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RESERVOIR MODELING USING SEISMIC ATTRIBUTES AND WELL LOG ANALYSIS OF "OAK" FIELD, NIGER DELTA, NIGERIA.

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Abstract:

This study examined the application of 3-D seismic and well log data for proper optimization and development of hydrocarbon potential in "OAK" field of Niger-Delta Province. For accurate reservoir modelling and property determination, five well logs and seismic data of 1480 to 1700 Xline and 5800 to 6200 Inline ranges were used to delineate two reservoirs of interest and to determine the average petrophysical properties of the two reservoirs. The average determined porosity with respect to reservoir A and B was 25% and 25.1%; permeability 1352md and 1328.23md; Net-To-Gross 80% and 89%; water saturation 32.8% and 32.7%; hydrocarbon saturation 67.2% and 67.3% and STOIIP was 136million STB and 128million STB respectively. This implies that the mapped reservoirs indicate hydrocarbon accumulation in large quantity. This study demonstrated the effectiveness of 3-D static modeling technique as a tool for better understanding of spatial distribution of discrete and continuous reservoir properties, hence, has provided a framework for future prediction of reservoir performance and production behavior of the reservoirs. However, appraisal wells should be drilled within the identified prospect areas to enhance optimization of the reservoir.

(I) INTRODUCTION

In exploration geophysics, subsurface structures and properties of interest include: the reservoir architecture, porosity, fluid Saturation, lithology and permeability. In the procedure for subsurface property modeling, it is usual that geophysicists first provide spatial distribution of seismic attributes from observed seismic record. Seismic attributes can be used for both quantitative and qualitative purposes. Quantitative uses include prediction of physical properties such as porosity or lithology (Leiphart and Hart, 2001; Sagan and Hart, 2006). Qualitative uses include detection of stratigraphic and structural features. Then from the derived seismic attributes, we can evaluate and estimate subsurface properties of interest using physical theories, statistical methods and geological model, along with well-log data. However, uncertainty in seismic interpretation may arise because of many inevitable causes: inconsistent acquisition conditions, lateral velocity variation, poor resolution of data, limited availability of data, insufficient geologic knowledge and many others.

The internal architecture of the "OAK" field fluvial reservoirs along with structural complexity caused by growth faults may result in bypassed reservoirs or compartments with additional reserves. This work basically entails the use of integrated 3D seismic and well logs to enhance oil and gas recovery in the basal part of the Agbada Formation.

(II) OBJECTIVES OF THE STUDY

The aim of this research is to model hydrocarbon reservoirs using quantitative seismic attributes and petrophysical properties of "OAK" Field, Niger Delta, Nigeria.

The objectives are: Characterize reservoir-rocks within "OAK" oil field., Generate Attribute maps for the mapped horizons to compliment the structural interpretation., Delineation of stratigraphic units from well log correlation. and Computation of petrophysical parameters such as porosity, permeability, hydrocarbon saturation and water saturation.

STUDY AREA

The "OAK" oil and gas field is situated within the western margin of the Niger-Delta. The Niger-Delta is situated in the Gulf of Guinea between longitudes 5°E and 8°E and latitudes 3°N and 6°N.

Due to confidentiality purpose, more details about the location of the study area were not provided.

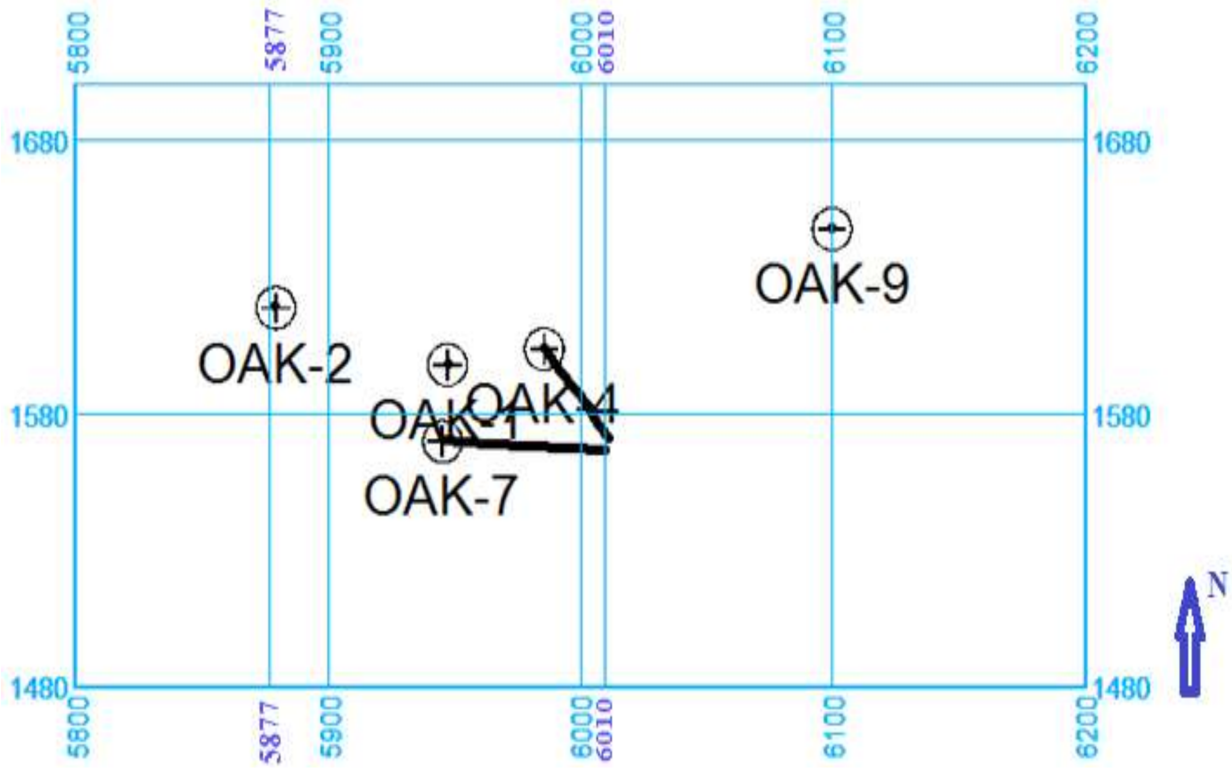


Figure 1: "OAK" field Base Map

(I) METHODOLOGY

A modern method of seismic interpretation technique, which is carried out on a work station is adopted for this research work. The interpretation was carried out on a workstation using the PETRELTM work flow tool, a product of Schlumberger interpretation system for reservoir characterization and visualization of seismic models. PETREL workflow tool, which is a windows based user friendly software was utilized.

DATA BASE

The following suites of material were used in carrying out the Reservoir modeling of "OAK" Field. All the data files are in standard digital format which include;

Base map of 'OAK' field depicting all in-lines, cross lines and well locations. Well header (ASCII Five composite well Logs (ASCII): these includes Gamma ray (GR), resistivity (RES) and density (RHOB). Seismic volume (SEG-Y). Check-shot survey data (ASCII), which was used to generate the Time-Depth conversion curve.

WELL CORRELATION

The logs are activated and displayed on the well section window, on which correlation is carried out using the lithology log (Gamma ray log), the resistivity is used to check the fluid contents present within the sediments i.e. hydrocarbon or water, whereas the neutron porosity and density logs are used to differentiate the kind of fluids present in a reservoir i.e. gas, oil or water and applying the principles of stratigraphy and facies distribution, the geological zones are divided into fine-scaled layers that capture the important facies with similar flow properties, are combined.

SEISMIC DATA IMPORT

The seismic volume is imported into a user defined folder in SEG-Y format. It is cropped and then realized. From the crop-realized volume, inline, crossline are inserted. After loading into memory, time slice is also inserted.

After the seismic volume is imported into the software, cropping and realization is carried out, so as to reduce the processing time due to the data and to chop away part that is not needed for work, leaving behind only the area of interest. A 3D window is opened and a new interpretation window to view and also start fault mapping. The faults were mapped on the cross lines and the continuity viewed on the inlines.

After importing our data, the first step in this modeling research work is to quality control various types of data and their consistency to avoid the possible problem of "garbage in equal's garbage out". A quality check of the well and seismic data indicated that they were of acceptable quality.

SEISMIC ATTRIBUTES ANALYSES

Seismic attribute analysis typically starts with a rock property analysis. Normally, a rock property study begins with an analysis of the rock properties measured by well logs. Generally, time-based attributes relate to structure, amplitude-based attributes to stratigraphy or hydrocarbons, and the frequency-based attributes to stratigraphy or reservoir characterization. Multicomponent seismic attributes can detect fractures and faulting and determine their orientation. Attenuation attributes can help in gas reservoir detection. If enough wells were present, key reservoir attributes can be used in an existing field to optimize production drilling.

(I) RESULTS AND DISCUSSION

Among other objectives, the 3-D structural interpretation of the seismic data was carried out to give an overview of the reservoir-trapping configuration in "OAK" field. As one of the major objective of the work, the depth structure maps were mapped for closures or structures that possess efficient trapping system suitable for hydrocarbon accumulation, development and production. These are necessary for projecting the horizons into areas where well control may not exist.

LITHOSTRATIGRAPHIC CORRELATION PANELS

Figure 2 depicts the lithostratigraphic correlation panel of the "OAK" field wells showing the gamma ray log, resistivity log, neutron log and density log. After close geologic scrutiny of the four wells and correlation of the reservoir sand and shale sequence, the tops and bases where identified for mapping round the seismic volume.

The general stratigraphy of the wells show a composition of alternating sand and shale layers. There is an increase in shale layer with depth along with a corresponding decrease in sand layer with depth. This is an indication of transition from Benin to Agbada formation.

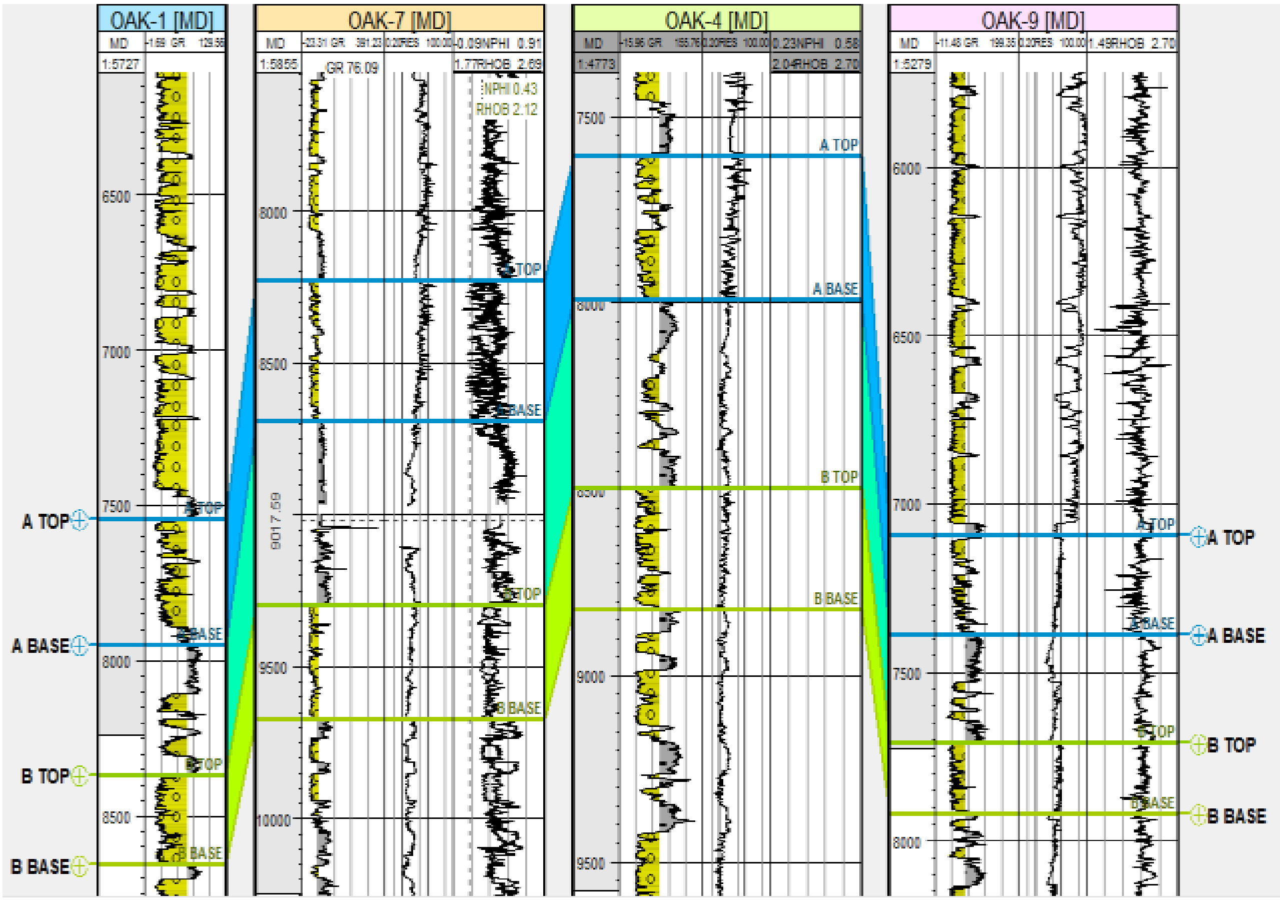
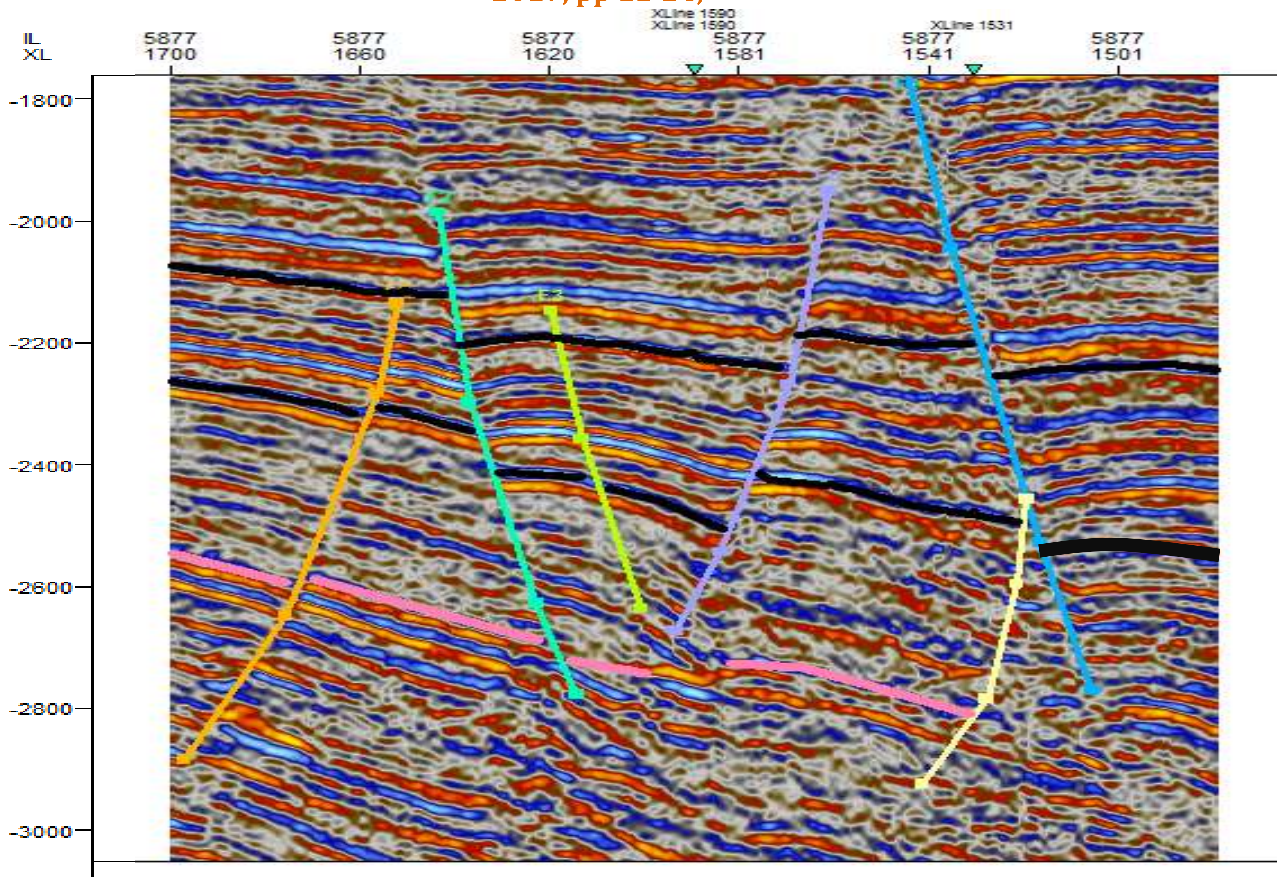


Figure 2 : Well log correlation panel of "OAK" Field.

SEISMIC-TO-WELL TIE

One of the first steps in interpreting this seismic dataset was to establish the relationship between seismic reflections and stratigraphy. Accurately tying wells and seismic information is a necessary step in reservoir characterization. Well-to-seismic tie was a major task for this interpretation project. It was used to correlate the well information (logs) to the 3D seismic volume. This enabled the comparison (crossplots) of well-based and the 3D seismic data.

Seismic-to-well tie is a key at any stage of the development of a field and is an essential step of the seismic interpretation workflow, bridging the gap between the time and depth domains.



A well section was created for the well to seismic tie, the sonic log, density and gamma ray log of OAK-7 well superimposed on inline 6010 that it passed through, to have an accurate correlation of both the log and the section.

SEISMIC SECTION OF THE MAPPED FAULTS AND HORIZONS

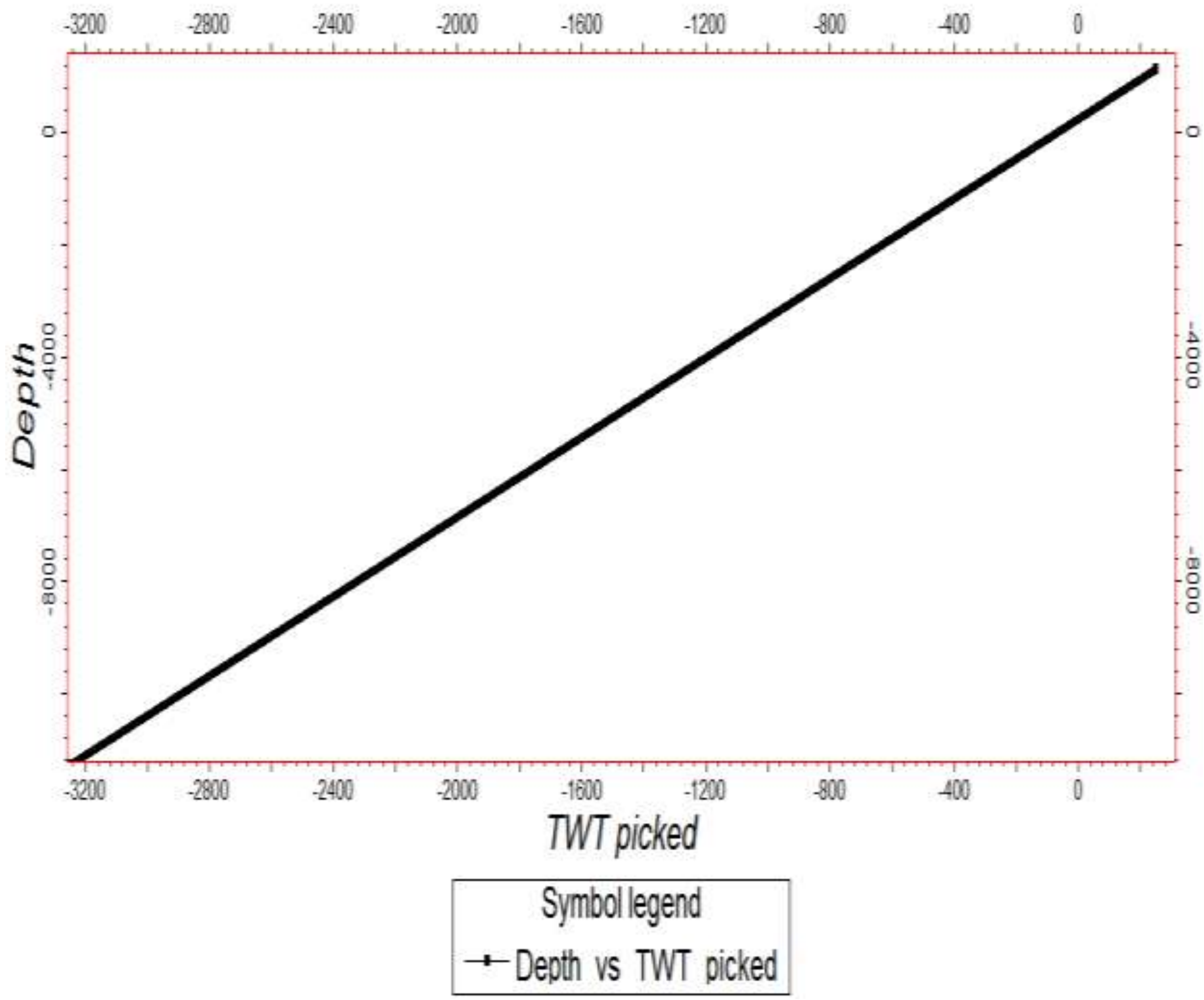
The exact horizons for the tops of the reservoirs were picked and this ensures that the interpretation process is consistent (Fig.4). The field is considered to have complex structures (classification, according to Doust and Omatsola, 1990.) and located in the distal delta. This is in the depobelt range of central swamp II and coastal swamp.

FAULT INTERPRETATION RESULT

The ''OAK field'' is a complex south-east dipping anticlinal structure, parallel synthetic and antithetic faults. Six faults were mapped with series of colours. Within the major fault blocks numerous subsidiary faults, both synthetic and antithetic, have been recognized but some additional small scale faults which may be present cannot be confidently mapped, especially at the deeper levels, due to relatively poor data quality.

Within the central area of the base map, there is considerable well control therefore, the fault positions are considered to be accurate at the mapped reservoir levels to the base of the B sands.

4.5 TIME AND DEPTH STRUCTURAL MAP INTERPRETATION



Time (Figure 4) and depth structural contour maps were produced for the two horizons defined on top of sand bodies, namely, Horizon A and B. Both types of structural contour maps show similar structural relationship. This linear relationship was also corroborated by the linear curve observed from the plot of depth against time using the check shot data of the "OAK-7" well (Figure 4).

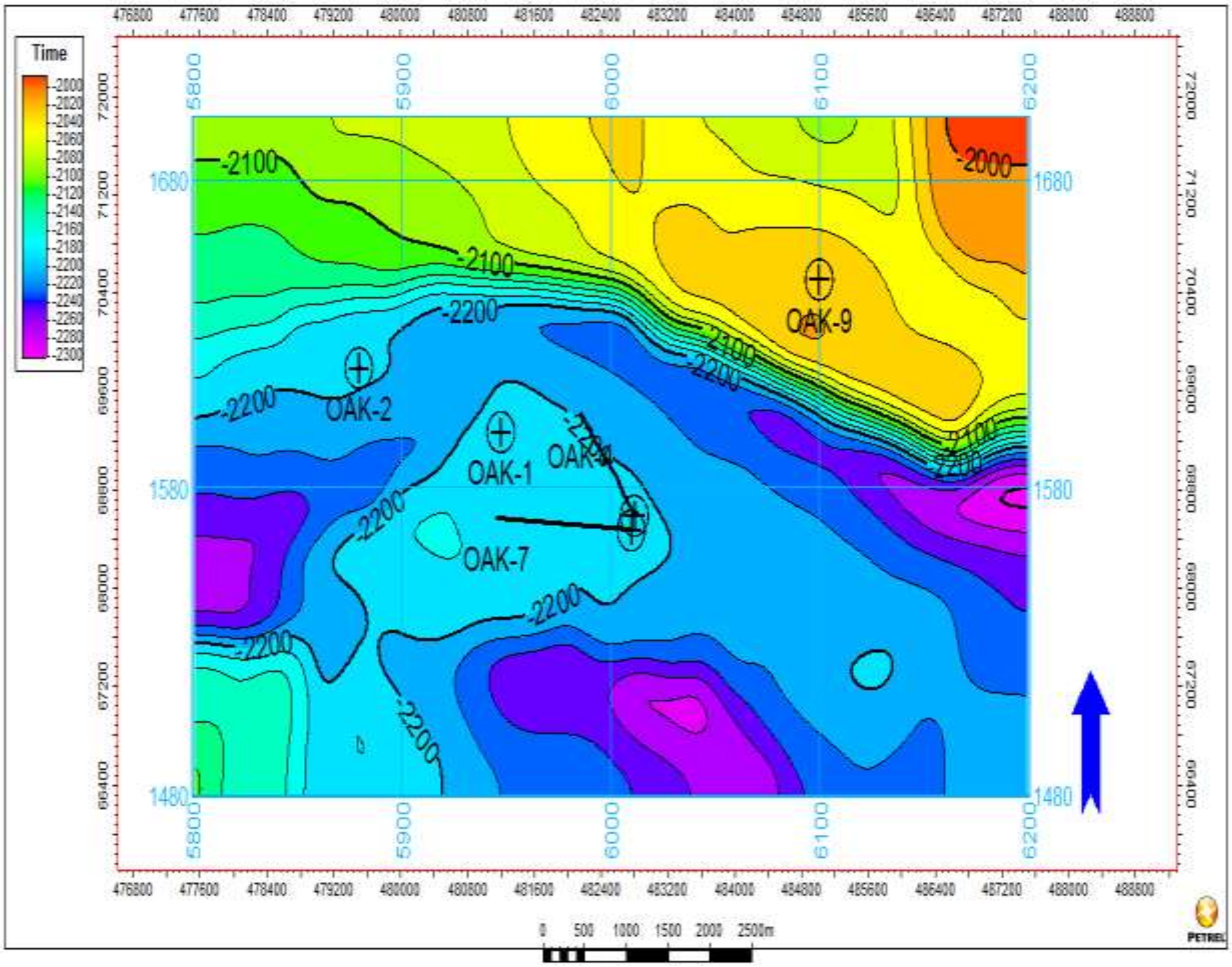


Figure 4: Time Structure map of Reservoir A

The depth map revealed the crest of the anticline at the depth of 7,550ft, which tied with what was obtained on the well logs. The anticline dip closure establishes the trap for the reservoir. Also, antithetic faults are growing and trending in the south-east direction as well as dipping in the direction. There is a two way fault assisted closure which covers an appreciable area for a good prospect for hydrocarbon. The hydrocarbon reservoir was mapped base on their low gamma ray counts and high resistivity values from the well log displayed on "PETRELTM". The throw of the fault range indicate that these faults are sealing based on (Whiteman, 1982) which postulated that faults are still conductive as long as their throw does not exceed 500ft. Since it is less than 500ft it is adjusted sealing because it will be justaposed by shale which is impermeable and will prevent the migration of hydrocarbon. The overall depth at which the reservoir is located from the depth map ranges from 7500 to 7950ft.Horizon B depth structural map revealed the crest of the anticline at the depth of 9050ft, which tied with what was obtained on the well logs. The depth map shows that the depth of the reservoir increases in the east-west direction away from the crest of the anticline, a two way closure (dependent on an antithetic fault) was cut through by a synthetic fault.

PETROPHYSICAL EVALUATION

A reservoir is a subsurface rock that has effective porosity and permeability which usually contains commercially exploitable quantity of hydrocarbon. Reservoir characterization is undertaken to determine its capability to both store and transmit fluid. Hence, characterization deals with the determination of reservoir properties/parameters such as porosity (Φ), permeability (K), fluid saturation, Net-to-gross among others.

NET-TO-GROSS RATIO

The gamma ray log was used to estimate the Net-to-gross ratio, by first determining the gamma ray readings of clean sand in the formation, using the formula:

$$N/G = \frac{\Sigma h_i}{H} = \frac{\text{Net reservoir}}{\text{Gross reservoir}}$$ (Asquith, 1994)

N/G = 80%

ESTIMATION OF POROSITY

The computation of porosity was done using Wyllie equation (1956) to estimate the density derived porosity. The density derived porosity ØD was calculated using the formula:

(Wyllie Equation, 1956)

Taking different points from the density log in the reservoir

$$\phi_{den} = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

i.e. $\rho_{b\,1}$, $\rho_{b\,2}$, $\rho_{b\,3}$, ρ_{ma} = 2.65 gcc and ρ_{fl} = 0.9 gcc (oil).

$Ø_D$ = 25%

ESTIMATION OF PERMEABILITY

Permeability is a measure of the ease with which a fluid (hydrocarbon and water in this case) can move through a porous rock.

$K = 307 + 26552\phi^2 - 34540(\phi \text{ x } S_w)^2$ (Owolabi et al., 1994).

K = 1,352 md

ESTIMATION OF WATER SATURATION

Water saturation (S_w) determination is the most challenging of petrophysical calculations and it's used to quantify its more important complement, the hydrocarbon saturation ($1 - S_w$).

S_w is the value in percentage of the pore volume in a rock occupied by the formation water. Determination of water saturation for the uninvaded zone was achieved by using the Udegbunam et al. (1988) equation given below:

$$S_w = \frac{0.082}{\phi}$$ (Udegbunam et al., 1988)

Where: Water saturation, S_w = 32.8%,Ø= Porosity

Table 1 : Average Petrophysical properties for Reservoir A and B.

RESERVOIR	POROSITY (%)	PERMEABILITY (millidarcy)	NTG (%)	WATER SAT. (%)	HYDROCARBON SAT. (%)	STOIIP (m STB)
A	25	1352	80	32.8	67.2	136
B	25.1	1328.23	89	32.7	67.3	128

SEISMIC ATTRIBUTES MODEL

FREQUENCY ATTRIBUTE MODEL

Technically, each individual frequency or band of frequencies could be considered an attribute. The seismic data was filtered at various frequency ranges in order to show certain geological patterns that may not be obvious in the other frequency bands. There is an inverse relationship between the thickness of a rock layer and the corresponding peak frequency of its seismic reflection. That is, thinner rock layers are much more apparent at higher frequencies and thicker rock layers are much more apparent at lower frequencies.

ROOT MEAN SQUARE AMPLITUDE SURFACE MAP

Root Mean Square Amplitude extraction was carried out on reservoir A and B level where the reservoir can be confidently identified on the seismic data from the well-synthetic tie. Amplitude anomalies exist at all levels where it was possible, both within the field itself and the surrounding areas. These anomalies are of two types: those that conform to structure, and those that appear to be appraisal i.e. doesn't conform to any structure. Amplitude being a seismic attribute was superimposed on the time structure map of horizon A and B to check its conformity to structure. Amongst the different types of amplitude which can be extracted (maximum positive and negative, average positive and negative e.t.c.), root mean square amplitude was chosen because of its unique characteristics as a good indicator of the presence of hydrocarbon (Mangal et al. 2004). R.M.S amplitude is obtained by summing all the square of all the amplitudes of the reflection and calculating the roots of the cumulative; high amplitudes with respect to amplitude distribution are direct hydrocarbon indicators (Mangal et al. 2004).

From figure 5 shows areas of high amplitude are within the closures which conform to the structure and this further confirms the presence of hydrocarbon (Mangal et al. 2004). The high amplitude is seen as the grey to yellow/red coloration. Also, a new prospect was discovered in the North-eastern part of the Amplitude surface map of reservoir-A due to the structural closure and it high amplitude.

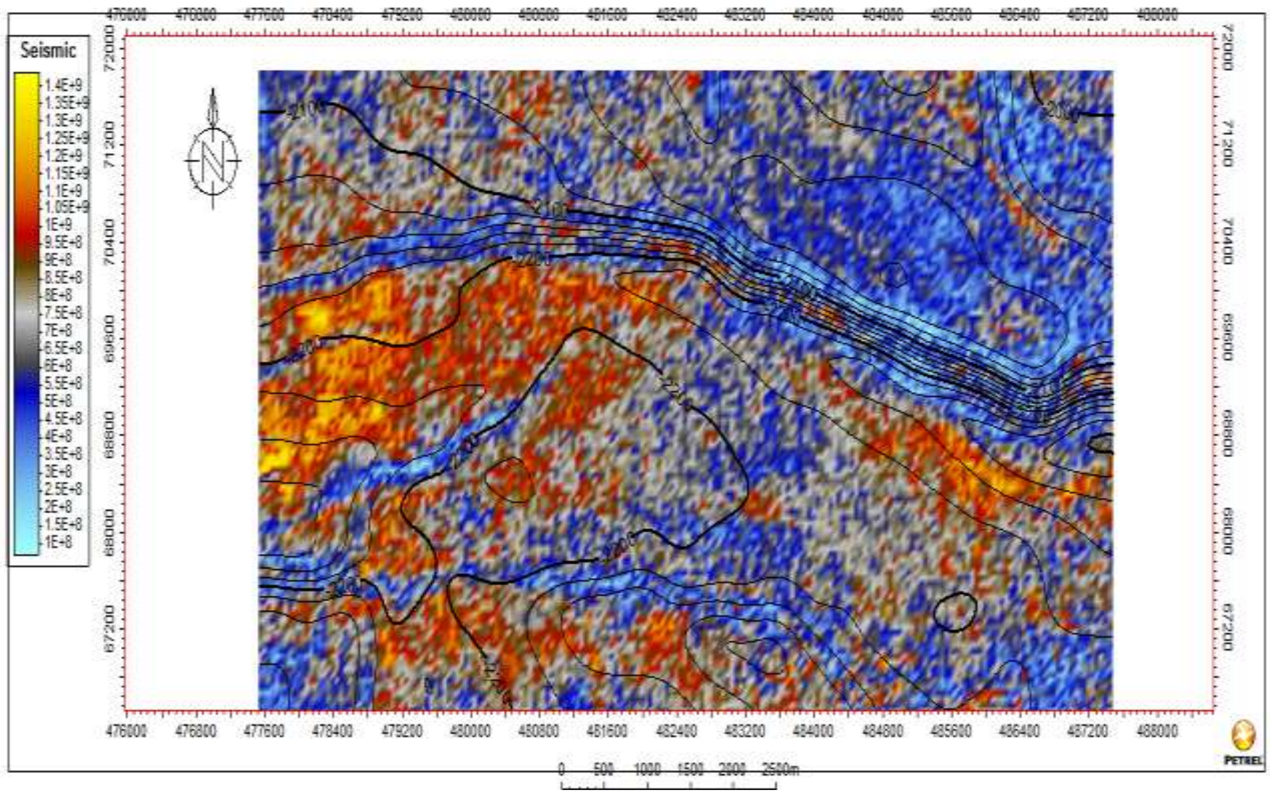


Figure 5 : RMS Amplitude Surface Map for Reservoir A.

The variance (the opposite of coherency) attribute is calculated in three dimensions and represent the trace-to-trace variability over a particular sample interval and therefore produces interpretable lateral changes in acoustic impedance. Similar traces produce low variance coefficients, while discontinuities have high coefficients. Because faults and channels may cause discontinuities in the neighboring lithologies and subsequently in the trace-to-trace variability they become detectable in 3D seismic volumes. Variance can thus be seen as the lateral counterpart of Root Mean Square Amplitude as the later indicates vertical variations.

The study displays the Variance attribute surface map superimposed on a time structure map, areas dotted with red coloration, which signifies high variance value, correspond to the location of the mapped faults (Law 2006).

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