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Use Of Seismic Attributes and Well Logs Data in Quantitative Reservoir Characterization of K-Field, Onshore Niger Delta Area, Nigeria.

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Abstract:*Reservoir characterization has long been identified as the main process employed in detailed description of any reservoir in order to properly study and analyze the reserve as well as to optimally place the wells for optima production of the reservoir. Seismic attributes of Field K is used in quantitative characterization of the reservoir, onshore Niger Delta Area of Nigeria. Three reservoir wellswere correlated for lithology delineation.Two reservoir sands were identified based on the similarities in geometry and petrophysical properties of the wells, while fault and Horizon were interpreted to generate the structural map of the field and reservoir in general. The seismic and well data were used to delineate the system tracts of the reservoir. The two hydrocarbon bearing reservoir-1 (Rev-1) and reservoir-2 (Rev-2) were correlated across the three wells using the log suite comprising the gamma ray, resistivity, bulk density neutron and sonic logs. Three main petrophysical parameters were determined for the study area, namely porosity (ϕ), water saturation (S_w) and shale volume (V_{sh}). The porosity values for Rev-1 ranges from 37% in Well-1, 31% in Well-2 and 25% in Well-3, while the values in Rev-2 ranges from 25% in Well-1, 24% in Well-2 and 22% in Well-3. The water saturation values for Rev-1 ranges from 61% in Well-1, 69% in Well-2 and 75% in Well-3, while the saturation values for Rev-2 ranges from 72% in Well-1, 75% in Well-2 and 76% in Well-3. The shale volume in the reservoirs-1 ranges from 13% in Well-1, 20% in Well-2 and 30% in Well-3 while the values in reservoir-2 ranges from 48% in Well-1, 25% in Well 2 and 32% in Well-3. The average effective porosity ranges between 22% and 37% which is expected because most reservoirs in Niger Delta basin are generally unconsolidated and have moderate to high porosity and permeability. Average water saturations in wells 1, 2, 3 are very good ranging between 21 and 42%. While the shale volume average between 13% - 48%. The sand thickness of the reservoirs ranges between 914ft -9820ft.From the results obtained, the reservoirs are fully quantitatively characterized using an integrated approach of incorporating the seismic attributes. We can deduce that reservoir-1 has more hydrocarbon fluid than reservoir-2.*

Keywords:*Seismic Attributes, Characterization, Porosity, Water Saturation, Shale Volume, Structural, Stratigraphy, Delineation, faults.*

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I. Introduction

The need for proper integration of 3-D seismic model with petrophysical data to improve exploration success has been a major techniques commonly use in the Oil and Gas industry for some time now. In mature petroleum provinces, where exploration and production strategies merge, detailed understanding of petrophysical properties in reservoir systems can be critical to the field planning and reservoir management. Reservoir Characterization is a process of integrating various qualities and quantities of data in a consistent manner to describe reservoir properties of interest in inter well locations (Ezekwe et al., 2005). The main purpose of reservoir characterization is to generate a more representative geologic model of the reservoir properties. The goal of any reservoir characterization or reservoir modeling is to understand the reservoir connectivity in static and dynamic conditions by integrating data from different sources, thus in building a geologic representation of what a reservoir is most likely to be, it is necessary to adequately capture the uncertainty associated with not knowing its exact picture **(**Odai et al., 2010). The advantage of using an integrated techniques/method (well and seismic) rather than well data only, is the fact that seismic data can be used to interpolate and extrapolate between and beyond sparse wells within the proposed field, thus an improved techniques, which aid to improve the accuracy of interpretations and predictions in hydrocarbon exploration and development. It also allows the geoscientist to interpret faults and channels, recognize depositional environments and unravel structural deformation history rapidly.

The use of seismic attributes (high fidelity resolution data) in reservoir characterization cannot be overemphasized because seismic attributes are very sensitive to lateral changes in geology as well as quite sensitive to lateral changes in noise. The success of any hydrocarbon exploration and exploitation program depends on the building of a reliable reservoir model. Furthermore, a reservoir's commercial life begins with exploration that leads to discovery, followed by characterization of the reservoir. However, the main challenge in reservoir development is the availability of limited data and huge uncertainty. The success of any reservoir characterization depends on the comprehensive integration of high resolution and fidelity data with well data. In most recent reservoir characterization, 3-D seismic attributes are calibrated against real and simulated well data (seismogram) to identify hydrocarbon accumulations and reservoir compartmentalization. The geometrical attributes have the capacity to enhance the visibility of the geometrical characteristics of seismic events and are sensitive to lateral changes in dip, azimuth, continuity, similarity, curvature and energy. These are used in faults or structural interpretation, while the physical attributes enhance the physical parameters of the subsurface relating to the lithology and stratigraphy for lithological classification and reservoir characterization which includes amplitudes, phase and frequency of seismic events.

Reservoir characterization includes determination of reservoir limits, structure, volume and reservoir proprieties such as porosity, water saturation, permeability, net pay thickness and volumetrics. Heterogeneity seismic attributes have been used in the past as a way of qualitatively inferring rock and fluid properties from seismic data, thus the Correlation of wells to obtain depth and thickness of hydrocarbon bearing zones and cross plot to discriminate the fluid types (oil or gas or condensate).

II. Location Of Study Area

The study area is located at Field- K, onshore Niger Delta Are of Nigeria.The Niger Delta is located on the West African continental margin at the southern end of Nigeria bordering the Atlantic Ocean and is situated in the Gulf of Guinea and is one of the most prolific hydrocarbon systems in the world. The Niger Delta, situated at the apex of the Gulf of Guinea on the west coast of Africa, covers an area of about 75 000 km^2as shown in Figure 1.

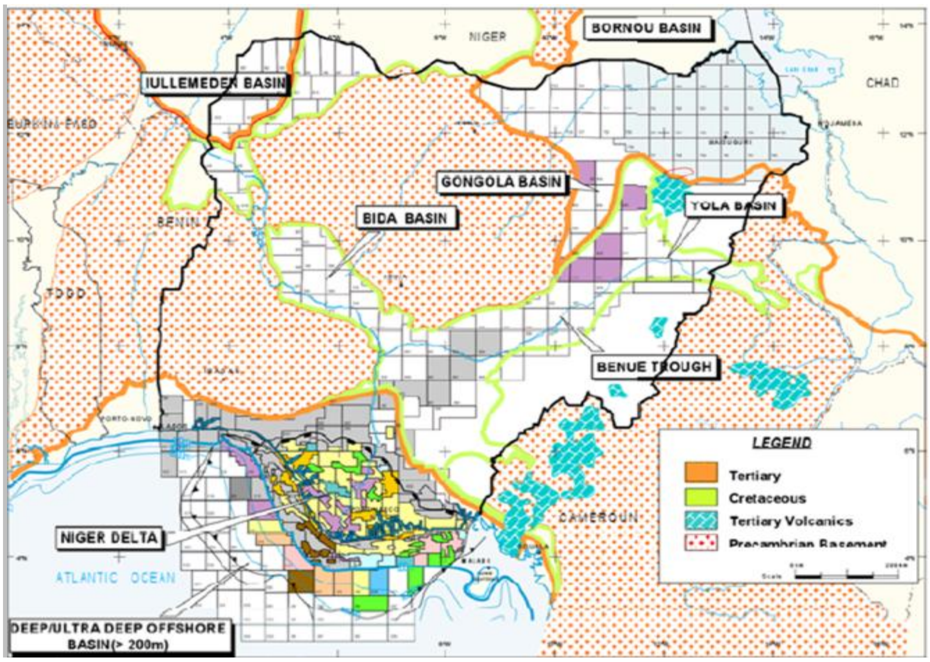

Figure 1: Geological map of Nigeria showing the Niger Delta Basin (ref: Total Nig. Plc)

GEOLOGY OF NIGER DELTA:

The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta Province andthe Delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of its development from the Eocene to the present, (Doust etal., 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km^2 (Kulke, 1995), a sediment volume of 500,000 km^3 (Hospers, 1965), and a sediment thickness of over 10 km in the basin depocenter. The Niger Delta Province contains only one identified petroleum system (Ekweozor et al., 1994). This system is referred to here as the Tertiary Niger Delta (Akata – Agbada), Petroleum System. The maximum extent of the petroleum system coincides with the boundaries of the province.

III. Stratigraphy Of Niger Delta:

The Tertiary Niger Delta was formed as a complex regressive off lap sequence of clastic sediments ranging in thickness from 900 – 1200 meters (**Etu-Efeotor, 1997**).The Niger Delta of Southern Nigeria according to Short and Stauble (1967) is an arcuate shape, wave and tide dominated prograding deltaic system and the sediments range from Eocene to Quaternary. Short and Stable; (1967) further divided the deltaic complex into three (3) major facie unite based on the dominant environmental inference.

The Akata Formation is the basal unit of the Tertiary delta complex. This lithofacies is composed of shales, clays, and silts at the base of the known delta sequence. They contain a few streaks of sand, possibly of turbiditic origin (Doust and Omatsola, 1989), and were deposited in holomarine (delta-front to deeper marine) environments. The thickness of this sequence is not known for certain but may reach 7000m in the central part of the delta. Marine shales form the base of the sequence in each depobelt and range from Paleocene to Holocene in age

The Agbada Formation overlies the Akata Formation and forms the second of the three strongly diachronous Niger delta Complex formations. This forms the hydrocarbon-prospective sequence in the Niger Delta. As the principal reservoir of Niger Delta oil, the formation has been studied in some detail. The Agbada Formation is represented by an alternation of sands (fluviatile, coastaland fluviomarine), silts, clays, and marine shales (shale percentage increasing with depth) in various proportion and thicknesses, representing cyclic sequences of offlap units. These paralic clastics are the truly deltaic portion of the sequence and were deposited in a number of delta-front, delta-topset, and fluvio-deltaic environments and range in age from Eocene to Pleistocene

The Benin Formation is the topmost sequence of the Niger Delta clastic wedge, and has been described as the Coastal Plain Sands which outcrop in Benin, Onitsha and Owerri provinces and elsewhere in the delta area. It consists of massive continental (non-marine) sands and gravels considered to have been deposited in the alluvial or upper coastal plain environment. Very little oil has been found in the Benin Formation (mainly minor oil shows). The formation is generally water bearing, thus the main source of potable ground water in the Niger delta.

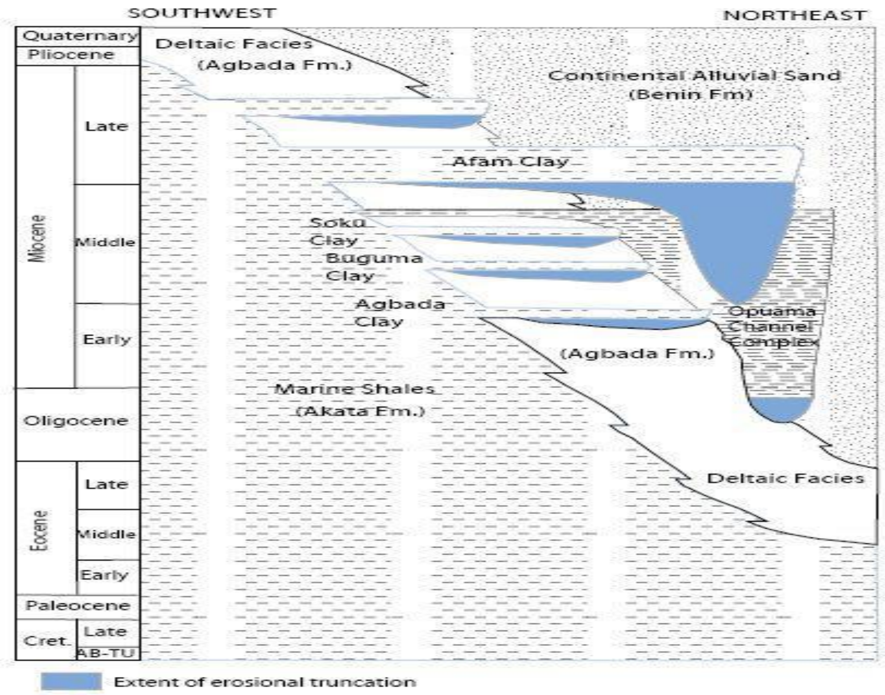

Figure 2: Stratigraphic column showing the three formations of the Niger Delta (Tuttle et al.1999, Modified from Doust and Omatsola, 1990).

FORMATION	LITHOLOGY	AGE	THICKNESS
BENIN	Continental Sands and Gravels.	Miocene – Recent	0 – 2,100
AGBADA	Paralic Sequence of Sand and Shale	Eocene – Recent	300 – 4,500
AKATA	Pro – Delta marine Shale and Clays with some turbidities sand bodies	Paleocene – Recent	600 – 6,000

Table 1: The stratigraphy sequence of the Niger Delta.(Short and Stauble, 1967).

IV. Literature Review

Omoboriowo et al., (2012) in characterizing the Konga field, onshore Niger Delta located at the southern Nigeria uses wire line logs and revealed that the rock properties are variable and controlled by environmental influence and depth of burial which showed the porosity of the reservoir sand ranging from good to very good and the permeability ranging from moderate to good. WhileNeoget al., (2010) used Well Test Analysis technique in addition to other reservoir characterization techniques to dynamically describe Dikom field, an onshore field in the Upper Assam basin located in the Assam-Arakan geological province in the North-Eastern part of India. They concluded that modern well test analysis is an effective tool for reservoir description for a field like Dikom with thin and deep seated sand units. It provides dynamic reservoir description by providing insight into fluid process taking place in the reservoir. However, they relied too much on Well Test data while relegating the hardest data (Core data) to the background.King (1998), quantitatively perform reservoir characterization of N'Sano field, Upper Pinda Reservoir, which is located offshore of Angolan province of Cabinda in approximately 250ft of water. They delineated the reservoir structure and Stratigraphy from the available data. A fine-scale geological model of the reservoir was produced using a facies-based geological modeling approach.

THEORETICAL:

There are two types of properties that will be used in reservoircharacterization, they are petrophysical (porosity, shale volume, watersaturation,permeability) and seismic - rock physics (elasticity, wave velocity). Someapproaches are needed tocharacterize reservoir by using well logs data to calculate.

Porosity (ϕ): this is the void or space inside the rock, they are very useful to store fluids such as oil,gas and water. They are also able to transmit those fluids to a place with lower pressure if they are permeable. Porosity calculation is one of the steps used for well log analysis. The most common method used to calculate porosity is neutron density log.

$$\phi = \frac{\rho_{ma} - \rho_{bulk}}{\rho_{ma} - \rho_{fl}} \qquad 1$$

Fluid Saturation (S_{fl}): This is the fraction of the formation pores volume occupied by formation Fluid. The pore of any formation must be saturated with fluid and the summation of the fluid saturations in any given formation rock must be 100%, there are two major form of fluid saturation namely Water saturation and hydrocarbon saturation, although other fluid can be present apart from water or hydrocarbon (such as carbon dioxide, air etc.). No formation can have zero water saturation irrespective of the hydrocarbon content. For water saturation we have

$$S_w = \left(\frac{a * R_w}{T_t * \phi^m}\right)^{\frac{1}{n}} \qquad 2$$

Shales Volume (V_{sh}):

This is the volume of shale formation and this can be calculated using any of the following method.The gamma ray log has several nonlinear empirical responses as well a linear response. The nonlinear responses are basedon geographic area or formation age. All nonlinear relationships are more optimistic, that isthey produce a shale volume value lower than that from the linear equation.

For Linear response

$$V_{sh} = IGR = \frac{GR_{\log} - GR_{\min}}{GR_{\max} - GR_{\min}} \qquad 3$$

While for nonlinear response, we have

Stieber Model: $$V_{sh} = \frac{IGR}{3 - 2IGR} \qquad 4$$

Clavier: $$V_{sh} = 1.7\sqrt{3.38 - (IGR + 7)}^{2} \qquad 5$$

Larionov: $$V_{sh} = 0.038(2^{(3.7* IGR)} - 1) \qquad 6$$

Permeability k: defined as the rock's ability to transmit fluid, higher permeability shows that the rock is able to transmit fluid easily and it means that the more hydrocarbon that can be produced daily,it is affected by many factors, such as shale volume, effective porosity and many other

$$K = 100 \ x \frac{\phi^2 x(1 - Swirr)}{Swirr} \qquad 7$$

V. Materials And Methodology

The study involved a detailed description of an onshore Niger Delta reservoir by integrating the seismic attributes with the logs data of the field for characterizing the reservoir.

Materials-

The dataset available for this study includes:

- 3D Seismic data of the study area
- Well Logs of the study area
- Well deviation survey data
- Checkshot survey data
- Schlumberger Petrel software (2013)

Method:

The 3-D seismic data (Seismic volume) and well data were systematically loaded into the Petrel software to generate the seismic section and using the inlines and crosslines, faults and horizon were mapped across the fields. Seismic grids and time slices were also developed,while the logs were loaded into the software to delineate the lithology and wells description. The Gamma ray log is used to delineate the clay or shale formation of the well (reservoir), with high gamma values indicating shale content while low gamma ray values indicates sand or clay formation the bulk density log is used to identify possible gas balloon structure within the reservoir formation. (Either gas-oil contact or oil-water contact).

Seismic Interpretation

The 3D Seismic volume loaded in readiness for interpretation, structural smooth and trace AGC volume attribute processes were then applied on the 3D volume.These was done to increase the continuity of the seismic reflectors, boost weak events for improved interpretability and to eliminate boosted noise**.**

Fault Interpretation

Geological fault interpretation was done on every inline, while arbitrary lines were taken where the fault pattern did not show clearly on the inline or trace (cross line). Major and minor discontinuities on the seismic lines were identified and picked. These are the major and minor faults respectively. The faults were identified on the inlines, traces and time slices at the representative levels. These identified faults were assigned names, colour-coded and correlated. The major faults in the field were mostly synthetic faults which are generally downthrown to the basin because of progradation. Antithetic faults were few and minor ones.

Horizon Interpretation

Having tied seismic to well data, horizon was identified, picked and interpreted. Horizon tracking was carried out on every in-lines and cross-lines before being refined to a denser grid on the inlines and crosslines. This mapping/ digitization was done across the entire seismic volume

Structural Interpretation and Mapping

The field structure is a rollover anticline, it is bounded to the northeast and to the Southwest by major synthetic growth faults that defines the field.As shown in the figure below, the reservoir is a Rollover anticline structure bounded to the North by the major (E-W trending) regional synthetic growth fault and to the Northwest by the fault with dip closures to the East and South. There is no occurrence of intra-reservoir faults. The oil accumulation is preserved by both fault and structural dip closure.

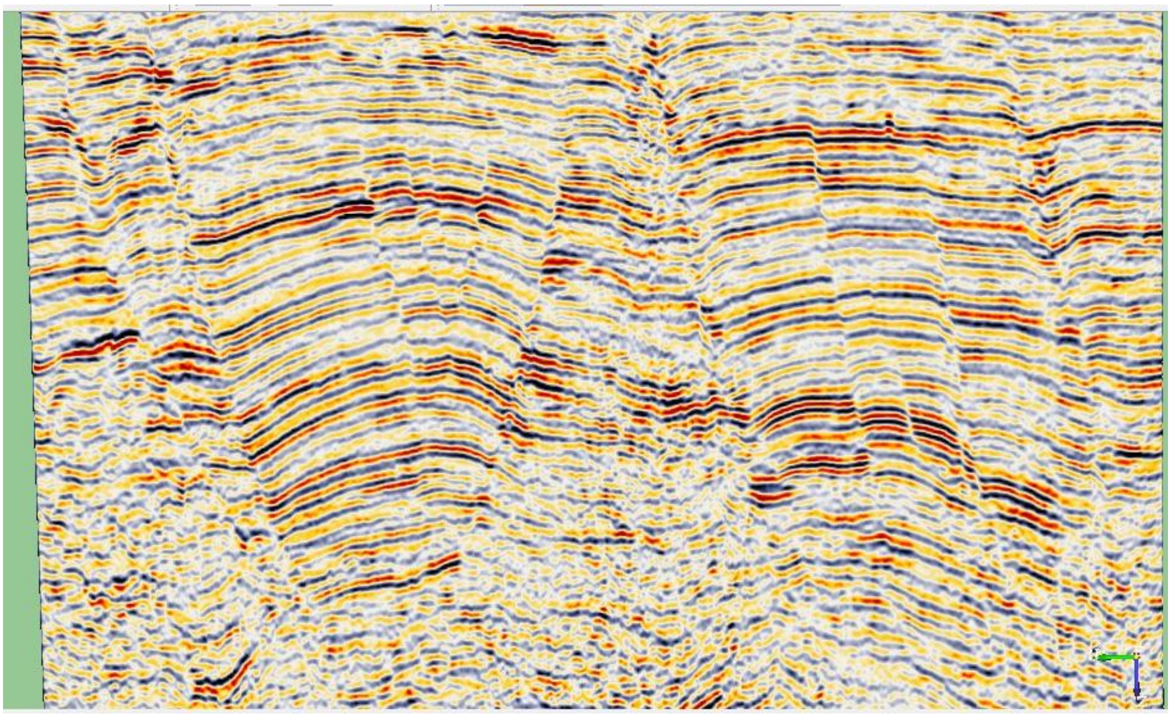

Figure: 3: Raw 3-D seismic data section of Study Area

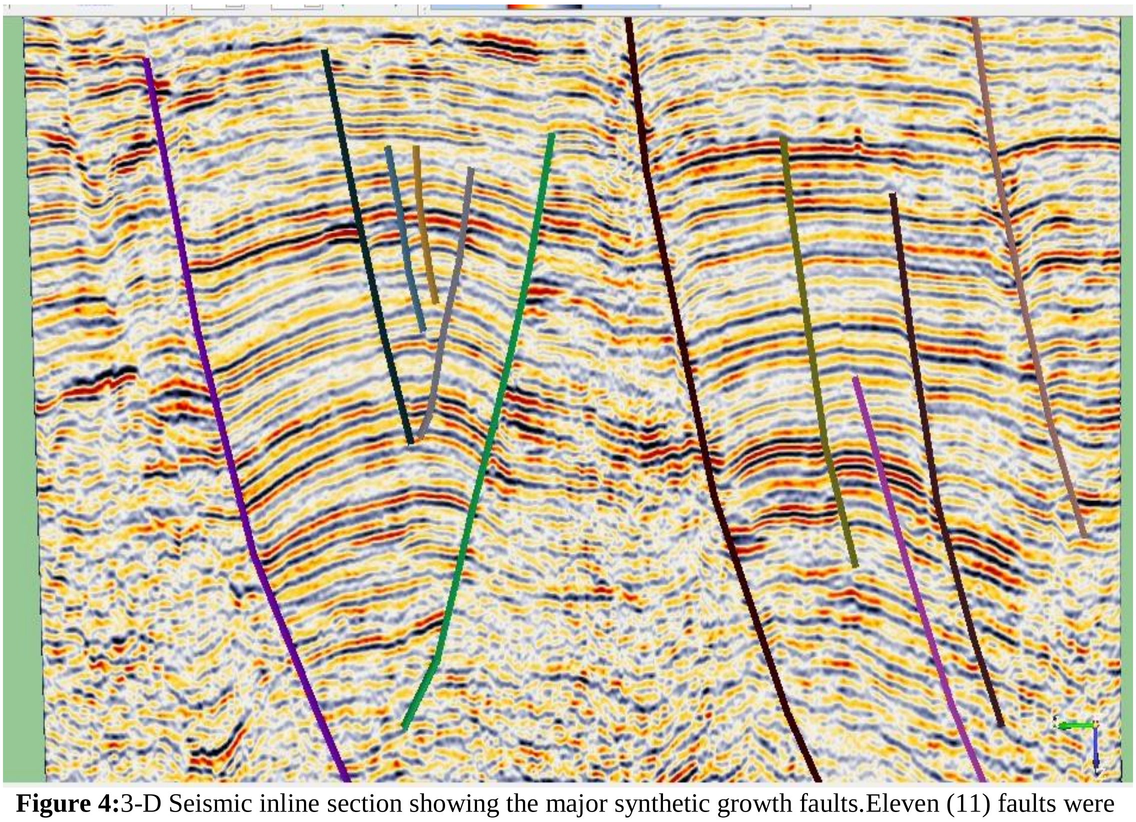

Figure 4:3-D Seismic inline section showing the major synthetic growth faults.Eleven (11) faults were delineated across the field with nine (9) faults trending NW-SE while two (2) faults trend NE-SW.

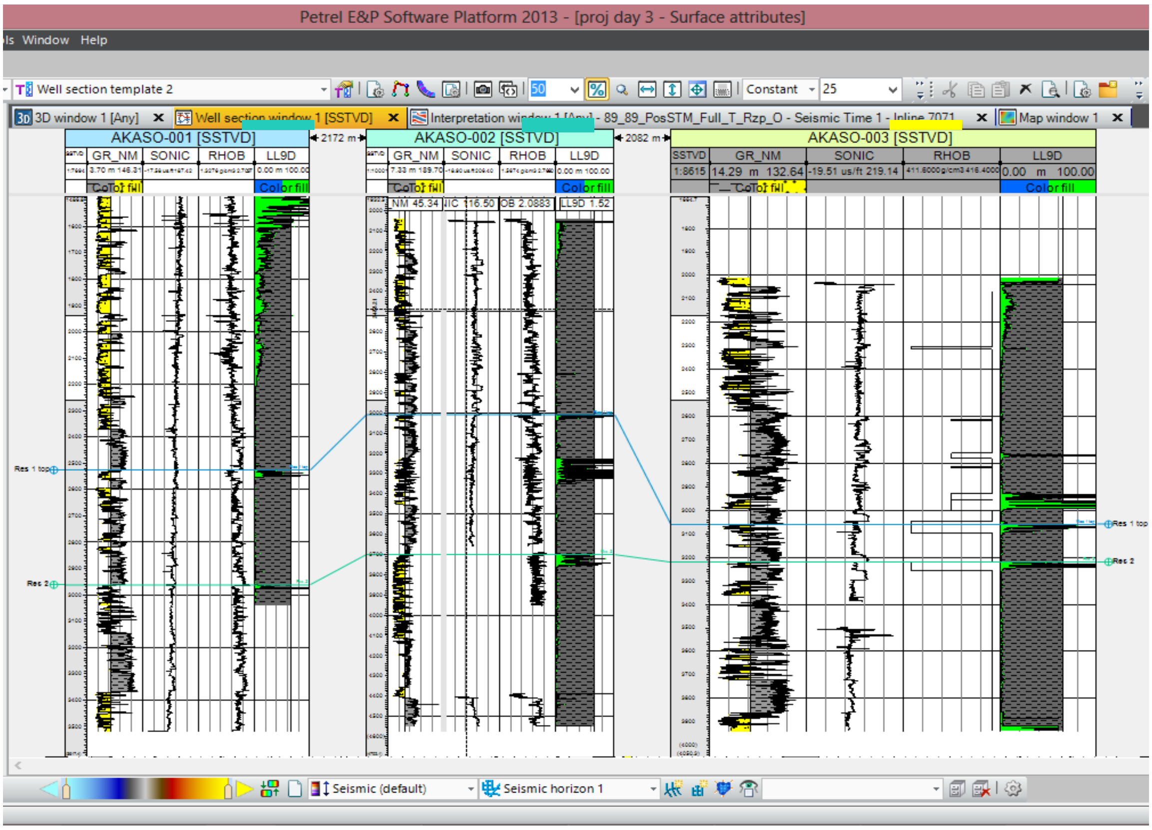

Figure 5: Wire line logs showing the stacking patterns and top-seal

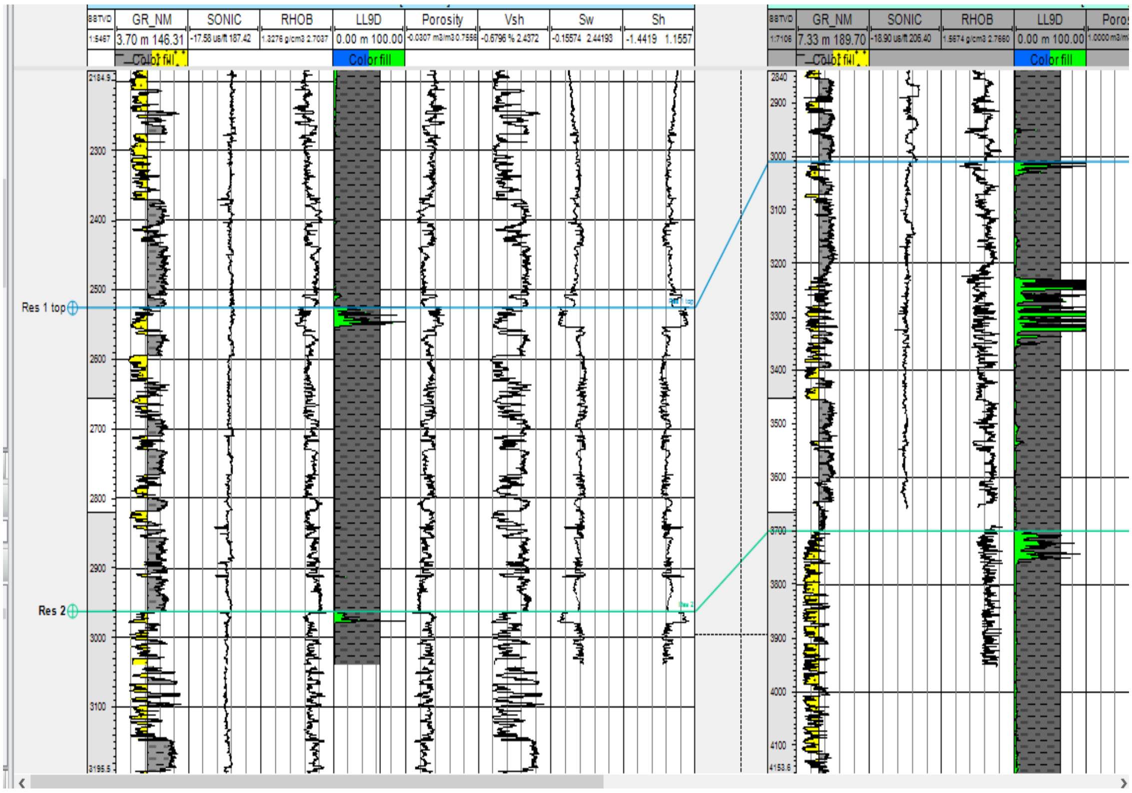

Figure 6: Porosity, shale volume, water saturation and hydrocarbon

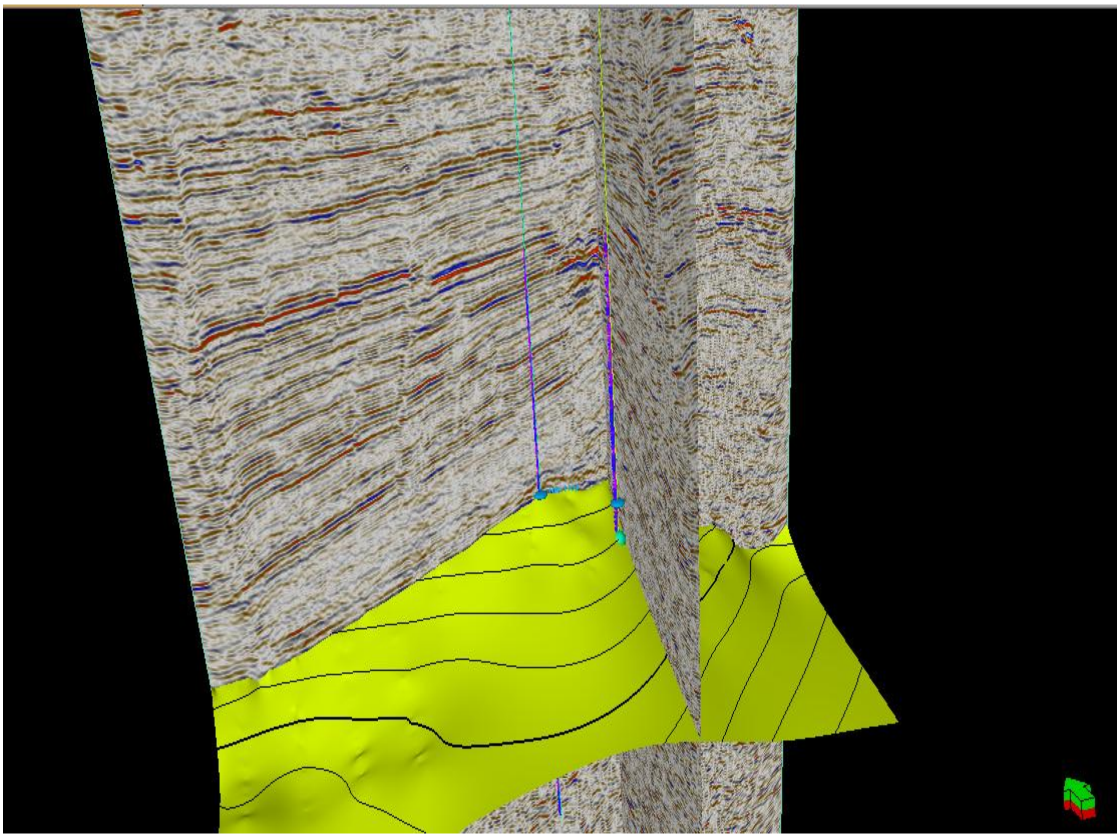

Figure 7: Surface attributes showing the three wells

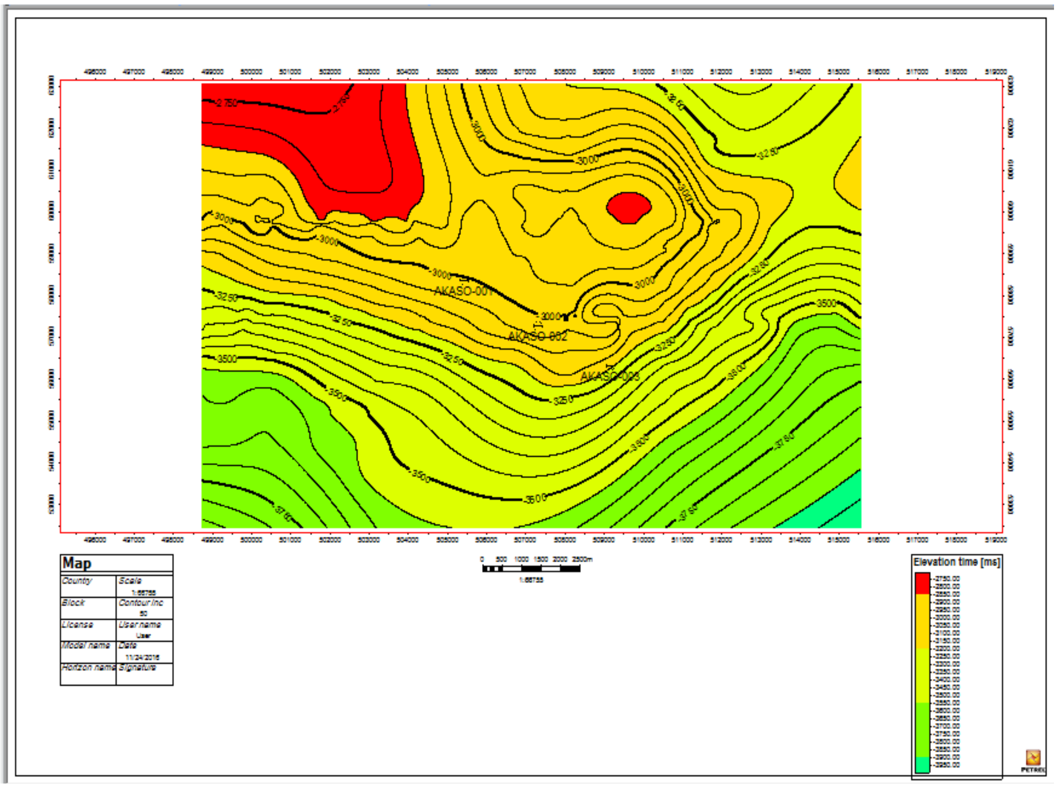

Figure 8: 2-D Top structure map of the reservoir (Two way travel time - TWT)

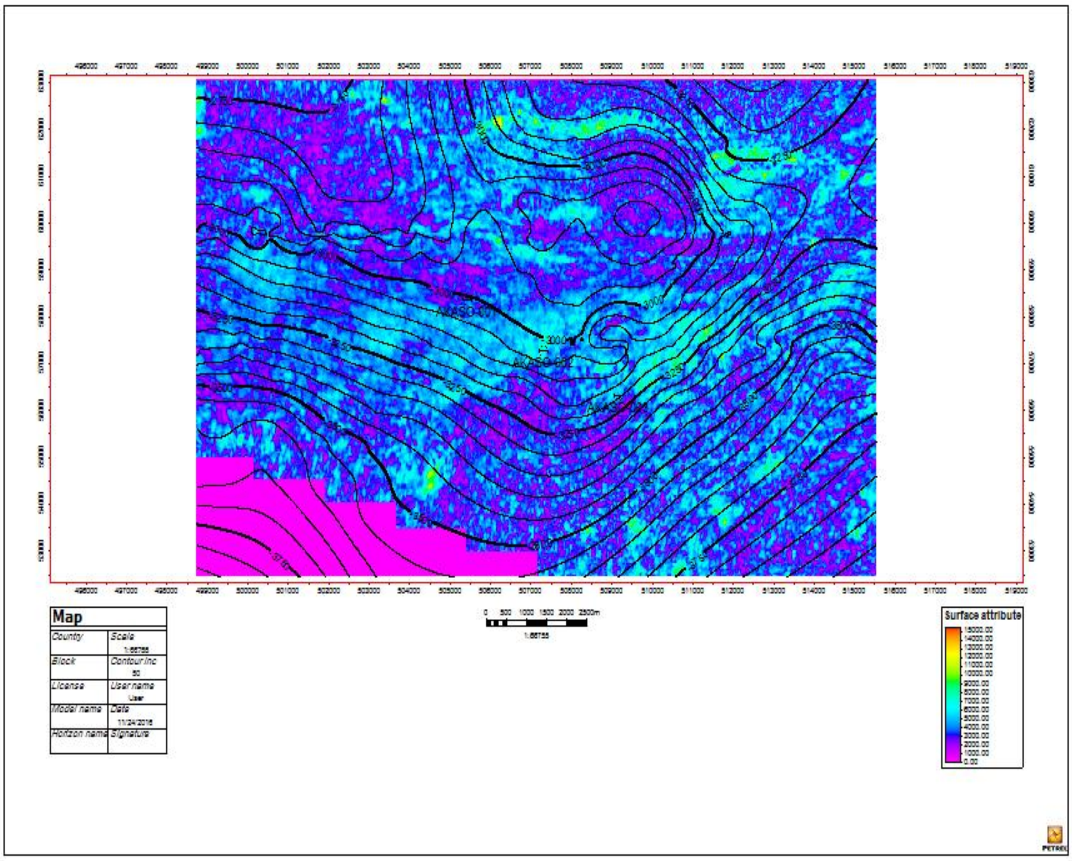

Figure 9: 2-D Top structure map of Reservoir (RMS Amplitude)

VI. Results And Discussion

The model reveals that the reservoir is a rollover anticline with dip closure to the south, east and west then bounded by growth faults to the north and north-west located on the footwall of the major (northern) growth fault. Eleven (11) faults were delineated, with nine (9) faults trending NW-SE and two (2) faults trending NE-SW, the major (regional) growth fault is an elongate east-west trending fault that assisted the reservoir dip closure in trapping the reservoir oil. The sequence stratigraphic analyses revealed that the reservoir exists within Highland and Lowland systems tract and that the reservoir is bounded on top by field-wide correlatable marine shales corresponding to regional flooding surface which serves as the top-seal for oil trapping in the reservoir. Well correlation shows lateral continuity of this sand (typical of barrier bar deposits) which pinches out to the southern and eastern part and implies that the reservoir producibility will be poor towards the south due to poor sand development. Hence, there are intra-reservoir heteroliths in some parts of the reservoir as observed in some wells.

The reservoir properties (especially porosity, water saturation,shale volume and hydrocarbon saturation) are generally good except in the southern and eastern part of the reservoir where a pronounced heterogeneity/ variability exists. The horizons mapped composed mainly of sand bodies and few intercalation of shales bodies as observed in the well formation. The similarities of the geologic and petrophysical properties at certain depth of interest across the reservoir provide the guide for accurate well to well correlation. Two hydrocarbon bearing reservoir-1 (Rev-1) and reservoir-2 (Rev-2),were correlated across the three wells using the log suite comprising the gamma ray, resistivity, bulk density neutron and sonic logs. Three main petrophysical parameters were determined for the study area, namely porosity (ϕ), water saturation (S_w)and shale volume (V_{sh}). The porosity values for Rev-1 ranges from 37% in Well-1, 31% in Well-2 and 25% in Well-3, while the values in Rev-2 ranges from 25% in Well-1, 24% in Well-2 and 22% in Well-3. The water saturation values for Rev-1 ranges from 61% in Well-1, 69% in Well-2 and 75% in Well-3, while the saturation values for Rev-2 ranges from 72% in Well-1, 75% in Well-2 and 76% in Well-3. The shale volume in the reservoirs-1 ranges from 13% in Well-1, 20% in Well-2 and 30% in Well-3 while the values in reservoir-2 ranges from 48% in Well-1, 25% in Well 2 and 32% in Well-3. The average effective porosity ranges between 22% and 37% which is expected because most reservoirs in Niger Delta basin are generally unconsolidated and have moderate to high porosity and permeability. Average water saturations in wells 1, 2,3 are very good ranging between 21 and 42%. While the shale volume average between 13% - 48%. The sand thickness of the reservoirs ranges between 914ft -9820ft.

From the results obtained, the reservoirs are fully quantitatively characterized using an integrated approach of incorporating the seismic attributes. We can deduce that reservoir-1 has more hydrocarbon fluid than reservoir-2.

VII. Conclusion

The integration of all available data (geophysical, geological, petrophysical) has led to the building of a consistent high resolution 3-D static model of the reservoir which can serve as input into reservoir simulation model. The 3-D model can be better applied in well planning compared with the 2-D reservoir map conventionally used for the same purpose. Reservoir characterization of this reservoir has led to detailed description and understanding of the reservoir and has provided a very effective reservoir management strategy for the reservoir.

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