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Formation Characterization and Identification of Potential Hydrocarbon Zone for Titas Gas Field, Bangladesh Using Wireline Log Data

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Abstract - Formation characterization is the progression of describing both physical and chemical properties of rocks and fluids they contain with the exploitation of available log data or core data. Petroleum formation is generally heterogeneous in nature. This heterogeneity is captured with different reservoir properties. To identify different properties of Titas Gas Field (well #16), various log data such as Gamma ray log, SP log, Calipar log, Density log, Neutron log, Sonic log, Deep induction resistivity log, Medium induction resistivity log, Spherically focused log etc. from well #16 are used. This paper focuses on different approaches to find diverse properties such as porosity (Φ), formation water resistivity (R_{wf}), water saturation (S_w), formation temperature (T_f) and finally the more effective zone for gas production. There are four sand zones (pointed out as B, D, F and H), four shale zones (indicated as A, C, E and G) and four sand mixed with shale zones (specify as I, J, K and L) within depth 2800m – 3557m. The formation temperature gradient (also called Geothermal gradient) was 0.00735^o F/m and temperature at depth 3535m was 110^o F. The difference between the true resistivity (R_t), resistivity of the invaded zone (R_i) and resistivity of the flushed zone (R_{xo}) nearly similar for sand zones but formation water resistivity was very low for zone H (3036m – 3186m). The average porosity (combining sonic porosity, neutron porosity and density porosity) of zones B, D, F and H were 25.57%, 26.20%, 23.93% and 20.63% respectively which are responsible for having a potential gas reserve. Considering all the parameters it may conclude that zone H (3036m – 3186m) is more effective zone of gas production.

Index Terms - Titas gas field, Lithology, Porosity, Resistivity, Effective gas productive zone.

1 Introduction

Formation characterization is the process of interpreting a combination of measurements taken inside a wellbore to detect and quantify oil and gas reserves in the rock adjacent to the well. It also define the determining both physical and chemical properties of rocks and fluids they contain. Formation characterization data can be gathered with Wireline logging instruments or logging-while-drilling tools. Due to prefect depth determination and near proximity of receiver to the formation, Wireline logs are playing an important role in formation characterization. Using these logs the porosity of the formation, formation water resistivity, gross thickness of the formation, water saturation, formation temperature, total resistivity of the formation etc. are determined. To determine these parameters various logs data receiving from Titas Gas Field (Well #16) is used.

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2 Locations of the Study Area and Its Present Condition

The Titas Gas field is located some 100 km away to the direction of northern-east from capital city of Bangladesh, Dhaka. It lies at the outskirts of Brahmanbaria town under petroleum exploration block-12 of Bangladesh under PSC, shown in Figure-1 [1]. This field was discovered by Pakistan Shell Oil Company in 1962. The structure is an elongate north-south asymmetrical anticline measuring about 190 km^2 with a vertical closure of 500m. Its geological condition is similar to the Sylhet Trough (Surma Basin) [2]. Interkomp Kanata Management (IKM) [3] studied about Geological, Geophysical and Petrophysical analysis of the Titas Gas Field in December, 1991 based on combined

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Figure - 1: Location of Titas Gas Field [1]

evidence of seismic data, well data and log data from Well No. 1 to 11 [4]. As per latest official re-estimation, total recoverable gas reserve of Titas gas field is 4,740 billion cubic feet (Bcf) (134km^3). Commercial gas production from this field was commenced in 1968 and till August 31, 2006 total 2,581.162 Bcf (7.30904×1010m^3) gas has been produced. The wells are spread (surface location) at six different locations stretched over about 8km distance. At present maximum 475 million cubic feet (13,500,000m^3) of gas is produced daily from 16 wells of this field and processing through 5 nos. glycol dehydration and 6 nos. Low Temperature Separation (LTS) type process plants and supplied to the transmission pipelines of Titas Gas Transmission and Distribution Company Limited (TGTDCL) and Gas Transmission Company Limited (GTCL). Condensate produced (540 bbl per day on an average) with gas as by-product is fractionated into MS (Petrol) and HSD (Diesel) through two fractionation plants.

3 Objectives

The main objectives of the research is to know and familiarize about different types of Wireline logs such as Density Log, Neutron Log, Sonic Log, Gamma ray Log, Resistivity Log etc. (Schlumberger, 1998) and by using this logs determine the gross and net thickness, porosity (Φ), formation water resistivity (R_w), formation temperature (T_f), formation resistivity (R_t), invaded zone resistivity (R_i) and resistivity of the flushed zone (R_{xo}) of the formation. Finally identify the potential zone which is effective for hydrocarbon reserve of this gas field.

4 Methodology

4.1 Lithology Identification

The Gamma ray (GR) log measures the natural radioactivity of the formations in the borehole. The log is therefore, useful for identifying lithology and for correlation purposes. Shale exhibit relatively high GR count rates due to presence of potassium ions in the lattice structure of clay mineral. On the other hand, reservoir rock (calcite, dolomite, quartz) exhibit relatively low GR count rates due to absence of potassium ions in the lattice structure of minerals which shown in Figure-3. Lower GR response and negative deflection of SP log (depend on mud type) from shale base line indicated sand or porous permeable zone. Lithology are also defined from the relation between Caliper log and bit size. For shale zone, caliper response greater than the bit size. When SP deflection positive but low GR response and Caliper response equal to bit size represent the mixed zone (Sand and Shale) [5 and 6].

4.2 Gross and Net Thickness of Lithology

The thickness of the lithology has been calculated from Gamma Ray (GR) and Spontaneous Potential (SP) logs [6].

4.3 Formation Temperature Calculation

Formation temperature (T_f) is important in log analysis. The resistivity of the drilling mud (R_m), the mud filtrate (R_{mf}) and the formation water vary with temperature. The temperature of a formation is determined by knowing using Asquith's (1982) linear regression equation [5].

$$Y = mx + c \quad \text{………………} \quad (1)$$

where, Y = Formation temperature (^{O}F); m = Slope (Geothermal gradient),

x = Formation Depth (meter); c = Constant (Surface Temperature)

Therefore,

$$m = \frac{\text{Bottom hole temperature} - \text{Surface temperature}}{\text{Total Depth (TD)}}$$

4.4 True Resistivity of the Formation (R_t)

True resistivity or the resistivity of the formation deep beyond the outer boundary of the invaded zone calculated directly from the Deep induction Resistivity curve.

4.5 Resistivity of the Invaded Zone (R_i)

Medium induction log resistivity curves measure the resistivity of the invaded zone (R_i). In a water bearing formation, the curve will read intermediate resistivity due to the mixture of formation water (R_w) and mud filtrate (R_{mf}) [5].

4.6 Resistivity of the Flushed Zone (R_{xo})

Spherically Focused Log (SFL) resistivity curves measure the resistivity of the flushed zone (R_{xo}). In a water-bearing zone, the curve will read high resistivity as results for freshwater mud filtrate (R_{mf}) high resistivity [5].

4.7 Determination of Porosity

Formation porosity was obtained from combination of any of the logs, especially Density Log, Neutron Log and Sonic Log.

4.7.1 Porosity from Density Log

The porosity can be calculated by the flowing equation

$$\Phi = (\rho_{ma} - \rho_b) / (\rho_{ma} - \rho_f) \quad \text{.....................} \quad (2)$$

where, ρ_{ma} is the density of the rock matrix (Sand or Sandstone = 2.65 g/cm^3); ρ_b is the bulk density (from logs paper) and ρ_f is the formation fluid density (For, Oil = 0.9 g/cm^3; Fresh water = 1.0 g/cm^3) [6]

4.7.2 Porosity from Sonic Porosity Log

The acoustic log measures the time for a high frequency acoustic wave and in that cases sonic porosity is estimated from Wyllie time average equation (Eq. 3), using the interval travel time of the wave through different lithologies [6].

$$\phi_s = (\Delta t - \Delta t_{ma}) / (\Delta t_f - \Delta t_{ma}) \quad \text{………………} \quad (3)$$

where, Δt is the sonic transit time at particular depth, Δt_{ma} is the transit time of rock matrix which is about 55.5μs/ft, 47.5 μs/ft and 43.5 μs/ft respectively for sandstone, limestone and dolomite and Δt_f is the transit time of the saturated fluid which is about 189 μs/ft for fresh water mud based system [6].

4.7.3 Porosity from Neutron Porosity Log

The neutron log measure the hydrogen density of the formation by bombarding the formation with neutrons and measuring the neutrons resulting from elastic scattering with the hydrogen. The neutron porosity is computed directly from the log [6 and 7].

4.8 Formation Water Resistivity (R_w)

Formation water is the water, uncontaminated by drilling mud that saturates the formation rock. The resistivity of

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this formation water is important interpretation parameter since it is required for the calculation of saturation from

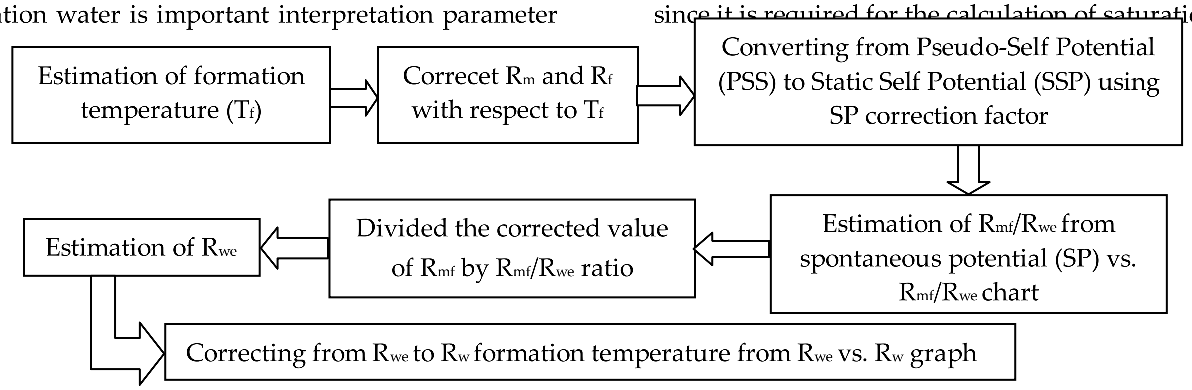

Figure - 2: Flow Chart for Formation Water Resistivity (R_w) Calculation [5, 6 and 8]

basic resistivity logs. The formation water resistivity can be calculated through the steps of Figure – 2.

4.9 Comparison between R_w and R_{mf}

For water bearing zones, the resistivity of the mud filtrate (R_{mf}) is much greater than the resistivity of the formation water (R_w) in freshwater muds and resistivity of mud filtrate (R_{mf}) approximately equal to the resistivity of the formation water (R_w) in saltwater mud. A freshwater mud (i.e. $R_{mf} > 3R_w$) results in a wet profile where the shallow (R_{xo}), medium (R_i) and deep (R_t) resistivity tools separate and record high (R_{xo}), intermediate (R_i) and low (R_t) resistivity. A saltwater mud (i.e. $R_w = R_{mf}$) result in a wet profile where, the shallow (R_{xo}). Medium (R_i) and deep (R_t) resistivity tool all are read low resistivity [5 and 6]. For hydrocarbon bearing zone, the resistivity of the mud filtrate (R_{mf}) is much greater than the resistivity of the formation water (R_w) for freshwater mud, and where R_{mf} is approximately equal to R_w for saltwater mud. A hydrocarbon zone invaded with freshwater mud results in a resistivity profile where the shallow (R_{xo}), medium (R_i), and deep (R_t) resistivity tools all record high resistivity [5 and 6].

5 Results and Discussions

5.1 Lithology and Thickness

Based on different logs interpretation, the lithology and gross thickness of Titas gas field at well #16, is shown in Figure - 3 and Table - 1.

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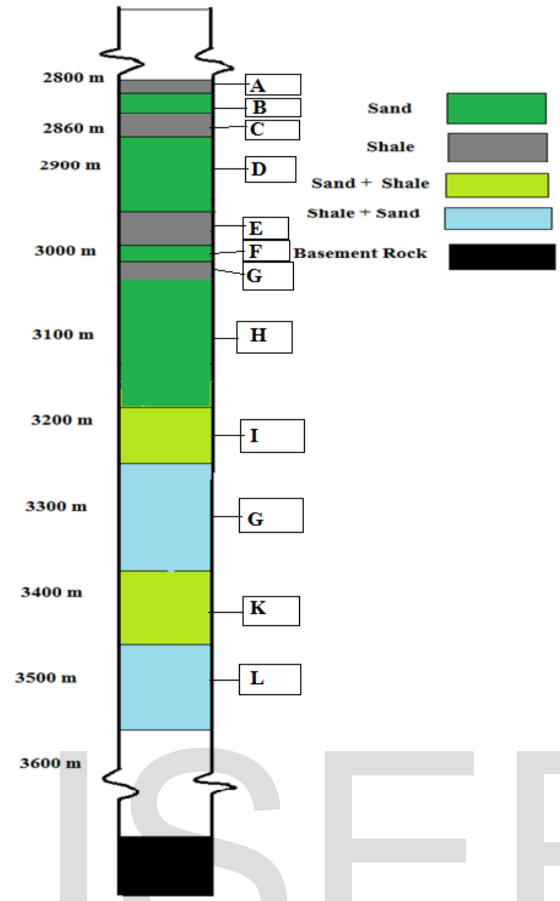

Figure - 3: Lithology of Titas Gas Field

Table – 1: Lithology and Gross Thickness of Titas Gas Field

Depth Range (m)	SP Deflection	GR Response	Caliper Response	Lithology	Remarks	Gross Thickness	Net Thickness	Net-Gross Ratio
2805-2820	Equal base line	High	> Bit size	Shale	A	15	13	0.867
2820-2843	Negative	Low	Equal bit size	Sand	B	23	20	0.870
2843-2871	Equal base line	High	> Bit size	Shale	C	28	25	0.893
2871-2959	Negative	Low	Equal bit size	Sand	D	88	85	0.965
2959-2997	Equal base line	High	> Bit size	Shale	E	38	36	0.947
2997-3017	Negative	Low	Equal bit size	Sand	F	20	18	0.900
3017-3036	Equal base line	High	> Bit size	Shale	G	19	16	0.842
3036-3186	Negative	Low	Equal bit size	Sand	H	150	145	0.967
3186-3255	Positive	Low	Equal bit size	Sand + Shale	I	69	65	0.942
3255-3380	Positive	Low	> Equal bit size	Sand + Shale	J	125	120	0.960
3380-3463	Positive	Low	Equal bit size	Sand + Shale	K	83	80	0.963
3463-3557	Positive	High	> Bit size	Shale + Sand	L	94	90	0.957

5.2 Formation Temperature

Taking the middle point of every zone and using the equation (1), the formation temperature curve with depth shown in Table – 2 and Figure - 4.

Table - 2: Formation Temperature of Various Zones of Titas Gas Field

Zone	Depth (m)	Temperature (°F)
A	2812	104.67
B	2831	104.81
C	2857	105
D	2915	105.43
E	2978	105.89
F	3007	106.10
G	3026	106.24
H	3111	106.87
I	3220	107.67
J	3317	108.38
K	3422	109.15
L	3510	109.80
Bottom	3535	110

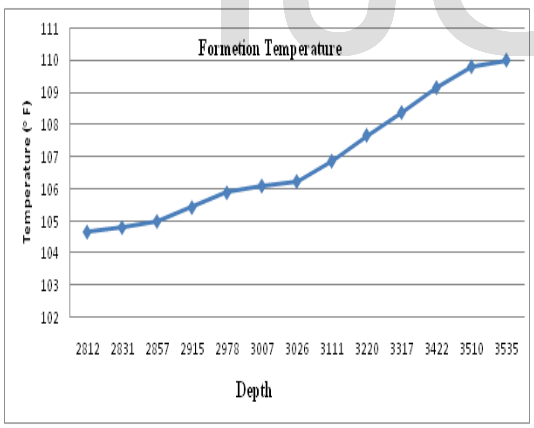

Figure - 4: Formation Temperature of Different Depth of Titas Gas Field

5.3 Resistivity of Different Zones and Formation Water

Interpreting Deep induction Resistivity curve, Medium induction log resistivity curves and Spherically Focused Log resistivity curves that collected from Titas gas field, the True Resistivity of the Formation (R_t), Resistivity of the Invaded Zone (R_i), Resistivity of the Flushed Zone (R_{xo}) are measured for every sand zone by taking the average value which given in Table - 3.

Table - 3: Resistivity of Different Zones and Formation Water Resistivity

Zone	Value			Formation Water Resistivity (R_w)
	R_t	R_i	R_{xo}	
B	11	14.40	18.75	0.78
D	11.47	14.47	21.24	0.80
F	13.13	17.25	25	0.54
H	36.13	38.55	45.31	0.53

5.4 Porosity

Take the readings of each log at every 5m intervals for all sand zones and considering the equation (2) and (3), the different porosity of different sand zone given in Table – 4 and Figure - 5.

Table - 4: The Different Porosity of Different Sand Zones

Zone	Value of Porosity			Average Porosity (%)
	Neutron	Density	Sonic	
B	0.185	0.219	0.363	25.57
D	0.239	0.294	0.253	26.20
F	0.195	0.262	0.261	23.93
H	0.215	0.226	0.178	20.63

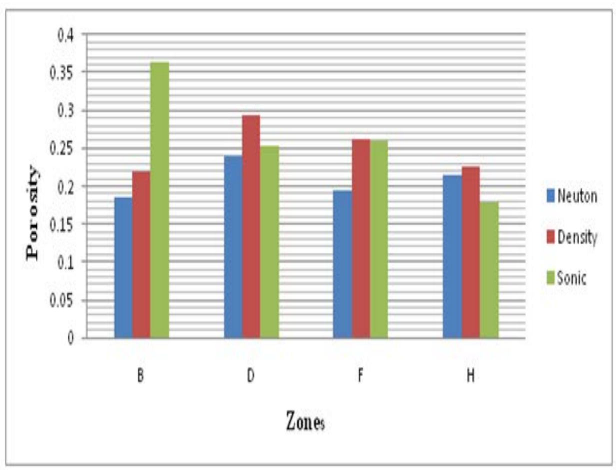

Figure - 5: Porosity of Different Sand Zones

6 Conclusions

Based on the interpretation and analysis of the Wireline data, which are obtained from Bangladesh Gas Fields Company Limited (BGFCL) of Titas gas field, it seen that the lithology of Titas gas field (Well #16), is mainly sand, shale, sand plus shale and shale plus sand zone within 2800m to 3535m. The sand zones are at depth of 2820m – 2843m, 2871m – 2959m, 2997m – 3017m, and 3036m – 3186m are represented as B, D, F and H and the net thickness of these sand zones is 268m. The density porosity for zone B, D, F and H are 0.219, 0.294, 0.262 and 0.226 respectively where the sonic porosity is 0.363, 0.253, 0.261 and 0.178 and neutron porosity 0.185, 0.239, 0.195 and 0.215 respectively. Considering all the parameters, it does identify that the zone H (3036m – 3186m) is the more effective hydrocarbon bearing zone than other sand zones.

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