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Evaluation of Gas Reservoir using Wireline Log Interpretation: Assam-Arakan Basin, India.

Dabo Mahmud Mohammed*[1], Saleem Isa Mohammed#[1]
[1]*Department of Geology, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India*
**Corresponding author: Dabo Mahmud Mohammed*

Abstract: *The study was embodied with quantitative analysis of petro-physical parameters for evaluation of Gas Reservoir using wire line Log Interpretation Assam-Arakan Basin, India, eleven permeable zone were identified in the study well, among these four zones were gas-bearing and the rest, were water-bearing zones. Relatively high resistivity, very low neutron logs and low-density log responses indicate hydrocarbon type is gas-bearing zone because of the large cross over effect than the water-bearing zone. The shale volume of these zones ranged from 4%-14% indicating a shaly sand dominating lithology and less affect the water saturation values in the gas reservoir. Average porosity of these zone ranged from 32%-37% which is within the limit for good hydrocarbon accumulation, water saturation ranges 29%-52% and permeability ranged from 73.64md-575.29md which is within the ranged for commercial gas accumulation. An average Bulk Volume of Water (BVW) ranged from 0.11-0.17 was show that the reservoir consists of mainly fine to very fine-grained sandstones and more or less at irreducible water state. The study showed that the gas reservoirs are good quality for commercial hydrocarbon accumulation and production.*
Keywords*— Petro physical Parameters, Gas reservoir evaluation, Wire line logs, interpretation.*

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I. Introduction

Wireline logs helped to define physical characteristics of reservoirs such as porosity, fluid saturation, hydrocarbon movability and permeability [1]. Petro-physical evaluation has a unique opportunity to observe the relationship between porosity and saturation [2]. Well log data are used to give erroneous values for water saturation and porosity in the presence of shale effect. The determinations of reservoir quality and formation evaluation processes are largely depend on quantitative evaluation of petro-physical analysis. Different authors carried out petro-physical analysis of gas reservoir of different gas field in the world, the analysis of reservoir sand of Titas-15 well using well log interpretation by Rahman et al. [3].

In this regard, the study was focused on the gas reservoir evaluation using wireline log interpretation. The objective of the study is to identify the gas zones of reservoir using composite log responses and to determine petro-physical parameters such as volume of shale, effective porosity, water saturation, and hydrocarbon saturation, permeability and to evaluate the formation.

II. Geology Of The Study Area

The present study is within the North East part of the Assam Arakan Basin (figure 1). The Assam Arakan Basin is located in the alluvial covered foreland shelf zone (known as Upper Assam Valley). The upper Assam shelf, a southeast dipping shelf is the foreland part of Assam-Arakan Basin [5]. It is bounded by the shield of Mikir hills towards its west and Mishmi hills along its northeastern boundary [4]. The upper Assam shelf contains about 7000m thick sediments of mostly Tertiary and Quaternary age [4] and contains several oil and gas fields (Figure 2).

A. *Depositional setting*

Syhlet Formation consists of limestone with shale and sandstone alternations, which are deposited in a shallow marine, carbonate ramp set up with pulses of clastic input [4]. 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 [4]. 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 [5]. 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.

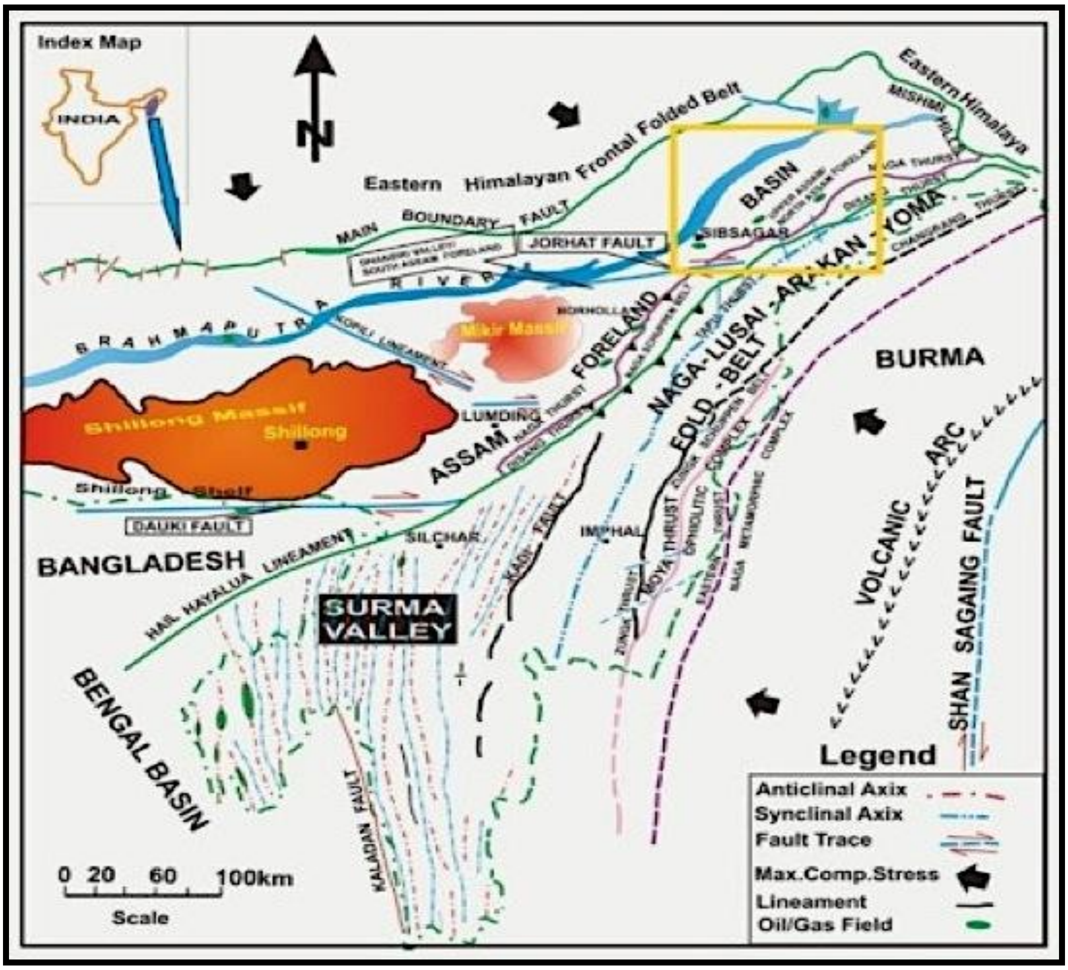

Figure 1. Generalized Geologic map of Assam Geologic Province showing the location of the study area [4].

B. *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) [4]. They contain predominantly land derived type II organic matter with TOC 1% – 4%. Reservoir rocks also include the Sylhet Formation limestones, Kopili Formation interbedded sandstones, Tura (basal) marine sandstones and Surma Group alluvial sandstone reservoirs in the upper Assam Shelf. The most productive reservoirs are the Barail main pay sands and the Tipam Group massive sandstones. Channel sands within upper Tipam and Girujan have minor gas accumulations in North Assam shelf and South Assam shelf respectively. The seals are available as Shelfal shales near the flooding surfaces at both the beginning and close of RST and TST cycles from Paleocene to Lower Oligocene. The shales within Oligocene fluvial and marshy flood plains provide the good seals to the constrained channels present in the inter-distributary area. In Bakobil sequence of the foreland system in south Assam shelf seal is provided by the transgressed shales, which encase the relict features, retro-gradational sands and tide/ storm derived sands. Seals also include Miocene shale's and clays in North Assam shelf. The thick clays of the Pliocene Gurjan Group provide the regional seal and are present in most part of the Assam shelf. Thus the Girujan acts as the regional seal in North Assam shelf area and Bokabil acts as regional cap in the South Assam shelf areas and most of the commercial hydrocarbon occurrences are seen below these sequences. Anticlines and faulted anticlinal structures, sub parallel to and associated with the northeast-trending Naga thrust fault, are the primary traps. Sub thrust traps are probably present below the Naga thrust sheet. Two major tectonic grains are imprinted on the Assam shelf. NE-SW is the older grain whereas East North East- West South West (ENE-WSW) is the younger one [5].

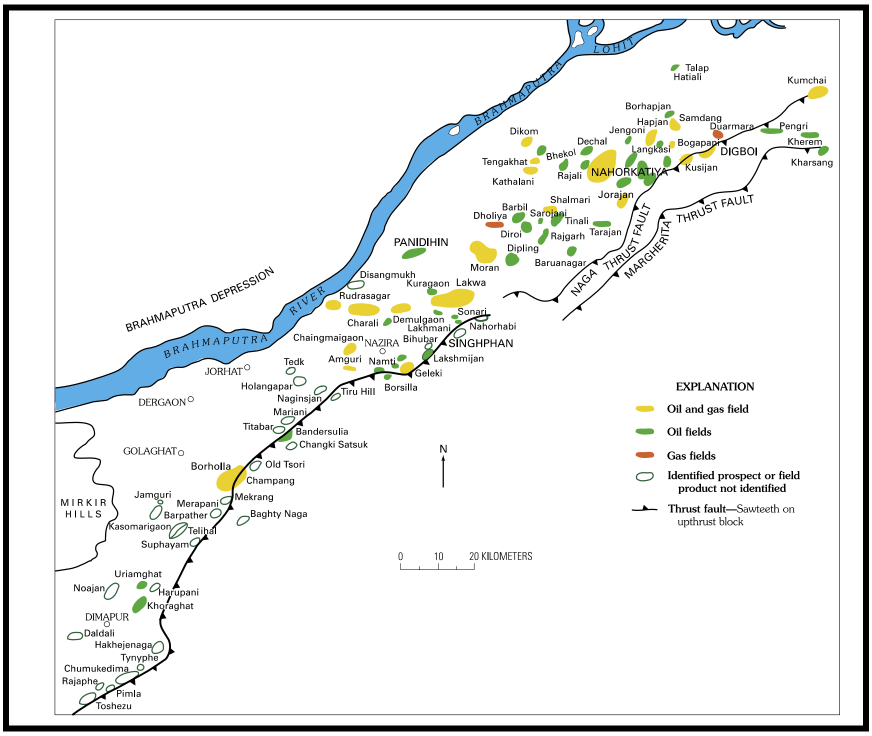

Figure 2 General Oil and gas fields and identified prospects in Assam geologic province (Modified from Naidu and Panda, 1997)[6].

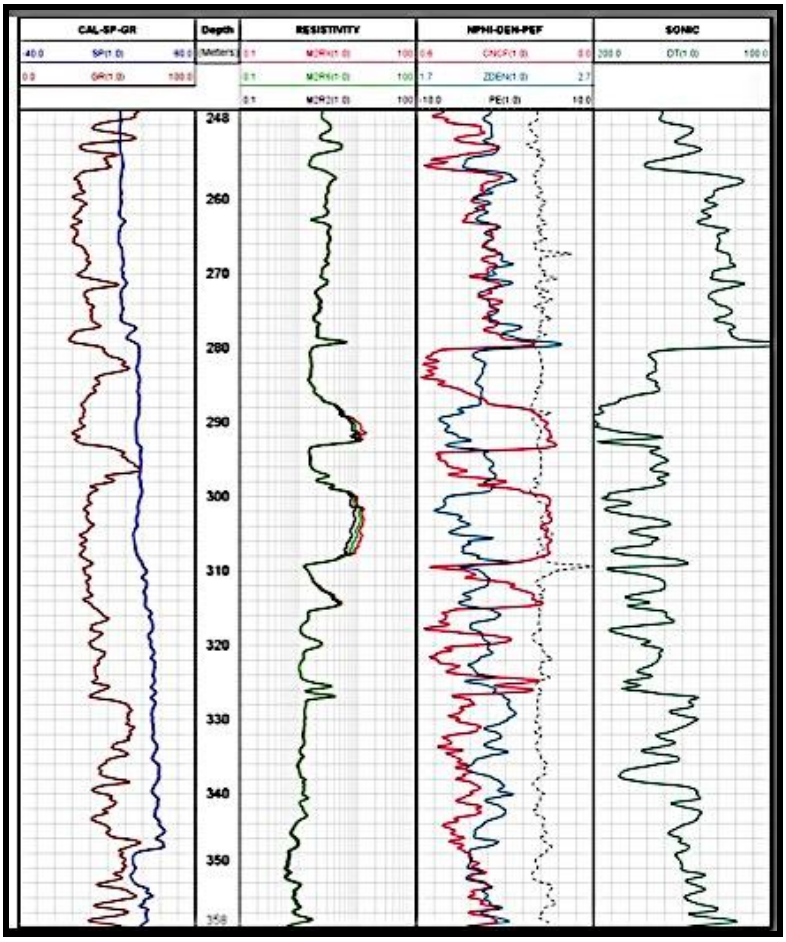

Figure 3: Composite conventional suite logs.

III. Materials And Method

The wireline logs from oil and gas field part of Assam-Arakan Basin was used for the study. The initial step in this log analysis is to identify the zones of interest i.e. the clean sand with hydrocarbon. Gamma Ray (GR) and Spontaneous Potential (SP) logs, which measures the natural radioactivity in formation and potential different in the formations (Track 1 figure 3) was used in identification of sand/shale lithology in the study area. The resistivity log represented in track 2 (Figure 3) in combination with the GR log and SP log were used to differentiate between hydrocarbon and non-hydrocarbon bearing zones. Consequently the zones of interest for petro physical interpretation were defined in terms of clean zones with hydrocarbon saturation (low GR, low SP and high resistivity).

The formation density and neutron logs were used for the differentiation of the various fluid types. The gas bearing zones are interpreted from crossover of porosity logs i.e. formation density and neutron logs. Oil zones are based on high resistivity values and water-bearing zones corresponds to vary low resistivity's.

The next step is shale volume estimation; shale volume (V_{sh}) was calculated using the Dresser Atlas, 1979 formula in equation (1), which uses values from the gamma ray (GR) in equation (2)

$$V_{sh} = 0.083[2^{3.7\times I_{GR}} - 1.0] \quad \text{.........(1)}$$

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{mix} - GR_{min}} \quad \text{.........(2)}$$

In equation (2), I_{GR} is the gamma ray index, GR_{log} is the picked log value while GR minimum and GR maximum indicate values picked in the sand and shale base lines respectively.

Porosity, ϕ_D was determined (Dresser Atlas, 1979) by substituting the bulk density readings obtained from the formation density log within each reservoir into the equation (3)

$$\emptyset_{Den} = \left(\frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}\right) - V_{sh}\left(\frac{\rho_{ma} - \rho_{sh}}{\rho_{ma} - \rho_f}\right) \quad \text{.........(3)}$$

Neutron porosity was picked from the log and 3% was added to correct it to sandstone neutron porosity.

Calculation of porosity value is also obtained from corrected Neutron-Density logs [7].

$$\Phi = \sqrt{\frac{\emptyset_{Ncorr^2} + \emptyset_{Dcorr^2}}{2.0}} \quad \text{.........(4)}$$

Where Φ_N, Φ_D is neutron and density porosities, ρ_b is bulk density, ρ_{ma} Matrix density (sandstone $2.65 g/cm^3$), ρ_f is fluid density (water is 1.0g/m,) ρ_{sh} is the shale density.

Sonic porosity was calculated using Wyllie's time – average equation in an unconsolidated sand and compaction factor was added to obtained the sonic porosity and Hichie empirical correction for hydrocarbon effect was also applied because the sonic derived porosity is too high [9].

$\Phi_s=(\Delta t_{log}-\Delta t_{ma})/(\Delta t_{fl}-\Delta t_{ma})* (1/Cp)$.........(5)

$Cp=\Delta t_{sh}*C/100$

$\Phi_{scorr}=\Phi_s-(V_{sh}*\Phi_{sh})$.........(6)

$\Phi=\phi_{scorr} * 0.7$ (gas).........(7)

Where Cp is the compaction factor, C is a constant which is normally 1.0 [9] Φ_s, is the sonic porosity, V_{sh} volume of shale, Φ_{scorr} corrected sonic porosity, Δt_{ma}, Δt_{log}, Δt_{fl} Δt_{sh} ,Φ_{sh}, are interval transit time for matrix (55µs/ft), log (from the log reading), and fluid (185µs/ft.), and porosity of shale adjacent to zone of interest, respectively.

Formation water resistivity Determination (R_w) Pickett plot was used to determine the formation water resistivity (R_w) as a result of poor SP and the formation is not a clean sand formation to use Archie equation, Pickett plot is based on observation that the true resistivity (R_t) is a function of porosity (ϕ), water saturation (S_w) and cementation exponent (m). It is actual a graphical solution of Archie's equation in terms of resistivity [10]. R_w is 0.7Ω-m.

Water Saturation (S_w) calculation Water saturation were calculated after porosity correction for shale effect using Indonesian equation.

$S_W=\{1/[R_t*(\sqrt{\phi_e^m}/a*R_W)+(V_{sh}^{(1-0.5Vsh)}/\sqrt{R_{sh}}]\}$.........(8)

Where, S_w is the water saturation V_{sh} is the volume of shale, R_{Sh} is the Shale resistivity, ϕ_e is the corrected neutron-density porosity, R_w is the formation water resistivity, R_t is the true resistivity from the deep resistivity log, a is the 1 (tortuosity factor). m, and n are equal to 2 as cementation factor and saturation exponent respectively.

Hydrocarbon saturation (S_h) is the percentage (%) of pore volume in a formation occupied by hydrocarbon, it determined for each zone of interest by

$S_h=(1-S_w)$……………………………………………………………...…………………....(9)

Permeability value were estimated from the following equation by [11]

$$k=\left(\frac{c\times\phi^{2w}}{W^4\times(\frac{R_w}{R_{tirr}})}\right)^2$$ ………………………………………………………………………………………(10)

Where, $W=\left[(3.75-\varphi)+\{\frac{\left[\log\left(\frac{R_w}{R_{tirr}}\right)+2.2\right]^2}{2}\}\right]^{½}$

$c=23+465\rho_h-188\rho_h^2$

Where, R_{tirr} is the deep resistivity at irreducible water resistivity, ϕ is the effective porosity, R_w is the formation water resistivity w and c=constant on hydrocarbon on hydrocarbon density, ρ_h is the hydrocarbon density (0.7 for gas).

Bulk volume of water (BVW) for hydrocarbon-bearing zone was calculated using Morris and Biggs [12] equation.

BVM= $S_w*\Phi$……………………………………………………………………………………………….(12)

III. RESULT AND DISCUSION

From the wireline log analysis specifically resistivity logs eleven permeable zones were identified from the composite log responses (Table 1). Among these permeable zones, four zones were identified, as hydrocarbons bearing zones.

TABLE 1: ***Show the identified fluid zones, type, Depth range and thickness of each zones identified.***

ZONES	FLUID TYPE	DEPTH RANGE (m)	THICKNESS (m)
1	Hydrocarbon bearing	X288-X293	5
2	Hydrocarbon bearing	X299-X309	10
3	Hydrocarbon bearing	X311-X315	4
4	Hydrocarbon bearing	X324-X327	3
5	water bearing	X333-X335	2
6	water bearing	X335.5-X338	2.5
7	water bearing	X339-X340	1
8	water bearing	X343-X354	1
9	water bearing	X353-X354	1
10	water bearing	X356-X358	2
11	water bearing	X358-X360	2

GR log value of these zones were average 40.4API indicate the value below it were show to be gas sand reservoir while the value above it were show to be shale. The SP log value were average -36mV indicate gas sand reservoir even though the Spontaneous Potentials is not well develop. The true resistivity (R_t) value of these zones was greater than the water bearing resistivity (R_0) values, the average true resistivity range from 5Ωm - 15Ωm suggest hydrocarbon bearing zones compare to resistivity of water bearing zone. The density, neutron and sonic logs of these zones were average 1.95g/cm^3, 0.18p.u and 171.75μs/ft. respectively, combinations of density and neutron log response (cross over) within the zone of interest support that hydrocarbon type are of gas (Figure 3) cross over is a good indicator of gas effect [13].

The quantitative analysis of wireline log data give the clue that whether the well would be commercial viable or not. Petro physical analysis determines different geometric properties of the reservoir such as lithology, shale volume, porosity, permeability, hydrocarbon saturation and bulk volume of water using available wireline logs. Within the study area, four hydrocarbon-bearing zones were identified and the calculated petro physical parameters are presented on table.

TABLE 2: ***Show the calculated petro physical parameters, such as Effective porosity (Φ_e), Water saturation (S_w), Permeability (K), Hydrocarbon saturation (S_h), and BVW.***

Depth Range (m)	Vsh (%)	Effective porosity ϕ_e (%)		Sw (%)	Sh (%)	K (Md)	BVW
		NPHI-DEN (ϕ_e)	Sonic Porosity (ϕ_{es})				
X288-X293	4	37	40	29	71	557.92	0.11
X299-X309	8	33	39	33	67	575.29	0.11
X311-X315	10	32	42	51	49	161.01	0.17
X324-X327	14	32	43	52	48	73.64	0.17

The average volume of shale of these zones from 4%-14% which convert to sand volume as 96%-86% the average shale volume within the zone of interest is 9% which show less affect, the water saturation value in the reservoir (Figure 4 Table 2) its indicate the reservoir is evidences of sand development [15]. The average log derived effective porosity value of these zone ranges between 32%-37% for neutron-density logs combination and 39%-42% for sonic porosity which indicate very good porosity in the gas reservoir similar observation of porosity value was made by Ajisafe [16] in "Y" filed Niger Delta Nigeria. The permeability of these zones ranges from 73.64md- 575.29md, which indicate good to very good permeability (Figure 5, Table 2), the gas reservoir zone one and two have high permeability compare to zone three and four which may be as a result of less volume of shale. The water saturation range between 29%-52% within the study area, the zones one and two have low water saturation compare to zone three and four which have high water saturation as result of conductive mineral that are present within the reservoir and also the shale volume in zone three and four is high compare to zone one and two table 2, Figure 4. The calculated bulk volume of water at zone of interest is the same at zone one and two and also at zone three and four, which indicate that the zone is homogeneous and at irreducible water saturation, water in an uninvaded zone (S_w) does not move because it is held on grain by capillary pressure, therefore hydrocarbon production from a zone should be free [13] (Figure 6 Table 2).

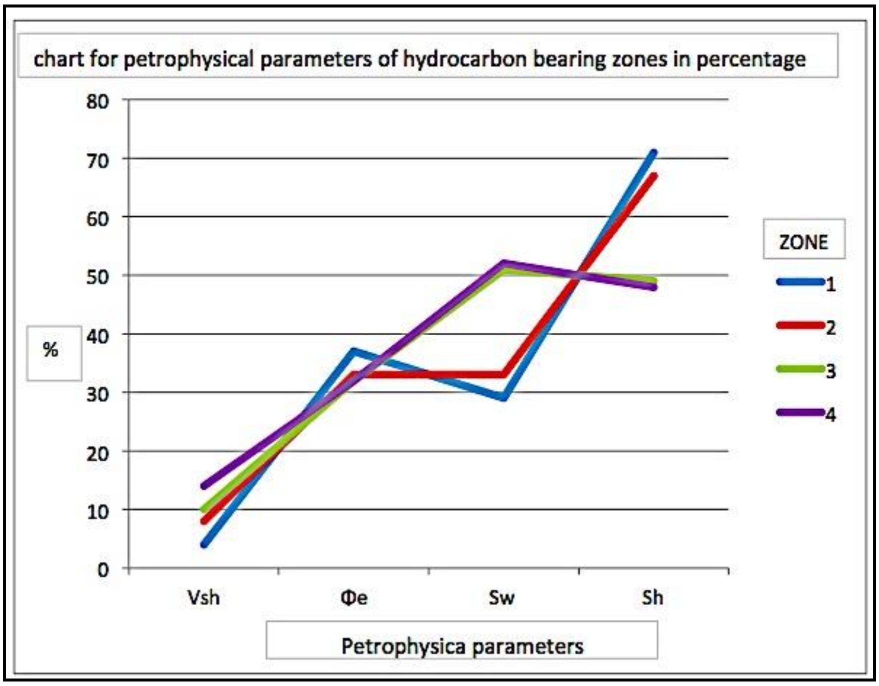

Figure 4: Calculated Petro physical parameters of the four hydrocarbon bearing zones.

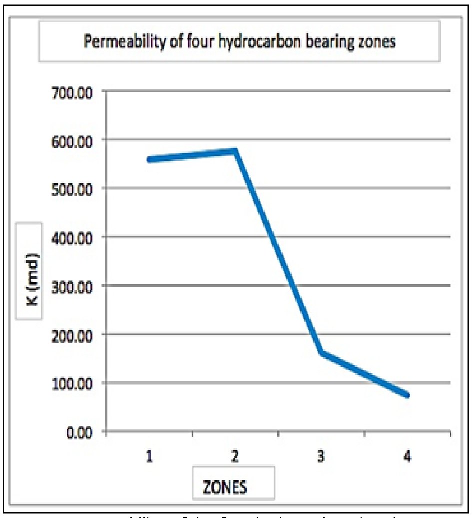

Figure 5: Permeability of the four-hydrocarbon bearing zones

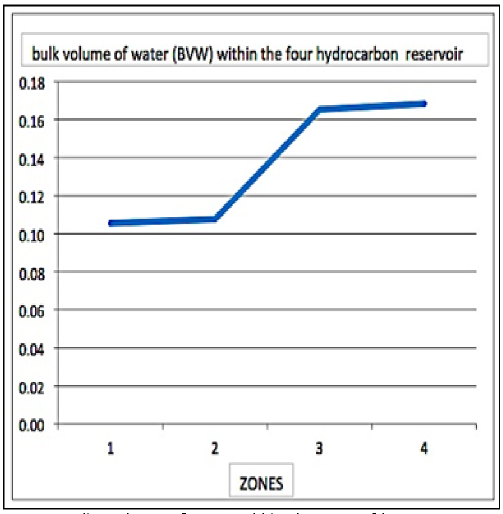

Figure 6: Bulk Volume of water within the zone of interest showing zones one and two having the same value and zone three and four having same values

IV. Conclusion

The Evaluation of Gas Reservoir using Wireline Log Interpretation Assam-Arakan Basin, India. Based on the composite log responses eleven permeable zone were identified in the study well, four zones were identified as hydrocarbon bearing zones and the rest are water bearing zones. The comparatively high resistivity log, low GR log, high SP log, very low neutron and low-density log responses indicates that hydrocarbon might be gas-bearing zones. The mean shale volumes of those zones are very low showing that shaly sand dominating lithology and less affect the water saturation values in gas reservoir. The porosity values ranges between 32%-37% indicate good porosity of the reservoir. The permeability values range between 73.64md-575.29md show that potential reservoir for hydrocarbon accumulation. The average water saturation values ranges between 29%-52% were convert to average hydrocarbon saturation (gas) 48%-71% indicate hydrocarbon accumulation. The bulk volume of water (BVW) of these zones ranges between 0.11-0.17 that reveals that the lithology of these zones is fine to very fine-grained sandstone develops in the gas reservoir. The Evaluation of Gas Reservoir using Wireline Log Interpretation showed a very good quantity with average of 33.5% porosity, Average of 9% shale volume with average hydrocarbon saturation 58.75% and average permeability of 341.965md. The studies suggest that the gas-bearing zones of the reservoir are prospective for commercial hydrocarbon accumulation and production.

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