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HYDROCARBON CHARACTERIZATION OF ANUWA FIELD, OFFSHORE DEPOBELT, NIGER DELTA BASIN

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Abstract

The study titled "Characterization of Reservoirs of the Anuwa Field in the Offshore Depobelt of the Niger Delta Basin" focuses on the evaluation and characterization of hydrocarbon-bearing formations using geophysical well logs. Data from gamma ray were analyzed alongside those from spontaneous potential, density, caliper, resistivity as well as neutron logs to determine the lithology, petrophysical parameters, and overall quality of the reservoirs. Six distinct reservoirs D5000, D5200, D7000, D8000, D2000, and C3000 were identified and evaluated based on their log responses. In Well 35, reservoirs D5200, D7000, and D8000 were encountered at depths between 7193.43 to 7607.44 ft, while Well 36 penetrated C1500, D5200, D7000, and D8000, between 5805.61 to 7634.36 ft. The computed petrophysical parameters showed gross thicknesses of 82.48–137.84 ft, net and thicknesses of 24.5–65.25 ft, net-to-gross ratios of 0.249–0.789, and shale volumes between 0.258–0.394. Porosity values ranged from 24–27%, water saturation from 22–34%, hydrocarbon saturation from 66–78%, and permeability from 95–151.5 millidarcies (md). These results indicate that the Anuwa Field reservoirs are composed mainly of good-quality, hydrocarbon-saturated sandstones with favorable storage and flow characteristics. The study emphasizes the critical role of geophysical well logging in subsurface formation evaluation. Unlike drill cuttings or core samples, which provide limited or discontinuous data. Well logs offer continuous, in-situ measurements that enable accurate delineation of lithologies and estimation of formation fluids. Advances in computer-based logging and interpretation have significantly enhanced hydrocarbon exploration and reservoir assessment. Overall, the findings demonstrate that Anuwa Field possesses economically viable reservoirs with promising production potential. The integration of modern well-logging techniques has proven essential in determining accurately the key petrophysical properties, most importantly porosity, permeability, saturation, and capillarity, which collectively define reservoir quality and productivity within the Niger Delta Basin (NDB).

Keywords: Well logs, Reservoir. Petrophysics, Hydrocarbon.

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1. Study Location

The studied field is located along the offshore depobelt of the NDB (Figure 1.1). Several wells overtime have been drilled in this area, few of which are water bearing, while some others are side tracks without complete details of logging. Two wells of the aforementioned wells drilled were employed for this study.

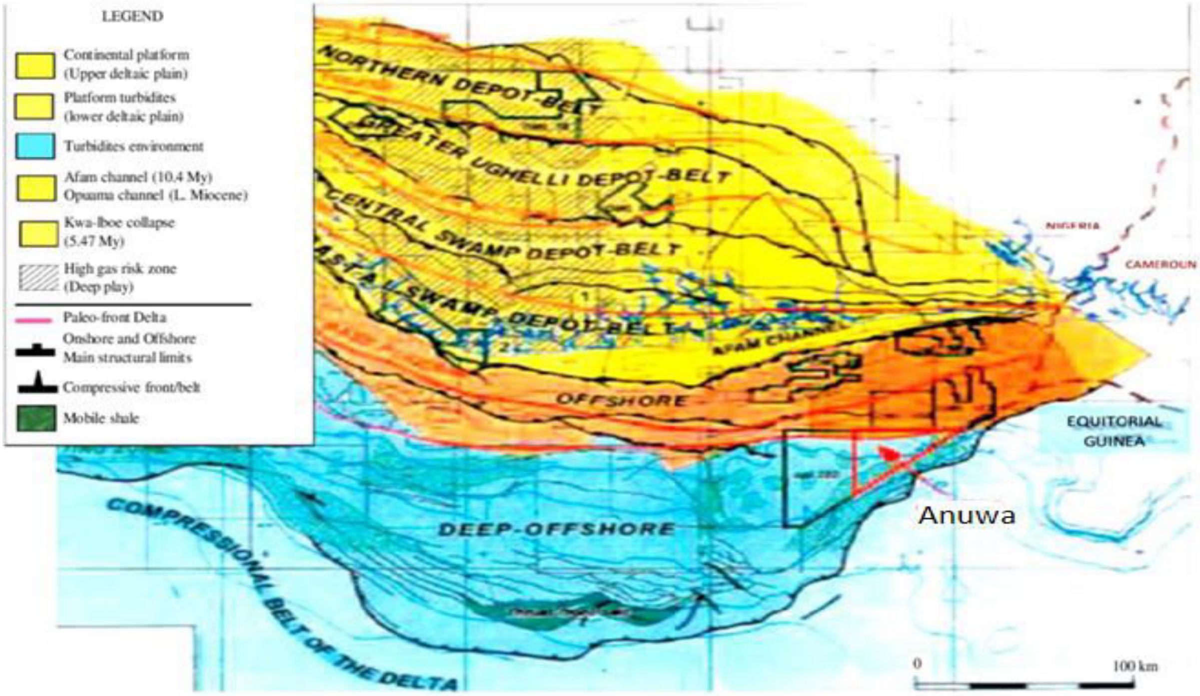

Figure 1. Study Area’s Location Map

2. Research Methodology

2.1 Data Acquisition and Description

This study utilized digital well log data obtained from two wells, designated Well-35 and Well-36, located in the Anuwa Field within the NDB’s offshore depobelt. The log data, provided in LAS (Log ASCII Standard) format, comprised Gamma Ray (GR), Spontaneous Potential (SP), Caliper, Resistivity (Micro, Shallow, Medium, and Deep), Density, and Neutron logs. These datasets were selected for their ability to capture the variabilities in lithologies, content of fluid, and petrophysical characteristics of the formations deemed to be reservoirs.

2.2 Data Loading and Preprocessing

The LAS files were imported into Techlog Workstation (Schlumberger) for processing, visualization, and interpretation. Upon loading, the data were subjected to quality control procedures to ensure data integrity. The electronic logs were validated against available hardcopy logs to confirm that no data corruption occurred during transfer or importation. Depth discrepancies, if present, were corrected by depth matching across all log runs to maintain uniformity.

2.3 Log Organization and Standardization

To ensure consistency in analysis, the log curves were organized standard tracks of display that are three in number within Techlog:

- Track 1: GR, Caliper, and SP curves.
- Track 2: Resistivity curves (Micro, Shallow, Medium, and Deep).
- Track 3: Density and Neutron porosity curves.

Dataset naming conventions were harmonized, and each log was assigned to its appropriate data family with standardized units. The first GR log run in each well was picked as the primary depth reference for calibration and correlation.

2.4 GR Log Normalization

GR logs from both wells were normalized in Techlog using quartile normalization through linear transformation notably at the 5th and 95th percentile values. This style minimized variability in inter-well conditions resulting from tool calibration differences and environmental effects. The normalized minimum and maximum values were subsequently calibrated to represent typical clean sand (20 API) and shale (140 API) responses, respectively. Well-35 served as the calibration reference well**,** having the most consistent and reliable GR signature across the study area.

2.5 Log Correction and Quality Control

After normalization, a cut-off value of 80 API was adopted to differentiate between sand and shale lithologies across the field. The logs were visually inspected for anomalies such as cycle-skipping or noise spikes introduced during logging. These spikes were identified and corrected using the despiking function in Techlog to enhance the accuracy of subsequent interpretations. Additional environmental and borehole corrections were applied where necessary to improve log fidelity.

2.6 Data Integration and Analysis

The corrected and standardized log datasets formed the foundation for both geological and petrophysical analyses**.** The processed data were employed to delineate lithological boundaries, identify reservoir zones, and estimate petrophysical properties including porosity, hydrocarbon saturation, water saturation as well as permeability**.** The integration of these parameters provided a robust basis for evaluating the reservoir quality and hydrocarbon potential of the Anuwa Field.

3.1 Lithology Identification

Lithological identification in this study was primarily carried out using GR, Caliper and even SP logs. The GR log records the radioactivity (natural) emitted by the geologic formations within the studied borehole, which provides a reliable basis for distinguishing between shale and non-shale (reservoir) lithologies. Shale formations typically contain radioactive elements such as potassium (K), thorium (Th)as well as uranium (U), particularly from the clay minerals illite, montmorillonite, and kaolinite**.** Thus, resulting in high GR count rates. Conversely, clean reservoirs like sandstone, limestone, and dolomite exhibit GR readings that are quite low, because these minerals lack radioactive constituents in their crystal structures. This distinction is illustrated in *Figure 3.7*, where the low GR response corresponds to cleaner, reservoir-quality sands, while higher readings indicate shale interbeds.

The SP log was also utilized to complement GR interpretation. It measures electrical potential difference (natural) between borehole fluid and formation water, which varies with lithology and fluid salinity. A negative SP deflection from the shale baseline typically signifies permeable or porous sand zones, depending on mud type and salinity contrast. When integrated with GR data, the SP curve helps refine lithological boundaries and confirm reservoir continuity.

Additionally, the Caliper log, which records the borehole diameter, was employed to verify lithological consistency and borehole stability. In shale zones, the borehole often enlarges due to clay swelling or caving, causing the caliper reading to exceed the bit size. In contrast, in competent sand or carbonate zones, the caliper readings generally match the bit size. Where SP deflection is positive, GR readings are moderate, and Caliper measurements approximate the bit size, the interval is interpreted as a heterolithic or mixed sand–shale zone. These relationships between GR, SP, and Caliper logs provided a reliable framework for defining lithological units across the study wells (as reflected in *Figure 2*).

3.2 Reservoir correlation

Reservoir correlation was performed to establish the lateral continuity, thickness variation, and stratigraphic equivalence of identified reservoir units in this study across the studied wells. The GR log served as the primary tool for this purpose, owing to its sensitivity to lithological changes and its reliability in distinguishing sand–shale alternations that characterize the Niger Delta depositional environment.

Reservoir tops and bases were identified from the normalized GR curves and then correlated laterally between Well-35 and Well-36 to trace the continuity of distinct sand bodies. The correlation process enabled the recognition of six major reservoir units (D5000, D5200, D7000, D8000, D2000, and C3000), each characterized by distinctive

GR motifs corresponding to specific depositional facies. Variations in GR amplitude and pattern were interpreted in terms of sedimentary energy, depositional environment, and shale intercalation**.**

This correlation framework provided valuable insights into the reservoir geometry, areal extent, and connectivity across the field. Zones displaying consistent low-GR signatures and matching depth intervals were interpreted as laterally continuous reservoir sands**,** whereas intervals showing abrupt GR changes or inconsistent thickness were attributed to lateral facies changes or structural discontinuities**.** The correlation panel constructed (as shown in *Figure 3*) thus forms the geological basis for petrophysical and volumetric evaluation of the Anuwa Field reservoirs.

3.3 Reservoir fluid identification

Fluid identification within the delineated reservoir intervals was accomplished through an integrated interpretation of Resistivity, Neutron, and Density logs in conjunction with GR log.

The Deep Resistivity log in this study was employed for the purpose of differentiating between hydrocarbon-bearing zones from water-saturated formations**.** High resistivity readings generally indicate hydrocarbon-bearing intervals, as hydrocarbons are poor conductors of electricity, whereas low resistivity values are characteristic of water-bearing formations due to the conductive nature of saline formation water. The deep resistivity tool minimizes the influence of borehole and mud filtrate effects, thereby reflecting true formation resistivity.

The Neutron–Density combination was utilized to further characterize fluid types and contacts**.** In clean, gas-bearing formations, a noticeable crossover occurs where the Neutron porosity curve lies to the left of the Density curve, indicating gas presence due to the lower hydrogen index of gas relative to liquids. In oil-bearing zones, the curves tend to track closely with moderate separation, while in water-bearing formations**,** the two curves overlap without crossover. These relationships were cross-checked against GR and SP signatures to confirm lithology and fluid distribution (as demonstrated in *Figure 4*).

By integrating these log responses, it was possible to identify oil-, gas-, and water-bearing intervals, delineate contacts of fluid (gas–oil or even oil–water interfaces), and evaluate hydrocarbon potential of each reservoir unit. This comprehensive multi-log approach ensured accurate characterization of the reservoir fluids and improved confidence in the petrophysical interpretations.

3.4 Petrophysical Parameter Estimation

Evaluation of Petrophysical properties was done to quantify the qualities of the reservoir and assess the hydrocarbon potential of the identified sand bodies within this studied Anuwa Field. The estimation of parameters like effective porosity (φeff), shale volume (Vsh)**,** water saturation (Sw)**,** permeability (K) and even hydrocarbon saturation (Sh) was performed using log-derived data from the processed and corrected GR, Resistivity**,** Neutron and of course Density curves within the Techlog environment. Thus, the following workflow and equations were applied.

3.5 Determination of shale volume

Computation of Vsh from the GR log by employing a linear GR index method was the foremost step. GR histogram was use, the essence of GR histogram is to get minimum and maximum GR. The Vsh was then calculated by employing the Larionov (1969) method of non- linear response. The following equation is used to determine the GR index ($\mathrm{I_{GR}}$):

$$\mathrm{I_{GR}} = \frac{\mathrm{GR_{log}} - \mathrm{GR_{min}}}{\mathrm{GR_{max}} - \mathrm{GR_{min}}} \qquad 3.3$$

Given that:

$\mathrm{I_{GR}}$ = GR index
$\mathrm{GR_{log}}$ = GR reading of the formation
$\mathrm{GR_{min}}$ = minimum GR (clean sand or carbonate)
$\mathrm{GR_{max}}$ = maximum GR (shale)

Virtually all these values have been read off in each reservoir, and having gotten the GR index, Vsh was then obtained using Larionov (1969) nonlinear response method shown in equation 3.4 below

$$V_{sh} = \frac{I_{GR}}{3-2\times I_{GR}} \qquad 3.4$$

Figure 5 and 6 show GR histogram of reservoirs in well 35 and 36 respectively, while figure 7 shows Vsh of reservoirs in well 35.

3.6 Porosity calculation

Porosity is the measured void spaces in a rock where fluids reside under pressure and temperature conditions. Computations of total porosity was done using density log. Density tool measures primary as well as secondary porosity in a clean formation of known RHOMA and RHOF, the following density derived equation was used.

$$DPHi = \frac{RHOMa-RHOB}{RHOMa-RHOF} \quad \text{(Eshimokhai and Akhirevbulu 2012)} \qquad 2.1$$

Where: *DPHi* = porosity derived from density, $RHOMa$ = density of the matrix, $RHOB$ = bulk density of the formation. RHOF= density of fluid (0.8 oil, 1.0 fresh mud and 1.1 salt mud). Figure 8 shows the porosity plot of this work.

3.7 Permeability estimation

Permeability measures the ease with which fluids like gas, oil or even water passes through inter-connected pore spaces within a reservoir unit. It is quite pertinent when predicting a reservoir’s production rate. Porosity - permeability transform (Timur’s equation) was used in estimating permeability.

$$K = a.\frac{Phi^b}{S_{wi}^c} \qquad 2.3$$

Where: a= 8581, B= 4.4 and C= 2

The permeability plot is as shown in Figure 8.

3.8 Net-to-gross ratio (NTG)

NTG is the clean sand proportion in juxtaposition to shale present in a reservoir unit. The gross sand (GS) means the whole unit thickness of the reservoir; the non-net sand (NNS) means the shaly sequences occurring in the entire thickness of the reservoir. The net sand is gotten therefore by subtracting the NNS from the GS. The NTG ratio reflects sand quality making them potential reservoirs. When the NTG value is higher it means that the sand quality for reservoir potential is better. NTG can therefore be obtained as thus:

Net reservoir = Gross reservoir – non reservoir thickness 3.1
NTG = Net reservoir / Gross reservoir (Amigun and Odole 2013) 3.2

The Net determination and Net to Gross cross plot is as shown in the Figures 9 below.

3.9 S_w determination

When calculating uninvaded zone S_w, the usual method requires you having the water resistivity *Rw* value of the studies formation. We do not have water analysis report where we can ordinarily get *Rw*, that is why we resulted using picket plot which is a function of total porosity and deep resistivity as shown in figure 9. Having gotten *Rw*, we calculated water saturation using Archie’s 1942 equation as shown below:

$$S_w = \sqrt[n]{\left(\frac{a}{\emptyset^m}\frac{R_w}{R_t}\right)} \text{ (Archie, 1942)} \qquad 3.3$$

Default values: a = 1, m = 2, n = 2

Where:
Sw = uninvaded zone’s water saturation;
Rw = resistivity of formation water
Rt = resistivity of the uninvaded zone in the formation

(Ø)= porosity
a = factor of tortousity
m = exponent of cementation
n = exponent of saturation

The picket plots and water saturation plots are shown in the Figures 8, while the picket plot is reflected in figure10 and 11 below

5. RESULTS AND INTERPRETATION

Different zones of reservoir formations were identified from GR, resistivity, neutron as well as density logs. Three (3) reservoirs were identified with well 35 penetrating three (3) reservoirs namely; D5200, D7000 and D8000 and Well 36 penetrated (four) reservoirs, namely; C1500, D5200, D7000 and D8000. The zones of interest include reservoir rocks (sandstone). A decrease in GR which is a deflection of GR response to the left with a corresponding increase in resistivity is an indication of low GR, with a corresponding increase in resistivity indicates the possibility of the occurrence of a zone of hydrocarbon reservoir, combining neutron and density logs can be referred to as a reliable gas reservoir unit indicator, because when there is a leftward shift in the density curve meaning lower density and right shift in neutron log meaning a crossover which produces a balloon effect that indicates zones of gas bearing rocks.

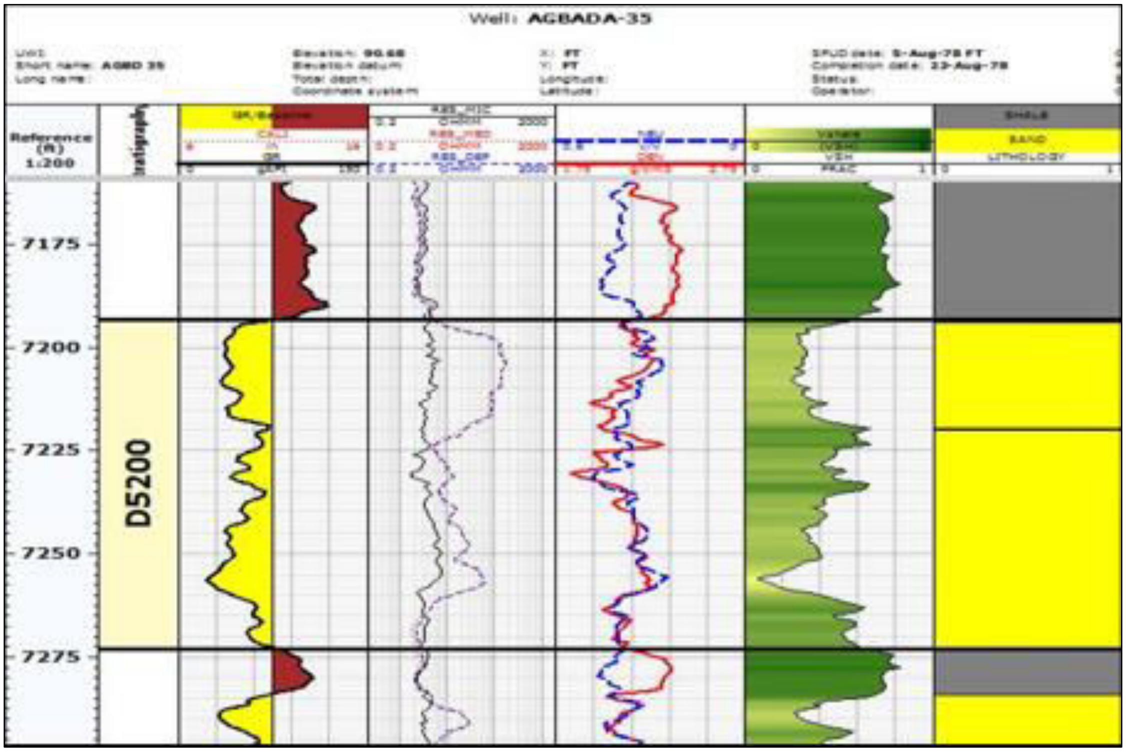

Figure 2. Identification of lithology/Reservoirs

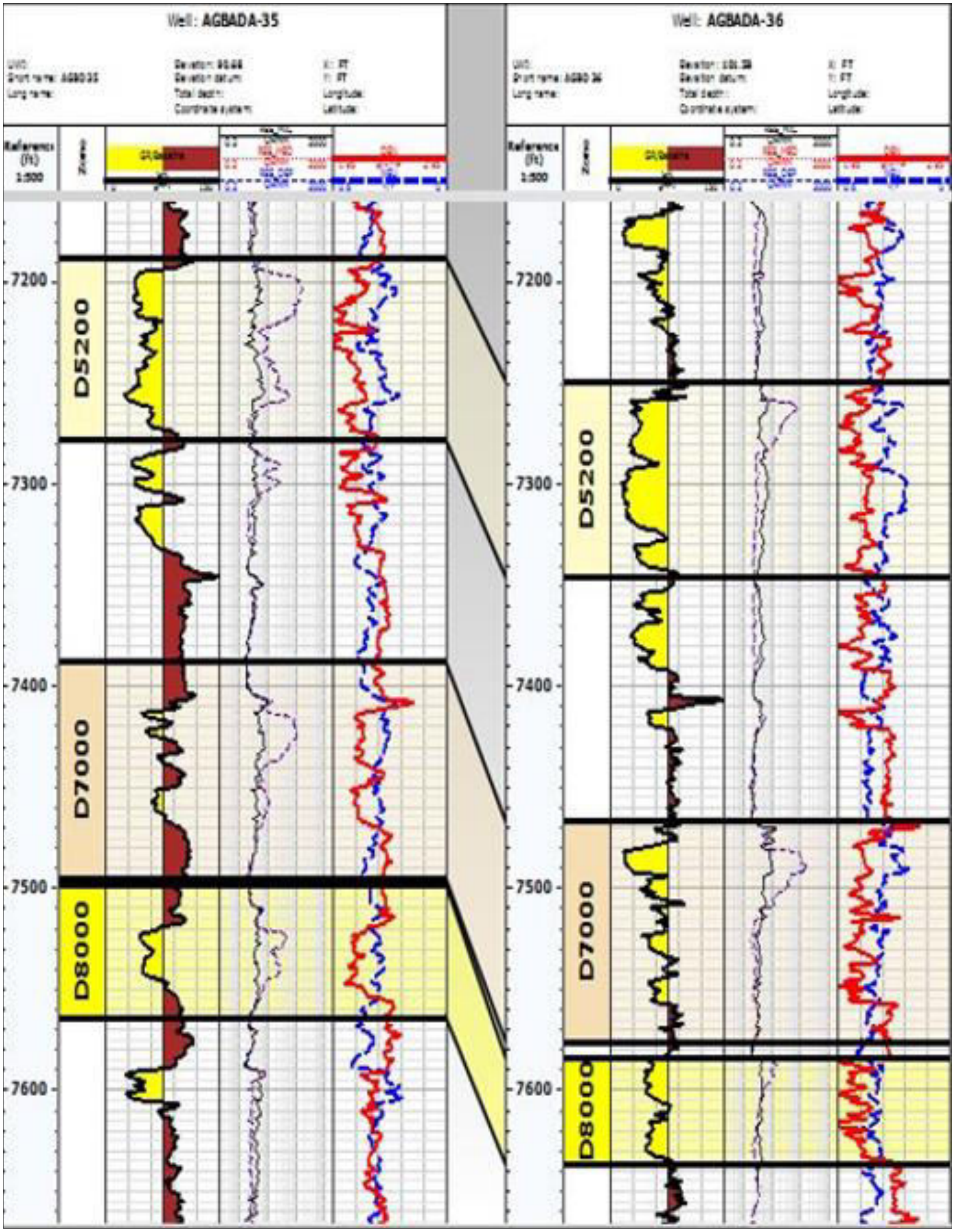

Figure 3. Correlation pannel

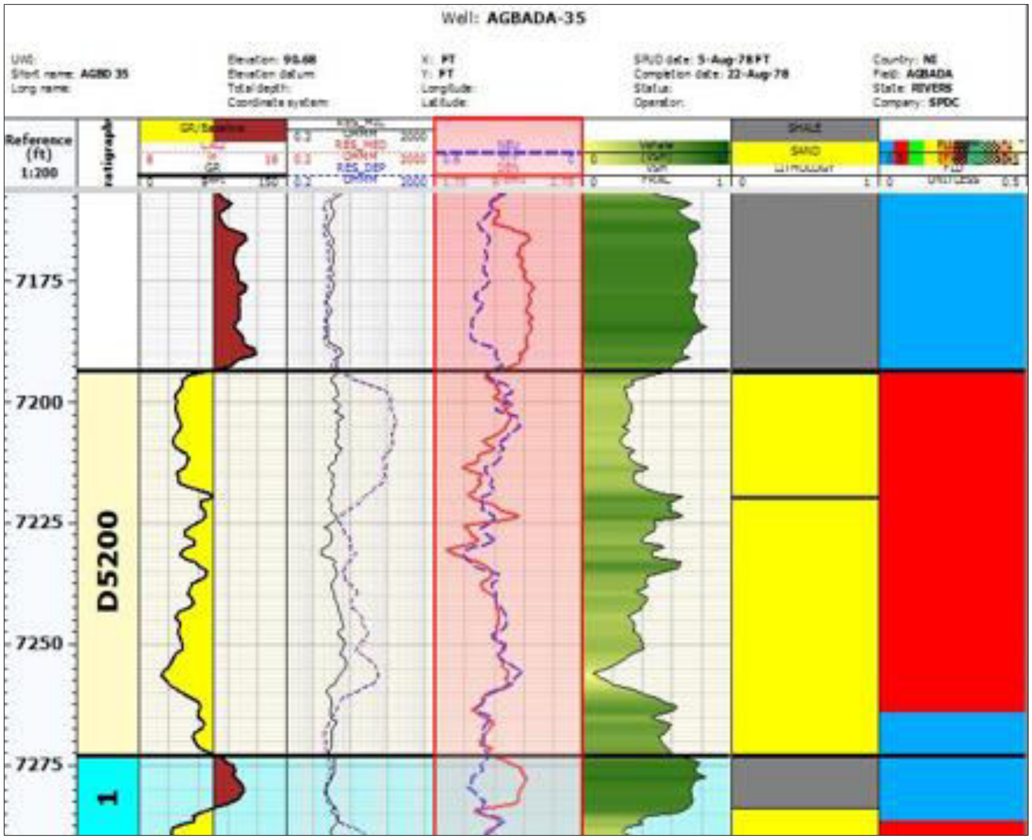

Figure 4. Hydrocarbon Identification of reservoir D5200, well 35

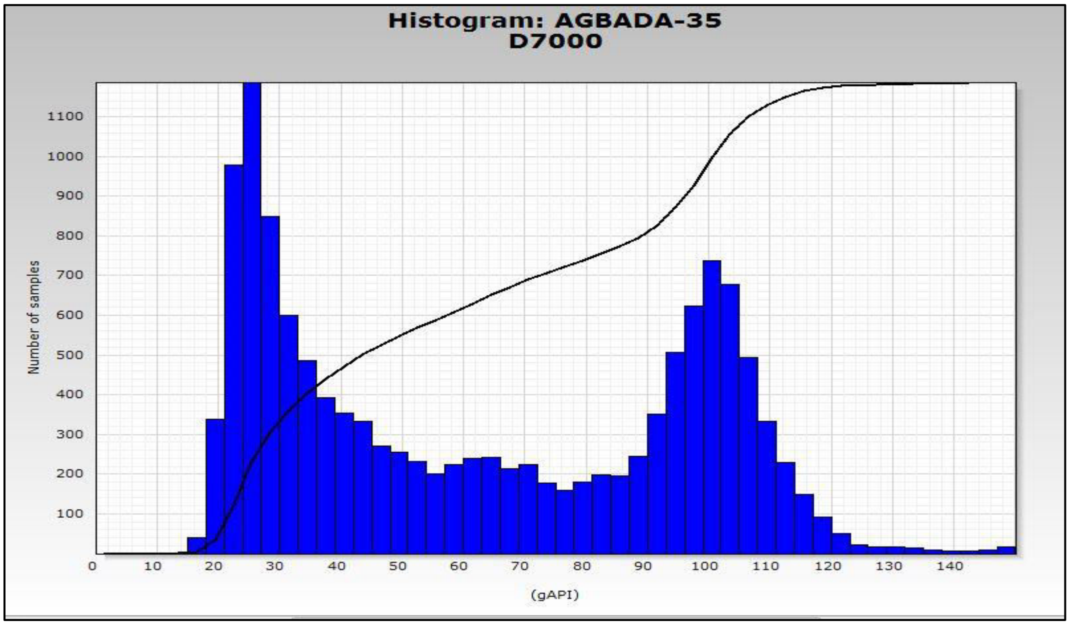

Figure 5. Vsh Histogram cross plot of reservoir D7000 well 35

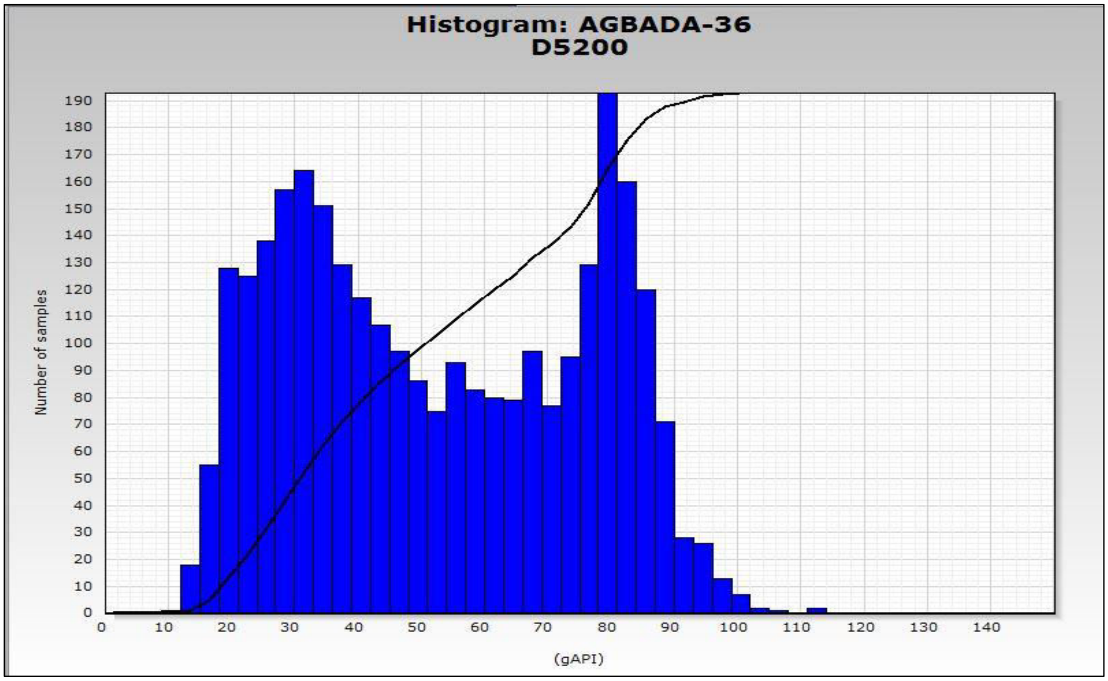

Figure 6. Vsh Histogram cross plot of reservoir D5200 well 36

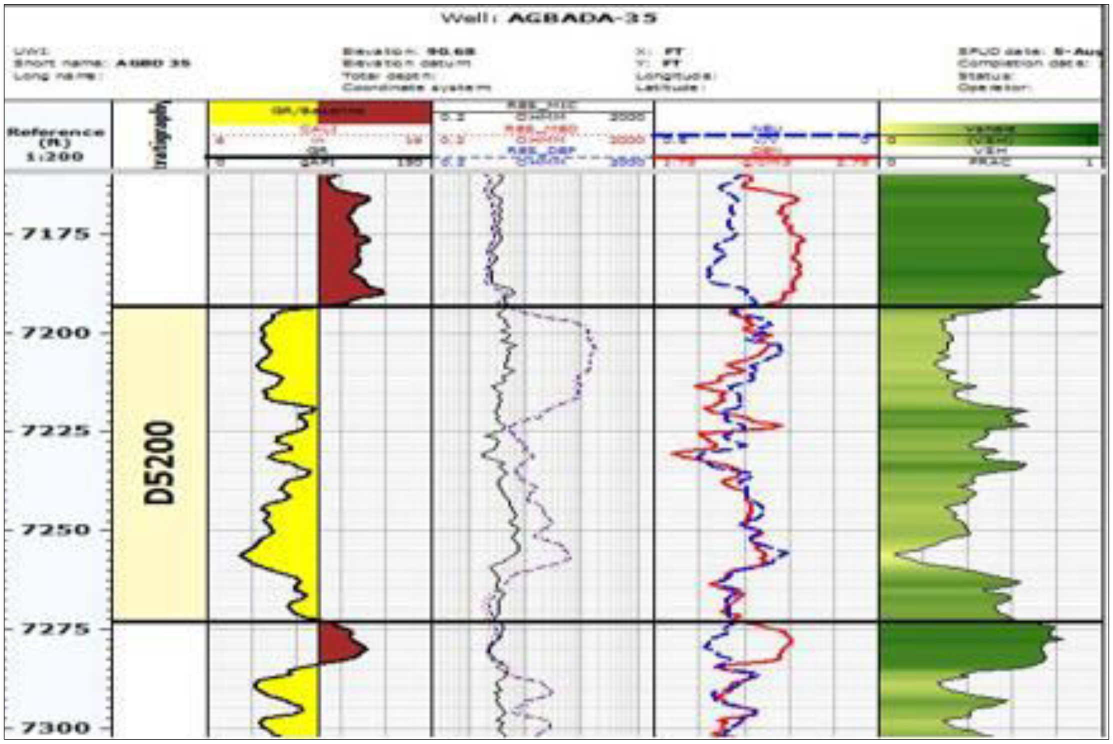

Figure 7. Cross plot showing Vsh of reservoir D5200, well 35

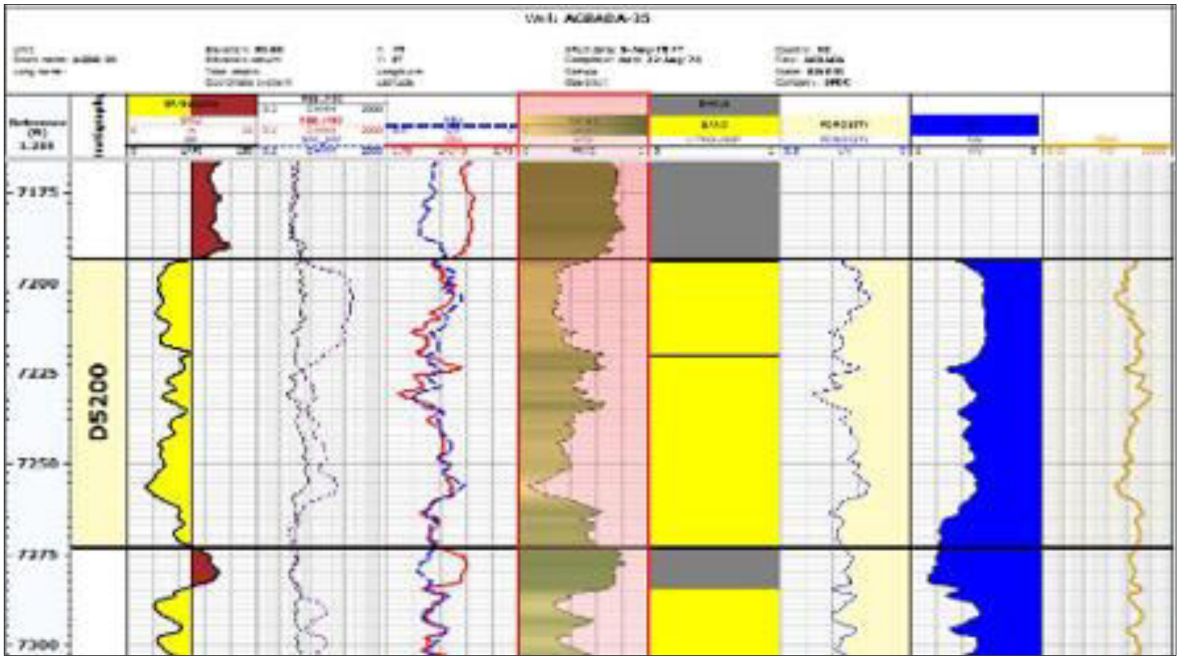

Figure 8: Porosity, Permeability and water saturation cross plot

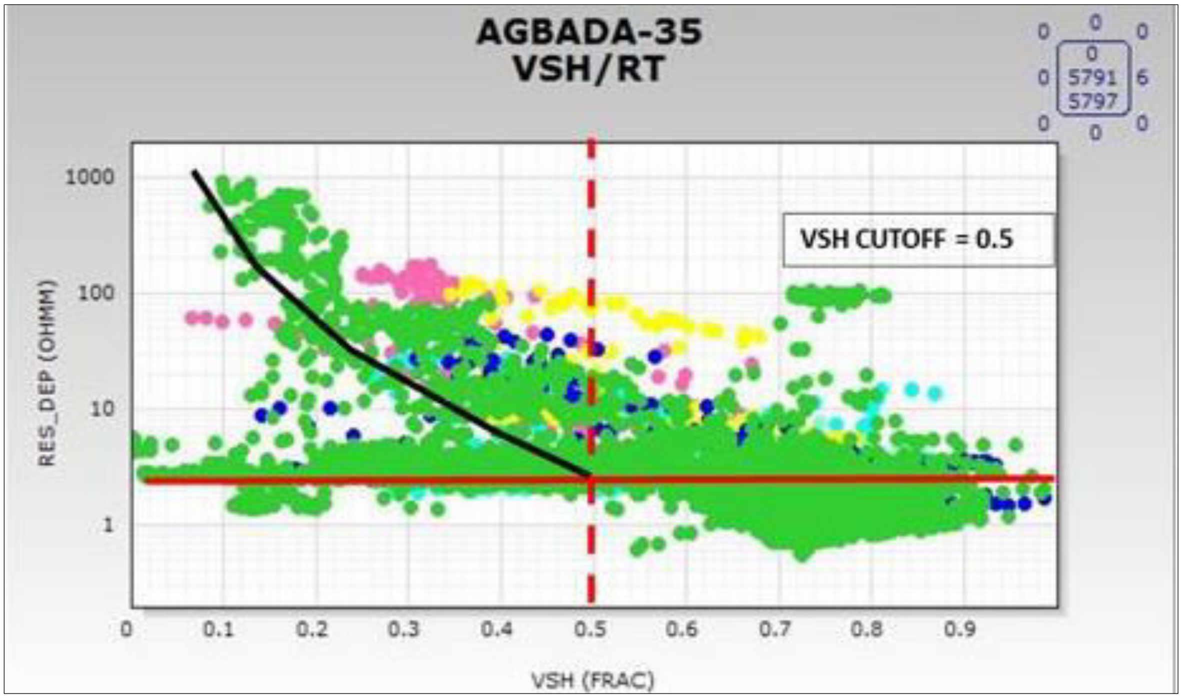

Figure 9: Net to gross determination plot

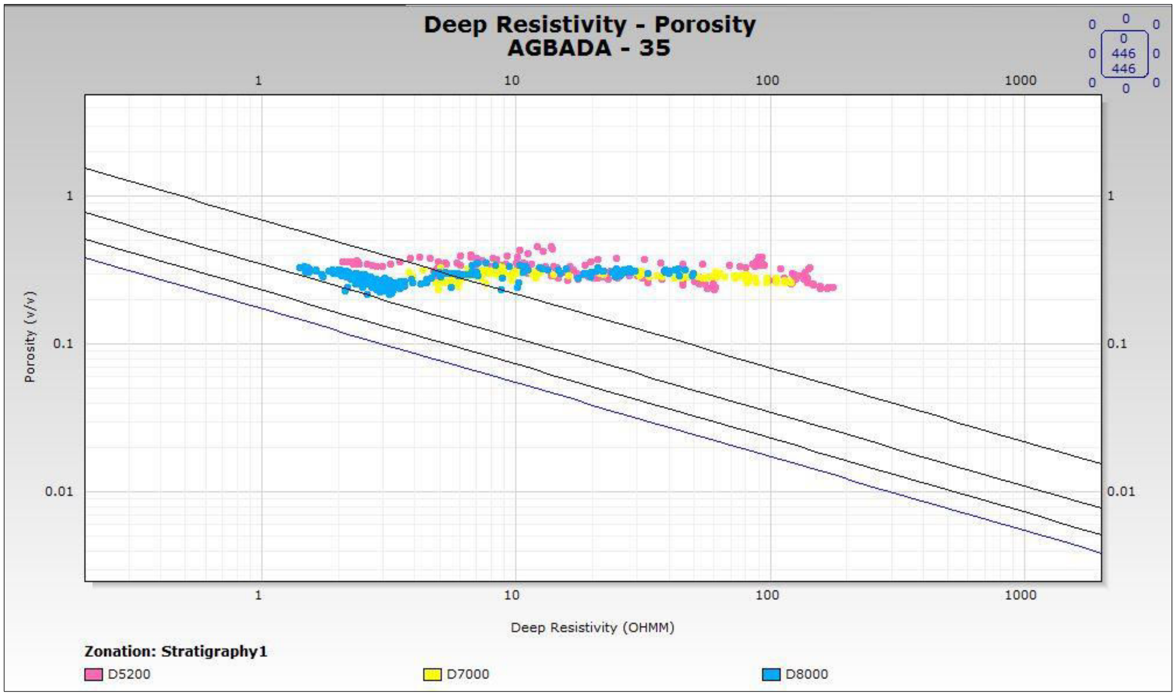

Figure 10. Pickett plots of reservoir D5200, D7000, and D8000 of well 35

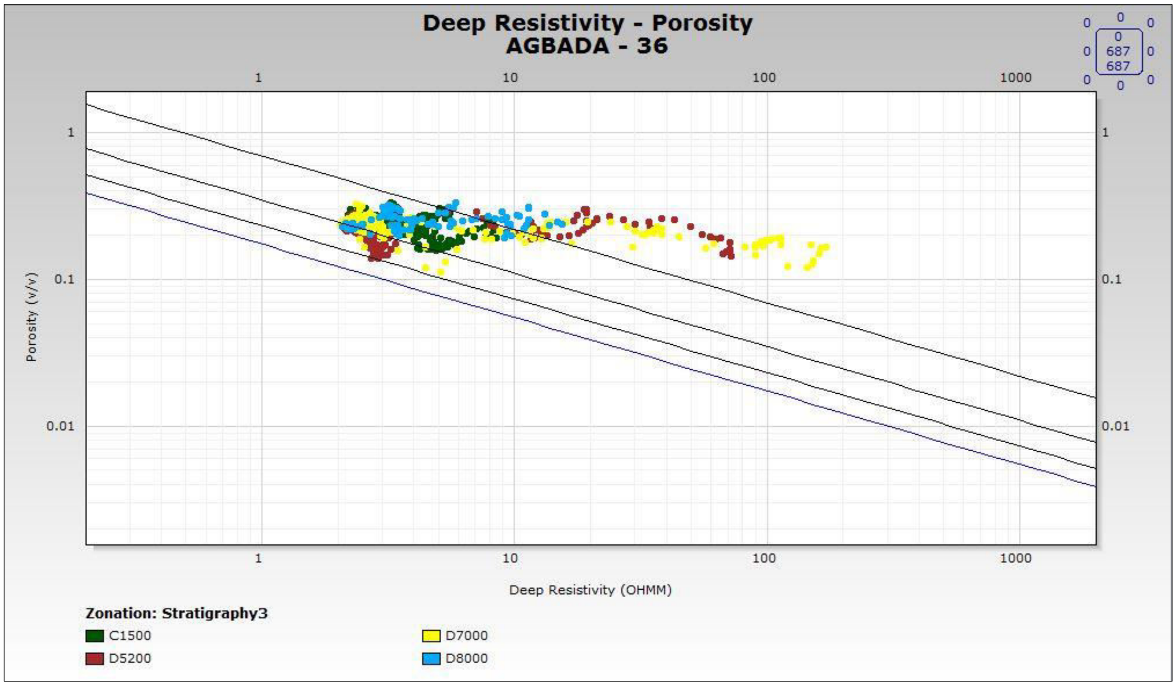

Figure 11. Pickett plots of reservoir D1500, D5200, and D7000 and D8000 of well 35

5.1 Well 35

In this studied well, three reservoirs in total, namely; D5200, D7000 D8000 were deciphered. The Vsh of these reservoirs range from 0.347v/v to 0.433v/v decimal. Suggesting that reservoirs within the Vsh values stated above goes beyond the limit of 15% that can possibly affect the water saturation. The porosity values for the reservoirs range between 23%-29%, which indicate good to very good porosity values Baker (1992). Reservoirs that pose high resistivity value is possibly a hydrocarbon zone, while the low values of water saturation and high resistivity for these reservoirs implies that these reservoirs are possibly hydrocarbon bearing. Table 1 summarises the computed petrophysical parameters for deciphered reservoirs in well 35.

Table 1. Well 35's computed petrophysical parameters summary table

Well	Zone	Top	Bottom	Gross	Net	NTG	Ø (%)	SW (%)	K (Md)	Sh (%)	Vsh
35	D5200	7193.43	7272.91	79.477	58	0.73	31	26	188	74	0.347
	D7000	7410.77	7466.73	55.958	23.5	0.42	29	27	115	73	0.433
	D8000	7519.85	7607.44	87.585	33.5	0.382	28	39	95	61	0.361

5.2 Well 36

In this well, 4 reservoirs; C1500, D5200, D7000 and D8000 were deciphered and they have thickness within 5932ft and 7634.36 range. The average Vsh of these reservoirs fall between 0.169v/v and 0.427v/v decimal. These values of Vsh observed are not within limits with potentials of affecting the water saturation values as posited by Hilchie, (1978) and suggestively indicate the clean nature of the reservoirs. On the average, the reservoirs' porosities (20%-31%) are good enough. The reservoirs' resistivity (Rt) values that was recorded is high and this quickly indicates that the zone is most likely a zone that bears hydrocarbon. These reservoirs' average water saturation ranges between 18% and 37%. While the low water saturation values of these reservoirs in this studied well 36 is indicates that within the reservoirs there is a high hydrocarbon saturation (see table 2). The petrophysical parameter averages for all reservoirs within wells 35 and 36 are seen in table 3

Table 2. Well 36 computed petrophysical parameters summary table

Well	Zone	Top	Bottom	Gross	Net	NTG	Ø (%)	SW (%)	K (Md)	Sh (%)	Vsh
36	C1500	5805.61	5932	126.394	31.5	0.249	25	33	135	67	0.354
	D5200	7257.5	7342.98	85.476	72.5	0.848	23	37	115	63	0.169
	D7000	7475.86	7557.75	81.885	25.5	0.311	22	18	109	82	0.244
	D8000	7584	7634.36	50.364	18	0.357	20	30	95	70	0.427

Table 3. Wells 35 & 36 reservoir petrophysical parameters' average values

Well	Zone	Gross	Net	NTG	Ø (%)	SW (%)	K (Md)	Sh (%)	Vsh
36 and 37	C1500	126.394	31.5	0.249	25	33	135	67	0.354
	D5200	82.4765	65.25	0.789	27	31	151.5	69	0.258
	D7000	137.843	24.5	0.3655	25	22	112	78	0.339
	D8000	137.949	25.75	0.3695	24	34	95	66	0.394

6. Conclusion

Petrophysical well logs were subjected to analysis for reservoir characteristic of 35, and 36 wells, offshore depobelt, Niger Delta. This study determined properties of reservoir like lithology, K_a, Ø, Net thickness, Vsh, Net/gross, S_w as well as hydrocarbon saturation from the employed well logs. From the analysis, lithologies of sand and shale were identified through the use of the GR and SP logs.

On the basis of these results gotten from this study, the following conclusion could be made. The reservoir qualities of the "Anuwa field" Niger Delta are deemed moderate to good. The gross, net sand, net to gross, hydrocarbon saturation and permeability averages range 82.4765 to137.949ft, 24.5 to 65.25ft, 0.249 to 0.789, 65.5 to 77.5% and 95 to 151.5md respectively. The reservoirs within the two wells averages porosity values ranging from 24% to 27%. The average Vsh range from 0.258 to 0.394v/v decimal, the Vsh in these wells are deemed fair enough to allow for fluid to flow freely. For most of the reservoirs, the Vsh values are well within the limits that could possibly not pose any effect on the value of S_w, suggestively indicating that that the reservoirs are most likely clean. The S_w average values range from 22.5 to 34.5%, the reservoirs that have lower S_w are more in number than those with higher S_w in the overall result.

References

Achie G.E (1942). The electrical resistivity log as an aid in determining Some Reservoir characteristics. Petroleum Transactions of the AIME, 146, 54-62.

Archie, G.E (1950). Introduction to petrophysics of Reservoir rock. American Association of Petroleum Geologists Bulletin 34(5), 943 – 961.

Burke, K.C Dessavagie, T.F.J & White A.J. (1971). The opening Of the Gulf of Guinea and the geological history of the Benue Depression and Niger Delta: nature Physics Science 2133(38) 51-55

Burke, K., Longshore drift, submarine canyons, and submarine fans in development of Niger Delta: *American Association of Petroleum Geologists,* 1972, 56, 1975-1983.

Coker, J.O., Idris, J.M., Ojo, O.F., Ikhane, P.R., Makinde, V. (2021). Application of Well Log Analysisin Assessment Of petrophysicalParameters of the Alpha Oilfield in Niger Delta, Nigeria Journal of Applied Geology and Geophysics PP 39-49.

Eshimokhai S. and Akhirevbulu O. E. (2012). "Reservoir characterization using seismic and well logs data (A case study of Niger Delta", Ethiopian journal of environmental studies and management (EJESM), Vol.5 no.4 (suppl.2).

Godwin O. Aigbadon, Goriola O. Babatunde, Mu'awiya B. Aminu,Changde A. Nanfa, Simon D. Christopher (2021). Depositional Environments and Reservoir Evaluation of Otuma Oil Field, Niger - Delta basin, Nigeria. European Journal of Environment and Earth Sciences.

Hansen-Ayoola A.O., Oladapo I., Ogunronke M., Taiwo R.M., Babatunde O.M.,Egbewale O.R. (2018). Petrophysical Analysis of Well Logs forReservoir Evaluation: A Case Study of the 'Beta' Field, Niger Delta. International Journal of Science, Engineering & EnvironmentalTechnology (IJOSEET), 3(6): 39-46.

Ighodaro, E.J; Okanigbuan, P.N; Okiotor, M.E; Idemudia N. (2019). Petrophysical Evaluation of Reservoir in A Selected Well (Z) in an Onshore Oil Field J. Appl. Sci. Environ. Manage, Vol. 23 (5) 917-925.

Lurogho Sayoleyi, Ideozu UIdeozu, Abe J (2020). Petro physical analysis of wells in explorer field, offshore Niger delta,Nigeria using well log and coredata.

Oluseun Adetola Sanuade, Adesoji Olumayowa Akanji, Abayomi Adesola Olaojo, Kehinde David Oyeyemi (2017). Seismic interpretation and petrophysical evaluation of SH field,Niger Delta. J. Petrol Explorer Prod Technol.

Omoja, U.C; Obiekezie, T.N (2021). Evaluation of Petrophysical Parameters of Reservoir Sand Wells in Uzot-Field,Onshore Niger Delta Basin, Nigeria. J. Appl. Sci. Environ. Manage. Vol. 25 (2) 157-171

Okolie O, Ideozu R.U, Chiazor F. I (2021). Reservoir modeling and petrophysical evaluation of kanga field onshore Niger delta.

Selley, R.C. (1997). African Basins (Sedimentary Basins of the World). Volume 3, Elsevier Science B.V., Amsterdam.

Tuttle, W.L.M Charpentier, R.R and Brownfield, M.E (1999). The Niger Delta Petroleum system: Niger Delta province, Nigeria, Cameroon and Equatorial Guinea, Africa, USGS. Denver Colorado. Open-file Report 99-50-H

Theophilus Aanuoluwa Adagunodo, Oyelowo Gabriel Bayowa, Oluwaseun Emmanuel Alatise, Adeola Opeyemi Oshonaiye, Olusegun Oladotun Adewoyin, Victor Onaolamipo Opadele(2022). Characterization of reservoirs and depositional study of J-PField, shallow offshore of Niger Delta Basin, Nigeria, Scientific African.

Prince Suka Momta, John Owate Etu-Efeotor, Charles Ugwu Ugwueze (2015). Petrophysical Characterization and Flow Models for AgbadaReservoirs, Onshore Niger Delta, Nigeria.American Journal of Geosciences

Ukuedojor Kingsley Oghenemeruo, Maju-Oyovwikowhe Gladys Efetobore (2019). Petrophysical Evaluation and Reservoir Geometry Deduction of Idje Field, Offshore Niger Delta Nigeria. Journal of Geosciences and Geomatics vol.7 no.4 157-171

Victor Cypren Nwaezeapu, Kingsley Chimaobi Ezenwaka, Tuoyo Adetutu Ede (2019). Evaluation of hydrocarbon reserves using integrated petrophysical analysis and seismic interpretation: A case study of TIM field at southwestern offshore Niger Delta oil Province, Nigeria, Egyptian Journal of Petroleum 273-280.

Weber K.J. (1971). Sedimentology aspects of Oil fields in the Niger Delta: Geological Society of mining, 50(3) 559-576.