International Journal of
Science Inventions Today
www.ijsit.com
ISSN 2319-5436
Research Article

SEISMIC AND PETROPHYSICAL CHARACTERIZATION OF SELECTED WELLS, NIGER DELTA

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ABSTRACT

Integrated 3-D seismic and petrophysical studies were carried out to enhance the characterization of the reservoirs in Hons field in the Lower Niger Delta. Available data include petrophysical logs (such as GR log, SP log, resistivity log, neutron and density logs) to enable appropriate characterization. Seismic data of SEG-Y format provided critical input for velocity analysis and structural seismic interpretations. The faults picked from the seismic section are normal faults which trend NW-SE direction, and can enhance the trapping of hydrocarbon as they serve as good hydrocarbon traps in the Niger Delta.. Synthetic seismogram was produced not only to match possible peak for peak and trough for trough in the area, but also to create a well-to-seismic tie. Petrophysical properties were determined for four wells in Hons field which penetrated two reservoirs of "F" and "L". The average petrophysical properties of reservoir "F" are pay thickness (137ft), porosity (18.47%), permeability (1085md), Net-to-Gross ratio (0.4371), oil saturation (55.88%) and stooip (65.41mmstb). And the average petrophysical properties of reservoir "L" are pay thickness (120ft), porosity (21.55%), permeability (1426md), Net-to-Gross ratio (0.7134), oil saturation (62.26%) and stoiip (65.19mmstb) respectively.

INTRODUCTION

Reservoir characterization is a process of describing various reservoir characteristics using all available data to provide reliable reservoir models for accurate reservoir performance prediction. It must be based on information from seismic reflection times, amplitude versus offset (AVO). Attributes, velocity data, seismic trace analysis and well logs and core analysis data. These subsurface data are integrated to predict the distribution of the reservoir variables. The need for proper integration of 3-D seismic model with petrophysical data to improve exploration success has been in use in the petroleum 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 reservoir management practices (AAPG Bulletin, 2005). To develop better models of reservoir properties and their distribution in Hon's field of the Niger Delta province, this study integrates 3-D seismic interpretation, rock petrophysical properties and their distribution to provide reservoir models for predicting reservoir performance.

The reality now is that oil-gas reservoir can be subdivided into architectural elements or compartments on the basis of several structural and stratigraphic features.

(A) AIM AND OBJECTIVES: The aim of this study is to integrate 3-D seismic and petrophysical data for the characterization of Hon's field, Niger Delta.

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(B) LOCATION OF STUDY AREA: Hon's field in Amukpe is within the greater Ughelli depobelt of the Niger Delta oil province, Ogwashi-Asaba formation. It is located within Longitude 05^{0}41'27"E to 05^{0}42'05"E and latitude 05^{0}51'55"N to 05^{0}52'03"N (Figure 1) on the Western part of the Niger Delta. This field contains four onshore wells: Gamin 2, Gamin 7, Gamin 9 and Gamin 11.

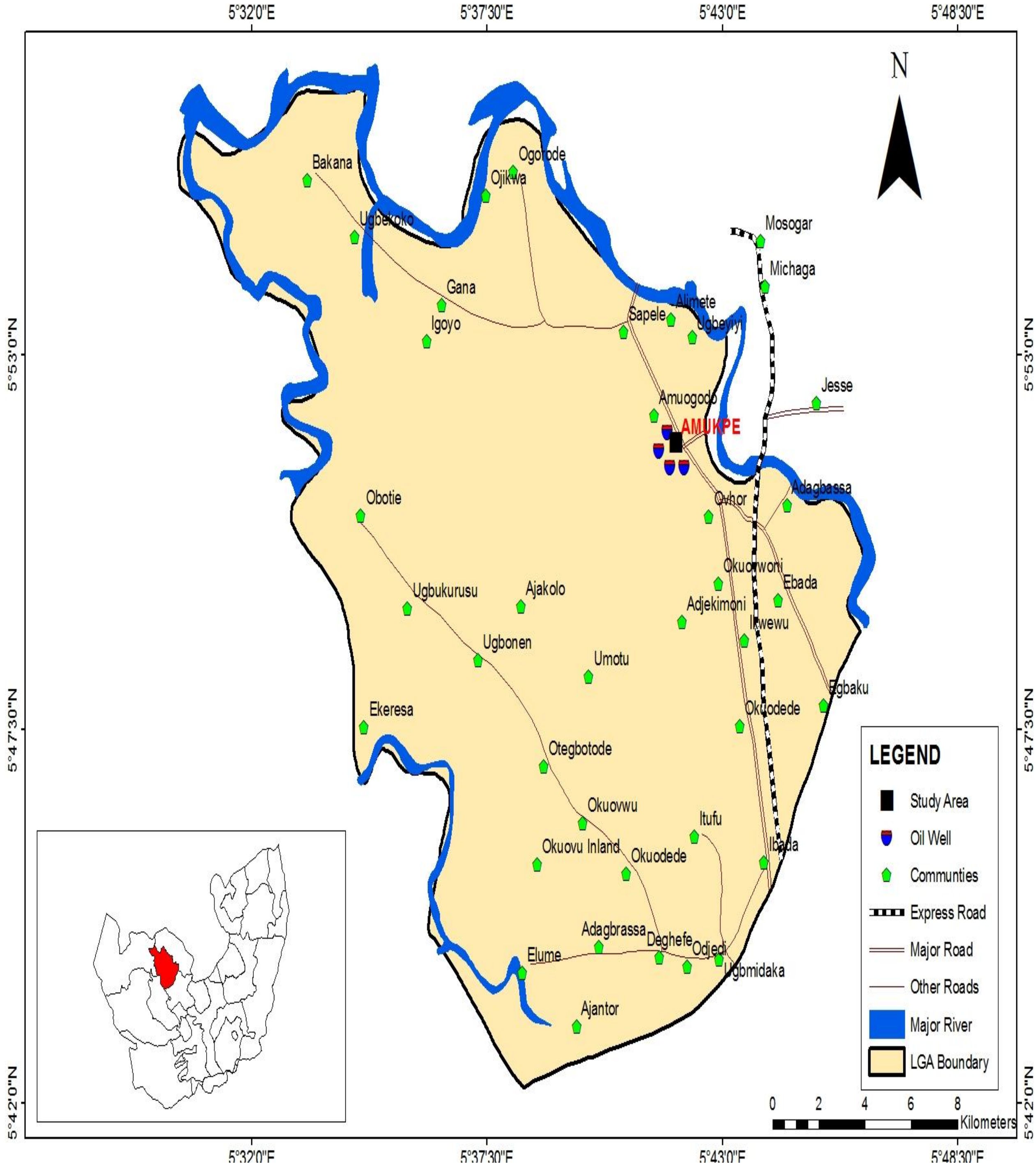


Figure 1: Map of Sapele Local Govt. Area, Delta State showing the Study Area

(C) LITERATURE REVIEW: Stonily (1966) and Burke. (1970 and 1972) analyzed and discussed the mega tectonics of the Niger Delta. The sedimentary tectonics of the tertiary delta was extensively described by Merki (1972) and Evamy. (1978). According to Burke (1972), the modern Niger Delta has three well developed submarine channels and numerous smaller gullies which extended from the mouth of the delta to the abyssal plain. Several other paleochannels have been recognized by Murat (1972); Omatsola and Cordey (1976) and Peters, (1984). Clay deposits have been identified in several of the paleochannels as important regional seal within the Niger Delta complex. These clay deposits have been identified as regional seismic marker horizons in the shallow offshore and could be used to correlate stratigraphic events (Beka and Oti, 1995).

On the other hand, Bouvier et al. (1989), report on the three dimensional seismic interpretation by employing fault sealing method in the Nun river field of the Niger Delta. He suggested that the complexities of the subsequent sealing of fault structures were clearly observed and are made plain by day. Furthermore, various theories and discussions have been put forward for the Niger Delta. Another for instance, Frank and Cordry (1967); Weber and Daukoru (1975); they all concluded that the major factors that control hydrocarbon distribution within the field were literal spill-point at the termination of discontinuous faults and seals or lack of seal along fault planes.

(D) STRATIGRAPHY OF THE 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-efetor, 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.

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

Table 1: The Stratigraphical sequence of the Niger Delta. (After Short and Stauble; 1967).

These three formations according to Short and Stable (1967), are locally designated from the bottom as Akata, Agbada and Benin formation respectively. Of all these three formations, the Agbada formation constitutes the main reservoir of hydrocarbon in the Niger Delta province.

(i) BENIN FORMATION: The Benin formation consists predominantly of massive, highly porous, fresh – water sandstones with shale/ clay interbeds. These sediments represent upper Delta – Plain deposits, so that the gravels and sandstones represent braided streams, point – bar channel fills, while shales and clays may represent back swamp – deposits (Weber, 1971). The thickness is variable but generally exceeds 2,000 meters in thickness. (Fig. 2.1) (Weber and Daukoru, 1973) while Merki in his own, attributed that, the formation records 4,000 ft in thickness (Merki, 1970).

(ii) AGBADA FORMATION: Weber and Daukoru (1973); explained the Agbada formation to the consisted of inter – bedded sand shales with a thickness of about 300 -4,500 meters (Table 2.1), (Fig. 2.2); Merki, (1976), suggests that the interbedded sand and shales have a thickness of about 10,000 ft (in the center of the Delta). The sandy parts constituted the main hydrocarbon reservoirs, and the shales, the cap rock, Weber, (1971).

(iii) AKATA FORMATION: The Akata Formation is mainly composed of marine shales with locally sandy and silty beds thought to have been laid down as turbidites and continental slope channel fills. The formation is said to be the main source rock for the Niger Delta complex. Its thickness depends on shale diaprism and flowage which the formation has been subjected to.

METHODOLOGY

(a) DATA BASE: The following data set were used for this work:

- 3-D Seismic data of SEG-Y format
- Well log data
- Checkshot data.

(b) 3-D SEISMIC DATA: Using the in lines and cross lines, the horizon of interest was mapped across the field. Within an inline, all the cross lines that intersected it can be seen, the same holds for all cross lines. Seismic grids were developed as the continuous reflections where picked along the in lines and cross lines. Using the T-Z function, two way times at the tops and bottoms of the horizon were converted into depth. The tops and bottoms of T-Z depths were used to tie log depths to the top and bottom of horizon "F-top" at various wells as well as "L-top".

(c) 3-D SEISMIC DATA PROCESSING: The field data were recorded in a multiplexed mode using the SEG-Y format, the data were de-multiplexed in transposing a big matrix seismic traces recorded at different offsets with a common hotpoint.

The transposing stage is the point in which data are converted to a convenient format used throughout the processing. Also involved is the trace editing where noise is traced with transient glitches or mono-frequency signals are deleted. Finally, the gain recovery function applied on the data to correct for the amplitude effects of wave front divergence. This was carried out on the travel time and processing sample period of 4msec. and re-sampling from 2msec to 4msec was analyzed.

(e) SEISMIC INTERPRETATION: 3-D Seismic data of SEG-Y format was interpreted using Petrel software, where a total of seven (7) normal faults and two (2) seismic horizons were picked across the seismic section. Five (5) normal faults trend in the NW-SE direction, typical to the type of faults in the Niger Delta Province. While the other two (2) trend in the NE-SW direction See figure 3

The major faults are clearly seen from the discontinuities of the reflectors on the seismic section which could be as a result of tectonic or subsurface activities in the area over geologic time.

The interpretation of the seismic horizons was done with the in lines and cross lines of the section. 3-D grid lines were being formed as the seismic horizons were picked. These grids show the displacement of the faults across the section and their trends.

After the picking of the seismic horizons, time surface map was produced which was later converted to depth surface map (i.e T-Z conversion)

(d) WELL LOGS: The well log data consisted principally of a set of wire-line logs gotten from four (4) drilled wells in the field of study.The logs were produced with the use of Petrel software after the data was compiled by Shell Petroleum Development Company of Nigeria (SPDC). Each of these wells constitute the Gamma-ray logs, Resistivity logs, SP logs, Bulk density and Neutron porosity logs.

The Gamma-ray logs were measured in American Petroleum Institute (API) units on a scale of 0-150 API from left to right, the density log measures in g/cc and increases from left to right. The Neutron log is reversed and increases from right to left. The SP and Resistivity logs also increase from left to right.

The Gamma-ray log run in this well (Gamin 7 of reservoir F) penetrated highly porous sand up to a depth of 2985.68m. This shows a deflection to the left of the Gamma-ray curve due to the presence of sand.

The Gamma-ray log was used to record formations radioactivity of naturally occurring elements (such as Uranium, Thorium and Potassium-40). This log can be used to calculate the volume of shale (V_{sh}) in a reservoir sand; to determine porous from non porous beds (i.e to distinguish sand and shale sequences); to determine bed boundaries within the formation and to determine environment of deposition.

Spontaneous potential (SP) log measures the potential difference down the wellbore, with a reference electrode placed at the surface (in a mud pit) and another electrode down the wellbore.

A difference in potential, gives the SP log readings. The SP log penetrated a sand body in Gamin 2 of reservoir "L" at a depth of 3400-3438m. At this depth, the SP log was seen to deflect to the left which is a reducing SP value due to the presence of sand. The sand body was seen to contain shale intercalations.

The SP curve reflects the lithology of the rock as depth increases down the subsurface. It can be used to determine possible environment of deposition from funnel, bell, cylindrical or blocky shape of the SP curve. The log can be use for reservoir correlation of reservoir sands between several wells.

SP logs can be used to show areas within the formation with low or high potential difference, as shales show very low a potential difference compared to sand which shows a high potential difference.

The Resistivity log run in the various wells is the Induction Lateral Log Deep (ILD).

The ILD measures the formation's resistivity deep into the formation (possibly the uninvaded zone). This log is used to determine formation water resistivity, Rw deep into the formation. It shows a deflection to the right (an increased resistivity value) at a depth of 3380-3410m (in Gamin 7 of reservoir "L") which is a possible indication of the presence of oil and gas accumulation within the reservoir formation.

The Bulk density and Neutron porosity logs were utilize to create possible gas balloon structure within the reservoir formation, to show gas-oil contact and oil-water contact. The Bulk density log measures the density of a given formation when the formation is bombarded artificially with a radioactive material while Neutron porosity log measures the concentration of hydrogen index in a formation

PRESENTATION OF RESULT

(d) STRATIGRAPHIC MODELING: In this part, the well logs were produced and read to understand the behavior of the different log signatures which yielded possible interpretations of bed boundaries between the sand and shale sequences, the log shapes which can be used to interpret environment of deposition, distinguish porous and non porous beds, determine areas within the sedimentary units where good resistivity kick can be observed and to give clue about hydrocarbon accumulation and a reasonable well correlation was done for both reservoirs.

(e) WELL TO WELL CORRELATION: This is the determination of structural or stratigraphic units that may be equivalent in time, age or stratigraphic position. It involves pattern recognition on well logs and the matching of such pattern of curves from one well to another. Accurate correlations of well logs are very important for reliable geologic interpretations. This provides subsurface information such as lithology, reservoir thickness, formation tops and bases, porosity and permeability of production zone, etc. (Tearpock and Bishke, 1991). The correlation of wells serves as excellent correlation aid in determining the lateral and vertical continuity of sands within the study area. Major sandstone units and depositional sequences were reviewed using Gamma-ray signatures from four (4) wells. The Gamma-ray, SP and the resistivity logs aided the correlation of these reservoirs across the wells.

Reservoir "F" was correlated at a depth of 2985m across the wells, which shows good thickness of sand units and resistivity kick while reservoir "L" was correlated at a depth of 3423m (.See figure 2)

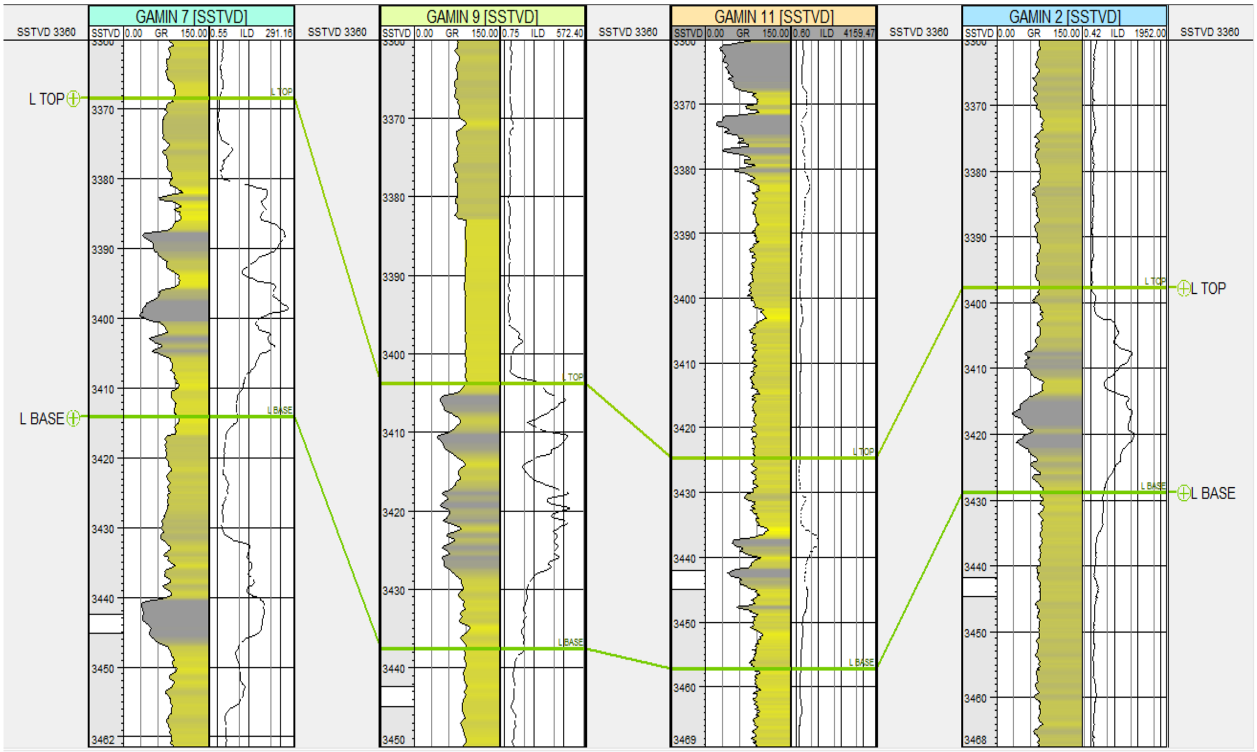


Figure 2: Showing Well Correlation of Reservoir "L".

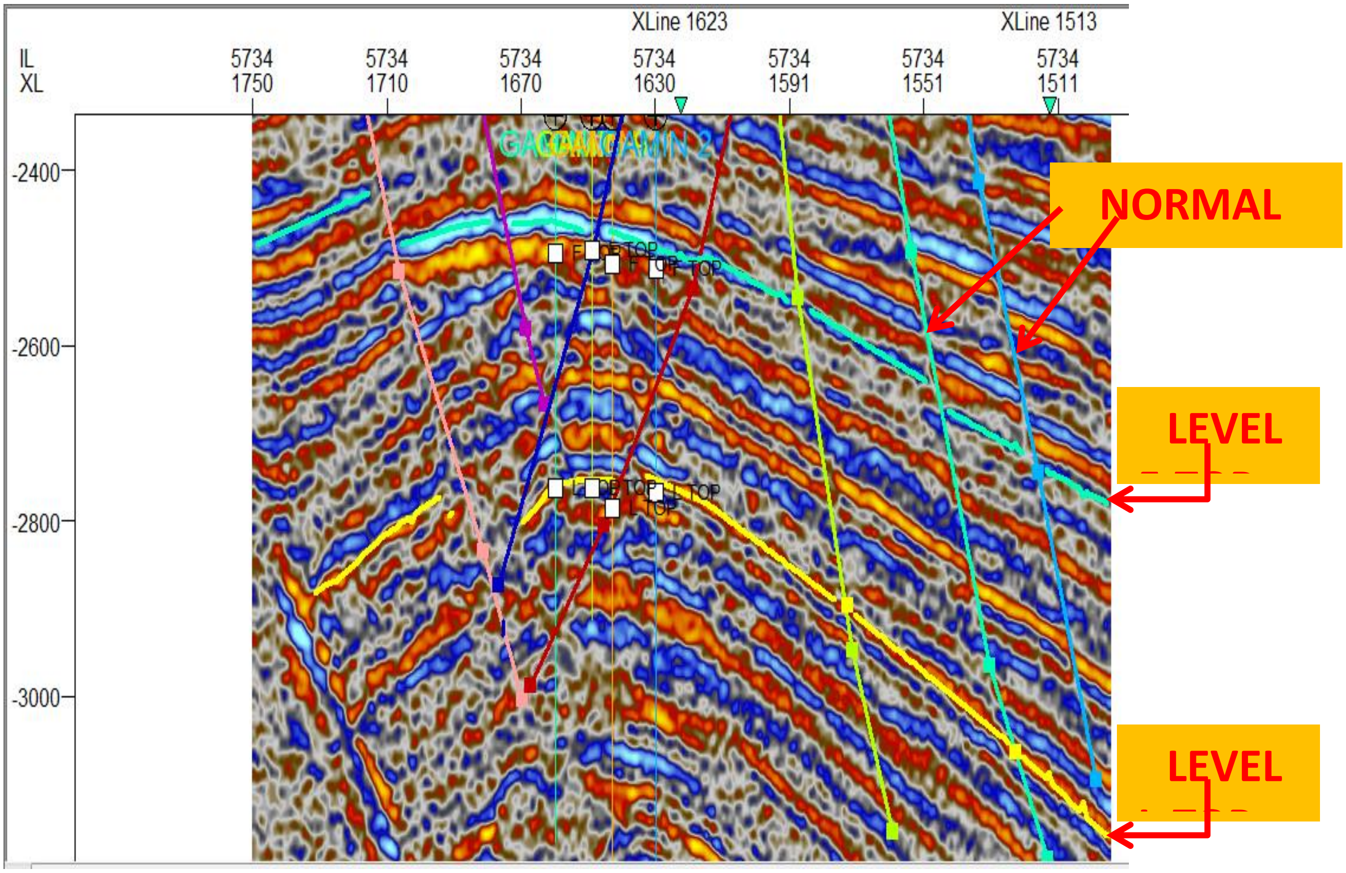
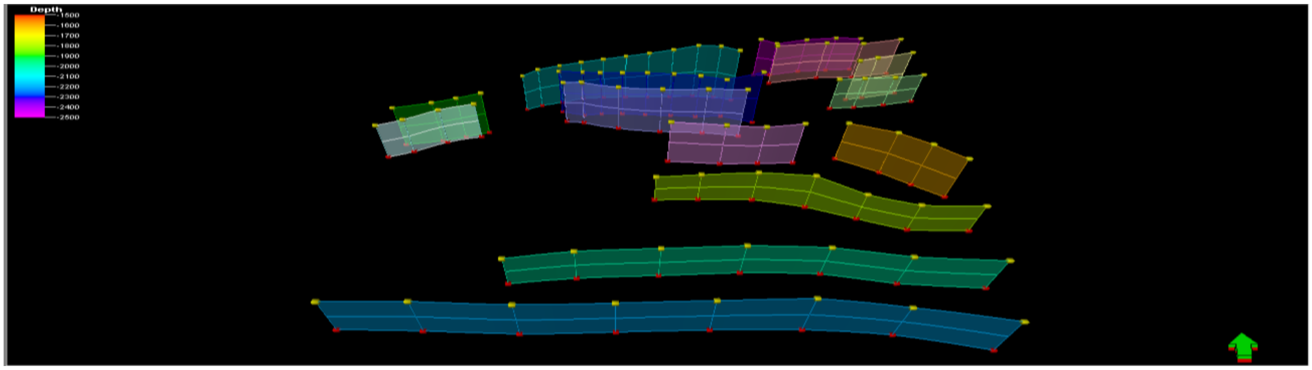


Figure 3: Seismic section showing wells, interpreted Horizons and

(f) STRUCTURAL MODELING: Modeling of the subsurface structural features in reservoir "F" and "L" of this study, involves the modeling of fault pillars which are done from fault polygons, producing horizon architecture and pillar gridding of the fault pillars, i.e. a 3-D grid of the fault pillars. Figure 4

LEVEL F



LEVEL L

RESERVOIR L

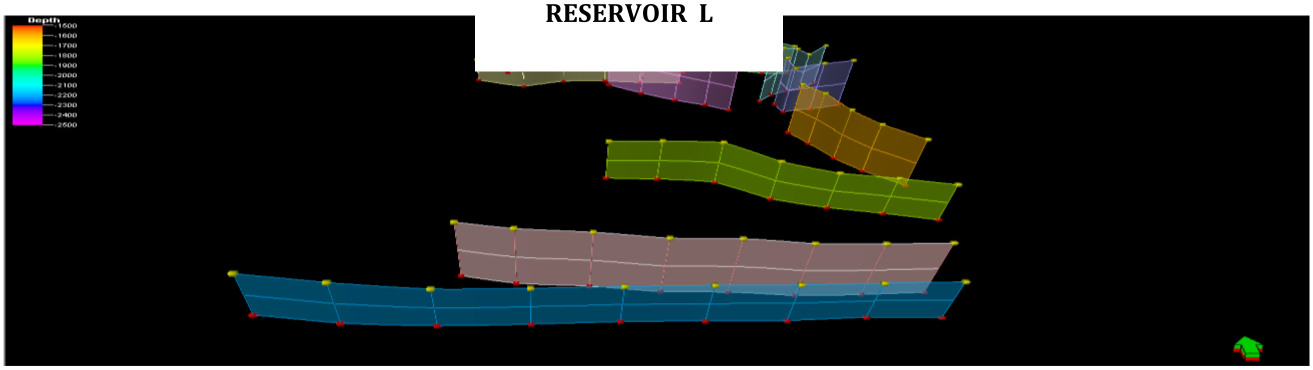


Figure 4: Fault modeling of reservoir "F" and "L".

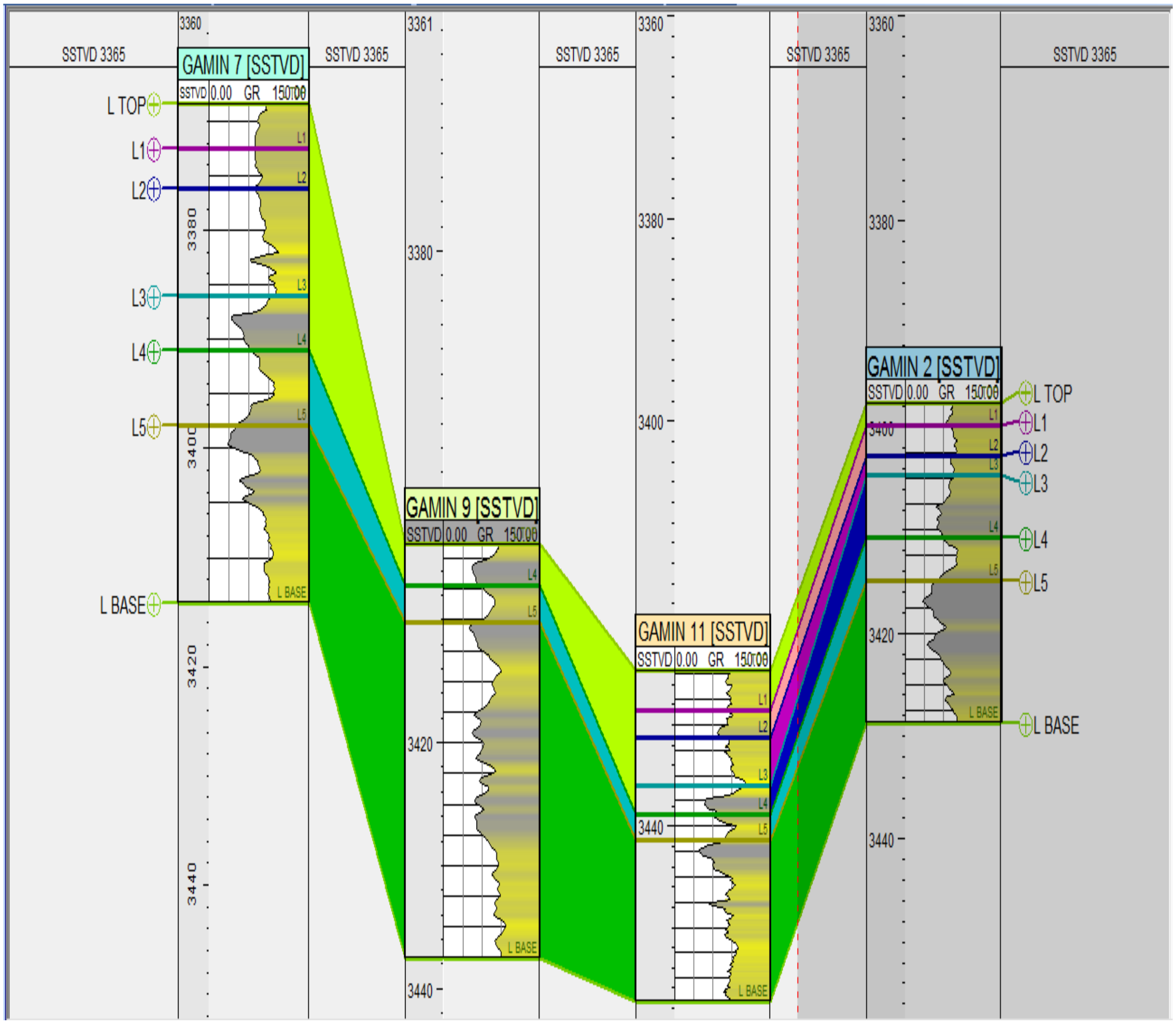


Figure 5: Well section showing zones across the wells in reservoir "L".

ZONE	LOG φ	UPSCALED φ	LOG SW	UPSCALED SW	LOG NTG	UPSCALED NTG
1	0.2006	0.1989	0.5088	0.4998	0.4242	0.4025
2	0.1868	0.1831	0.4655	0.4695	0.3557	0.2800
3	0.1723	0.1667	0.4968	0.5119	0.2500	0.2032
4	0.1953	0.1881	0.4461	0.4621	0.3930	0.3303
5	0.2569	0.2511	0.3600	0.3663	0.6887	0.6685
6	0.2932	0.2574	0.2889	0.3435	0.9408	0.7500
7	0.2018	0.2029	0.4563	0.4525	0.6072	0.6095

Table 2: Showing a comparison between the mean upscale petrophysical parameters and well logs for reservoir "F".

DISCUSSION OF RESULT

The interpretation on Hon's field located in Amukpe, is an attempt to review the subsurface structural features and the characterization of reservoirs of the Ogwashi-Asaba formation. The interpretation involved an understanding of the existing knowledge in the areas as well as the geological hypothesis within the overall framework of the Niger Delta geology in which this field lies. The existing information put as attributedly based. In addition, this field is known to have seven (7) growth faults, five (5) of them trend in the NW-SE direction and the others trend in the NE-SW direction.

The results from this study showed that 3-D seismic data in SEG-Y format and well log data were properly integrated for the characterization of "F" and "L" reservoirs. The well logs were analysed to produce stratigraphic models from which reservoir sands, bed boundaries, porous and non porous beds as well as other geologic properties were determined for accurate well correlations . Faults and seismic horizons were interpreted from the seismic section produced from the seismic data. Most of the faults trend in the NW-SE direction and some in the NE-SE direction .

Synthetic seismogram was produced (using checkshot data) not only to match possible peak for peak and trough for trough in the area, but also to create a well-to-seismic tie.

PETROPHYSICAL EVALUATION / CALCULATION: Porosity and permeability are the main petrophysical properties of a reservoir rock and have a vital impact on the evaluation processes at all stages. This project involved the analysis of well logs 3-D seismic data from a field in the Southern part of the Niger Delta by identifying candidate sand formations in each well and then calculating petrophysical parameters for these potential reservoirs. As a result of this study, two (2) different units were identified in the Formation by using the gamma ray log data.

Properties such as porosity, permeability, water saturation, facies, Net-to-Gross, etc. were modeled for both reservoirs during property modeling. Computation of cumulative flow capacity and cumulative storage capacity of the hydrocarbon pore fluid were done using certain formulae mentioned above in order to obtain the amount of hydrocarbon in plac. (Table 2).

The horizons were mapped which composed mainly of sand bodies and a few intercalation of shale beds as was revealed in the well log information. The composition of this intercalation of marine shale and continental sand is known to be of Agbada formation. The similarities of the geologic and petrophysical properties of certain depth of interest across the reservoir provide the opportunity for accurate well-to-well correlation.

Hon's field is known to have an average petrophysical properties of "F" reservoir are pay thickness (137ft), porosity (18.47%), permeability (1085md), Net-to-Gross ratio (0.4371), oil saturation (55.88%) and stoiip (65.41mmstb). And the average petrophysical properties of "L" reservoir are pay thickness (120ft), porosity (21.55%), permeability (1426md), Net-to-Gross ratio (0.7134), oil saturation (62.26%) and stoiip (65.19mmstb) respectively.

In summary, it is necessary to say that based on the existing characteristics of this field, the reservoir rock units are prolific for hydrocarbon exploration.

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