

# Evaluation of Hydrocarbon-Bearing Reservoir Intervals Using Conventional Well Logs and Crossplot Techniques: A Case Study of Chevron Field

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*Abstract- This study evaluates hydrocarbon-bearing reservoir intervals within the Chevron Field, Niger Delta Basin, using conventional well logs and crossplot techniques for reservoir characterization and hydrocarbon identification. Gamma ray, resistivity, density, and neutron logs from three wells (CHEV\_001, CHEV\_002, and CHEV\_003) were integrated to identify reservoir units and determine key petrophysical parameters. Two major reservoirs, CHEV\_1 and CHEV\_2, were identified within the Agbada Formation and are characterized by low gamma ray values, elevated resistivity responses, and density–neutron crossover effects indicative of hydrocarbon-bearing sandstone formations. Crossplot analyses revealed low shale volume, moderate to good porosity, and significant hydrocarbon saturation within the reservoirs. The resistivity–porosity relationship further confirmed that highly porous intervals correspond to hydrocarbon-saturated zones. Reservoir thickness analysis showed progressive thickening toward the eastern section of the field, suggesting enhanced reservoir development and improved hydrocarbon storage capacity. The integrated interpretation indicates that the identified reservoirs possess favorable petrophysical properties and significant hydrocarbon potential. The study demonstrates that conventional well logs and crossplot techniques provide an effective approach for reducing uncertainty in reservoir characterization and hydrocarbon prospect evaluation in the Niger Delta Basin.*

dealing with some of the uncertainty in the subsurface data, but most times integrating them with modern interpretation methods is increasingly important. Despite the abundant hydrocarbon potential in the Niger Delta Basin, accurate identification of hydrocarbon-bearing intervals remains challenging due to lithologic heterogeneity, fluid ambiguity, and reliance on incomplete subsurface datasets. Conventional well logs offer a cost-effective approach, but their optimal integration for reliable reservoir evaluation is still an important challenge (Oyeyemi et al., 2018; Oyebamiji & Oluwadare, 2020; Orji et al., 2024; Atolagbe & Ogungbesan, 2023). Ogbamikhumi and Igbiginigie (2020) stated that prospect identification also involves the observation made to identify seismic response that can be related to hydrocarbon presence commonly known as direct hydrocarbon indicator (DHI). Asquit and Krygowski (2004) stated that, crossplot are very important tools in reservoir evaluation because they allow you to compare two or more petrophysical log parameters simultaneously in order to distinguish lithology, pore fluids, and hydrocarbon-bearing zones. In hydrocarbon exploration, crossplots help reduce ambiguity that may arise when interpreting individual well logs separately.

## I. INTRODUCTION

Decades of exploration have covered most of the obvious onshore and shallow offshore fields in the Niger Delta. New discoveries are increasingly in deeper, more complex reservoirs, which cost much more to locate and develop. This calls for a constant conventional evaluation of reservoirs in the Niger Delta Basin. Conventional logs like gamma ray, density-neutron, and resistivity remain useful in

This study uses gamma ray, resistivity, density, and neutron logs to determine and correlate reservoir intervals throughout the wells under investigation. Additionally, it seeks to ascertain important petrophysical characteristics of the identified reservoirs, including shale volume, porosity, water saturation, and hydrocarbon saturation. Furthermore, in order to characterize the reservoir, the study plans to assess lithology and fluid distribution using

crossplot methodologies, including density–neutron and gamma ray crossplots. The study also aims to evaluate reservoir quality and continuity in the Chevron Field for hydrocarbon prospect evaluation, as well as to identify hydrocarbon-bearing zones by integrating well log responses and crossplot analysis.

## II. GEOLOGY OF THE STUDY AREA

Chevron Field is situated on the passive continental margin close to the western coast of Nigeria, West Africa, between 3°N and 6°N and 4°E and 8°E in the middle marsh Niger Delta on the Gulf of Guinea (Tuttle et al., 2015). One of the largest Tertiary delta systems in the world, the Niger Delta spans approximately 75,000 km<sup>2</sup>. It was created at a failed rift junction during the separation of the African and South American plates. It is made up of three main lithostratigraphic formations and a massive, 12-kilometer-thick regressive clastic sequence (Figure

1). The Agbada Formation (12,139 feet vertical depth and mostly sand) was deposited during the Eocene after the Akata Formation (9,000 feet vertical depth and mostly shale) was deposited during the Paleocene. The underlying shale diapirs were brought on by this loading. The Benin formation, which is 95% sandstone and has a vertical depth of 6562 feet, was then deposited during the Oligocene and is still being deposited now. The Eocene is when the Agbada formation first appeared. Whiteman (1982) described that majority of the formation is made up of channel and shoreface sands, with a small amount of shales in the higher portion and intercalation of sands and shales in an equivalent ratio at the lower half of the basin, Chevron Field is located in the Niger Delta's Agbada formation, which is the basin's main hydrocarbon-bearing sequence.

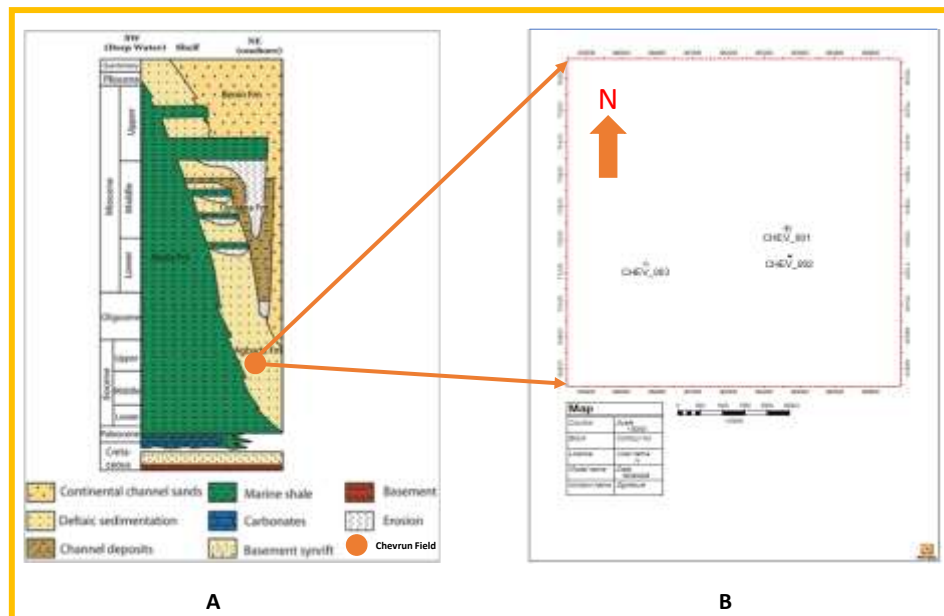


Figure 1. (A) Stratigraphic Framework of the Niger Delta Basin Showing the Benin, Agbada, Akata and Opuama Formations (modified after Doust and Omatsola, 1990). (B) Base Map of the study area showing the three (3) wells drilled in the Chevron Oil Field

## III. SOURCE OF DATA

The Nigerian Upstream Petroleum Regulatory Commission (NUPRC) assisted Shell Petroleum Development Company (SPDC) in obtaining the dataset. The information includes 3D seismic data,

well log, deviation, and checkshots. Depth, permeability, resistivity, gamma rays, shale volume, density, deep resistivity, microresistivity, P<sub>sonic</sub>, primary wave velocity, and caliper are all embedded in well logs.

#### IV. METHOD OF ANALYSIS

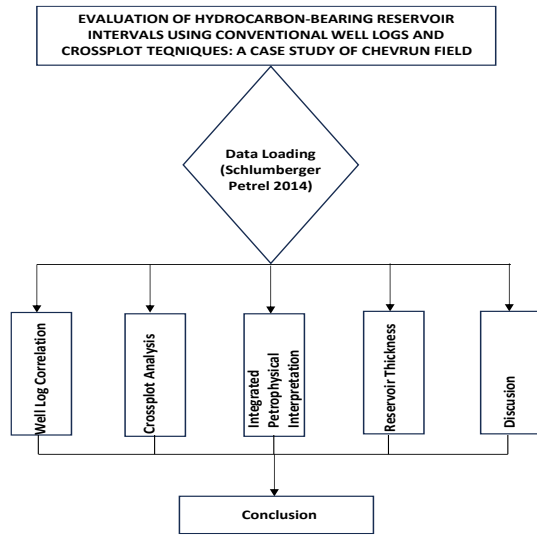


Figure 2. Summarized workflow illustrating the study methodology

#### Volume of Shale ( $V_{sh}$ )

The normalized Gamma-Ray log with the neutron and density, or a combination of several logs, can be used to estimate the shale volume in the target zone. A common method in petrophysical analysis using traditional logs is to estimate shale volume ( $V_{sh}$ ) using gamma-ray (GR) observations. Nevertheless, there are a number of drawbacks to this approach. These include the inadequacy of linear equations, which frequently overestimate shale volume, the occurrence of radioactive materials in non-clay lithologies, which can cause errors, and the challenge of acquiring clean shale and sandstone intervals for precise calibration.

$$V_{shND} = \frac{PHIN - PHID}{PHIN_{SH} - PHID_{SH}} \quad (1)$$

Where: PHIN is the neutron porosity, PHID is the density porosity,  $PHID_{sh}$  is the neutron porosity of the shale, and  $PHIN_{sh}$  is the density porosity of the shale (Sennaoui et al., 2026).

#### Porosity ( $\phi$ )

There are several ways to measure porosity. Some rely on core samples, while others use mathematical models and well-log data. Techniques for estimating porosity using transit time analyses that utilize

interval velocities derived from seismic traces are particularly noteworthy. With respect to this research the porosity was calculated from the well-log data using equation 2 (Asquith & Krygowski, 2004; Rider & Kennedy, 2011).

$$\phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \quad (2)$$

where  $\phi$  is density-derived total porosity;  $\rho_m$  is the matrix density;  $\rho_b$  is bulk density; and  $\rho_f$  is fluid density.

#### Water Saturation ( $S_{wirr}$ )

This is the water held in the pore spaces by capillary forces. When a zone is at irreducible water saturation ( $S_{wirr}$ ), the water saturation in the uninvaded zone ( $S_w$ ) will not move because it is held in grains by capillary pressure. For most reservoir rocks, irreducible water saturation ranges from less than 10% to more than 50% (Schlumberger, 1989). It was determined from the equation given by Asquith and Gibson (1982).

$$S_{wirr} = \sqrt{\frac{F}{2000}} \quad (3)$$

$$F = \frac{R_0}{R_w} = \frac{a}{\phi^m} \quad (4)$$

Where F is Formation factor,  $R_0$  is resistivity of rock fully saturated with water,  $R_w$  is resistivity of formation water, a is the Tortuosity factor (usually  $\approx 1$ ),  $\phi$  is the porosity (fraction) and m is the cementation exponent (commonly 1.8-2.0 for sandstone) (Archie, 1942).

#### Hydrocarbon Saturation ( $S_h$ )

Hydrocarbon saturation refers to the percentage of pore volume in a reservoir rock occupied by oil or gas. Because hydrocarbons and water share the available pore space, hydrocarbon saturation is determined by calculating water saturation first and subtracting it from 100%. It can be calculated using equation 5 (Archie, 1942; Asquith & Gibson, 1982).

$$S_h = 1 - S_w \quad (5)$$

## V. RESULTS

### Petrophysical Analysis

The well log correlation panel of CHEV\_001, CHEV\_002, and CHEV\_003 wells Figure 4 reveals the stratigraphic continuity of reservoir units across the Chevron Field. Correlation of the gamma ray, density-neutron, and resistivity logs enabled the identification of two major reservoir intervals designated as CHEV\_1 and CHEV\_2. These units are laterally persistent across the three wells, indicating a relatively continuous depositional system and suggesting favorable reservoir connectivity within the field. The gamma ray log signatures show that the correlated intervals are characterized by low gamma ray values, which indicate relatively clean sandstone formations with minimal shale content. These sandstone units are enclosed by shale layers that display higher gamma ray responses, thereby serving as effective stratigraphic markers for delineating the top and base of each reservoir. The continuity of these shale markers across the wells supports the reliability of the established correlations.

The density-neutron log combination further confirms the reservoir quality of the identified intervals. Noticeable crossover between the density and neutron curves occurs within portions of the CHEV\_1 and CHEV\_2 sands, which is commonly associated with hydrocarbon-bearing zones. This crossover suggests the presence of gas or light hydrocarbons within the sandstone intervals, while zones lacking significant crossover may indicate water-bearing sands or shale interbeds. The consistency of these responses across the wells strengthens the interpretation of productive reservoir sections. Resistivity log responses show increased values within the correlated sandstone intervals relative to adjacent shale layers. Elevated resistivity is generally associated with hydrocarbon saturation, as hydrocarbons exhibit higher electrical resistance than formation water. The high resistivity signatures observed within CHEV\_1 and CHEV\_2 suggest that these units likely contain hydrocarbon accumulations.

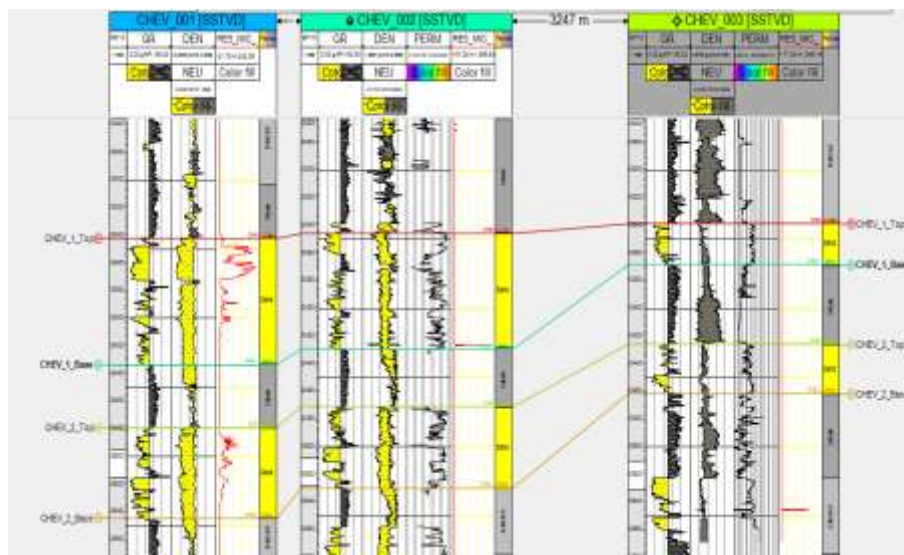


Figure 4. Well Log Correlation Panel Showing Correlated Reservoir Intervals Across CHEV\_001, CHEV\_002 and CHEV\_003 Wells in Chevron Field

In contrast, the surrounding shale intervals exhibit lower resistivity responses, reflecting their non-reservoir characteristics. The correlation also reveals subtle structural variation across the field. The reservoir tops and bases show slight changes in depth between the wells, suggesting a gentle structural dip

or minor stratigraphic relief. CHEV\_003 appears slightly deeper relative to CHEV\_001 and CHEV\_002 for some intervals, which may reflect local structural control or depositional thickening. Despite these depth variations, the continuity of the

reservoir units indicates that the sand bodies maintain lateral extent across the study area.

Geologically, the correlated intervals are interpreted to occur within the Agbada Formation of the Niger Delta Basin, which is characterized by interbedded sandstone and shale sequences deposited in paralic environments. The sandstone units represent potential reservoir facies, while the shale intervals act as sealing units. In general, the correlation panel demonstrates that CHEV\_1 and CHEV\_2 are laterally extensive reservoir sands with petrophysical characteristics indicative of hydrocarbon presence, making them significant targets for further reservoir evaluation and development.

#### Crossplot Analysis and Reservoir Characterization

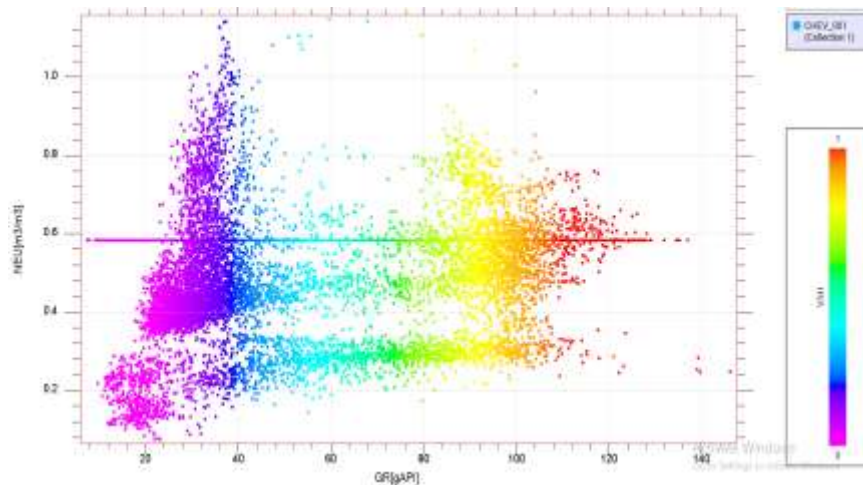


Figure 5. Crossplot of Neutron Porosity (NEU) versus Gamma Ray (GR) for Lithology and Shale Volume Interpretation in CHEV\_001 Well

The density–neutron crossplot in Figure 6 significantly improves fluid discrimination and lithology in the reservoir units. The predominance of sandy lithologies in the designated intervals is confirmed by the clustering of data points inside the sandstone region. Hydrocarbon-bearing zones, especially gas accumulations, are indicated by the separation or crossing between the density and neutron responses. Cooler hues in the crossplot

The neutron porosity (NEU) against gamma ray (GR) crossplot in Figure 5 shows clear clustering patterns that distinguish shale-rich lithologies from clean sandstone. The data points represented by cooler colors such as blue and green are concentrated within low gamma ray zones, indicating clean to moderately clean sandstone formations with relatively low shale content and favorable reservoir properties. On the other hand, greater gamma ray responses, which are linked to shale-rich intervals and worse reservoir quality, are correlated with warmer hues like yellow and red. The data point distribution indicates that the discovered reservoir sands are appropriate for hydrocarbon accumulation due to their low shale volume and significant porosity.

typically represent intervals with higher effective porosity and lower density, indicating improved reservoir quality and possible hydrocarbon presence. Warmer hues are indicative of thicker, less porous intervals, which could be water-bearing zones or shale interbeds. Thus, the concept of productive reservoir sands within CHEV\_1 and CHEV\_2 is supported by the observed color distribution.

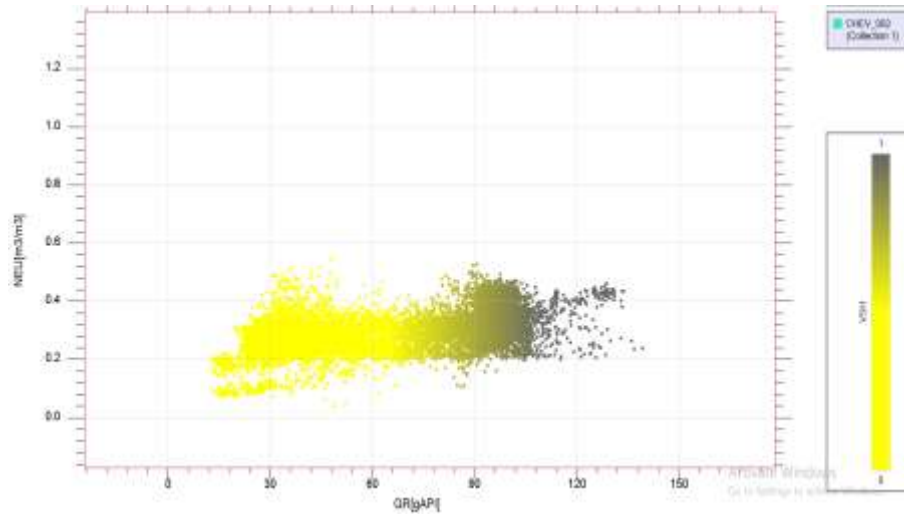


Figure 6. Crossplot of Density (RHOB) versus Neutron Porosity (NEU) Showing Hydrocarbon-Induced Crossover and Reservoir Characterization in Chevron Field

The relationship between porosity and resistivity across reservoir intervals is shown in Figure 7. According to the crossplot, intervals with high porosity values also show higher resistivity responses, which are a common sign of hydrocarbon saturation. Because oil and gas are more resistant than formation water, data points that are represented by warm colors like yellow and red are clustered in the high-resistivity regions, indicating zones that are

probably saturated with hydrocarbons. On the other hand, zones with inferior reservoir quality or water-bearing intervals are indicated by colder hues grouped around lower resistivity values. The crossplot's trend indicates that the reservoir units have substantial hydrocarbon saturation in addition to sufficient storage capacity.

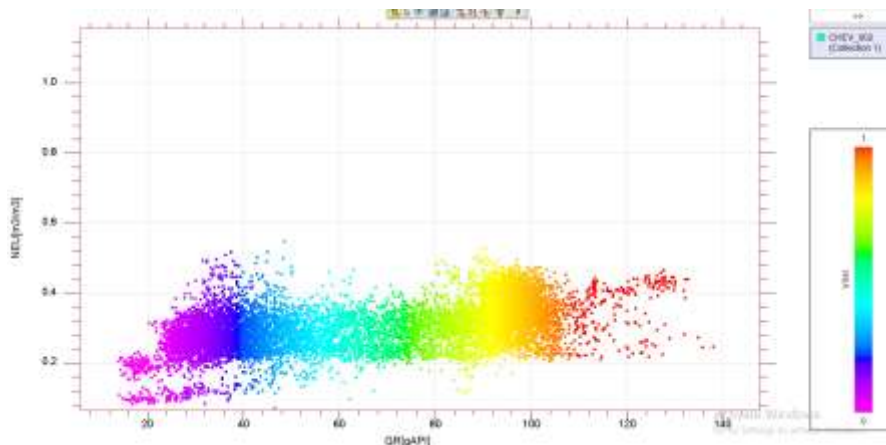


Figure 7. Crossplot of Resistivity versus Porosity for Identification of Hydrocarbon-Bearing Reservoir Zones in Chevron Field

To offer a thorough reservoir characterization of the Chevron Field, Figure 8 combines the petrophysical responses obtained from the crossplots and well log studies. The figure's color fluctuations draw attention to variations in fluid saturation, porosity, and

lithology throughout the reservoir intervals. Depending on the attribute being displayed, warmer colors imply shale-rich or hydrocarbon-saturated zones, while cooler colors typically suggest cleaner, porous sandstone units with good reservoir qualities.

The CHEV\_1 and CHEV\_2 reservoirs are laterally continuous sandstone formations with moderate to good porosity, low to moderate shale concentration, and noticeable hydrocarbon saturation, according to the integrated interpretation.

In general, the crossplot studies show how well-suited traditional well logs and petrophysical methods are for detecting hydrocarbon-bearing intervals, assessing reservoir quality, and differentiating lithology in the Chevrin Field.

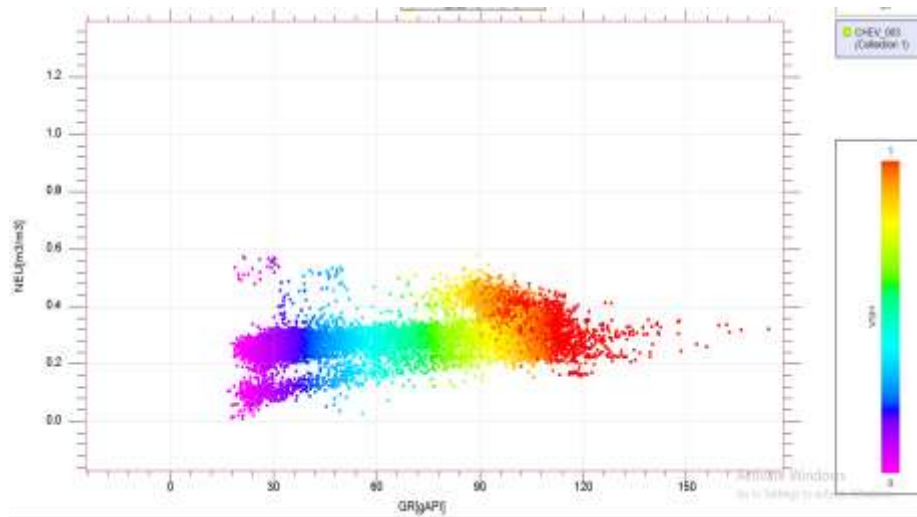


Figure 8. Integrated Petrophysical Interpretation Highlighting Lithology Distribution and Hydrocarbon Saturation within the CHEV Reservoir Intervals

#### Reservoir Thickness Distribution and Isopach Analysis

The reservoir thickness map (Figure 9) presented in the study area reveals significant lateral variation in reservoir development, which has important implications for hydrocarbon accumulation and reservoir prospectivity. The map shows a progressive increase in reservoir thickness from the western portion of the field toward the eastern section. Thickness values range from approximately 123.07 m in the western flank to over 202.42 m in the eastern region, indicating differential sediment deposition across the field. The color gradient, which transitions from warm colors (red, orange, and yellow) to cooler colors (blue and purple), represents increasing reservoir thickness. Areas characterized by cooler colors correspond to thicker sediment accumulation and better reservoir development. The thicker reservoir intervals observed in the eastern part of the field suggest enhanced accommodation space and increased sand deposition, which are favorable conditions for hydrocarbon accumulation. In deltaic environments such as the Niger Delta, thicker sandstone packages are commonly associated with improved porosity, permeability, and storage

capacity. These thicker zones therefore represent potential reservoir sweet spots capable of hosting significant hydrocarbon volumes. The concentration of contour closures around the thicker sections further suggests localized structural or stratigraphic trapping conditions that may enhance hydrocarbon entrapment.

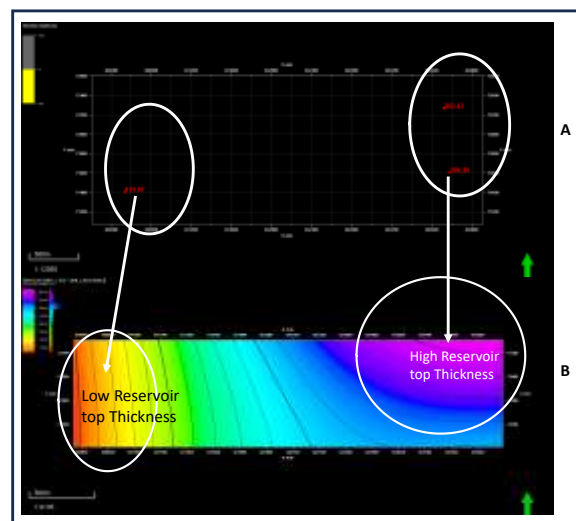


Figure 9. 2D CHEV\_1 Reservoir Thickness

Conversely, the thinner reservoir zones identified in the western portion of the field may indicate reduced sediment supply, possible erosional effects, or depositional thinning. Such areas are less favorable for substantial hydrocarbon accumulation due to reduced reservoir capacity and continuity. The gradual thickening trend toward the east may also reflect the direction of sediment progradation and depositional energy within the basin. The isopach configuration further supports the interpretation of a structurally influenced depositional system, where reservoir thickening may be controlled by syndepositional faulting and accommodation space development. In hydrocarbon exploration, thicker reservoir intervals are significant because they increase the likelihood of effective hydrocarbon generation, migration, and storage. When integrated with petrophysical and seismic attribute analyses, the thick reservoir zones identified on the map correspond to areas of enhanced reservoir quality and higher hydrocarbon prospectivity.

Ultimately, the thickness distribution map shows that because of the increased reservoir thickness, better reservoir continuity, and larger potential storage capacity, the eastern portion of the research region has the best circumstances for hydrocarbon accumulation. This lends credence to the theory that managing hydrocarbon distribution in the field is mostly dependent on reservoir geometry and depositional architecture.

## VI. DISCUSSION

The integrated petrophysical and crossplot analyses provided valuable insight into the reservoir quality and hydrocarbon potential of the Chevrin Field. The well log correlation panel (Figure 4) revealed two laterally continuous reservoir units, CHEV\_1 and CHEV\_2, across CHEV\_001, CHEV\_002, and CHEV\_003 wells. The low gamma ray responses observed within these intervals indicate relatively clean sandstone formations with minimal shale content, while the elevated resistivity signatures suggest significant hydrocarbon saturation. The occurrence of density–neutron crossover within portions of the reservoirs further supports the presence of gas-bearing sands. The crossplot analyses enhanced lithology and fluid discrimination within

the field. The neutron porosity versus gamma ray crossplot (Figure 5) clearly distinguished clean sandstone intervals from shale-rich zones, with cooler colors representing low shale content and favorable reservoir properties. Similarly, the density–neutron crossplot (Figure 6) confirmed hydrocarbon-bearing intervals through noticeable crossover effects associated with gas saturation. The resistivity–porosity crossplot (Figure 7) showed that intervals with high porosity correspond to elevated resistivity values, indicating the coexistence of good storage capacity and hydrocarbon saturation.

The integrated petrophysical interpretation (Figure 8) revealed that the reservoirs are dominated by clean to moderately shaly sandstone units with moderate to good porosity and appreciable hydrocarbon saturation. Furthermore, the reservoir thickness map (Figure 9) showed progressive thickening toward the eastern portion of the field, where thickness values exceed 200 m. These thicker zones are interpreted as areas of enhanced reservoir development, improved continuity, and greater hydrocarbon storage capacity, making them the most prospective regions within the study area. The study demonstrates that the integration of conventional well logs, crossplot techniques, and reservoir thickness analysis provides an effective approach for reservoir characterization and hydrocarbon prospect evaluation within the Niger Delta Basin.

## VII. CONCLUSION

This study successfully evaluated hydrocarbon-bearing reservoir intervals within the Chevrin Field, Niger Delta Basin, using conventional well logs and crossplot techniques. Integration of gamma ray, resistivity, density, and neutron logs enabled the identification and correlation of two major reservoir units, CHEV\_1 and CHEV\_2, across CHEV\_001, CHEV\_002, and CHEV\_003 wells. The correlated reservoirs exhibited low gamma ray responses, elevated resistivity signatures, and density–neutron crossover effects, indicating clean sandstone formations with significant hydrocarbon saturation. Crossplot analyses effectively distinguished lithologies and fluid types within the reservoir intervals. The neutron porosity versus gamma ray crossplot revealed low shale content and favorable

porosity characteristics, while the density–neutron crossplot confirmed hydrocarbon-bearing sands through pronounced crossover responses. In addition, the resistivity–porosity relationship demonstrated that highly porous intervals correspond to elevated resistivity values, suggesting good hydrocarbon saturation and reservoir quality.

Reservoir thickness distribution and isopach analysis showed progressive thickening toward the eastern section of the field, indicating enhanced sediment deposition, improved reservoir continuity, and greater hydrocarbon storage capacity in that region. The thicker reservoir zones therefore represent the most prospective hydrocarbon accumulation areas within the study area. In general, the study demonstrates that conventional well logs integrated with crossplot and thickness analyses provide an effective and reliable approach for reservoir characterization and hydrocarbon prospect evaluation in the Niger Delta Basin. The identified reservoir intervals possess favorable petrophysical properties and significant hydrocarbon potential, making them viable targets for future exploration and field development activities.

#### REFERENCES

- [1] Oyeyemi, K.D., Olowokere, M. T., & Aizebeokhai, A. P. (2018). Hydrocarbon resource evaluation using combined petrophysical analysis and seismically derived reservoir characterization, offshore Niger Delta. *Journal of Petroleum Exploration and Production Technology*, 8, 99-115.
- [2] Oyebamiji, J. O., & Oluwadare, O. O. (2020). Formation Evaluation of J Field, Niger Delta Using Well Log Data. *Journal of Environment and Earth Science*, 10(2).
- [3] Orji, O., Egwuonwu, G. N., & Okpara, A. O. (2024). Petrophysical Property Evaluation and Reservoir Characterization in the B-Field, Niger Delta. *Journal of Basic Physical Research*.
- [4] Atolagbe, M., & Ogungbesan, G. (2023). 3D Structural Interpretation and Petrophysical Evaluation of Reservoirs in M Field, Onshore Niger Delta, Nigeria. *Journal of Natural Sciences Research*.
- [5] Tuttle, M., Charpentier, R., Brownfield, M. (2015). *The Niger Delta Petroleum System: Niger Delta Province, Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa*. United States Geologic Survey.
- [6] Doust, H., & Omatsola, E. (1990). Niger Delta. In J.D. Edwards & P.A. Santosgrossi (Eds.), *Divergent/Passive Margin Basins (AAPG Memoir 48, pp. 201-238)*.
- [7] Sennaoui, B., Ling, K., Pothana, P., & Delshad, M. (2026). Dataset for integrated petrophysical analysis and 3-D geological model development of the Bakken unconventional reservoir (Sanish Field). *EarthArXiv*. <https://doi.org/10.31223/X5WV1G>
- [8] Alexander Ogbamikhumi, A., & Nosa Samuel Igbini, N. S. (2020). Rock physics attribute analysis for hydrocarbon prospectivity in the Eva field onshore Niger Delta Basin. *Journal of Petroleum Exploration and Production Technology*, 10(8), 3127–3138. <https://doi.org/10.1007/s13202-020-00975-5>
- [9] Whiteman A (1982) *Nigeria: its petroleum geology, resources and potential: Graham and Trotman Ltd., vol 1, pp 114–131*
- [10] Asquith, G. B., & Gibson, C. R. (1982). *Basic well log analysis for geologists*. American Association of Petroleum Geologists (AAPG), Tulsa, Oklahoma
- [11] Schlumberger., (1989). *Log Interpretation, Principles and Application*. Schlumberger Wireline and Testing, Houston, Texas, 21-89.
- [12] Archie, G.E. (1942). The electrical resistivity log as an aid determining some reservoir characteristics. *Transactions of the AIME*, 146(1), 54-62
- [13] Asquith, G., & Krygowski, D. (2004). *Basic well log analysis (2nd ed.)*. Tulsa, Ok: American Association of Petroleum Geologists.
- [14] Rider, M., & Kennedy, M. (2011). *The geological interpretation of well logs (3rd ed.)*. Rider-French Consulting Ltd.