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Research Article

STRUCTURAL ANALYSIS OF SEISMIC REFLECTORS AND PETROPHYSICS OF 'BUMA' FIELD NIGER DELTA

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ABSTRACT

This work was targeted at analyzing structural sound-wave reflectors along with petrophysical features of BUMA oil-based area Niger Delta. The researcher combined well-records from 6-wells and sound-wave data in this work to evaluate and ascertain geological features of reservoir rocks within this study area in Niger Delta. The well-records and sound-wave details were inserted into Petrel software as data analyzer. The well-record data was employed to ascertain Petro-physical and reservoir features which comprises of bed boundary delineation, shale and sand sequence modelling, porous/permeable for possible reservoir sand bodies that were crucial in area of well-to-well connections and volumetric assessment. The variables used are processes and interpreted to ascertain hydrocarbon (HCs) capability across these wells. Two reservoir area were defined and connected across this area and ranked based on average results from petrophysical features. Reservoirs D5000 and E1000 were noted as good reservoirs because of their Petro-physical features in terms of porosity, permeability and water saturation. Petrophysical features of HC producing area outlined in well D5000 was 14% porosity, 1450mD permeability along with 40% HC saturation. Also, well E1000 showed 15% porosity, 1680MD permeability and 13% for HC saturation. The sound-wave details being tool for sound-wave analysis was utilized to structural sound-wave interpretation for faults and trap system for HC pore fluids in this area. However, seven faults were ascertained from sound-wave sections and labelled F1-F7. The structural sound-wave assessment of reflectors aided in exposing faults undetected because of poor resolution. The sound-wave details were equally deployed for well-to-seismic connections along with details from check-shot. The outcome from STTOIP for reservoir D5000 was 62mmstb and reservoir E1000 was 67mmstb. From these outcomes well E1000 is more productive compare to well D5000 and this field has producible oil.

INTRODUCTION

Background to the Study:

The research on the procedure and pattern that create reservoir underneath the ground level of the earth is called structural analysis. (Tear-pack and Bisch, 2002 and Rowland, 2013). It equally comprises of analyzing procedures that might have deformed sediment fill that occupy the reservoir. The fundamental of sound-wave structure analysis is structure explanation of sound-wave data. Sound-wave details and information composed of three part (Liner, 2004): The time taken for sound-wave energy to move, the length of the involved sound wave, and information concerning sound-wave form are elements to monitor and consider.

But the first out of these four features are employed in sound-wave structural analysis, however four of them should be utilized in stratigraphic assessment. Explaining faults on reflected sound-wave pictures is the main heart of sound-wave structural analysis. The foundation to understand faults using reflected sound-wave details is to detect reflection continuation and termination style. The structural context of this study area is ascertained by space-based geometry of these faults, which serves as the foundation for structural analysis. (Achyuta and Soumyajit, 2018).

Statement of the Problem:

Several scientists and reservoir engineers from around the globe collaborated on design of numerous models which they believe would be very helpful tin attempt to have better understanding of structure-based architecture and reservoir features characteristics. Also, using sound-wave reflectors and their corresponding amplitude responses in underground model simulation based on geophysical fundamentals and principles on reservoir rocks will contribute appreciable to present geology of this studied region.

Aim and Objectives of the Study:

The goal of this study is to analyze and interpret sound-wave reflectors, and also their petrophysical features, in connection to probable reservoirs in Niger Delta's Buma' field.

The objectives of this research include:

1. To model possible well-to-well correlation of reservoir sand from well record data

2. To utilize the ascertained well record models obtained or generated from recorded signatures for lithological analysis;

3. To map faults and sound-wave horizons with the aid of sound-wave reflectors (structural analysis)

4. To evaluate petrophysical properties of the reservoirs delineated across 'Buma' field Niger delta.

Scope of the Study:

The scope of this research is limited to the use of well-records and 3D-sound-wave for the interpretation structure-based sound-wave reflectors and petrophysical assessment (pore fluid) of hydrocarbon zones.

Theoretical Frame-Work of Sound-wave Reflection:

Exploration seismology has been used extensively in natural resources exploration (Sheriff and Geldart, 1995; Dentith & Mudge, 2014). Sound-wave exploration is among the geophysical technique which involves mirroring underground layers using artificially produced sound wave data. Ground level recording gadgets also called geophones are utilized to detect possible reflected sound energy that come from certain sound source (dynamite explosion) which flow down into underground earth ground level layers and partially reflected to earth ground level at different geological bounds. The sound records generated from field study unavoidably contain some reflected signals from underground underlaying rocks and equally contains numerous forms of unwanted noise. Thus, during data assessment and processing such as migration, deconvolution and stacking procedures, several unwanted impacts are eliminated or reduced to nearest minimal level. Sound-wave reflection explanation involves structure-based analysis and sound-wave sequence procedure and involves tracking appreciable geological bound and producing notable and needed two-way-time (TWT) horizon ground levels. These TWTs ground levels, as well as sound-wave volume itself, could be employed to create high-definition structure-based maps, pinpoint anomalies in stratigraphic patterns and give or present detailed fault information.

Benefits and Limitations sound wave reflection:

The main benefits noticed in the use sound-wave tool are given below:

1. The tool could give correct depth-structure model for bottom of water when sound speed are correctly used.
2. Utilization of Post-acquisition procedure

The main limitations of sound-wave tools are:

1. Both sound-wave source along with corresponding receiver must be underwater and this pattern cannot be used across emerging sand on shore.
2. The tool involved is appreciably costly
3. Data could be infiltrated by noise
4. Post-acquisition procedure could be needed in places where appreciable structure relief is available.

These sound-wave tools are equally employed in spot study modelling. For these forms of study, sound data are needed at irregularly and non-form spaced intervals at water ground level. The initial high-amplitude which reflect event is mostly explained as water-bottom reflection. Notice that these spot data mostly can never be correctly moved because of aliasing issues.

Stratigraphy of the Niger Delta:

This are could only be generalized from exposed and settled Cretaceous layer in corresponding basin to northeast--Anambra area. From Campanian period down to Paleocene period, shore path was naturally in concave form and moved down to Anambra area (Hospers, 1965) which result to convergent long shone drift that created tide-dominant deltaic sediment during wrongdoings and river-dominant sediment during deteriorations (Reijers and others, 1997). Shallow water-based clastic were accumulated farther more and within current Anambra area and this was expressed by "Albian-Cenomanian Asu River shale, Cenomanian-Santonian Eze-Uku and Awgu shales, and Campanian/Maastrichtian Nkporo shale, among others (Nwachukwu, 1972; Reijers and others, 1997). The distribution of Late Cretaceous shale beneath the Niger Delta is unknown". During Paleocene period, the main transgression also called Sokoto transgression according to Reijers et al (1997) started with Imo shale which was accumulated within Anambra area towards northeast and Akata-shale towards Niger Delta area towards southwest. During Eocene period, coastline vert became convexly rounded, long shore deviate and switch to converge, and sediment changed and altered to become wave-dominant (Reijers et al, 1997).

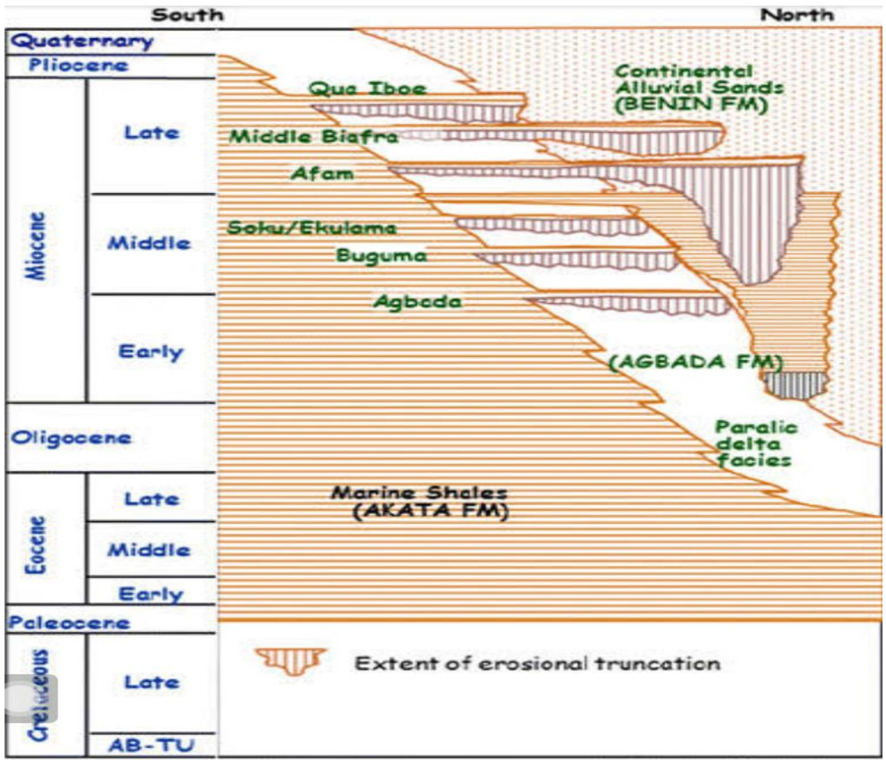

Figure 1: Stratigraphy of the Niger Delta

Petroleum System of the Region:

The Niger-delta, oil window which is expressed as source-rock interval lies within top end of Akata basin and low end of Agbada FM. To southern west end, upper part of oil window is low stratigraphically around 4000' lower than upper end of Akata lower end Agbada section; Evamy aet al, 1978). Some scholars like Nwachukwu and Chukwure, 1986; Doust and Omasola, 1990 and Stache 1995 linked this distribution on top of this oil window to thickness and sand/shale proportion of overburden sediment which comprised of Benin Fm. and Agbada Fm. Sandy continental residue possess lowest heat gradient; paralic Agbada Fm. Possess certain intermediate heat gradient and marine, hyper-pressured Akata Fm possess highest heat-based gradient (Ejedawe et al, 1984). Therefore, within these deposit-belt, depth for temperature is based on gross sand/shale distribution. If sand/shale proportions are the only factors, then distal water-based underground temperatures will be increased because sand proportion are low. Contrary to this, depth of HC kitchen section is supposed to be deep compare to delta proper being that depth for oil generation involved integration of factors such as time, temperature, distortion arising from tectonic impact (Beka and Oti, 1995).

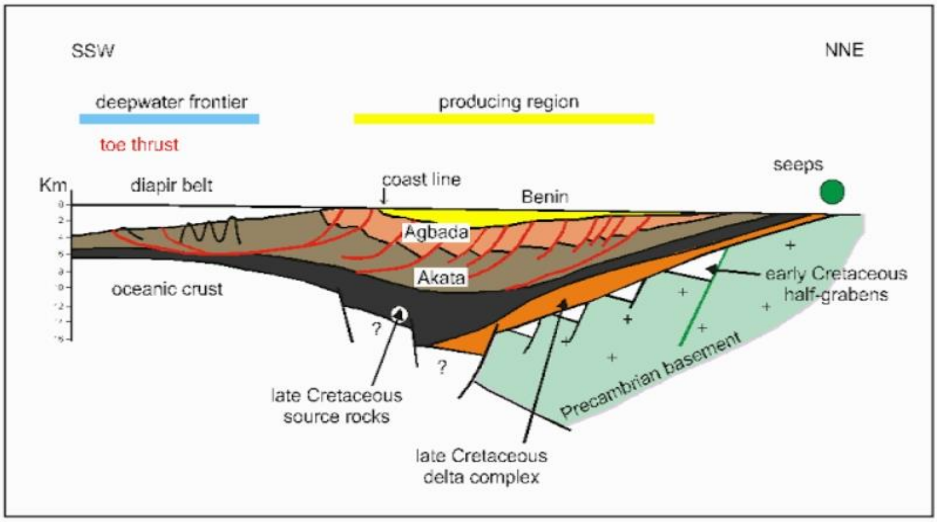

Figure 2: Petroleum System of Nigeria's Niger Delta

Area of Study:

The study area BUMA FIELD is located around Latitude 5°56'0" E, 6°8'0"E and longitude 4°59'0" N, 4°50'0" N.

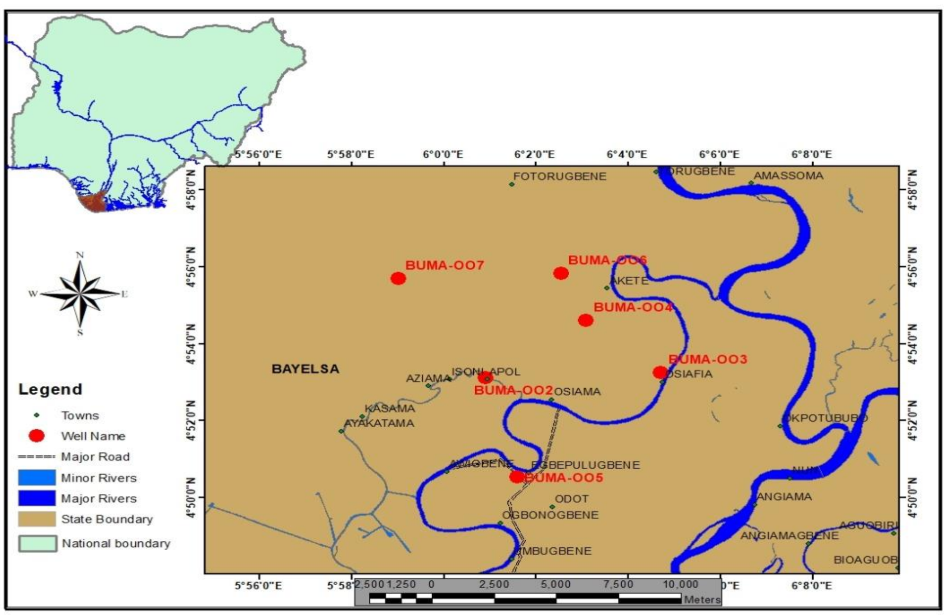

Figure 3: Location Map of Study Area

MATERIALS AND METHOD

Data Set:

The principal project data used are Sound-wave Seg-Y Data, well-logs which comprises of Gamma-ray, Density-log, Neuron-log, sonic-log and Resistivity-logs. Check shot data for time depth conversion and well formation (well coordinates and deviation).

RESULTS AND DISCUSSIONS

The results from the study show that Sound-wave data and the Well-log data were properly integrated for characterization this Buma field reservoirs.

From analysis dome on well-logs, models were generated from which reservoir sands typical of Agbada Fm in Niger Delta basin is shown by deflection of GR log signature to the left, bed boundaries between shale and sand lithologies, porous and non-porous beds as well as other geologic features were accurately determined and well-correlations carried out FIG

On sound-wave section, structure-based interpretations were conducted out in which seven major faults were identified, FT 1, FT 2, FT 3, FT 4, FT 5, FT 6 and FT 7. The faults trend in East-West direction whereas others trend NE-SW and NW-SE. Also identified were two HCs bearing horizons “D5000” and “E1000”

A synthetic seismogram was generated using check shot data not just to match peak to peak or trough to trough but also to create well-to-sound-wave tie (fig. 3.9). The sound-wave horizons were used to create time Ground level maps which were used to convert to depth ground level maps using the T-Z curve (figs. 3.14, 3.15, 3.16, 3.17 and 3.18).

A 3-D static reservoir model of two reservoirs “D5000” and “E1000” was also established showing the positions of the six Buma wells and how they penetrate the reservoirs (fig. 3.21). Petrophysical analysis of two reservoirs D5000 and E1000 was done and average petrophysical features are as follows:

Reservoir D5000 has thickness of 108 ft., porosity (0.1380 in fraction), water saturation (0.3816 in fraction), Net-to-Gross (0.5108 in fraction), permeability (1463 md) and STOOIP (61.94mmstb).

Reservoir E1000 has thickness of 126 ft., porosity (0.1456 in fraction), water saturation (0.1322 in fraction), Net-to-Gross (0.4341 in fraction), permeability (1678 md) and STOOIP (66.71mmstb) (Table 4.3).

Parameters for qualitative evaluation of permeability:

AVERAGE K VALUE (md)	QUALITATIVE DESCRIPTION
<10.5	POOR TO FAIR
15 – 50	MODERATE
50 – 250	GOOD
250 -1000	VERY GOOD
>1000	EXCELLENT

Table 1: Parameters for qualitative evaluation of permeability

PERCENTAGE POROSITY (%)	QUALITATIVE DESCRIPTION
0 - 5	NEGLIGIBLE
5 – 10	POOR
15 – 20	GOOD
20 – 30	VERY GOOD
>30	EXCELLENT

Table 2: Parameters for qualitative evaluation of porosity

RESER VOIR	AREA (acre)	THICKNES S (ft)	POROSITY (frac)	WATER SATURATI ON (frac)	NET – TO – GROSS (frac)	K (md)	STOOIP (mmstb)
D5000	2234	109	0.1374	0.3915	0.5109	1453	61.95
E1000	1873	126	0.1456	0.1322	0.4341	1678	66.71

B_{oi} =1.66

Table 3: Average Petrophysical Properties for Reservoirs D5000 and E1000 with STOOIP

Petrophysical Properties and Volumetric Analysis of the Reservoirs:

In carrying out petrophysical evaluation of reservoirs, porosity and permeability are two important properties to be considered which leads to estimation of water-saturation, Net-to-Gross and STOIIP for each of two reservoirs (Table 1). For reservoir sand units to contain appreciable quantity of HCs pore fluid there has to be good thickness, porosity and permeability values along with low water-saturation. From petrophysical analysis, it is observed that two reservoirs exhibit these petrophysical features but E1000 reservoir appear to be best having massive thickness, porosity, permeability and lower water-saturation values than D5000 reservoir making its STOIIP value (66.71mmstb) greater than of D5000 reservoir (61.95mmstb).

All petrophysical results were generated in petrel from logs using these algorithms:

IGR= (GR-10)/ (110-10)

VSH=0.083*(POW (2, (3.7*IGR))-1)

Poro= (2.65-RHOB)/ (2.65-1)

Sw_ud=0.082/Poro

NTG=If (Poro<=0.2 and VSH>=0.2, 0, 1)

PermX=307+26552*(Pow(Poro,2))- 34540*Pow((Poro*Sw_ud),2)

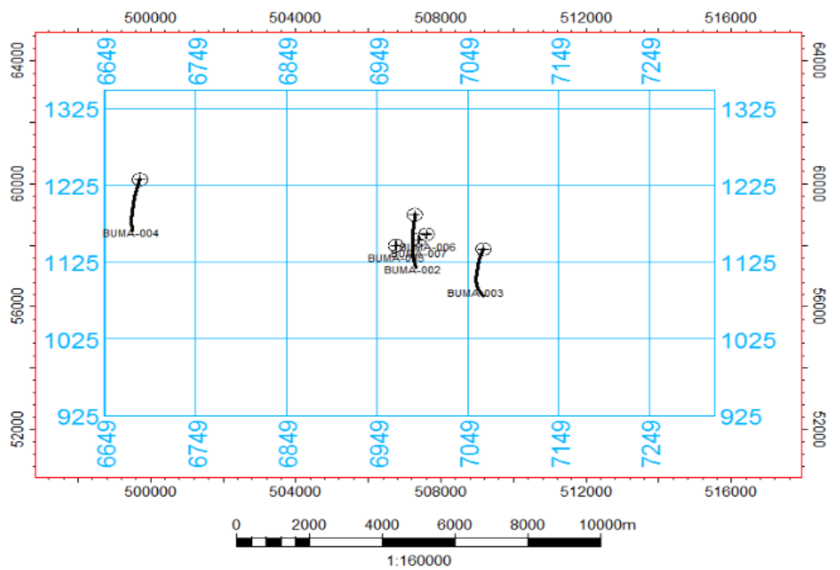

Figure 4: Base map of wells drilled in the study area

Data Loading and Analysis:

The sound-wave and well data were originally loaded into Petrel Software from which base map, sound-wave section and digital data were extracted and used for further analysis. The base map is comprised of grid lines that surrounds six-well in field at their individual coordinates created by trace cross-correlation through various wells

Data Quality Assessment:

The data set obtained was crosschecked for to ensure they are suitable in terms of quality and to prevent possible challenges on the data. During this crosscheck for quality, different issues where noticed: Only few well has sonic and check shot. BUMA 004 and 002.

Some aspects of this sound-wave data analyzed were noisy and appears as if some aspects analyzed were cut and joined resulting to unexpected discontinuity of structure-based trends.

Lithology Determination:

The reservoir interval was chosen or selected using group of lithologic-log (Gamma ray), and resistivity log (LLD). The reservoir sand was identified by a low gamma ray contrast and a high resistivity contrast.

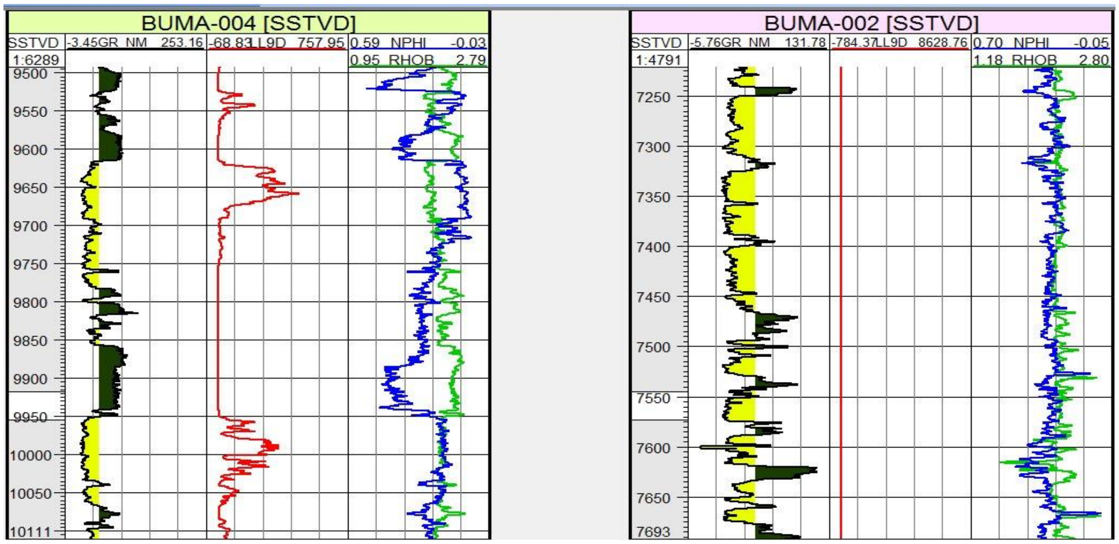

Figure 5: lithology determination

Well Correlation:

Correlation is mapping or mirroring of lithology across well profile in any study area. It is the creation of this link between one well and another. Well-correlation is carried out to ascertain structure and stratigraphic strata that have time, age and stratigraphic equivalence. This is done by recognizing some patterns on well-logs and matching them with adjacent wells from one well to another. The signatures from gamma-ray indicate type of lithology in which left-hand deflection indicate sand sections whereas the one to the right shows a shale unit.

Underground data like lithology, reservoirs, formation-tops and bases, porosity, and permeability of production area are available from well correlation. Well correlation also helps in determining lateral and vertical continuity of sands within the study area. Well log correlation was done for six well. (Buma: 02, 03, 04, 05, 06, 07). The correlation was done at defining lateral continuity and thickness of the sand existent in the wells.

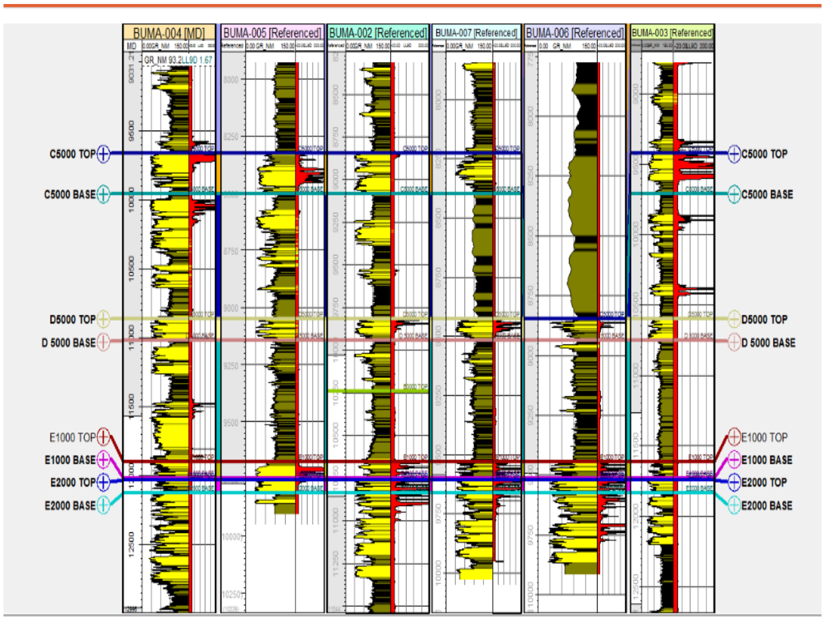

Figure 6: Well correlation of GR and Resistivity log for all the wells.

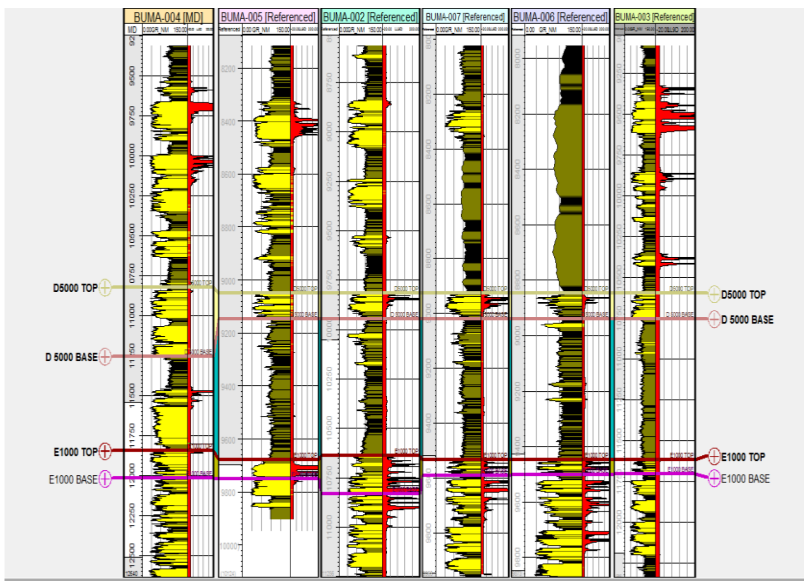

Figure 4.7: A plot of GR and Resistivity-log that show reservoir D5000 and E1000

Three reservoirs where encountered E1000, D500 and C5000, but the C5000 at various depth. Reservoir C5000 lacked lateral continuity, therefore it was neglected.

Well-To-Sound-Wave Tie:

Well-to-sound-wave tie is done to establish changes of sound-wave feature as stratigraphy changes across basin as well as connections between sound-wave events and their boundary ground levels or sequences. There is advanced technique of well to sound-wave tie which is termed Synthetic Seismogram. Well-logs provide vertical resolution that highly greater than that obtainable with sound-wave data. They could be useful to identify certain deposition features (channels, Para sequences, etc.) that may have been poorly resolved sound-wave all. Conversely, sound-wave data provides dense lateral control that allow faults and pinch-out which cannot be identified using well control alone to be interpreted.

Synthetic seismogram is created by computing reflectiveness series based on time from layered sound-wave impedances (Kearey and Brooks, 2000). Synthetic seismogram create means for tying well-log data with actual sound-wave record and thus giving geologic meaning to sound-wave data (Sheriff, 1997). Synthetic seismogram will aid to identify reflections and to determine sound-wave events that are related to particular bound ground levels or sequences.

The process pin in petrel was selected and several variables for generating synthetics and tying it to sound-wave were inputted using check-shot, well Buma 004. Well tops D5000 and E1000 show that synthetic was tied with sound-wave volume as expected (Fig 3.9). Tying well-Log to sound-wave, the check shot data was used by loading the TWT (two way travel time) and velocity. Since, velocity = distance/ time

Where TWT = (time) 2

Also, the particular sand Top on the sound-wave section was identified through the guidance of the well log kicks indicating HC bearing sands.

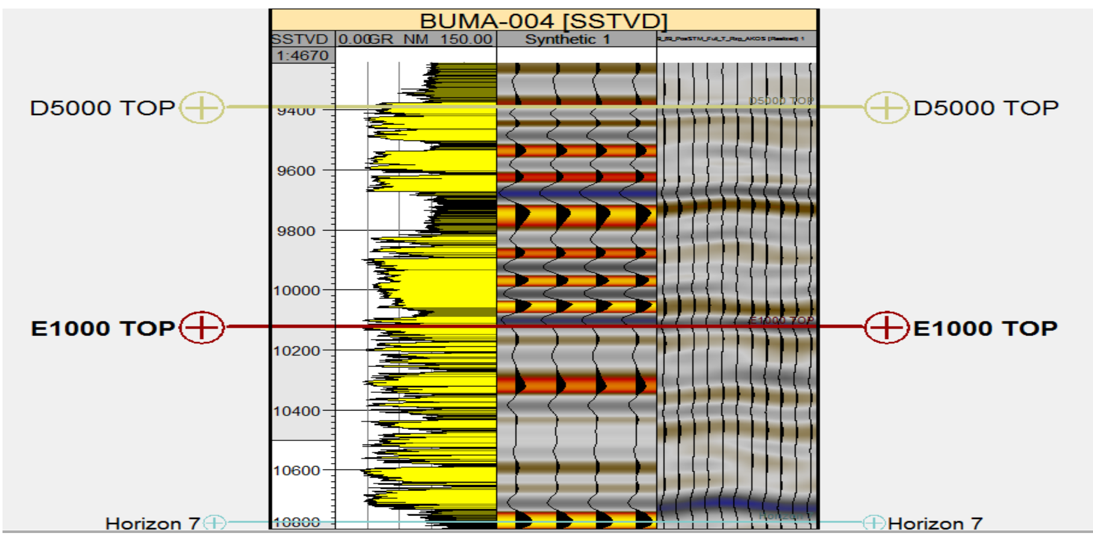

Figure 7: Showing Sound-wave to well tie using well 004 of Buma Field

Structural Analysis:

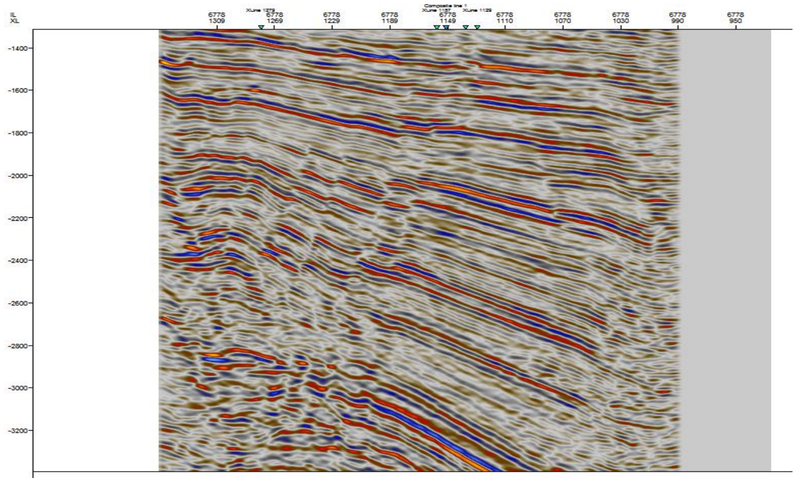

Figure 8: Showing Sound-wave section

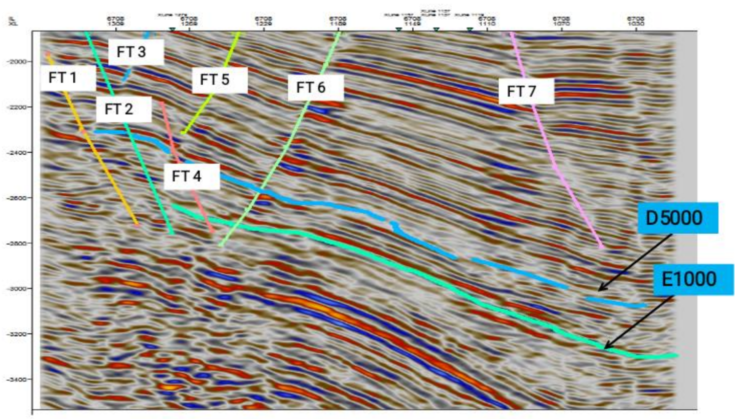

Figure 9: Sound-wave inline 6708 showing Fault and Horizon Mapping

Check-shot:

The check shot is T-Z (Time-Depth) curve used to convert sound-wave data which is in time to depth that is from time map to depth map

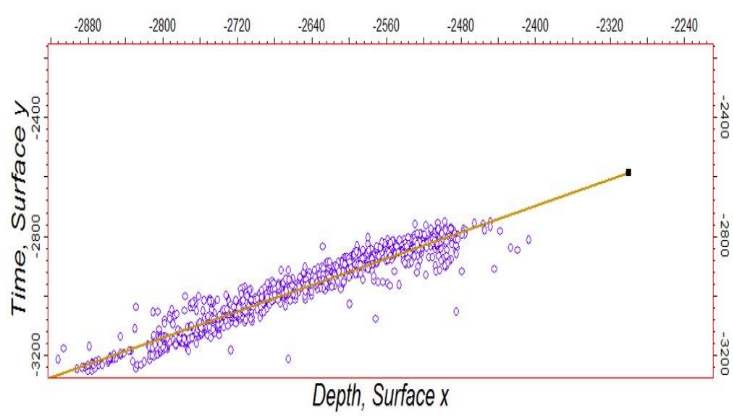

Figure 10: T-Z CURVE: Check shot plot

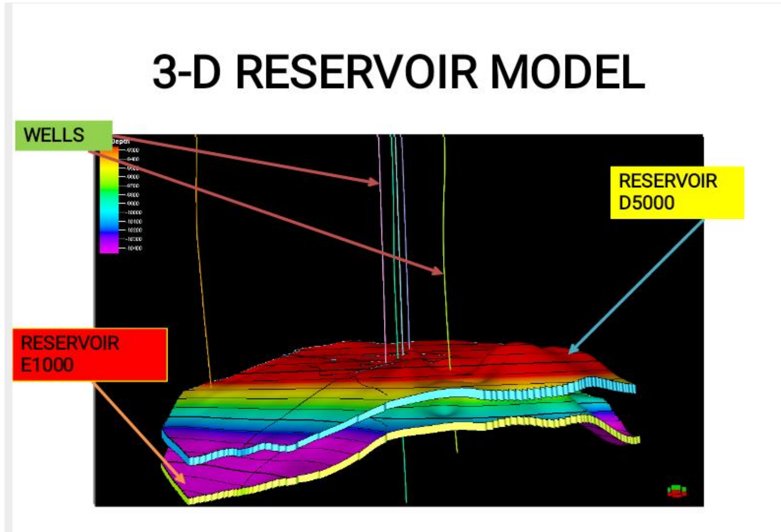

Figure 11: 3-D Reservoir Model Showing the Positions of the six Buma Wells and the two Reservoirs D5000 and E100

Summary of Findings:

From sound-wave interpretation of Buma field, area is associated with seven main faults (growth faults) typical of structure-based faults common within Niger Delta which may have contributed to trapping of HC pore fluid in these reservoirs D5000 and E1000 respectively.

The well-log analysis shows models where signatures from GR-log deflecting to right (dark green) indicates shale sequence whereas deflection to left (yellow) depicts reservoir sand units. Furthermore, petrophysical analysis of these two reservoirs D5000 and E1000 shows low water saturation, good thicknesses, porosities, permeability, net-to-gross, and STOIIP values for two reservoirs. These values further proof prolific nature and economic viability of reservoirs most especially E1000 reservoir (Table 4.1). This work was targeted at analyzing structural sound-wave reflectors along with petrophysical features of BUMA oil-based area Niger Delta. The researcher combined well-records from 6-wells and sound-wave data in this work to evaluate and ascertain geological features of reservoir rocks within this study area in Niger Delta. The well-records and sound-wave details were inserted into Petrel software as data analyzer. The well-record data was employed to ascertain Petro-physical and reservoir features which comprises of bed boundary delineation, shale and sane sequence modelling, porous/permeable for possible reservoir sand bodies that were crucial in area of well-to-well connections and volumetric assessment. The variables used are processes and interpreted to ascertain hydrocarbon (HCs) capability across these wells. Two reservoir area were defined and connected across this area and ranked based on average results from petrophysical features. Reservoirs D500 and E100 were noted as good reservoirs because of their Petro-physical features in terms of porosity, permeability and water saturation. Petrophysical features of HC producing area outlined in well D500 was 14% porosity, 1450mD permeability along with 40% HC saturation. Also, well E100 showed 15% porosity, 1680MD permeability and 13% for HC saturation.

The sound-wave details being tool for sound-wave analysis was utilized to structural sound-wave interpretation for faults and trap system for HC pore fluids in this area. However, seven faults were ascertained from sound-wave sections and labelled F1-F7. The structural sound-wave assessment of reflectors aided in exposing faults undetected because of poor resolution. The sound-wave details were equally deployed for well-to-seismic connections along with details from check-shot. The outcome from STTOIP for reservoir D500 was 62mmstb and reservoir E100 was 67mmstb. From these outcomes well E100 is more productive compare to well D500 and this field has producible oil.

In conclusion, these two reservoirs “D5000” and “E1000” which are typical of Agbada formation within Niger-Delta basin constitute better pore fluids within reservoirs considering fault traps (growth faults) observed from structure-based interpretation of sound-wave data together with analysis of well-logs and their petrophysical features (porosity, permeability, thickness, net-to-gross, water-saturation values). Perforations could be carried out in process of drilling. The reservoirs are capable of producing good flow rates and can store quite appreciable volume of hydrocarbon as a result of their porosities and permeability.

Therefore, the reservoir sand units are prolific and can be explored for hydrocarbon and show their economic viability

CONCLUSION

In conclusion, the two reservoirs “D5000” and “E1000” which are typical of the Agbada formation in the Niger Delta basin constitute better pore fluids within the reservoirs considering the fault traps (growth faults) observed from the structural interpretation of the seismic data together with the analysis of the well logs and their petrophysical properties (good porosity, permeability, thickness, net-to-gross, low water saturation values). Perforations can be carried out in the process of drilling. The reservoirs are capable of producing good flow rates and can store quite appreciable volume of hydrocarbon as a result of their porosities and permeability.

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