



Reservoir Characterization, petrophysical analysis and prospect identification of 'UQ' field, southern Niger Delta, Nigeria

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Abstract

The prospect evaluation of the UQ field using integrated 3D seismic and well log data from four wells (UQ-12, UQ-3, UQ-4 and UQ-5) has been carried out in this research. The study identified and assessed the plays, prospects, and components of the petroleum system within the 'UQ' Field to determine its actual potential and its economic viability for investment and development. The well logs and seismic data were incorporated to delineate four hydrocarbon bearing reservoirs and quantitatively estimate their prospectivity. The reservoirs (R_1, R_2, R_3 and R_4) were correlated across the field, with some appreciable reduction in net sand down dip. Structural analysis has been carried out using seismic data, which aided in the mapping of major, antithetic, and synthetic faults with four horizons (constrained by identified reservoir sand from the logs) that were gridded to create top structural maps.

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Petrophysical results using well log derived parameters and time-depth structural maps were obtained. Surface attributes, which are highly amplitude supported, were utilized to capture prospective zones better. The study showed that the R_1 reservoir has a very good porosity of 30%, an appreciable shale volume of 39%, and a high hydrocarbon saturation of 89% with an oil and gas phase. Similarly, the R_3 reservoir comprises shaly sands with very good average porosity of 27% and high average hydrocarbon saturations of 68%. Surface attribute analysis reveals the existence of hydrocarbon-bearing closures characterized by moderate to high root mean square amplitude and average energy values within R4 sand at the north eastern and south western parts of the field. These values are closely consistent with those obtained for R-2, which hosts the producing wells. Using these methods, this study has unravelled two new prospective zones with economical hydrocarbon volumes within the R_4 reservoir allowing for increased hydrocarbon volumes from the already producing field. Overall, the project aims to provide valuable insights into

the technical, economic, and environmental aspects of the UQ field, which can contribute to informed decision-making and the sustainable development of Nigeria's energy sector.

Keywords: Well Logs; Seismic Section; Petrophysics; Prospect; Hydrocarbon; Volumetric

1.0 Introduction

The 'UQ' field is a significant natural gas resource located in the Southeastern part of Nigeria. The field has attracted considerable interest from the oil and gas industry, and its economic potential has led to calls for a comprehensive prospect evaluation to determine its true worth (Akpabio, 2017). The onshore Niger Delta fields where 'UQ' belongs is renowned for its intricate geological formations, which combine sediments from the ocean, rivers, and deltas that have been formed over millions of years. Nigeria has a strategic interest in maximizing the exploration and production potential of its hydrocarbon resources as Africa's top oil producer and a prominent worldwide participant in the energy sector.

According to (Akpan *et al.*, 2018), the UQ field has substantial prospects for resource extraction and commercialization due to its estimated hydrocarbon reserves. Multiple reservoirs, including the UQ, UQ North, and UQ Deep reservoirs, each having distinct geological and petrophysical characteristics, make up the UQ field. Initial estimates suggest the presence of huge volumes of both crude oil and natural gas, and the field has showed signs of having significant oil and gas reserves (Oyinloye *et al.*, 2016).

Prospect evaluation is a crucial process that involves assessing the commercial viability of an oil or gas field before a significant investment is made (Ehinola *et al.*, 2017). It is a complex procedure that includes geological and geophysical studies, seismic imaging, well data analysis, reservoir modelling (Harry and Akata,

2019), and financial risk analysis (Ibe *et al.*, 2020). The UQ field, which is located in the coal-rich Anambra Basin, has both onshore and offshore potential (Etesin *et al.*, 2015). The exploration and development of the field could significantly impact Nigeria's energy security, providing a source of clean and affordable natural gas to boost electricity generation, industrial growth, and revenue generation (Aigbedion and Aigbedion 2011). Such evaluation entails a thorough analysis of the field's geological traits, reservoir qualities, and economic feasibility. For the purpose of locating probable hydrocarbon traps and calculating the amount of recoverable resources, it is essential to comprehend the geological formations, sedimentary environments, and structural complexity of the UQ field (Essien *et al.*, 2018). Undertaking a comprehensive prospect evaluation of the UQ field requires significant technical expertise, financial capacity, and careful planning (AsUQ *et al.*, 2018). The study's goal is to identify and assess the plays, prospects, and components of the petroleum system found in the UQ Field. It also involves performing a risk analysis on each prospect and calculating the amounts of hydrocarbons that will initially be placed there.

1.1 Location and Geology of the Study Area

The Lower Benin Formation of the Niger Delta Basin, precisely, is where the UQ Field is situated in southeast Nigeria (Figures 1 and 2). It can be found in the populous Akwa Ibom State. The actual Niger Delta Basin is located in southern Nigeria and is bounded to the south by the Gulf of Guinea. The hydrocarbon-rich region that has made a substantial contribution to Nigeria's oil and gas output includes the UQ Field (Akpan *et al.*, 2018).

The basin spans the whole Niger Delta and has an area of around 1,200,000 square kilometers (km²). It is located between the latitudes of 3° to 6° N and longitudes, 5° to 8° E. Depobelts,

which are the most active area of the delta at each stage of expansion, were created as the Niger Delta sediments prograded southwest from the Eocene to the Recent (Doust and Omatsola, 1990). Based on their stratigraphy, sedimentological, faunal data, and age

relationships, the basin can be split into three diachronous lithostratigraphic units. From bottom (oldest) to top (youngest), the units are the Akata, Agbada, and Benin Formations (Short and Stuable, 1967; Weber and Daukoru, 1975).

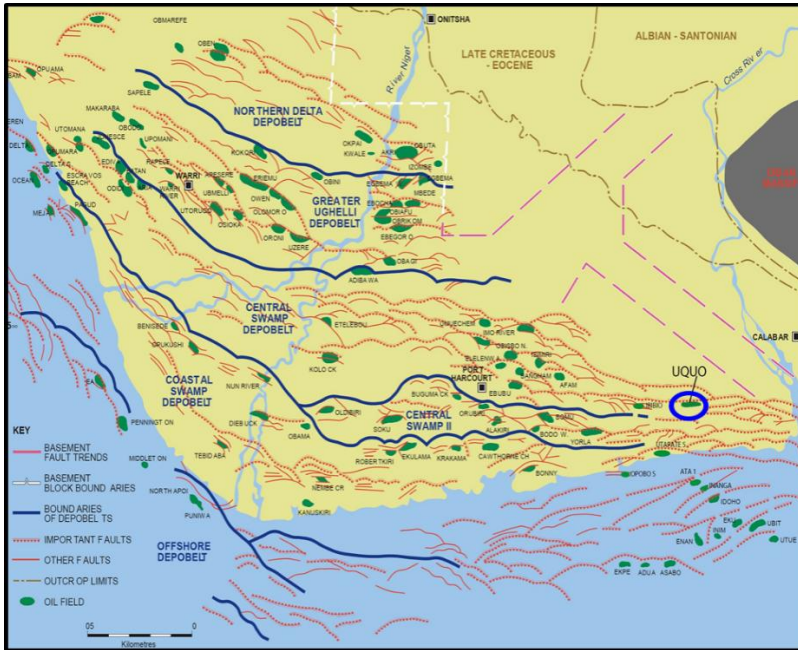


Figure 1: Map of the study area

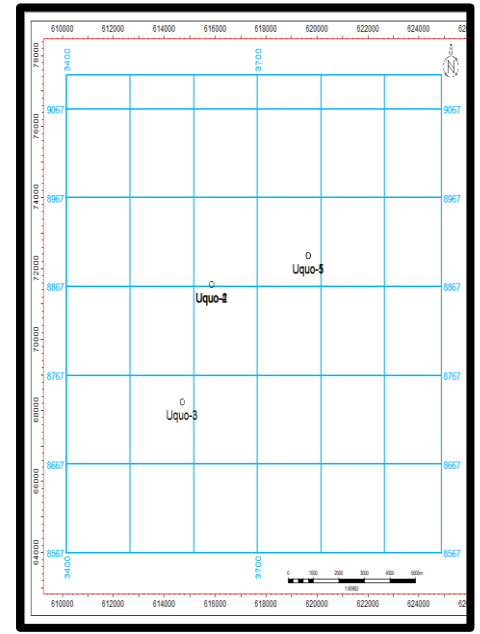


Figure 2: Base map of the study

2.0 Materials and Methodology

Frontier Oil and Gas Limited contributed the datasets used in this investigation. Among these is a post-stacked, SEG-Y-formatted 3D seismic survey that covered an area of 133 square kilometers. A composite log made up of the deep resistivity, bulk density, gamma ray, RHOB, and NPHI logs from the four wells (UQ 2, UQ 3, UQ 4, and UQ 5) in LAS format. In.txt format, deviation data were also made available. Throughout the study, the conversion from time to depth domain was done using checkshot data. Tables 1 and 2 each have a summary table with data obtained, log information, and a description. Figure 4 shows the wells' geographic spread. For this study, a workstation with the Petrel 2014 software suite was utilized.

2.1 Methodology

The sequence in which the data interpretation was carried out is demonstrated in the workflow (Figure 3) below.

The Gamma Ray Index (IGR) was calculated by using Equation 1.

$$IGR = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \quad (1)$$

where I_{GR} is the Gamma ray index, GR_{log} is the Gamma ray reading of the formation, GR_{min} is the minimum gamma ray (clean sand) and GR_{max} is the maximum gamma ray (shale).

Well log data were used in this analysis to generate rock properties using the following formulae:

$$GST \text{ (Gross sand thickness)} = \text{Base of Sand} - \text{Top of sand} \quad (2)$$

NST (net sand thickness) = (base + top of sand-shale) (3)

Equation (3) applies if shale is present in the formation and if not, NST will be the same as GST in Equation (2).

NTG (Net to gross) = (NST-GST) (4)

Porosity: The porosity was determined by substituting the bulk density readings obtained

from the density log within each reservoir into the Equation 5.

$$\phi_T = \frac{\rho_{mat} - \rho_b}{\rho_{mat} - \rho_f} \quad (5)$$

where ρ_{mat} = density of rock matrix, ρ_b = Bulk Density and ρ_f = Fluid Density

Table 1: Summary of datasets available

DATA AVAILABLE	DETAILS
SEISMIC	Area coverage: 133km ²
	TYPE: 3D
	Time Range: 0 - 10000ms
WELLS	WELL COUNT: (4 Wells)UQUO-2,3,4,5.
	CHECKSHOT DATA: Uquo 3 and 5
	WIRELINE LOGS
DYNAMIC DATA	PRESSURE DATA

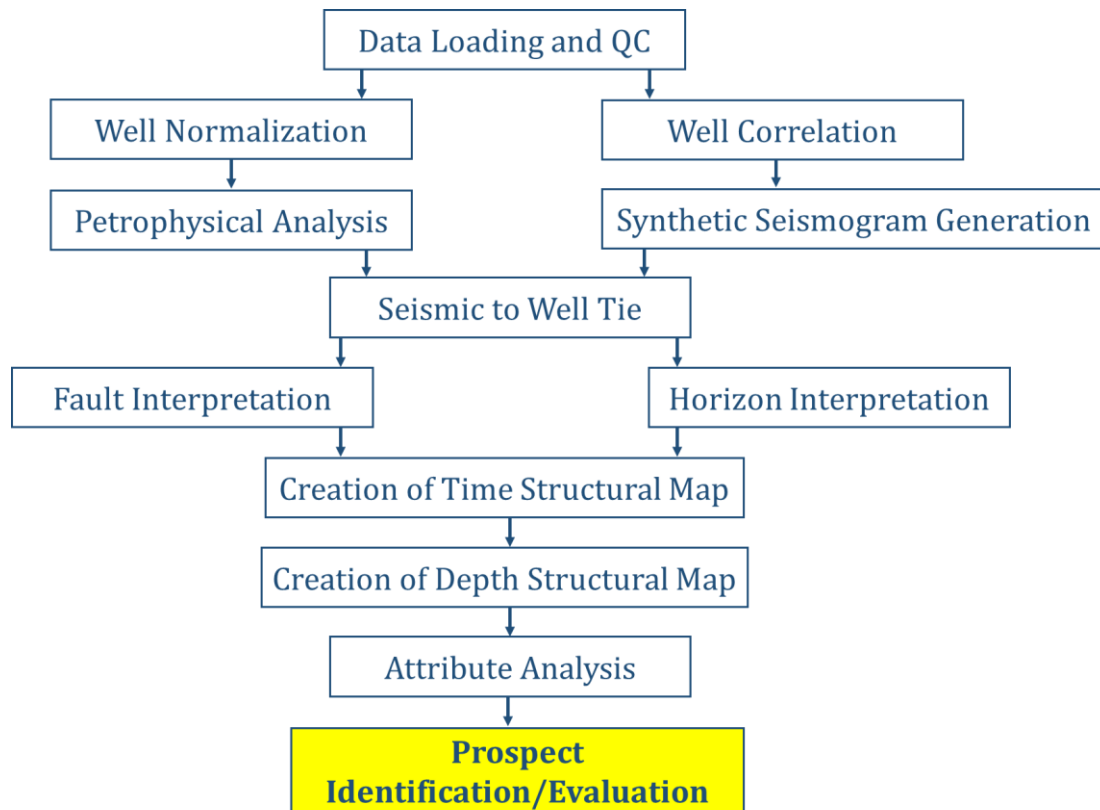


Figure 3: Workflow for Prospect Identification in UQ Field

The criteria for classifying porosity given by Baker (1992) are:

$\emptyset < 0.05$ = Negligible, $0.05 < \emptyset < 0.1$ = Poor, $0.1 < \emptyset < 0.15$ = Fair, $0.15 < \emptyset < 0.25$ = Good, $0.25 < \emptyset < 0.30$ = Very good $\emptyset > 0.30$ = Excellent.

The determination of the water saturation (SW) for the uninvaded zone was achieved using the Archie's (1942) equation for a clean sand model given in Equation 6.

$$SW = \left(\frac{R_o}{R_t} \right)^{\frac{1}{n}} \quad (6)$$

where R_o = resistivity of rock filled with water, R_t = resistivity of suspected oil zone and n = saturation exponent (generally 2).

Formation Factor: The formation factor was determined from the Archie's (1942) equation in Equation 7:

$$\phi = \left(\frac{a}{F} \right)^{\frac{1}{m}} \quad (7)$$

where ϕ = Porosity, a = constant (0.62) and m = cementation exponent (2 for sands).

3.0 Results and Discussion

3.1 Well Correlation

Correlation is good In order to provide a thorough description of the reservoirs and ascertain the lateral continuity of the sand intervals, the lateral continuity of the hydrocarbon bearing sand intervals was connected across the field using the GR and Resistivity logs. Figure 4 displays the correlation chart and cross-section of the wells, which are located from West to East in the following order: UQ-3, UQ-4, UQ-2, and UQ-5. Determined and designated as R_1, R_2, R_3, and R_4, the four sand intervals. The correlation experiment demonstrated that the

four reservoirs can be recognized, mapped, and correlated throughout the field's wells and that they have strong continuity and are typically elongate (Figure 4). From the north to the south, it is seen that the sand intervals become thinner as they approach the basin, indicating a prograding sequence. For fluid typing, or to distinguish the hydrocarbon-bearing sand interval across the field's wells, resistivity and gamma ray logs were employed. The Benin Formation's blocky sand interval exhibits low resistivity, which is suggestive of the use of fresh water as the formation fluid (Figure 4). These wells were referred to as "Dry wells" because the resistivity logs of the wells on the eastern leg of the survey (UQ-5) were found to have sand intervals that corresponded with low resistivity curves, indicating that the fluid within the reservoirs is mostly saline water. The intervals of Agbada Formation found in Wells in UQ-3, UQ-4, and UQ-2, were shown to correlate with increased resistivity values, which may indicate the accumulation of hydrocarbons.

3.2 Petrophysical Evaluation

Table 2 summarizes the pay for the reservoirs, focusing on porosity and Net to Gross in the UQ Field. While the porosity values are between 24% and 30% and can be quantitatively rated as very good, the Net to Gross ratio (NTG) ranges from 0.53 to 0.81 (Etu-Efeotor, 1997). These numbers are comparable to those reported for the Niger Delta, where the concentrations in reservoir rocks vary from 15 to 40%. 40% was suggested by Edwards and Santogrossi (1990) for the principal Miocene paralic sandstone reservoirs in the Niger Delta. With depth, it was found that the sand intervals' reservoir properties deteriorated. While the deeper reservoirs R_3 and R_4 indicate a declining trend with values of 27%, the R_1 and R_2 reservoirs have porosities of 30% and 27%, respectively.

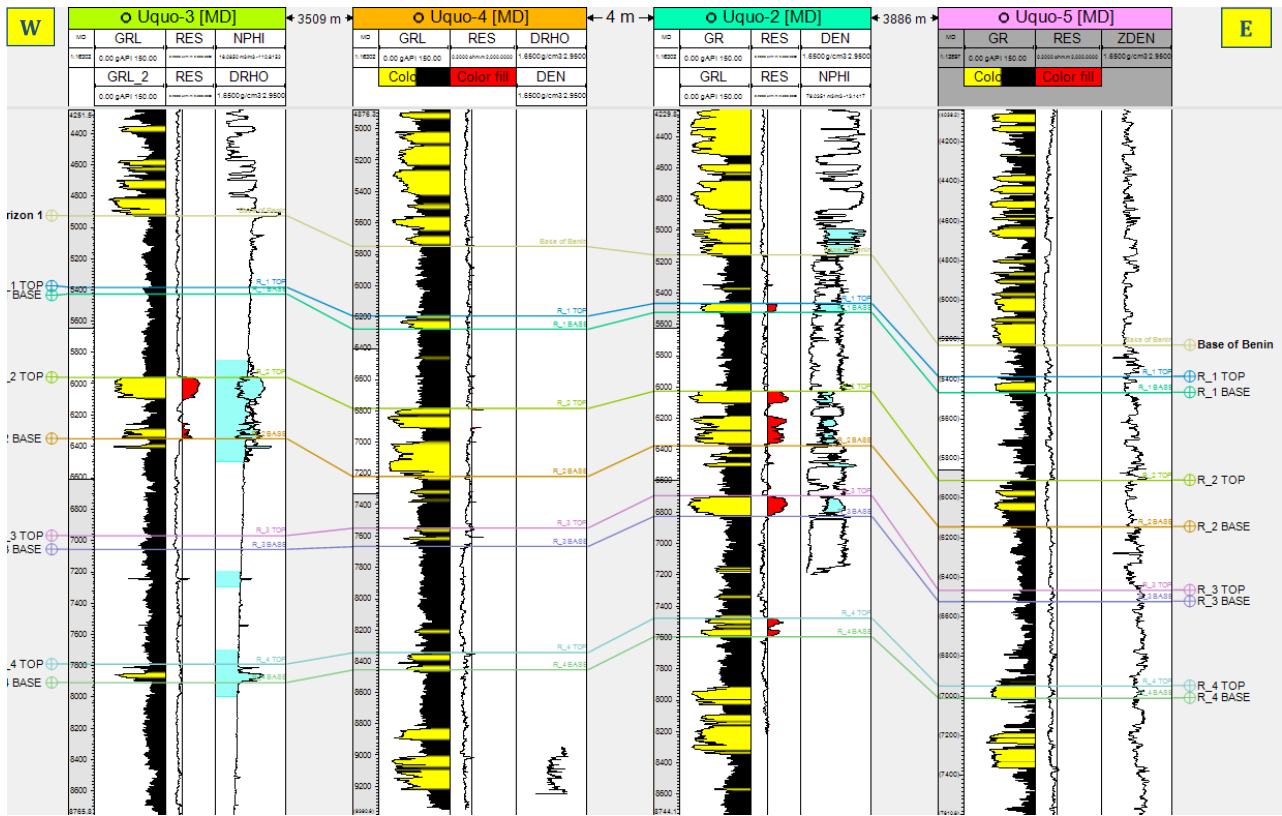


Figure 4: West-East correlation of hydrocarbon bearing sand across wells in UQ Field

Volumetric estimation of the original hydrocarbon in place makes use of static parameters such as the area of accumulation (A), pay thickness (h), porosity (ϕ), and initial fluids saturation (S_w) of the reservoir. The

estimation of hydrocarbon at reservoir condition (HIIP) was done using Equation 5.

$$HIIP = A \times h \times \phi \times (1 - S_w) \quad (8)$$

Table 2: Petrophysical summary of UQ Field

PETROPHYSICAL SUMMARY					
Sand	Gross (ft)	Net (ft)	N/G	Phi	Sw
R_1	218.87	157.42	0.71	0.30	0.17
R_2	428.69	333.05	0.81	0.27	0.41
R_3	584.76	414.94	0.69	0.27	0.32
R_4	296.32	175.76	0.53	0.24	0.36

3.3 Hypertextual Seismogram

The accuracy of the maps increases as the geoscientist has more control over charting the subsurface. By comparing seismic and borehole data, control can be improved. The main method for determining this correlation

is the synthetic seismogram (commonly referred to as the "synthetic"). Figure 5, which illustrates strong links between events on the well and the field seismic was created using the check shot data.

3.4 Seismic Interpretation

Figure 6 displays a structural framework with distinct oriented growth faults highlighted, selected at every tenth inline, and traced throughout the seismic study. In the seismic survey, three major faults- faults 1, 2, and 3- are mapped, and it is seen that the reservoirs

are located over anticline structures that are bounded by the closure of two significant synthetic faults, which creates the structural dip closure (trap) that is responsible for hydrocarbon buildup in the field (Figure 7).

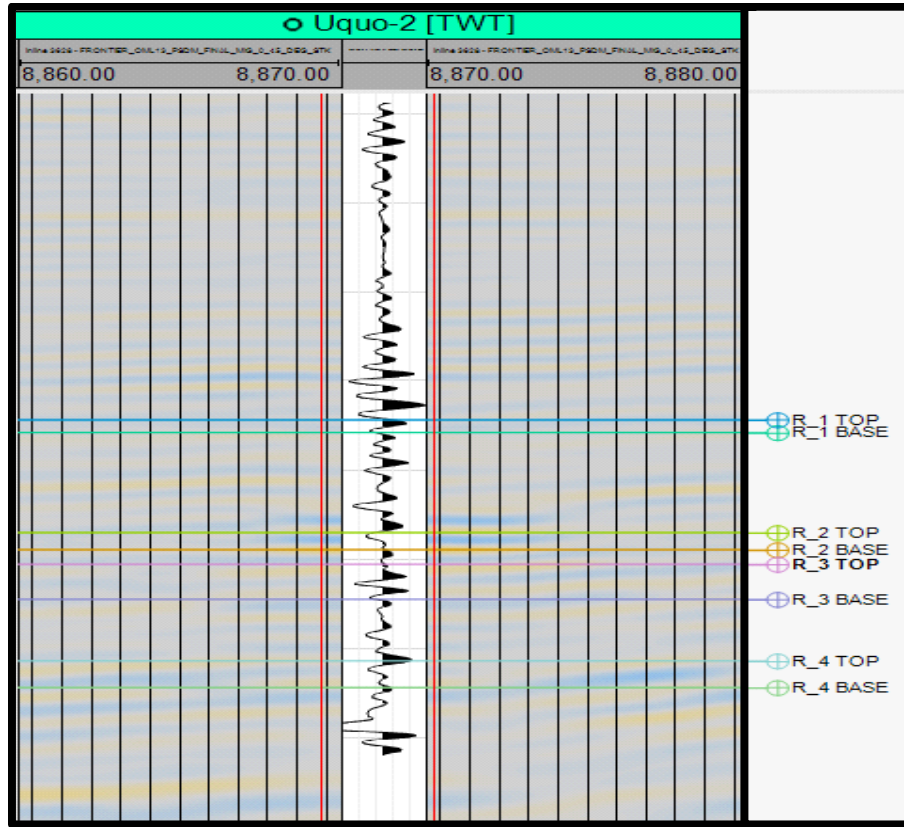


Figure 5: Synthetic Seismogram generated for UQ field

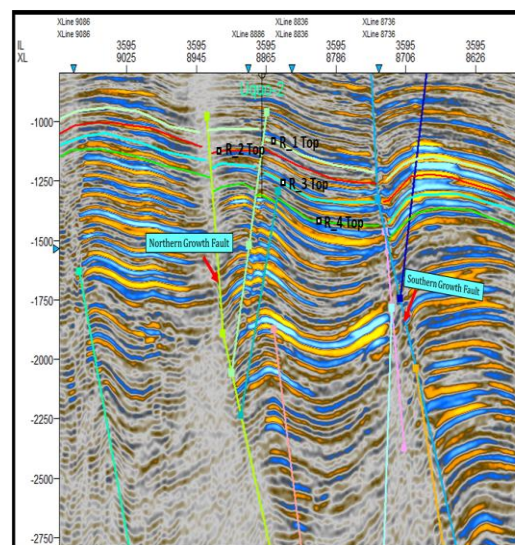
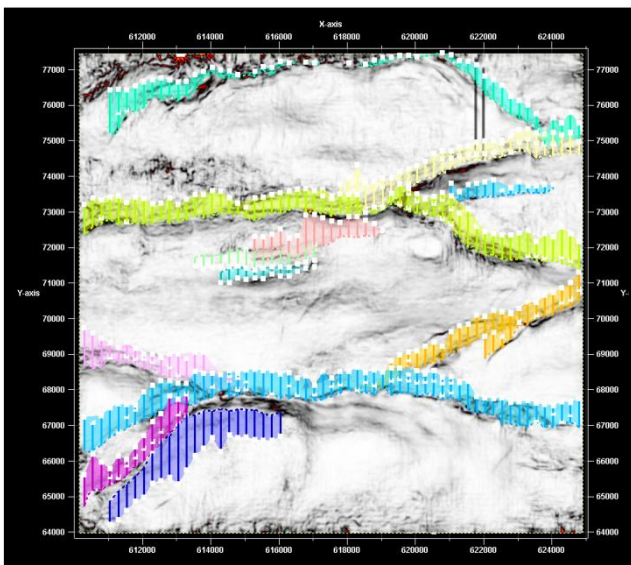


Figure 6: Structural framework showing faults picked on Variance attribute; fault follows the W-E trend across the UQ Field.

3.5 Reservoir Description and Horizon Interpretation

Four primary horizons noted on the well logs were selected and interpreted across the

seismic survey based on the seismic-to-well linkages. Within the seismic section, the four hydrocarbon-bearing sand units (Sand R_1 to R_4) are mapped. In Figure. 9 - 12, contour maps displaying the reservoir R_1, R_2, R_3, and R_4's most accurate representative

geology are shown as both time (Isochron) maps and depth (Isopach) maps. The primary faults that caused the closure and contributed to the buildup of hydrocarbons in the Field are depicted on the maps.

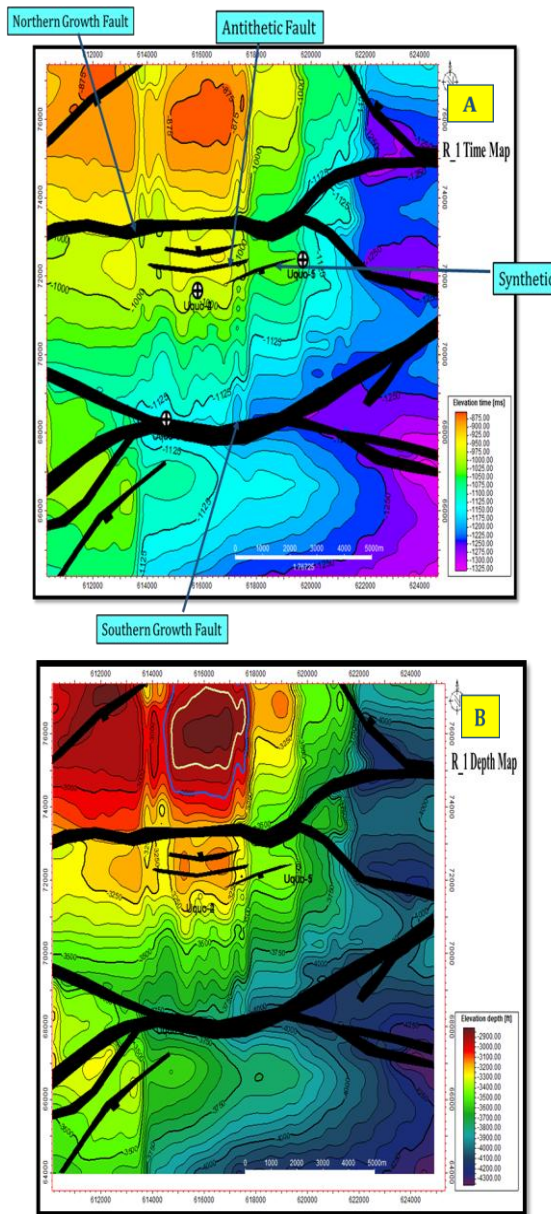


Figure 9: A.) Time map B.) Depth Structure Map of R_1 reservoir showing accumulation of gas and oil at the closure between Fault 2 and Fault 3

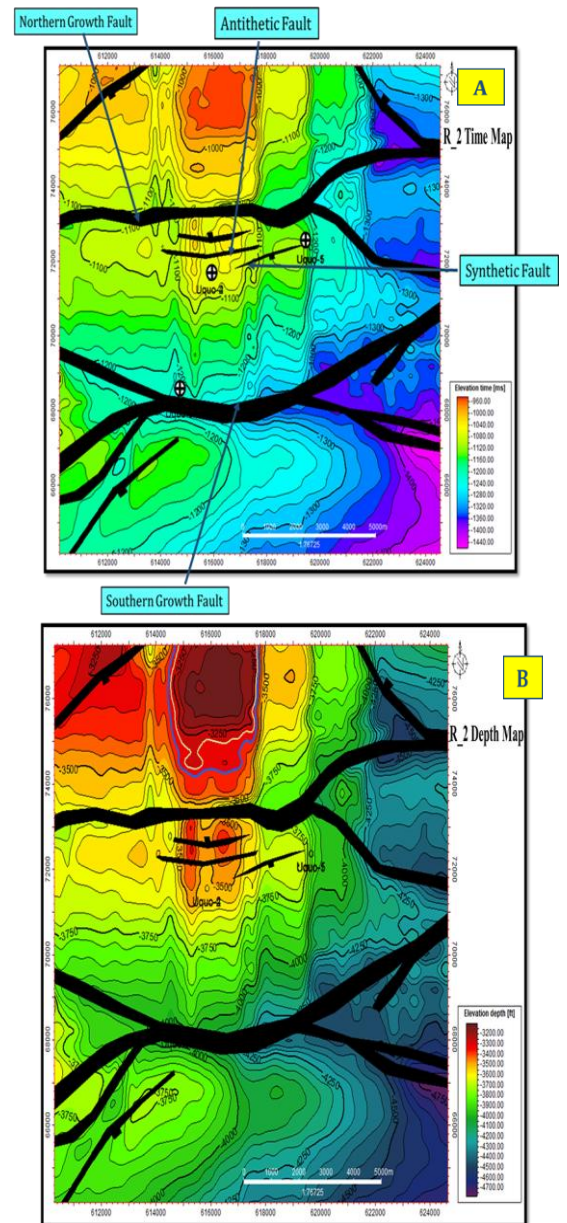


Figure 10: A.) Time map B.) Depth Structure Map of R_2 reservoir showing accumulation of gas and hydrocarbon prospect closure between Fault 2 and Fault 3

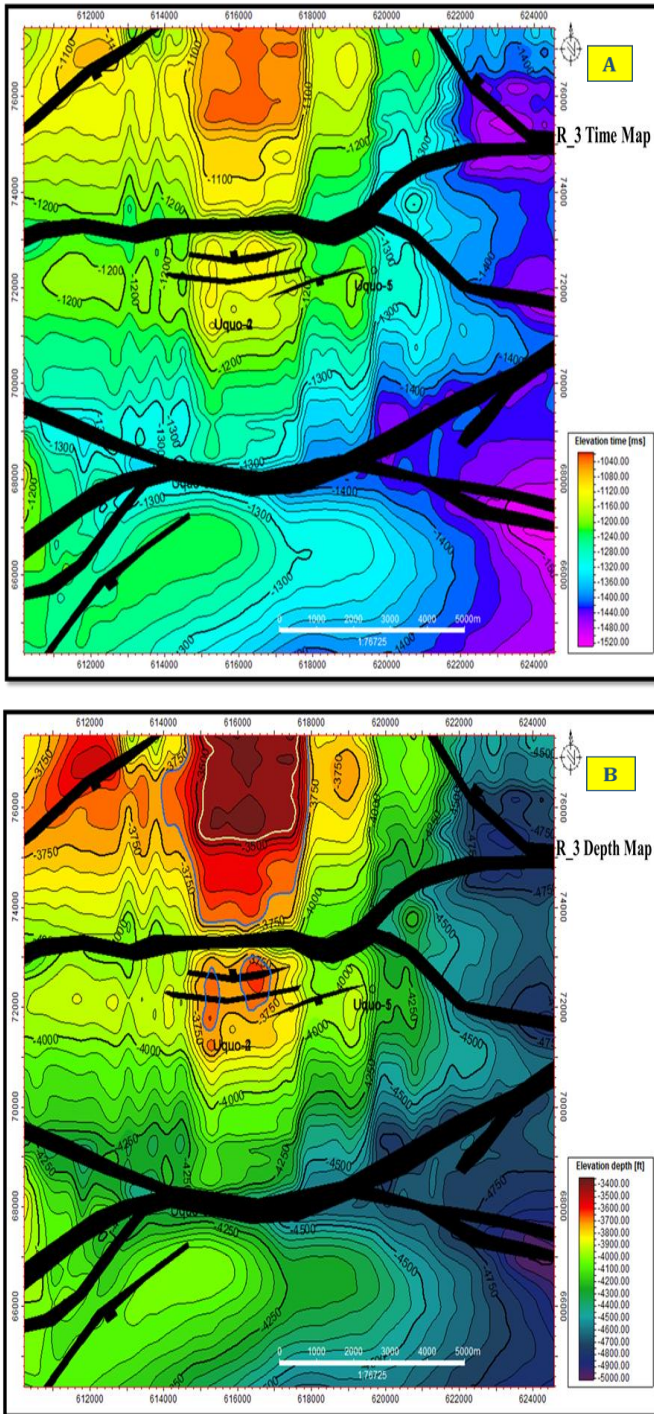


Figure 11 A.) Isochron map B.) Depth Structure Map of R_3 showing accumulation of oil and hydrocarbon prospect at the closure between Flt2 and Flt3

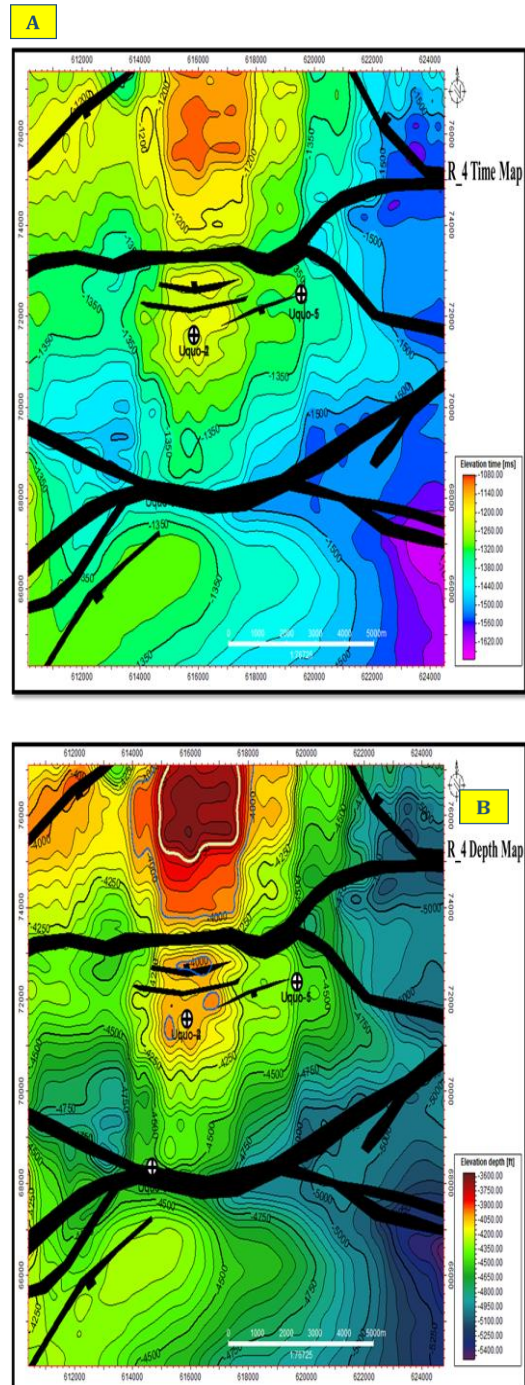


Figure 12 A.) Isochron map B.) Depth Structure Map of R_4 showing accumulation of oil and hydrocarbon at the closure between Flt2 and Flt3

3.6 Prospect Identification

The study area's seismic characteristics analysis identified potential zones that the drilled wells did not reach. Due to their utilization as Direct Hydrocarbon Indicators (HDI) (Figure 13),

RMS amplitude properties were chosen and employed in this study. On the basis of the seismic attributes assessed on time slices and vertical transects, two prospects (prospects 1 and 2) are identified. The seismic features that are suggestive of the presence of hydrocarbon

accumulations are used to identify the anomalies. The interpretation of hydrocarbon-filled sand is supported by high original

amplitude values (Figure 13) and localized high values of the RMS amplitude attribute inside the high original amplitude region.

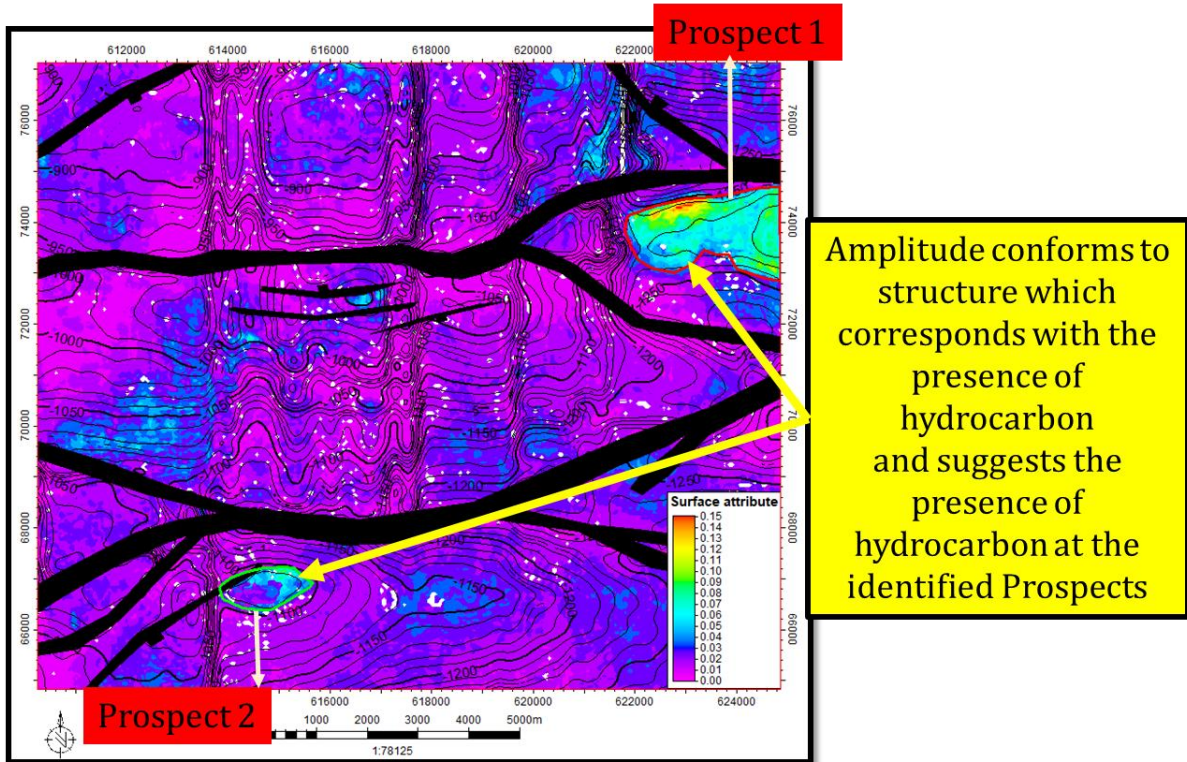


Figure 13: RMS amplitude extraction showing prospective hydrocarbon zones.

3.7 Volumetric Estimation of Identified Prospects

The volumetric estimation for most likely recoverable reserves of the prospects from table 3 is calculated using the formula in Equation 9:

$$STOIP = \frac{GRV \times WF \times N/G \times \phi \times S_o \times CF}{B_o} \quad (9)$$

where GRV is Gross Rock Volume (estimated from the map), WF is Wedge Factor, N/G is Net/ Gross ratio (estimated from well log), ϕ is Porosity, S_o is oil Saturation (1- S_w), CF is conversion Factor and B_o is shrinkage factor for oil

Table 3: Volumetric result for Prospect 1 and 2

Prospect	Area (acre)	GRV (adrift)	Wedge Factor	N/G	PHI	So	Bo	CF	STOIP (MMBOE)	Recovery Factor	Recoverable Resource (MMBOE)
Prospect 1	736.278	19703.8	0.8	0.81	0.30	0.7	1.25	7758	19.7	0.44	8.68
Prospect 2	264.371	7346.38	0.6	0.81	0.30	0.7	1.25	7758	5.5	0.44	2.43

4.0 Summary and Conclusion

Utilizing well logs and 3D seismic data volume, the UQ Field in the Niger Delta basin was evaluated. The study of well logs and

petrophysics was done utilizing log suites from four wells. In the field, four reservoirs at various intervals in the well logs were plotted. The reservoirs' petrophysical characteristics

revealed a general deterioration in quality with depth. Some of the reservoirs' hydrocarbon types revealed that they do contain oil and gas. According to seismic interpretation, the field is heavily faulted, with the faults creating structures for the entrapment and accumulation of hydrocarbons. The four wells that were drilled in the field targeted the structural traps. The tops of the surveyed reservoirs' seismic amplitude attribute maps revealed that the structural trap-enclosed regions of the reservoirs have comparatively high amplitudes (bright spots). As a result, four (2) potentials were found in the UQ Field. To increase the field's viability, it is advised that these prospects be tested. A great potential for commercial hydrocarbon production, particularly natural gas, has been identified in UQ field as shown by the prospect appraisal. The thorough evaluation of geological and reservoir parameters served as a reliable basis for choosing the field's prospective location. According to the analysis, the UQ Field has excellent reservoir properties, including a high porosity of 30%, a high net to gross ratio of 81%, a low water saturation ratio of 17%, and a large gross rock volume that may support sustained gas production. In order to maximize output and reduce risks, the prospect appraisal also emphasized the significance of continual monitoring and reservoir management procedures. The effective development and operation of the UQ Field will depend on regular monitoring of reservoir performance, the application of enhanced recovery techniques, and adherence to environmental and safety standards. Overall, the prospect evaluation gives the UQ Field a good prognosis, positioning it as a valuable asset for Nigeria's hydrocarbon exploration and production. The evaluation's conclusions will be used as a foundation for decisions and investments in the future, promoting regional development, economic growth, and energy security.

Conflict of Interest: Authors declare that there is no conflict of interest

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