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Petrophysical Well Log Analysis for Hydrocarbon exploration in parts of Assam Arakan Basin, India

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Summary

Well logging is a study of acquiring information on physical properties of rocks that are exposed during drilling of an oil well. The key purpose of well logging is to obtain petrophysical properties of reservoirs such as Porosity, Permeability, hydrocarbon saturation etc., for hydrocarbon exploration. Logs also tell us about the fluids in the pores of the reservoir rocks. Petrophysical parameters such as effective porosity (Φ), water saturation (S_w), formation water resistivity (R_w), hydrocarbon saturation (S_o) and true resistivity (Rt) are evaluated by using the well log data. In the present study, an attempt has been conducted to describe the application of various open-hole logging tools such as gamma ray, neutron density, resistivity and caliper logging tools to determine the petrophysical properties of reservoirs. The present study portrays the interpretation of well log data using the openhole logs in parts of Assam Arakan Basin. Well log analysis revealed that the range of formation water resistivity (R_w) vary from 0.32 Ω-m in the deeper subsurface to 0.89 Ω-m in the shallow surface indicating the presence of fresh water bearing sands at shallow depth. An interesting zone is identified on logs at the depth of 2214.0 m with GR value of 85api, resistivity of 18 Ω-m and average porosity of 27.14% as calculated which corresponds to be hydrocarbon bearing. Oil Water Contact is encountered at the depth of 2250.0 m with R_w of 0.59Ω-m. It is noted that the sandstone formations are separated by Shale markers which act as seals for respective formations. Thus, well logging techniques gives maximum information at a very minimal cost. They quickly have found wide application and have shown phenomenal development year by year in the industry. This acts as a driller's tool during complication. Hence, no hydrocarbon can be produced without the intervention of Logs.

***Keywords**: Well log analysis, Hydrocarbon Exploration, Petrophysics*

Introduction

Well logging is the practice of making a detailed record of the geologic formations penetrated by the well. Geophysical well logging technique is introduced by Schlumberger brothers in Alsace, France in 1927. Logging is done either on a visual inspection of samples brought to the surface (geological logs e.g. cuttings logs, core-logging or petro-physical logging) or on physical measurements made by instruments lowered into the hole (geophysical logs) (Ofwona, 2010). Immediately after the well is drilled, the formations are exposed to well-bore. This is an opportune time to determine the properties of rocks using *open-hole* logging tools. In wells with complex trajectories, companies include logging tools as part of drilling tool assembly. This approach is termed as **L**ogging **W**hile **D**rilling (LWD) (Schlumberger, 2000). Important logs include temperature, pressure, gamma, neutron, cement bond log, caliper log and resistivity. Geophysical well logging is characterized into three main types – Openhole logging, Cased hole logging and Production logging. Petrophysics is the study of physico-chemical properties of rocks and their interactions with the surrounding fluids. The main objective of petrophysical well log analysis is to transform well log measurements into reservoir properties like porosity, permeability, oil saturation etc. Formation Evaluation can be generally defined as the practice of determining the physical properties of rocks and the fluids that they contain. The objective of formation evaluation is to locate, define and produce a given reservoir and also quantitatively the thickness of the reservoir, effective porosity, water saturation and permeability. The proposed study aims at interpretation of well log data and quantitative evaluation of petrophysical properties such as water saturation etc. in parts of Assam Arakan Basin.

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Geology of the study area

The present study deals with the NE part of the Assam Arakan Basin (figure 1). The Assam Basin is located in the alluvial covered foreland shelf zone (known as Upper Assam Valley) and contains several oil and gas fields.

Depositional Setting

Syhlet formation consists of limestone with shale and sandstone alternations which is deposited in a shallow marine carbonate ramp set up with pulses of clastic input. Kopili formation consisting of dominantly finer clastics is divided into units i.e. Lower one with more number of sand layers and upper one with predominantly shale. The deposition of Kopili unit represents a deltaic to tidal set up in a broadly regressive regime. The sand layers in lower unit show coarsening as well as fining upward cycles and possibly deposited in a distributary mouth bar to tidal channel environment. Tipam formation is a wide spread stratigraphic unit in the entire Assam shelf consisting of dominantly coarser clastics. The unit is characterized by massive sandstone with minor intervening shales and shows a distinctive blaky nature in electrolysis.

Petroleum System

Source rocks with excellent oil and gas generation potential occur within Barail shale contacting carbonaceous shale with thick coal seems (Oligocene) and Kopili shale (Eocene). They contain predominantly land derived type II organic matter with TOC – 1% – 4%. The reservoirs in this oil basin are sandstones in Barail and Tipam formations. The Girujan Clay acts as the main cap rock for accumulation in Upper Assam Valley. The oil fields generally exhibit structural control over accumulations-mostly anti-clinal structures affected by faults trending ENE-WSW and NNE-SSW with throws ranging from a few to 300 m.

Materials and Methods

Knowledge of the subsurface comes primarily from drilling which is a very expensive process. Geophysical logging offers an opportunity to determine the composition, variability and physical properties of the rocks around the well thereby enabling a proper understanding of the subsurface at a cheaper cost (Ofwona, 2010). Types of geophysical open hole logging tools used in hydrocarbon exploration: (1) Natural Gamma Ray (NGRT) Log (2) Spectral Density (SDL) (3) Compensated Neutron (DSN) Log (4) Caliper log (5) Spontaneous Potential (SP) log and (6) Resistivity Log

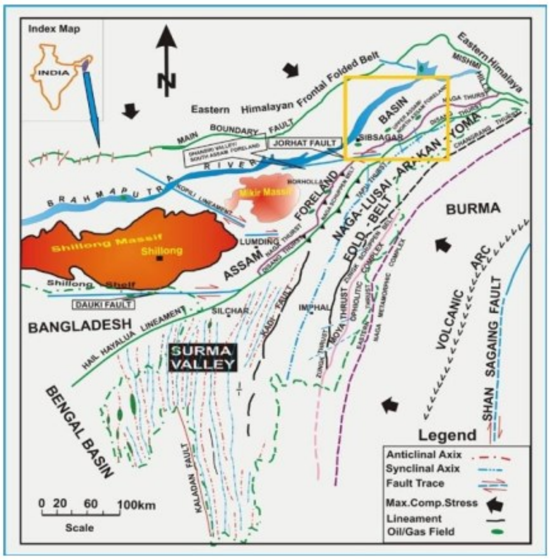

Figure 1: Illustrates the location map of the Study Area as enclosed in a square

Data Collection

The data used in the present study consists of a suite of well logs. The well logs consist of Gamma ray, Resistivity, Neutron Density and Sonic logs which are used in evaluating Petrophysical properties such as Porosity (ϕ), Hydrocarbon saturation (S_o), Water Saturation (S_w) and Water Resistivity (R_w) and hence in estimating the hydrocarbon potential of the area (Eshimokhai and Akhirevbulu, 2012).

Archie's Equation

In Archie's equation, F is called the formation resistivity factor or Formation Factor (FRF)

- $F = a/\phi^m$, where a is tortusity factor (1 for sandstones), ϕ is Porosity, m is cementation exponent (2 for sandstones)
- $S_w^n = R_o/R_t$, where R_t – True Formation Resistivity (oil, water, rock), R_o – Resistivity of water in pay zone

- $R_o = FR_w$, where F – Formation Factor, R_w – Formation Water resistivity

Therefore, $S_w^n = FR_w/R_t$, where F – Formation Factor, R_w – Formation Water resistivity, n – Saturation exponent, which describes the geometry of the current flow path through the water body in the presence of hydrocarbon

- $\phi = (\rho_{ma} - \rho_b)/ (\rho_{ma} - \rho_{fl})$, where ϕ - Porosity, ρ_{ma} – Matrix Density, ρ_b – Bulk Density (from Log), ρ_{fl} – Fluid Density

Porosity can also be evaluated from modified Archie's equation in the presence of shale. Therefore, $S_w^n = R_w/\phi^m R_t$

Indonesian's Equation

- $S_w^n = 1/\{\surd R_t(V_{clay}^{(1-Vcl/2)}/ \surd R_{clay} + \phi^{m/2}/\surd aR_w)\}$

Where R_{clay} – Resistivity of Clay/Shale in formation, V_{clay} – Volume of shale/clay present in formation

- $V_{clay} = (GR_{log} - GR_{clean\ sand})/(GR_{clay} - GR_{clean\ sand})$

Where GR_{log} – Gamma ray log reading in zone of interest (API units), $GR_{clean\ sand}$ – Gamma ray log reading in 100% clean sand, $GR_{clay/shale}$ – Gamma ray log reading in 100% shale

Quick look Evaluation

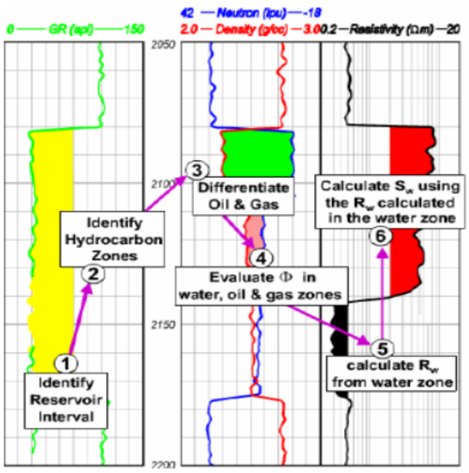

Figure 2: Illustrates a workflow for petrophysical analysis using well log data

Results and Discussion

Evaluation and identifying reservoir zone is based on the ability of the interpreter to make use of available data in interpreting various parameters (Eshimokhai and Akhirevbulu, 2012). The analysis of well logs in this study has been successfully completed. To illustrate the application of logging techniques and to establish the hydrocarbon potential in one block of Assam Arakan Basin, a section is taken comprising of three (3) formations.

Results of the interpreted well logs revealed that Barail Formation top is encountered at 2310.0 m and this contains sections of clean sands with minor shale in it. GR log records 30-40 api in sand zone. These sands having R_t value of 4 Ω-m and porosity about 27-30% are interpreted to be water bearing. R_w of water bearing sands in this section is interpreted as 0.32Ω-m. This formation is overlain by shale (marker) and is indicated on GR log with value of 102api. Bokabil Formation is encountered at depth 2048.0 m. This formation is grouped into 3 zones. Lower section consist predominantly sandstone and minor shale alternations, Middle section includes majorly shale and minor sandstones and Upper section have sandstones with minor claystones. An interesting zone (HC Bearing) is identified on logs at depth 2214.0 m with resistivity of 18 Ω-m and porosity about 27.5% as calculated and GR log records 85api. Oil Water Contact (OWC) is interpreted at a depth 2250.0 m and R_w= 0.59Ω-m. Tipam Formation consists of sandstone with minor intervening shales. Multiple water bearing zones are encountered on logs with formation water Resistivity value of 0.89Ω-m. Such high value of formation water resistivity surmises the sands are fresh water bearing and no zone of interest is encountered in this section. From the well logs used, (Figure 3) and the results obtained in (Table 1) reflects the reservoir zones and also the Petro-physical parameters are obtained from the well logs. It is noted that these zones are separated by Shale markers which act as seals for respective formations. **Table 1** below lists the petrophysical properties in the interesting zone which is encountered in the Bokabil formation.

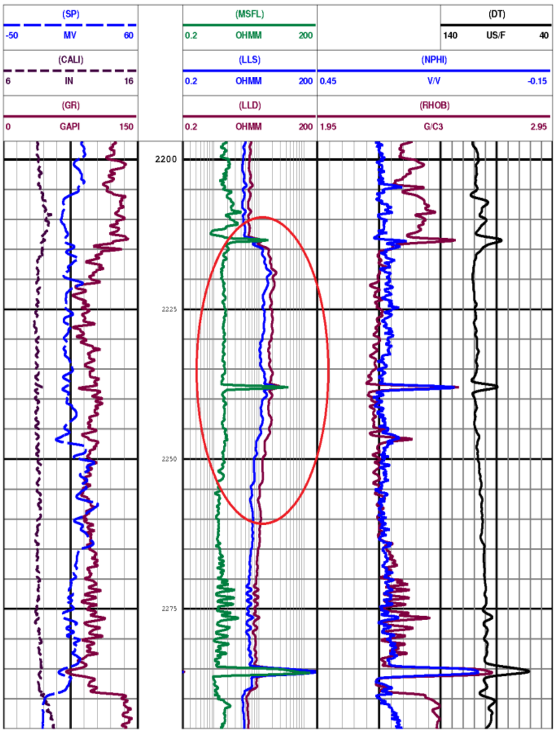

Figure 3: Composite Log for Well indicating very high resistivity zone (interesting) denoting the hydrocarbon rich section as emphasised in red encircled portion

Calculations of various paramters for Well

$S_W = \sqrt{(a*R_w)/((\phi_{avg})^2 * R_t)}$

For water bearing sands $S_W = 1$,

R_t in water bearing sands = 8 Ω-m, therefore formation water resistivity $R_w = (\phi_{avg})^2 * R_t$

$R_w = (0.2714)^2 * 8 = 0.59$

For calculating water saturation in Interesting zone, (R_t =18 Ω-m)

$S_W = \sqrt{(a*R_w) / ((\phi_{avg})^2 * R_t)}$

$= \sqrt{\{(1*0.59) / ((0.2714)^2*18)\}}$

= 0.66 or 66%

Hence oil Saturation is also inferred to be equal to 34%, as $\mathbf{S_o = 1 - S_W}$

Conclusion

Quantitative porosity and water saturation values obtained from Petro-physical well log analysis are good enough for hydrocarbon production. Various conclusions have been figured out from the above study:

- Well logging and petrophysical well log analysis in the study area is done and a section illustrating application of well logging is taken into account.
- Logging has encountered three (3) different formations in this section and each separated by a shale marker.
- Bottommost is the Barail formation which includes clean sands with traces of shale. Resistivity of 4Ω-m and porosity of 27 – 30% is computed in this section and hence the sand is inferred to be water bearing sand with no hydrocarbons in it.
- Top of Barail sandstone is encountered at 2310 meters which is overlain by a shale marker of thickness around 20 meters and showed 102api value on GR log.
- Above Barail sand, lays Bokabil formation which is divided into three section (lower, middle and upper)
- Lower section consist predominantly sandstone and minor shale alternations, Middle section includes majorly shale and minor sandstones

Interval (m)	True Formation Resistivity (R_t) (Ω-m)	Formation water Resistivity (R_w) (Ω-m)	Neutron Porosity (ϕ_N)	Log Density (gm/cc) (ρ_{log})	Density Porosity (ϕ_D)	Average Porosity ($\phi_{avg}=\phi_N+\phi_D/2$)	Water Saturation (S_W)
2215 – 2254	18	0.59	0.27	2.20	0.273	0.2714	66%

Table 1: Computed Petrophysical Parameters from Well

- while Upper section have sandstones with minor clay stones. Top of this formation is at the depth of 2048 meters.
- A HC Bearing zone is identified at depth 2214.0 m with resistivity of 18 Ω-m and porosity about 27.5%.
- Oil Water Contact is deduced at a depth 2250.0 m with formation water resistivity of 0.59Ω-m.
- Above this formation rests the Tipam formation which is separated by Bokabil formation with the shale thickness of around 100 meters. Tipam Formation consists of sandstone with minor intervening shales.
- Multiple water bearing zones are encountered with a very high formation water Resistivity value of 0.89Ω-m. Such high value of formation water resistivity surmises that the sands are fresh water bearing with high salinity.
- In Summing up, the logging tools have been found to be quick, reliable and economic means to evaluate the properties of reservoir encountered in wells. Therefore, they quickly have found wide application and have shown phenomenal development year by year in the industry.

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