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Petrophysical Analysis and Well Correlation: A Case Study of Abura Oil Field

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Abstract: *A suite of geophysical measurement while drilling (LWD) logs from an oil field in Niger delta have been examined and analyzed. The logs include gamma ray (used for the identification of lithology), resistivity/conductivity (used for the delineation hydrocarbon bearing reservoirs) and neutron and formation density) tools (used to map out gas bearing zones). Lithostratigraphic correlation sections of four wells (A1, A2, A3 and A4) depict that the subsurface stratigraphy is that of sand – shale interbedding. Three prominent hydrocarbon bearing reservoirs (L,P andS), located at depths of 9,650ft (2,943m), 10,650ft (3,248m) and 12298ft (3935m)were identified and mapped. Petrophysical parameters of the reservoirs which included porosity, hydrocarbon saturation, volume of shale, formation resistivity and formation factor were computed. The reservoirs have averaged porosity of 30.2%, water saturation 19.7% and hydrocarbon saturation of 80.3%.These research findings will contribute immensely in oil field development programs, in terms of correlation of well that will be drilled in the Niger Delta basin, which has a formation that is laterally extensive. This will help to define certain subsurface parameters.*

Keywords: *Logs, Hydrocarbon, Petrophysical, Reservoirs, Formation*

1. Introduction

Generally, the earth constitute of rocks that varies in properties (i.e. chemically and physically). The complexity of the earth due to thenon-homogeneity impedes the ability to explore its resources maximally. Hence, the ability to understand the physical and chemical properties of the earth has been in use at greater extents for the detailed study of the subsurface and it constituents. A potential tool in use has been the contrast in physical properties of the subsurface constituents. The earth's properties include: magnetic susceptibility, dielectric constants and gravity constants, elastic properties among others. Investigation of the earth's interior using geophysical methods, involves taking measurement at or near the surface of the earth for analysis that can expose both vertical and lateral variations of the physical properties of the earth's subsurface. The significance of hydrocarbon to the present day economy has called for so many methods that are geology and geophysics based. The uses of exploratory wells that are drilled through prospective geological structures have been of greater assistance in evaluating the hydrocarbon potential of so many locations. In order to know the quantity of hydrocarbon accumulation in reservoir rocks (sandstone, limestone or dolomite), some basic petro physical parameters must be evaluated. These parameters include porosity, thickness and extent of formation, hydrocarbon saturation and permeability. Logs ranging from electrical, nuclear and acoustic have been in use for deriving these parameters. Well logs are used to correlate zones suitable for hydrocarbon accumulation, identify productive zones, determine depth and thickness of zones, distinguish between gas, oil and water in a reservoir and to estimate hydrocarbon reserves. In this paper a suite of borehole geophysical logs is utilizes for the evaluation of the hydrocarbon potential of an oil field in Niger Delta. (Hardage, 1983).

2. Location of the Study Area

The oil field is called ABURA OR OLM 65. It is located at Emadadja community in Udu L.G.A, Delta state. The study area is located within the onshore continental margin, south west Niger Delta (see figure 1 and 2). It occupies an area enclosed by the geographical grids of latitude 5.30 and 5.40°N and longitude 6.00 and 6.20°E. This oil field is owned by Nigeria Petroleum Development Company (NPDC).

Figure1. *Map of Niger Delta Region. (Cholet and Pauc, 2008).*

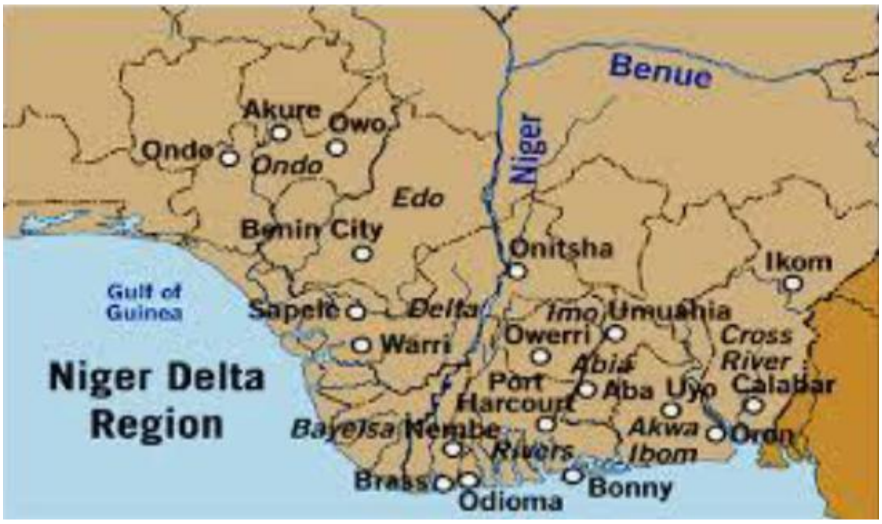

Figure2: *Map of Niger Delta Region. (Cholet and Pauc, 2008).*

3. Methodology

3.1. Well Correlation

Normally, measurement while drilling or logging while drilling is the procedure of acquiring the new log. This tool is set up with the drill string and sent down the subsurface. This tool is set up with client's specification or the geologist's direction for proper functioning. This tool is sent down hole to the subsurface, as they drill, the tool measures and records the both the physical and chemical properties of the formation. The information gotten from the formation is sent to the surface via the drilling mud, which transports it along with the cuttings from the well. This information is captured as pulses by sensor or detectors, then sent to the computer unit, where they are being filtered or remove spikes (removal of noise generated by drilling bit or down hole noise). After the filtration, the log is ready and sent to the geologist for correlation with an older well drilled in that area for guidance as they drill further.

3.2. Evaluation Technique

To measure porosity, we employ the mathematical expression,

$$Log_{10}\,\phi = aN + B \qquad (1)$$

Φ = True porosity

a, B are constants, and N is the neutron tool reading.

Calibration is necessary for the above calculation as matrix materials have different effects on the neutron log, which change with porosity.

To calculate the fractional porosities, the previous expression in equation 91) can be rearranged as follows:

$$Pb = \phi^* Pfl + (1-\phi) Pma \quad (2)$$

$$Pb = \phi^* Pfl + Pma - \phi^* pma$$

$$Pb - Pma = \phi^* Pfl - \phi^* Pma$$

$$Pb - Pma = \phi^*(Pfl - Pma)$$

This implies that porosity, Φ

$$\Phi = \frac{Pma - Pb}{Pma - Pfl} \quad (3)$$

where e Pma is a constant and *P*b = Bulk density (read directly from the density log)

Φ = porosity

$$\Phi = \frac{Pma - Pb}{Pma - Pfl}$$

*P*b = bulk density is read directly from the density log.

*P*fl = 0.8 since density of oil between the range of 0.5-0.9

*P*ma = 2.65

3.3. Permeability Estimation

Permeability (K) of sandstone is the ability of the fluid inside the pores (interconnected) to flow out of the rock matrix. This usually determines the flow rate of the fluid out of the sand. It is expressed in (DM). In this project, permeability (K) of hydrocarbon bearing zones in the well was estimated using generalized Niger Delta model. The process of this permeability calculation relates the porosity distribution to the permeability by the mathematical expression in equation (4).

This is done by varying the constant a & b shown below:

$$\text{Log (K)} = a^* \phi + b \quad (4)$$

Equation (4) can also be rewritten as

$$K = 10^{(100^*a\phi) + b} \quad (5)$$

In the Niger delta, the following are used:

Range 1: porosity > 20%, a = 0.20 and b = -1

Range 2: porosity >16%, < 20%, a = 0.35 and b = -3

Range 3: porosity >12% ≤ 16%, a = 0.25 and b = -2

Range 4: porosity >5% ≤ 12%, a = 0.23 and b = -2

Range 5: porosity ≥ 5%, a = 0.20 and b = -2.

3.4. Hydrocarbon Estimation

Estimation of hydrocarbon in place or oil in place (OIP) involves the determination of the thickness of each reservoir, computation of porosity, water saturation, selection of cut and determination of reservoir geometry. The volumetric estimation of hydrocarbon in place is of fundamental importance. Any development project on a field obviously depends on the oil and gas in place in the reservoir rock.

Volume of oil initially in place is given as:

$$OIIP = GRV^*NTG^*\phi So \text{ Barrel} \quad (6)$$

$$STOPIIP = 7758^*\phi^*NTG^*So \quad (7)$$

Then the recoverable reserves N = STOIIP*Ro

Where 7758 is the conversion factor that converts cubic meter of OIIP to stack tank barrel

VN = Volume of impregnated rock, or net pay volume.

GRV = Gross volume.

So = Hydrocarbon saturation.

Ro = Primary recovery factor.

Bo = Formation volume factor.

4. Results and Discussion

The evaluation of the hydrocarbon potential of an area is dependent upon a range of factors that are geology and geophysics based. The basic understanding of the formation and critical evaluation and interpretation of geophysical/geological data and features are not negligible. Constructed correlation panel were made available to depict the general stratigraphy and subsurface geometry of the rock strata. Here in this research, 4 wells (**A1, A2, A3** and**A4),** were evaluated. Reservoir parameters such as Permeability (K), Porosity, Water saturation (**Sw**), Hydrocarbon saturation (**Sh**), Bulk Volume Water (**BVW**), Irreducible water saturation (**Swiir),** Volume of shale **(Vh),** (TABLES 1, 2 and 3) have been carefully analyzed as a way to describe and evaluate the hydrocarbon potential and economic viability of "ABURA" oil field.

Table1. *Results of the Petrophysical Analysis of Reservoir L.*

Well	Thickness (ft)	(ϕ)%	(Vh)%	(Sw)%	(Sh)%	(BVW)%	(Swiir)%
A1	33	30	9	13	87	10	6.0
A2	207	30	8	100	00	10	6.0
A3	30	30	35	30	70	10	5.5
A4	60	32	4	15	85	11	6.0

4.1. Reservoir analysis

Shown in table 1, 3 and 3 are the results of Petrophysical Analysis of Reservoir L, P and S.

Table2. *Results of the Petrophysical Analysis of Reservoir P*

WELL	Thickness (ft)	(ϕ)%	(Vh)%	(Sw)%	(Sh)%	(BVW)%	(Swiir)%
A1	99	30	41	19	81	10	6.0
A2	97	28	9	95	05	10	6.0
A3	90	32	12	22	78	10	6.0
A4	50	32	30	82	18	15	6.0

Across the wells, reservoir L shows an average porosity of 30.5% and Volume of shale of 14%. In **A1, A2**and **A4** it has an averaged hydrocarbon saturation of 80.7%. **A2** is 100% water saturation. The wells show almost constant values of Bulk Volume Water and irreducible water saturation. This is suggesting homogeneity of the zone as regards irreducible water saturation.

Across the wells, reservoir P shows averaged porosity and volume of shale of 30.5% and 23% respectively. **A1**and **A3** shows averaged hydrocarbon saturation of 79.5%.The values of hydrocarbon saturation in **A3** and **A4** are not inviting at all.

Table3. *Results of the Petrophysical Analysis of Reservoir S*

WELL	Thickness (ft)	(ϕ)%	(Vh)%	(Sw)%	(Sh)%	(BVW)%	(Swiir)%
A1	**103**	**30**	**17**	**18**	**82**	**10**	**6.0**
A2	**97**	**29**	**14**	**32**	**68**	**10**	**6.0**
A3	**75**	**27**	**06**	**06**	**94**	**2**	**7.0**
A4	**113**	**32**	**05**	**95**	**05**	**2**	**7.0**

Across the wells, reservoir S shows an averaged porosity of 29.5% and Volume of shale of 10.5%. In **A1, A2** and**A3** it has an averaged hydrocarbon saturation of 81.3%. **A4** shows little hydrocarbon saturation. **A1** and **A2** show constant values of Bulk Volume Water, while **A3**and **A4**values also have the same values. If the values for Bulk Volume Water, calculated at several depths in a formation, are constant or very close to constant, they indicate thatthe zone is homogenous and at irreducible water saturation **(wirr).** When a zone is at irreducible water saturation, water captured in the uninvaded zone will not move because capillary forces hold it. Thus, hydrocarbon from a zone at irreducible water saturation should be water-free (Morris and Biggs, 1967). Also, low bulk volume water values across reservoirs are an indication of high hydrocarbon potential.

4.2. Reservoirs Correlation

The alternation of sands and shale in various proportions and thicknesses within the evaluated depth conforms to that of the Agbada formation. The evaluated depth and the thicknesses of the various overlaying shale units, suggest a comfortable room for accumulation of matured hydrocarbon-prospective sequence in the studied area. The thickening of the lithologic unit at one end with subsequent thinning at the other end could be as a result of delay in depositional periods or difference in the volume of sediments deposited per time. From the correlation panel there are series of synthetic and antithetic faults that are closing up on each other, forming closures and indications of rollovers and collapsed crest as explained by Doust and Omotsola (1990). Rollover anticlines are good traps for hydrocarbon. Therefore the trapping mechanism is assisted by the faults and the anticlinal structures which collectively form the structural closures. Obviously the reservoirs are juxtaposed against shale; hence the reservoirs are structurally controlled. They have good seals /cap rocks and traps. The presence of hydrocarbons in these identified traps is confirmed using measurement while drilling method of logging (Kearey and Brooks, 1991).

4.3. Gas Bearing Zones

Figure 3 shows the depth of occurrence of gas in the reservoir. The presence of gas in a formation leads to a reduction in neutron porosity with a corresponding increase in density porosity. Thus an increase in contrast between these logs (Neutron **(NPHI)** and Formation Density **(RHOB)** was picked as an indication of gas presence in the sand unit, while closeness in the logs signature shows that the reservoir sand is oil-bearing. Consequently, Gas-Up-To **(GUT)** and Gas-Down-To **(GDT)** were also delineated between 10600ft and 10700 ft in A3.

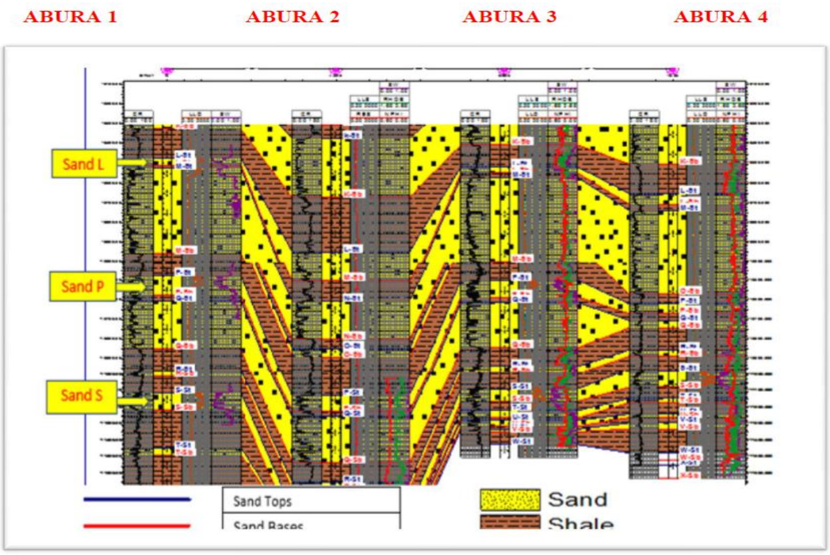

Figure3. *Lithology and Reservoir correlation for ABURA 1- ABURA 4*

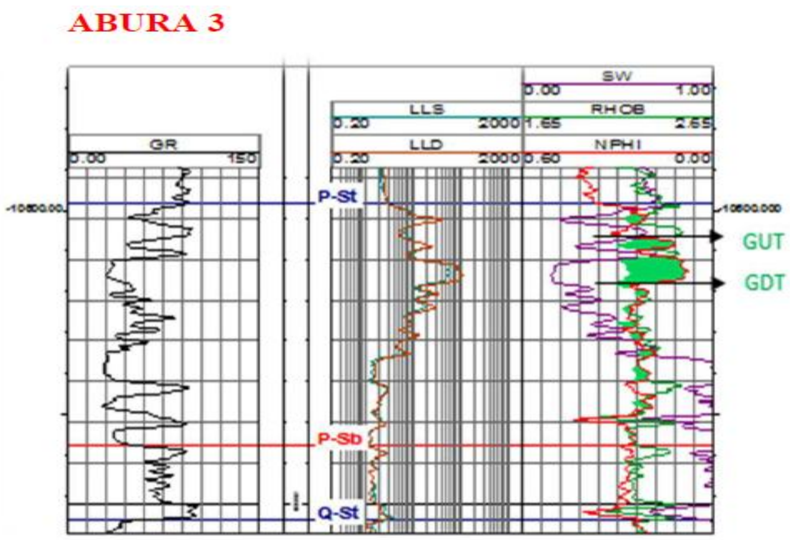

Figure4. *Detailed Lithology and Reservoir correlation for ABURA 3*

5. Conclusion

Neutron, density, gamma ray, resistivity logs were employed in the analyses and examination of an oil field in western Niger Delta. Four wells, A1, A2, A3 and A4 were considered. Lithostratigraphic correlation section of these wells depicts that the subsurface stratigraphy is that of sand shale interbedding. Three hydrocarbon bearing reservoirs (L,P and S) of varying thicknesses were identified and mapped at the depths of 9,650ft (2,943m),10,650ft (3,248m) and 12298ft (3935m) respectively. Across the wells, reservoir L shows an averaged porosity of 30.5 % and volume of shale of 14%. In **A1, A3**and **A4** it has an averaged hydrocarbon saturation of 80.7%. **A2** is 100% water saturated. Reservoir P shows averaged porosity and volume of shale of 30.5% and 23% respectively. **A1** and **A3** shows averaged hydrocarbon saturation of 79.5% the reservoir is not economically viable in **A2** and **A4** at all. Reservoir S shows an averaged porosity of 29.5% and Volume of shale of 10.5%. In **A1, A2** and **A3** it has an averaged hydrocarbon saturation of 81.3%. The reservoir is not yielding well in **A4**.

It is therefore recommended that 3-D seismic data should be incorporated to allow for detailed and complimentary study of “ABURA” Oil field. This will give room for the generation and analyses of 3-D images that will show more revealing details of the geometry of the geologic features and also the area extent with which volumetric reservoir estimations can be calculated.

Also vertical seismic profiles should be acquired in fields that have been left for long, (especially areas that were acquired in 2-D in the 80s) to avoid drilling a dry well.

Also, companies and host communities should have a Memorandum of Understanding and adhere to it, to avoid shutdown of the Rig or Crisis between the company and the host community.

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