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Attribute Analysis and Structural Modeling of X Field, Niger Delta, Southern Nigeria

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---***ABSTRACT***---
The accuracy of hydrocarbon reserve estimation rest largely on the quality of the generated field geologic model as well as how frequently the model is updated with new knowledge. The acquired data from the multinational oil company were quality checked. Different logs were investigated across the field using Gamma Ray and Resistivity log signatures. Sand bodies were investigated across the field after which they were correlated. Horizon and fault mapping were carried out on the seismic data, after which the structural modeling continued with the layering and zonation process. The thickness of the sand bodies ranged from 42ft to 173ft, and the hydrocarbon saturation ranged from 51% to 79%. The porosity also ranged from 17% to 24%, while the NTG ranged from 27% to 94%. These are fantastic indicators of economic accumulations. The generated model affirmed a growth-fault assisted hydrocarbon accumulation.
Key Words*: Geologic Model; Horizon and Fault Mapping; Layering; Zonation; Hydrocarbon Saturation*

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I. INTRODUCTION

As the world's population increases, so also does human need. However, the need for energyranks among the most important. The recent energy landscape has called for thediversification of fuel sources, hereby creating an energy mix. The progress made in the fieldof renewables has been very enriching to our world. However, the fact remains thatconventional oil will remain an important energy source for years to come. Geologic models attempt to construct subsurface accumulations with the aid of state-of-the-art software packages. The output is very critical, as it helps management and economists make informed decisions on how best to develop the accumulation. 3D modeling is the spatial representation of reservoir properties such as porosity, permeability, saturation, capillarity, etc; in order to capture key heterogeneities and reservoir connectivity. It generally requires a combination of conceptual stratigraphic models and geostatistical simulations [3].

The integration of seismic data for reservoir modeling purposes was a challenge at earlier times. The Extensional Drift method for example, failed in the construction of quality and representative contour maps. The Collocated Cokriging technique [11] however surmounted this through the integrated stochastic simulation into the production of the maps. Another significant challenge encountered in the modeling of reservoirs was the development of a realistic fault model that could develop the route to incorporate realistic structural geometries in static and dynamic reservoir modeling. In response to this,representative realistic faults [16] was proposed, and this became a baseline for future well planning and reservoir studies in the Niger Delta. Reservoir modeling operations without the use of information from Core data [10] presented a powerful method of integrating data from different sources in the prediction of reservoir properties across an oil field.3D modeling provides a very powerful tool necessary for proper characterization of properties such as channel orientation, continuity and connectivity [14].

The objective of this project work is to build a 3D- structural and stratigraphic model for X field, which just came into operation in 2016. This would entail integrating all the datasets made available by the multinational oil company. The output of this work would help to advise on planning field development strategies.The research area is situated in the onshore coastal swamp depositional belt in eastern Niger Delta. It is situated within latitudes 4° 19' 00'' N and 4° 50' 00'' N , longitudes 6° 02' 30'' E and 7° 10' 00''E (Fig. 1).

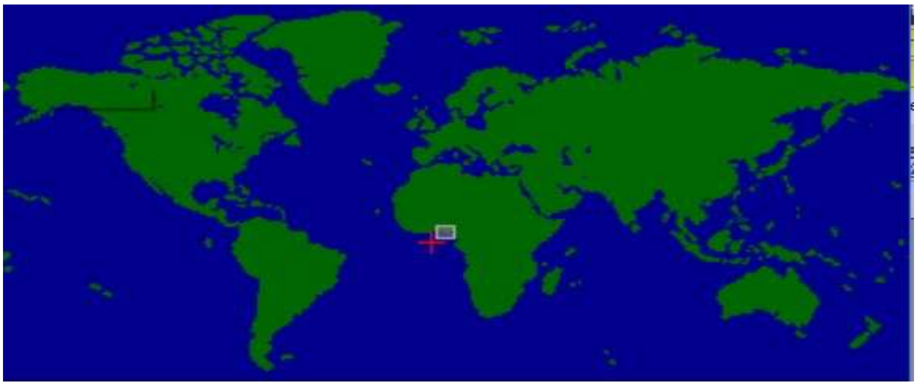

Figure 1. Location of the Field in Niger Delta

The Niger Delta is a coarsening upward regressive sequence of Tertiary clastic sediments divided into three lithostratigraphic units representing prograding depositional facies. The units include the Akata Formation at the base of the delta, Agbada Formation overlying the Akata Foundation and the Benin Formation overlying the Agbada Formation. The Akata Formation is a marine sedimentary succession laid in front of the advancing delta. It consists of undercompacted shales. The Agbada Formation is characterized by paralicinterbedded sandstone and shale with a thickness of over 3,049m[15]**.** The Benin Formation is the youngest lithostratigraphic unit in the Niger Delta. It is Miocene-Recent in age with a minimum thickness of more than 6,000 ft (1829m) and is made up of continental sands and sandstones (>90%) with few shale intercalations.

II. EXPERIMENTAL PROCEDURE

The GEOGRAPHIX software was made use of for lithostratigraphic modeling while The PETREL software was used for fault analysis, horizon modeling and pillar gridding processes. Prior to the use of the PETREL software, there was need for georeferencing, in order to relate the field location to a ground system of geographic coordinates. For this purpose, the PowerPlan: NIGERCM6E coordinate reference system was used.

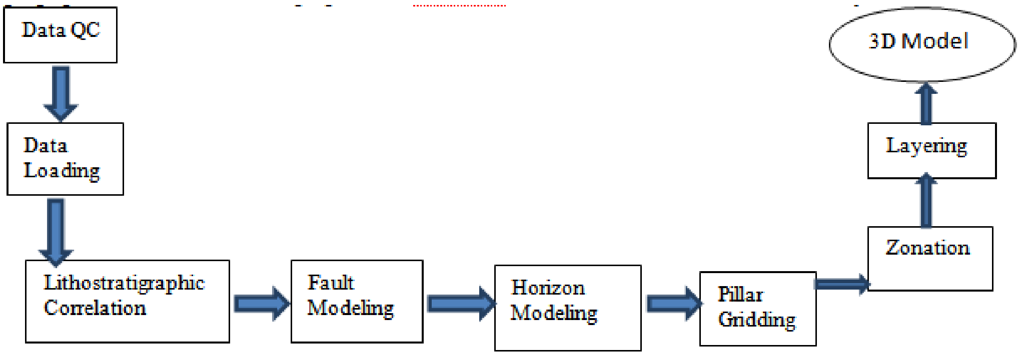

Figure 2. Research Workflow

Dataset: The dataset that was used to carry out the project work consisted of:

- A well header information for six (6) wells i.e. AKOS-002 to AKOS-007. The Easting of these wells ranged from 499486.344 to 507625.406 field units, while the Northing ranged from 56351.141 to 58466.981 field units. The total depth of the wells also ranged from 9950 ft to 14916ft.
- A well path information, which when loaded made some of the wells slightly deviated i.e. not completely vertical wells.
- A total of forty-two (42) wireline logs in all the wells were used for this study. These log readings were the measurements of different petrophysical properties e.g. radioactivity, resistivity, wellbore integrity; against depth throughout the entire trajectory of the wells. The logs measured included Depth log, Sonic log, Caliper log, Neutron Porosity log, Bulk Density log, Gamma Ray Log and the Deep Resistivity Log.
- Checkshot data for AKOS 003
- Zero offset realized post stack, time migrated seismic volume. It has 673 inlines and 425 crosslines. The inline has a length of 10600.00 units and an interval of 25.00, while the crossline has a length of 16800.00 units and an interval of 25.00. The number of samples per trace is 1501, while the total numbers of cells are 429, 323,525. The two-way time (TWT) runs from the sea bottom (zero) to 2 seconds.

III. METHODOLOGY:

The Gamma Ray log was used to identify the various lithologies across the wells. It was set to a scale of 0-200 API, and a central cutoff of 95 API units was applied. Hydrocarbon saturated zones were then identified with the combination of shallow (LLS) and deep (LLD) resistivity log readings. The hydrocarbon zone was further separated into oil and gas zones with the combination of neutron and bulk density logs (the balloon effect principle). The GOC was subsequently identified as the depth at which the balloon effect stops, and the two logs start tracking close to each other. The caliper log reading was also monitored in order to ascertain the degree of data integrity. V_{SH}, S_w, Ø and NTG were subsequently calculated for each sand package as seen by the various wells (Table 1).

The fault interpretation was then carried out on both the inlines and crosslines at every 10th inline and crossline seismic record using the 3D autotracking tool on PETREL. The Seismic –to-Well tie was achieved using Checkshot Data for AKOS-003. The sonic and density logs were multiplied in order to derive an impedance log after which the reflection coefficients at the impedance changes were calculated. The generated pulse was then convolved with the reflection coefficient series to generate individual wavelets (Fig. 4), which were then summed to get a synthetic seismic trace.

The horizons were also carefully mapped across all inlines and crosslines after which surfaces were generated. The Corner Point gridding process was then used to generate the structural model, which commenced immediately after the fault modeling. This was then followed with zonation and layering processes.

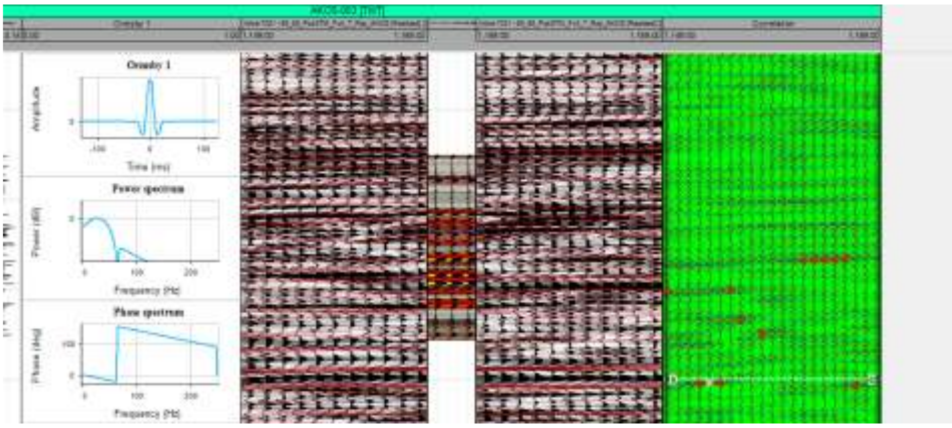

Figure 3. Achieved Seismic to Well tie

Table 1. Equations used in the derivation of properties

Petrophysical Parameter	Equation Used
Volume of Shale (VSH)	$I_{GR} = \frac{GRlog - GRmin}{GRmax - GRmin}$ $V_{SH} = 0.83(2^{(3.7 \times IGR)} - 1.0)$ (Dresser Atlas, 1979)
Water Saturation (Sw)	$S_w = \sqrt[n]{\left(\frac{a}{Øm} \times \frac{Rw}{Rt}\right)}$ $S_{wirr} = \sqrt{\frac{F}{2000}}$ Archie
Porosity (Ø)	$\Phi D = (\rho ma - \rho b)/(\rho ma - \rho f)$
Net to Gross (NTG)	$NTG = \frac{Net\ sand}{Gross\ sand}$

IV. RESULTS AND DISCUSSION

Prior to the correlation of the sand bodies, the BENIN base was marked across all the wells. This represented a significant paleogeographic surface, as it signaled the movement from Benin Formation into the hydrocarbon bearing Agbada Formation. The location of the BENIN base was recognized as the point at which

a noticeable and concurrent steep decline in the reading from the deep induction log occurs across the entire wells used for correlation (Obaje,2009). Thinning out of sand facies was noticed in the Sands C and F.
The line of section considered for the correlation ran from AKOS 004 to AKOS 003 (Fig. 4) due to the basic understanding that correlation is better done basinward i.e. from the edge to the deeper part of the basin. This way, it will be easier to identify sand bodies than thin out.

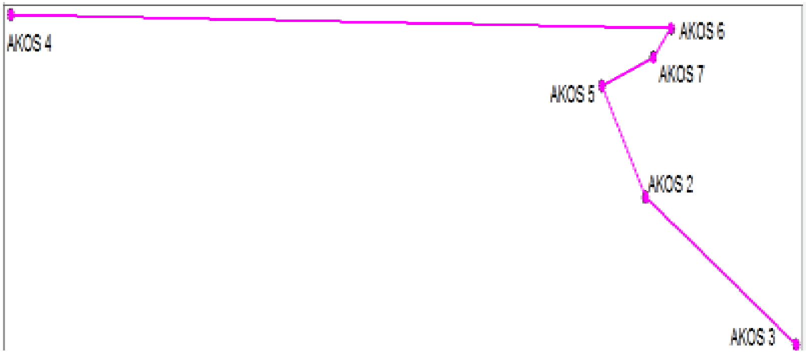

Figure 4. Adopted line of section for lithostratigraphic correlation.

Lithostratigraphic Correlation:
Five (5) sand bodies were delineated across the entire well section based on well log responses and these are presented in Table 2. The thickness of the sand packages ranged from 42ft in Sand D to 174ft in Sand G.

Table 2. Qualitative Interpretation of the reservoirs

Sand		**A**	**B**	**C**	**F**	**G**
Fluid		Gas	Gas, Oil	Gas, Oil	Gas, Oil	Gas,Oil
HWC (ft)		-7855 (DLGC)	-8330 (GOC), 9218 (DHOC)	-8958 (HWC), -8880 (GOC), -8475 (OUT)	-9548 (GOC) , -9145 (GDT)	-9991 (GOC), -9400(GOC), -9469 (GOC), -9623(ODT), -10594 (ODT)
AKOS - 004	Top (ft) Base (ft)				9484 9634	9940 10060
AKOS - 006	Top (ft) Base (ft)			8909 8946	9137 9182	9314 9414
AKOS - 007	Top (ft) Base (ft)			8798 8885		9392 9482
AKOS - 005	Top (ft) Base (ft)	7836 7885	8200 8350	8432 8523		9559 9639
AKOS - 002	Top (ft) Base (ft)		9148 9321			10533 10643

The reservoirs exhibited very good to excellent properties indicative of economic accumulations (Tables 3 to 7).

Table 3. Petrophysical Evaluation of Reservoir A

Well	**Ø (%)**	**VSH (%)**	**Sw (%)**	**Shc (%)**	**Swirr (%)**	**NTG (%)**
AKOS - 005	20.6	24	40.3	59.7	8.55	67.1

Table 4. Petrophysical Evaluation of Reservoir B

Well	**Ø (%)**	**VSH (%)**	**Sw (%)**	**Shc (%)**	**Swirr (%)**	**NTG (%)**
AKOS - 002	20.8	8.6	35.4	64.6	8.46	73.7
AKOS - 005	20.8	15.9	24.2	75.8	8.46	76.9

Table 5. Petrophysical Evaluation of Reservoir C

Well	**Ø (%)**	**VSH (%)**	**Sw (%)**	**Shc (%)**	**Swirr (%)**	**NTG (%)**
AKOS - 005	24.2	14.4	42.2	57.8	7.28	50.8
AKOS - 006	18.2	20.8	33.2	66.8	9.67	66.1
AKOS - 007	22.9	13.2	23.3	76.7	7.69	88.9

Table 6. Petrophysical Evaluation of Reservoir F

Well	**Ø (%)**	**VSH (%)**	**Sw (%)**	**Shc (%)**	**Swirr (%)**	**NTG (%)**
AKOS - 004	20.7	13.3	24.9	75.1	8.51	70.9
AKOS - 006	17.9	28.2	48.6	51.4	9.84	27.4

Table 7. Petrophysical Evaluation of Reservoir G

Well	Ø (%)	VSH (%)	Sw (%)	Shc (%)	Swirr (%)	NTG (%)
AKOS - 002	20.7	17.8	22.5	77.5	8.51	57.4
AKOS - 004	22.5	10.3	21.2	78.8	7.83	93.6
AKOS - 005	21.1	16.5	26.8	73.2	8.34	57.3
AKOS - 006	20.7	17.4	21.1	78.9	8.51	63.1
AKOS - 007	21.1	17.6	22.4	77.6	8.34	59.3

Structural Interpretation:

Fault Analysis: A total of ten (10) faults were picked and traced across all inlines (Fig. 6). Seven (7) of the mapped faults are synthetic while the other three are antithetic i.e. major faults trend in the NE-SW direction. This suggests a basinward downward slumping generated by the unstable underlying Akata Formation. The fault system was subsequently converted into a framework for the structural model (Fig. 7).

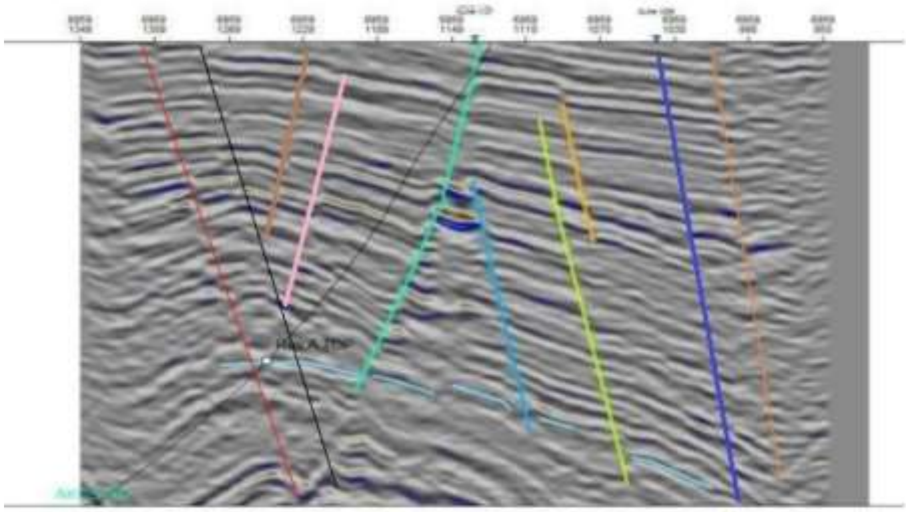

Figure 6 Mapped Fault patterns across inlines

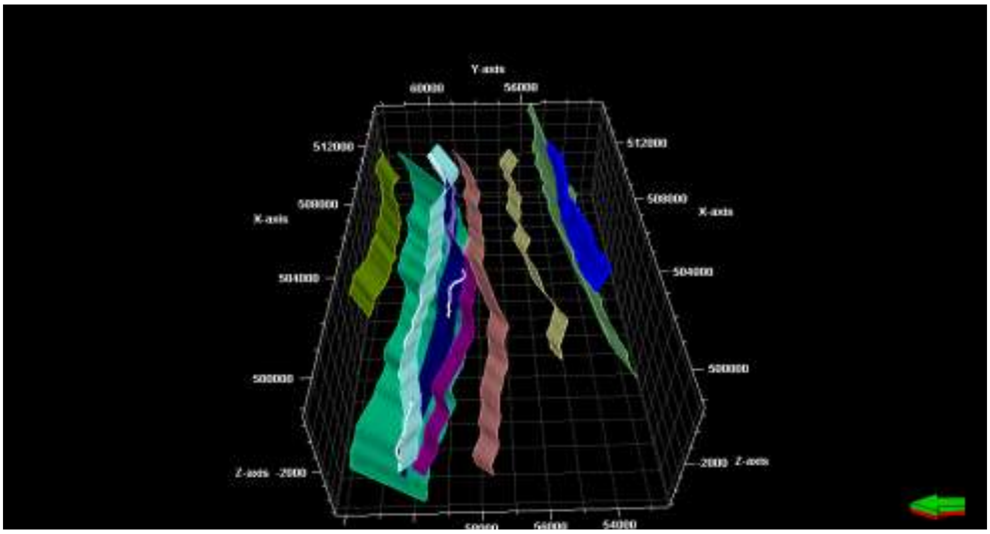

Figure 7. Mapped Fault patterns across inlines

Horizon Mapping: On achieving a good seismic to well tie (Fig. 8), horizons were picked along the inlines and the crosslines (Fig. 9). The use of a realized seismic volume ensured that the seismic traces were very coherent all through the horizon modeling process.

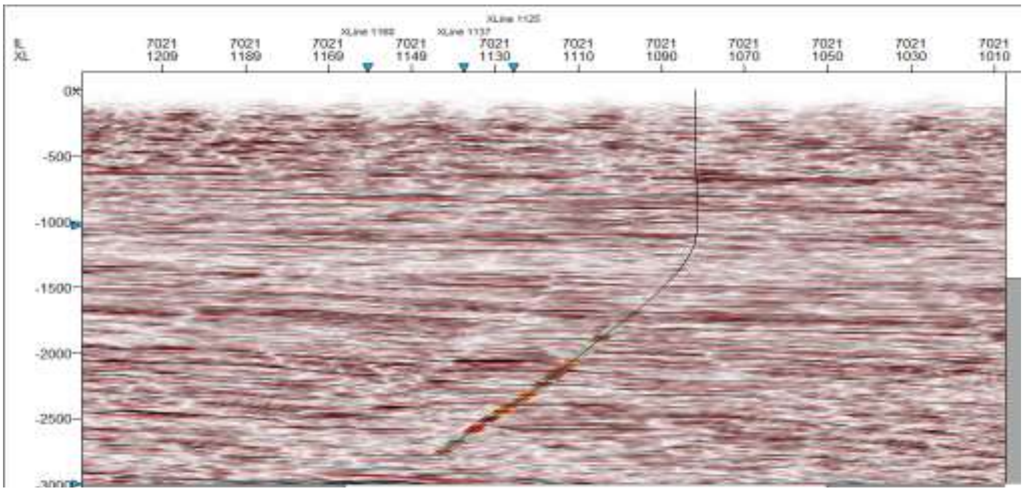

Figure 8 Achieved Seismic to Well tie

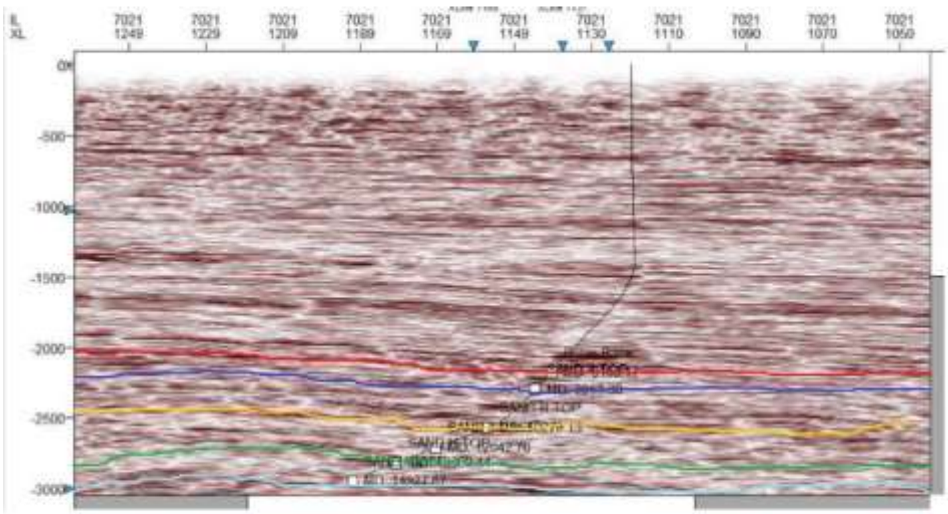

Figure 9. Interpreted Horizons

Pillar Gridding : To get out the shape of the reservoir, an external grid was created (Fig. 10). The generation of structural model done in the process of pillar gridding preserves a small amount of features from well logs and seismic data. The modeled faults were also used for this process. The result of this pillar gridding was a 3D grid with its Top, Mid and Base skeleton; which represent the top, mid and base shape points of the key pillars of the modeled faults.

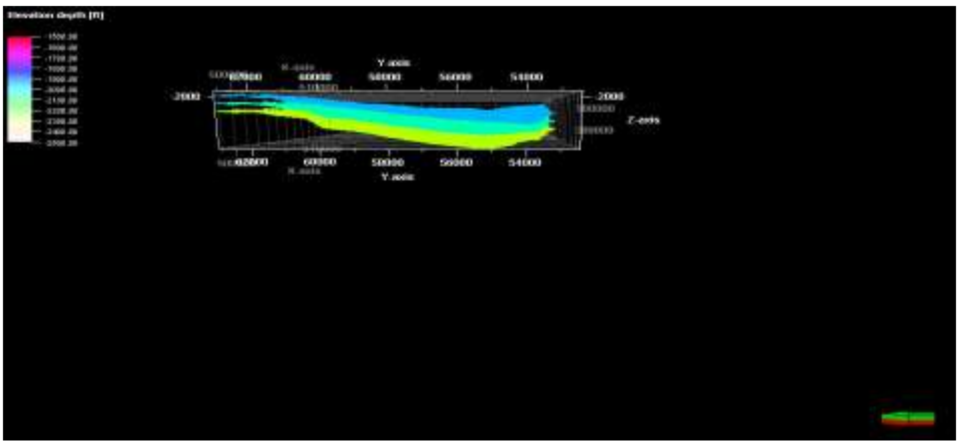

Figure 10. Pillar grid showing the top, middle and base skeletons.

Zonation: Through the aid of the generated horizons, the division of the structural model into zones corresponding with the lithostratigraphic zones was also possible (Fig. 11).

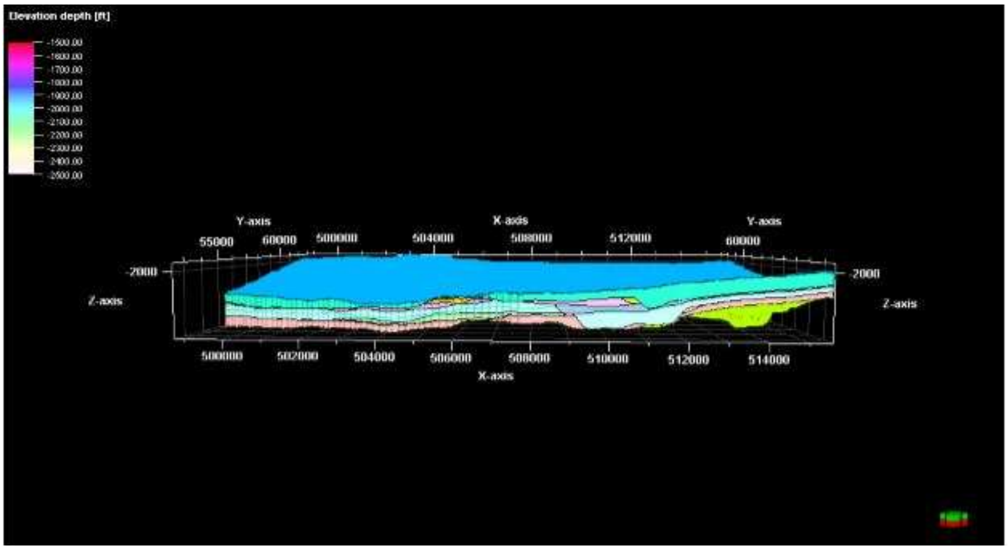

Figure 11. Zonation results in the generated model

V. CONCLUSIONS

A detailed study of X field, offshore Niger Delta revealed the stratigraphic framework and the hydrocarbon bearing reservoirs. The dataset used included 3D time migrated seismic volume, checkshots, 42 wireline log information for six wells. The study set out to build a 3D model consistent with structural and stratigraphic principles.

The well logs were interpreted and correlated. Identification of the sand packages was based on the lithostratigraphic correlations across the entire well by the use of the GEOGRAPHIX software. The seismic data was interpreted using the PETREL software. The well-to-seismic tie identified the horizons on the seismic volume. Interpretation was done to establish the reservoir tops and bases. The porosity, water saturation, net-to-gross and the volume of shale were also estimated.

The project built a 3D model for X field which identified laterally extensive sand packages. Five hydrocarbon bearing sands (A, B, C, F and G) were identified on the logs. Reservoir G was the thickest and most laterally extensive. The hydrocarbon saturation range of 51% to 79% also represented good petrophysical properties.

I recommend the sourcing of Biostratigraphic data to further correlate the wells. This is because Biostratigraphic information holds one of the most valid and traceable trends that can be propagated across the entire well. This would aid the proper understanding of the displacement of hydrocarbon bearing sediments over time.

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