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
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matter between 21.15 to 36.76%, and fixed carbon between 27.32 to 51.9%.

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 \( \Phi_N \). 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.

\( \Phi_D \), 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 (\( \rho_a \)), the Coal Porosity was determined by using the equation:

\[
CoalPorosity = 100 \left( \frac{0.65}{\rho_a} \right)^{0.6}
\]
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The permeability was calculated by using the equation:

\[
\text{CoalPermeability} = \frac{10 \times \text{Porosity}^3}{24}
\]

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.

\( \rho_e \) = Electron density of the formation.

\( \mu \) = a constant depending upon the tool geometry.

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

\[
\rho_a = \rho_b \left(\frac{Z}{A}\right)N
\]

where

\( Z \) = Atomic Number,

\( A \) = Atomic Mass,

\( N \) = Avagadro’s number (6.02 \times 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.

Relation between Overburden Pressure and Permeability

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.
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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

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:

\[ y = 8E-08x^2 + 0.067 \]

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

**Fig 7:** Resistivity and Porosity –Seam RX
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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) Seem RIX-A:
   \( y = 1 \times 10^{-6}x + 0.102 \)

2) Seem RIX:
   \( y = 1 \times 10^{-7}x^2 + 0.071 \)

3) Seem RVI:
   \( y = 1 \times 10^{-8}x^2 - 5 \times 10^{-5}x + 0.046 \)

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 vicinity. 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.

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

**Neutron Density Overlay**

*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.
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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 Equaution:

\[ V = \frac{V_L P}{P_L + P} \]

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:

\( \text{Gas Content} = \text{Desorbed Gas} + \text{Residual Gas} + \text{Lost Gas} \)

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.

![Gas Content vs Overburden Pressure](image)

**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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