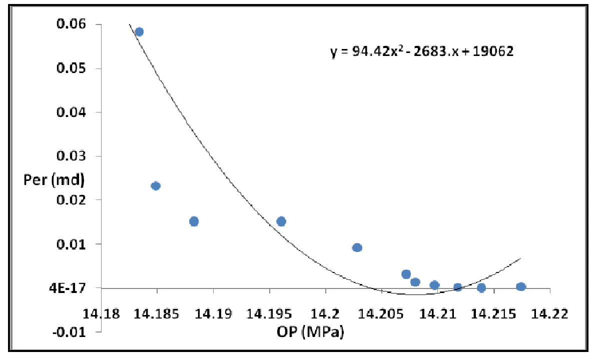

Fig 6: Overburden Pressure and Permeability –Seam LOCAL

Relation between Resistivity and Porosity of the coal seams

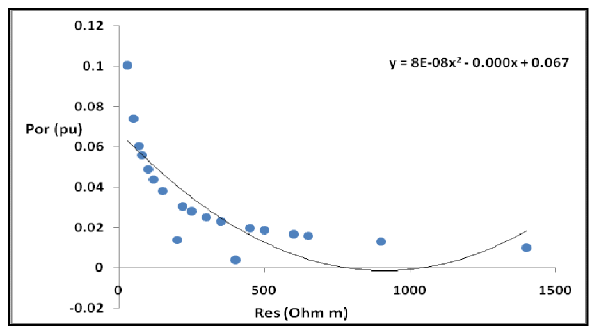

Fig 7: Resistivity and Porosity –Seam RX

Result: The resistivity of the formation is seen to increase with decrease in the porosity. This may be explained as increase in porosity results in decrease in the high resistive coal matrix. This in turn reduces the resistivity of the formation. The variation of the resistivity with the porosity for the seam RX can be best represented by:

$$y=8E\text{-}08x^2+0.067$$

The following seams also show a similar variation which are represented graphically below:

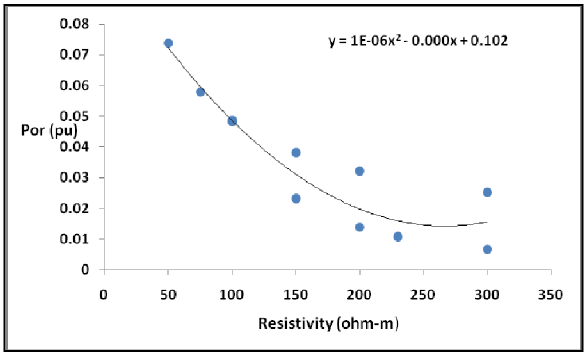

Fig 8: Resistivity and Porosity –Seam RIXA

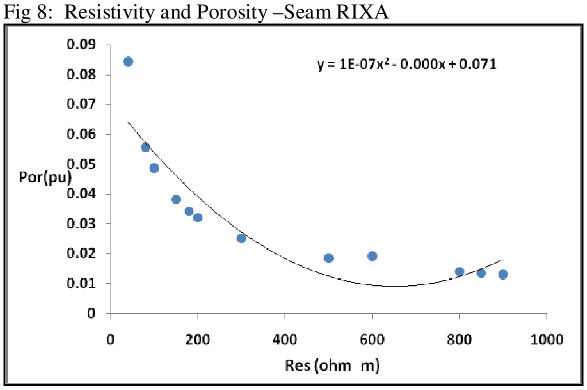

Fig 9: Resistivity and Porosity –Seam RIX

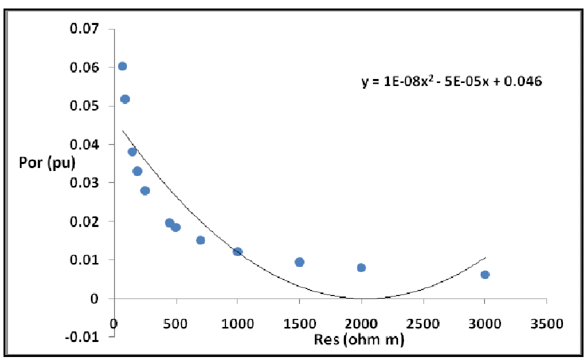

Fig 10: Resistivity and Porosity –Seam RVI

The seams RIX-A, RIX and RVI were studied individually and their resistivity too are found to decrease with the increase in porosity. Hence the result obtained from seam RX is evidently supported by RIX-A, RIX and RVI.

The variations of resistivity with porosity are best explained by the following relations:

1) Seam RIX-A:

$$y=1E\text{-}06x^2+0.102.$$

2) Seam RIX:

$$y= 1E\text{-}07x^2+0.071$$

3) Seam RVI:

$$y= 1E\text{-}08x^2\text{-}5E\text{-}05x+0.046.$$

Relation between Density and Porosity of the coal seams

Coal is a low density formation and is relatively more porous than shale present in its viscinity. The fractures and the cleats present in the coal contribute mainly to the porosity. Hence the coal seams are expected to show a combination of low density and moderate porosity.

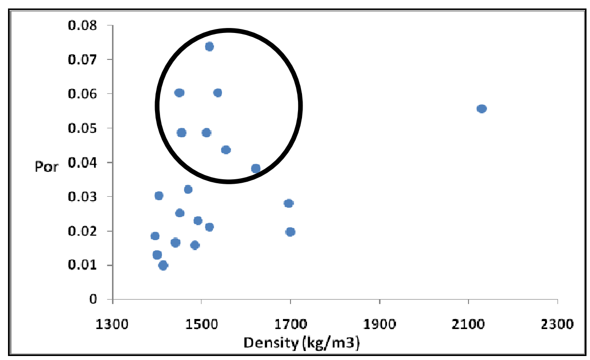

Fig 11: Density and Porosity –Seam RX.

Result: The low density and high porosity zone (marked in the above plot) is the response corresponding to the coal seams, whereas the observations corresponding to the low porosity and relatively high density may indicate some shaly coal or some pore blocking materials such as Calcite.

The observations for the other seams are again compared graphically.

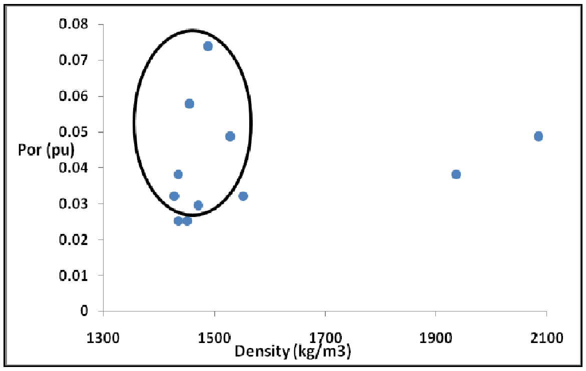

Fig 12: Density and Porosity –Seam RIX-A.

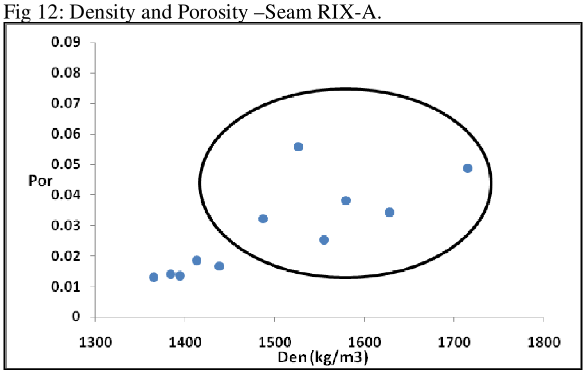

Fig 12: Density and Porosity –Seam RIX

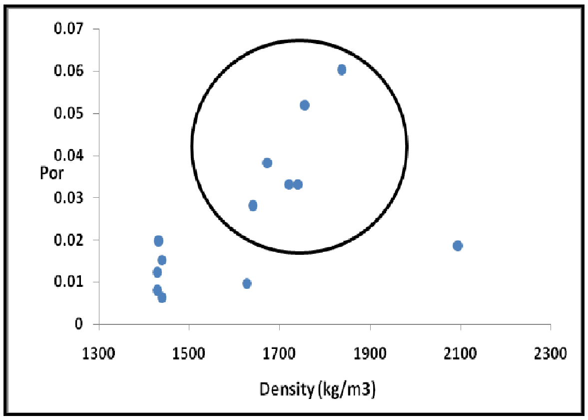

Fig 13: Density and Porosity –Seam RVI

Each of the above mentioned seams responds to low density and relatively high porosity.

Neutron Density Overlay

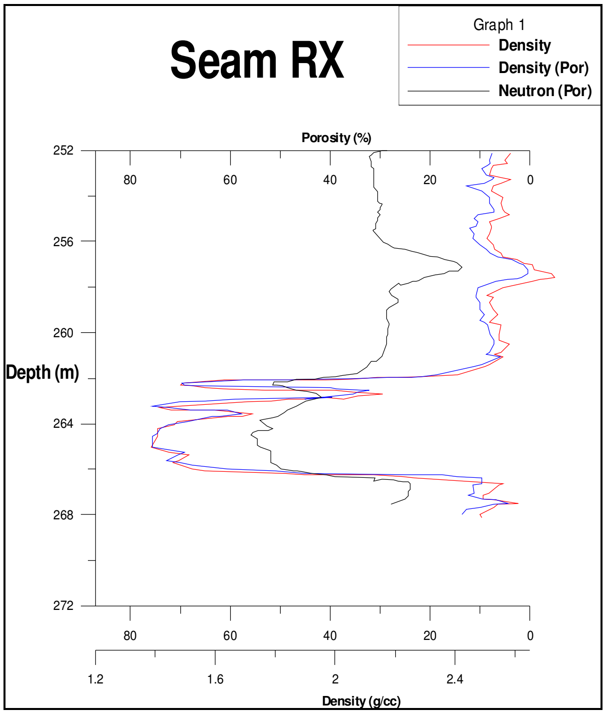

Fig 14: Neutron Density Overlay- Sandstone Compatible

Result: The neutron density overlay has been prepared to study the shale-sand sequence of the formation in the vicinity of the seam R-X.

The overlay is prepared on compatible sandstone scales so that an idea regarding the shale/sand sequence can be drawn near the seam R-X. The gamma log provided supporting evidence to the conclusion drawn from the overlay.

From the depth of 252 m to about 262 m, the neutron porosity is greater than that of the density porosity, which clearly indicates a shaly formation. Further, the density log provides another evidence of it as the density of shale varies about 2.65 g/cc.

Below the shaly part, the density decreases to about 1.5g/cc, and the neutron response increases. In coal, the neutron response is contributed by the hydrogen as well as the carbon content, so it is expected to increase relative to shale. Thus, at the depth interval 262m-265m, the coal seam R-X exists. Again the successive formation is shale which follows the seam RX.

Gas storage in the coal.

Typically, coal can store much more gas in adsorbed state, relative to other conventional reservoirs. 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 between the gas storage capacity and the pressure is given by the Langmuir Eqauation:

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

where V is the adsorbed gas volume.
P is pressure.
V_L is Langmuir volume constant.
P_L is Langmuir pressure constant.

The 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 sealed in the Canister. This is determined by extrapolating the initial desorbed volume curve with time using square root time relationship.

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

Comparison of the Gas Content with:

OVERBURDEN PRESSURE.

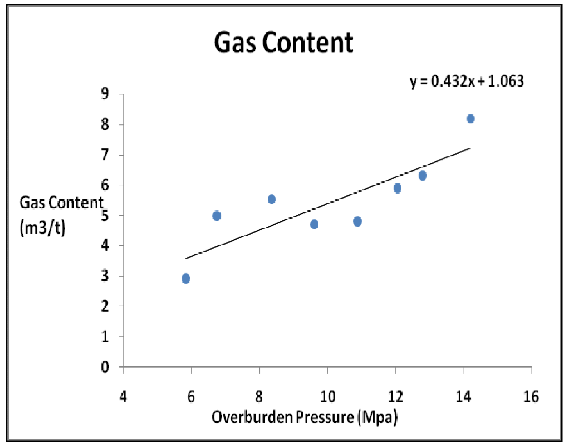

Fig 15: Overburden Pressure and Gas Content.

Result: The Overburden Pressure increases with depth. The increase in overburden pressure will result in more adsorption of gas. Hence, the gas content is directly dependent on 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:

$$Y=0.432x+1.063$$

Further, the overburden pressure increases with depth. It is implied, therefore, that the Gas Content is related to the depth of the coal seams.

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, but shale is a tight porous formation.
2) The increase in overburden pressure decreases the permeability of the coal seams.
3) The coal porosity decreases with the increase in the resistivity of the formation.
4) The coal formation corresponds to the low density and moderate porosity relative to the surrounding shale which has much higher density and low porosity.
5) The neutron porosity is more in coal relative to shale due to the presence of carbon as well as the hydrogen content of the formation, whereas the shale can be identified by the increment of the neutron porosity than the density porosity in a neutron-density overlay.
6) The gas content in a coal seam is linearly related to the overburden pressure acting on the seam.

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