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LITHOSTRATIGRAPHIC INTERPRETATION AND SEISMIC ATTRIBUTES ANALYSIS FOR RESERVOIR CHARACTERIZATION IN SOME PARTS OF NIGER DELTA

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Abstract

In this study, well logs parameter crossplots were used for lithstratigraphic analysis, reservoirs were delineated from wells and the petrophysical parameters were obtained, seismic attributes were analyzed to map the lateral area extent of reservoirs, as direct hydrocarbon indicator (DHI) and to map faults.
Lithostrastigraphy analysis from well logs parameters crossplots revealed intercalation of sand and shale within the wells, the relationship between the log properties shows that sand has high porosity range of (0.3-0.6) , low acoustic impedandance range of (4,600- 6,000)(m/s * g/cm^3), low Vshale range of (0-0.3) and low density range of (1.6–2.2 gm/cc), while shale has low porosity range of (0.1-0.3) and high acoustic impedandance range of (6000- 7500)(m/s * g/cm^3), high Vshale range of (0.3-0.16) and high density range of (2.2-2.6 gm/cc).
Two hydrocarbon reservoirs R1and R2 respectively were revealed from Well logs analysis. Petrophysical parameters were evaluated with the gross thickness ranges from 80 m to 130 m. Net pay ranges from 40m to 80m. The Net/Gross ranges from 0.42 to 0.62, density porosity ranges from 0.23 to 0.31, hydrocarbon saturation ranges from 0.60 to 0.72 and volume of shale ranges from 0.02 to 0.11. Seismic attributes when used as DHI, it has helped to know the hydrocarbon prospects directly on seismic sections. It has also shown its ability to map the area extent of reservoir.

Keywords: reservoir characterization; seismic attributes; crossplots; lithostratigraphy & Niger delta.

1. Introduction

Agbada formation of Niger delta is made up of intercalation of sand and shale, complicated nonlinear relationship between well log properties sometimes makes it difficult to accurately distinguish sand and shale within the wells.

Modern 3D seismic data and the associated extracted attributes have allowed better description of reservoir heterogeneities and more realistic assessment of hydrocarbons in place [1].

Lithostratigraphic analysis is best done using well log properties crossplots, this will clearly distinguish the lithology base on these well log parameter values.

Direct hydrocarbon indicators (DHL) can be used in mapping reservoir area extent on seismic sections [2]. These indicators are valuable mapping tools because they suggest the presence of hydrocarbons directly on seismic sections [3].

A seismic attribute is a quantitative measure of a seismic characteristic of interest. It is therefore possible to use seismic attribute to map the area extent of hydrocarbon reservoir and geological features such as faults.

1.1 Location and geological settings of the study area

A delta is formed from the deposition of sediments at the mouth of a river where it is discharged into the sea with more than one channel called distributaries. It results from a stream reaching a body of water such as the sea and building a deposit of sediments because of the reduction of its velocity of flow. Study field is located at the onshore field is located within onshore part of the Niger Delta (Figure 1).

The thick wedge of the Niger delta is considered to consist of three units Akata, Agbada and Benin formations (Figure 2). These formations are strongly diachronous and cut across the time stratigraphic units which are characteristically S-shaped in cross section. The typical sections of these formations are described by [4] and summarized in a variety of papers [5-7].

Niger Delta is delineated by the geology of southern Nigeria and southwestern Cameroon (Figure 2). The northern boundary is the Benin flank--an east-northeast trending hinge line south of the West Africa basement massif [8]. The northeastern boundary is defined by outcrops of the Cretaceous on the Abakaliki High and further east-south-east by the Calabar flank a hinge line bordering the adjacent Precambrian. The offshore boundary of the province is defined by the Cameroon volcanic line to the east, the eastern boundary of the Dahomey basin (the eastern-most West African transform-fault passive margin) to the west, and the two kilometre sediment thickness contour or the 4000-meter bathymetric contour in areas where sediment thickness is greater than two kilometres to the south and southwest.

Petroleum occurs throughout the Agbada Formation of the Niger Delta; however, several directional trends form an "oil-rich belt" having the largest field and lowest gas:oil ratio [8-10].

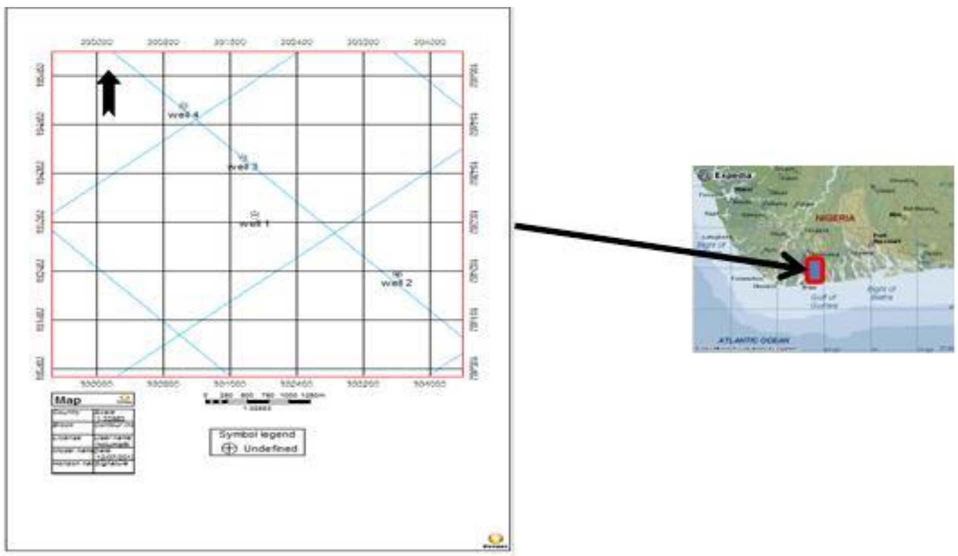

Figure 1 Location and Base Map of the Study Area showing Seismic Lines and Wells.

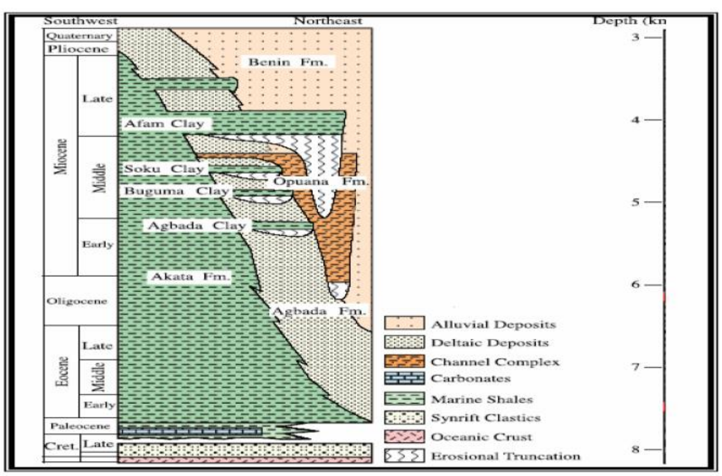

Figure 2 Stratigraphic column showing the three formations of the Niger Delta. Modified from [11-6] .

2. Materials and methods

2.1 Well logs petrophysical analysis

Suites of well logs from the field, these include gamma ray log, resistivity log, neutron log, density log, volume of shale log, water saturation log and sonic log, in (Las) format were fed into the softwares. 3 D seismic data in SEGY format was fed into the petrel, checkshot data was used to tie wells with seismic data.

2.2 Lithostratigraphic analysis

Gamma ray log was used to delineate lithology (Sand and shale bodies). Sand bodies were identified by deflection to the left due to the low concentration of radioactive minerals in sand while deflection to the right signifies shale which is as a result of high concentration of radioactive minerals in it. Gamma ray log was set to a scale of 0-150 API, central cut off of 75 API units in which less than 75API was interpreted to be sand while greater than 75API was interpreted to be shale. Well logs parameters were crossploted. Resistivity log was used with Gamma ray log to delineate potential reservoirs. Intervals that have high resistivity are considered to be hydrocarbons while low resistivity zones are water bearing intervals.

2.3 Reservoir area extent mapping

Area extent of each reservoir was mapped using attributes (envelope extraction and variance), Seismic attributes are very useful in its continuity, and its hydrocarbon potential [12].

3. Results and discussion

Two hydrocarbon bearing reservoirs R1 and R2 were delineated across the field using well log data (Figure 3). R1 and R2 occur at depth; (1320 m) and (1580 m) respectively in well 4, (1320 m) and (1575 m) respectively in well 3, (1330 m) and (1590 m) respectively in well 1. The two reservoirs thins out within well 2, it can be seen that well 2 consists of water all through.

Tables 1 and 2 show petrophysical summary within wells 1-4. Reservoir R1 gross thickness ranges from (80m-92m), net thickness ranges from 40m -50m, N/G ranges 0.50-0.57, density porosity ranges from 0.28-0.31, oil saturation ranges from 0.60-0.67 and V_{shale} ranges from 0.02 – 0.06. Similarly, Reservoir R2 gross thickness ranges from (120m-130m), net thickness ranges from 50m -80m, N/G ranges 0.42-0.62, density porosity ranges from 0.23-0.29, oil saturation ranges from 0.65-0.72 and V_{shale} ranges from 0.02 – 0.11.

Table 1 Petrophysical parameters obtained for reservoir 1

Well	Top(m)	Bottom (m)	Gross (m)	Net (m)	N/G	Porosity	S_H	V_{shale} (fraction)
4	1320	1400	80	42	0.53	0.31	0.63	0.02
3	1320	1400	80	40	0.50	0.28	0.60	0.06
1	1330	1400	80	52	0.57	0.31	0.67	0.04

Table 2 Petrophysical parameters obtained for reservoir 2.

Well	Top(m)	Bottom (m)	Gross (m)	Net (m)	N/G	Porosity	S_H	V_{shale} (fraction)
4	1580	1710	130	80	0.62	0.26	0.72	0.02
3	1575	1705	130	75	0.58	0.29	0.69	0.08
1	1590	1710	120	50	0.42	0.23	0.65	0.11

Figures 4 (a-f) show the facies analysis using well log properties crossplot. Across these figures there are variations in lithology between sand and shale under constant values of log parameters. For instance, (a) shows two facies types (sand and shale) having same acoustic impedance value but different values of density. (b) shows changes in values of density as agaainst nuetron and it can be seen that sand has low density (1.6–2.2 gm/cc) compare with shale density (2.2-2.6 gm/cc). (c) shows the crossplot of impedance and V_{shale}. V_{shale} shows its ability as lithology log, it can be seen clearly that sand occupies the the region with low value of V_{shale} (0-0.3) while shale covers the region of high value of V_{shale} (0.3-0.16. (d) shows the crossplot of GR and acoustic impedance , it can be seen that shale occupies high gammar ray values (75-150 API) while sand covers the region low gammar ray (0-75API) and 75API indicate the facies turning or cut off point, two facies types (sand and shale) having same acoustic impedance value but different values of density. (e) shows the relationship between porosity and acoustic impedance it can be seen that sand has high porosity range of (0.3-0.6) and low acoustic impedandance range of (4,600- 6,000) (m/s * g/cm^3) while shale shows low porosity range of (0.1-0.3) and high acoustic impedandance range of (6000-7500) (m/s * g/cm^3). (e) shows the crossplot of depth and acoustic impedance, there is intercarlation of sand and shale within the well. impedance shows its strenght as lithology tool here with sand having low acoustic impeadance range of (4,600- 6,000) (m/s * g/cm^3) and shale having high acoustic impedance range of (6000- 7500) (m/s * g/cm^3). Figure 5, shows the 3 D seismic view (inline, Xline and Z component).

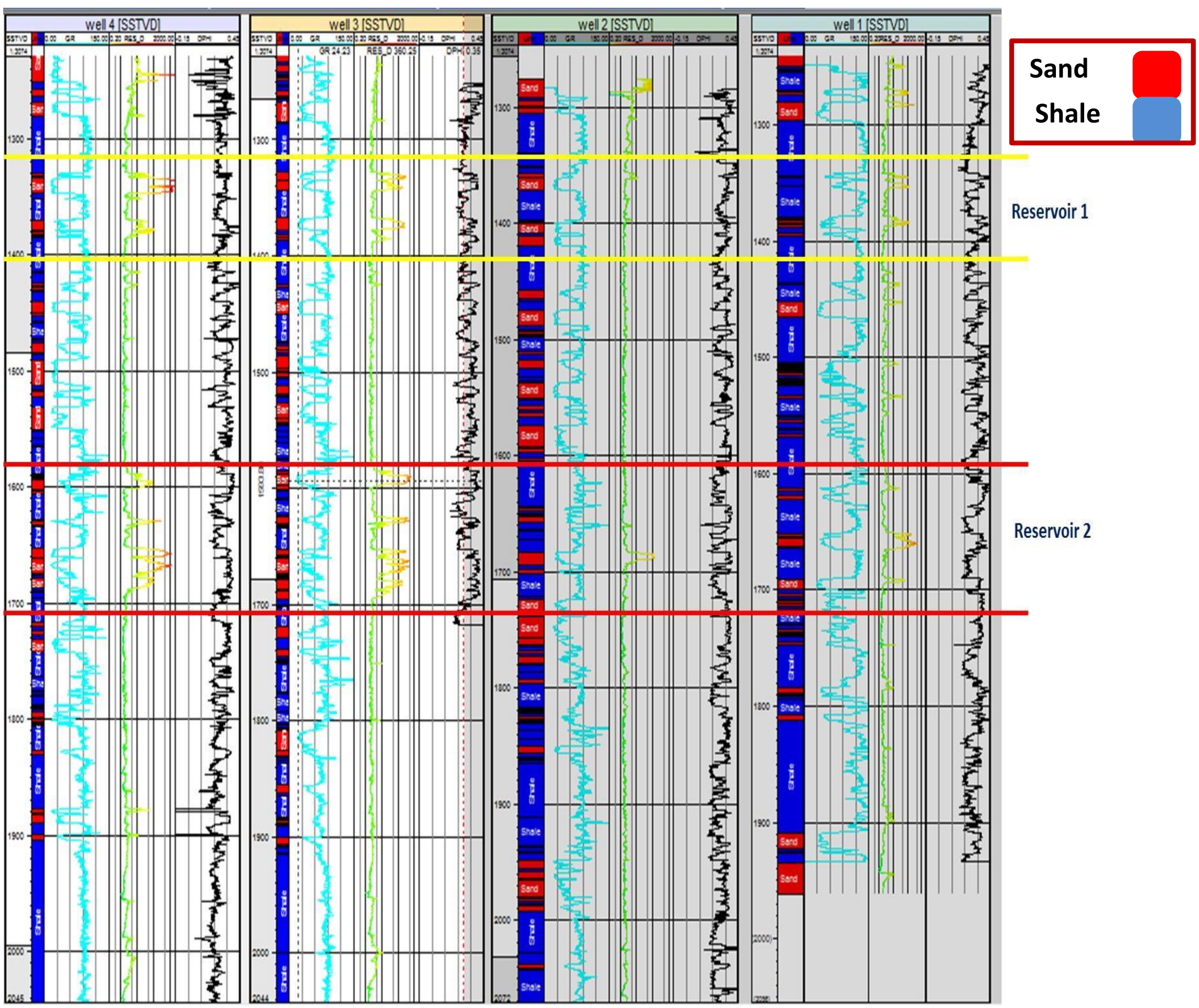

Figure 3 Well Correlation Panel Across wells 4, 3, 2, and 1 showing Reservoirs 1 and 2.

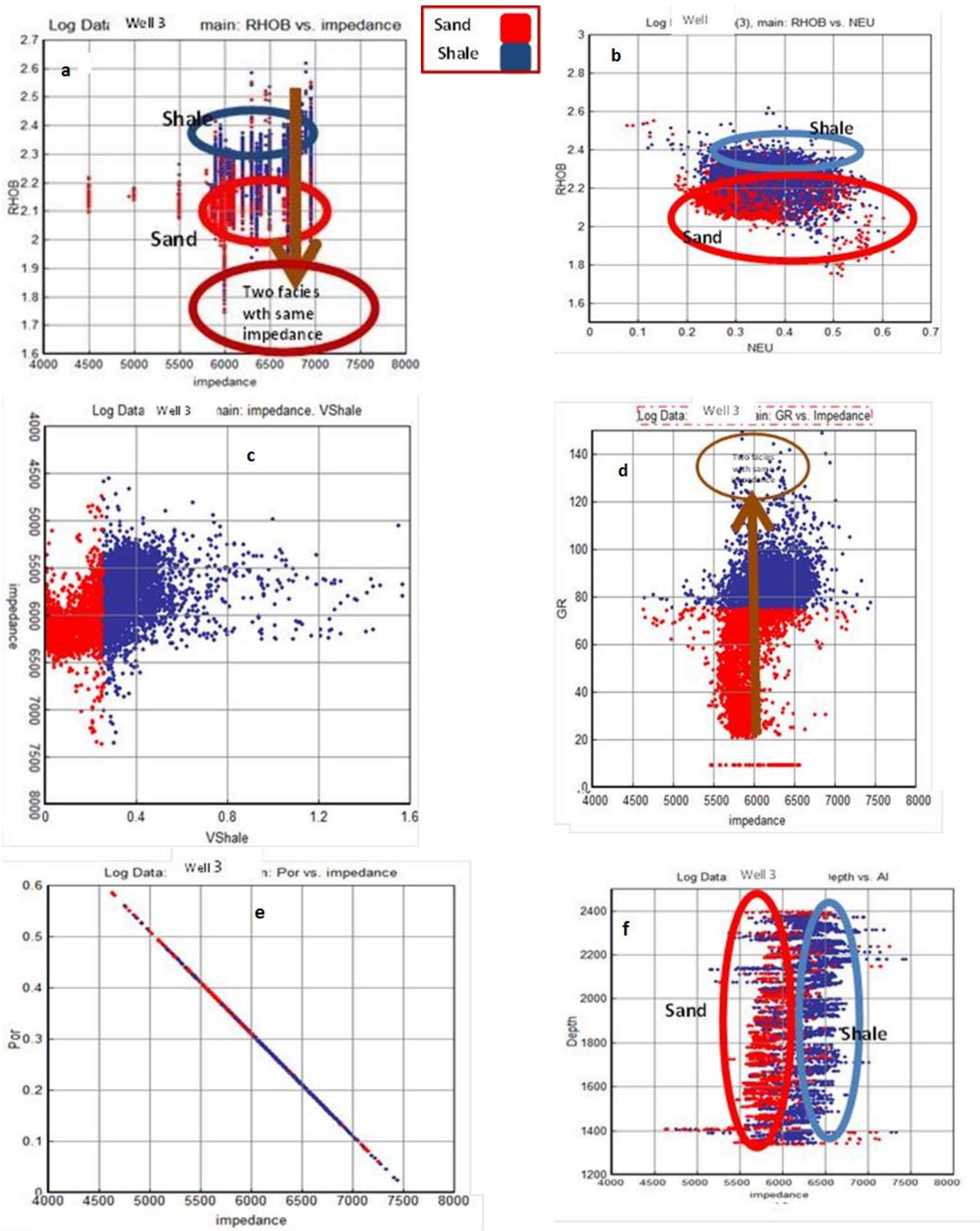

Figure 4 Crossplot analysis at well 3 between (a) Density and Impedance, (b) Density and Neutron (c) Impedance and V_{shale} (d) Gamma ray and impedance, (e) Porosity and Impedance and (f) Depth and Impedance.

The wells are also displayed. The checkshot data was imported and attached to appropriate wells, the wells were uploaded on the seismic section and the GR and RES logs were displayed, the reservoir tops were mapped (Figure 6).

Seismic attributes both variance and envelope extraction where used in this study. Variance was used to map faults figure 7. In order to confirm the presence of hydrocarbon, to map new hydrocarbon prospect and also to map the lateral area extent of reservoirs, attribute analysis was carried out. The envelop extraction was used to map the two reservoirs both at time slice 1500 ms and 1750 ms as shown in Figures 8 and 9. A new hydrocarbon prospect was identified directly on the seismic section Figure 9.

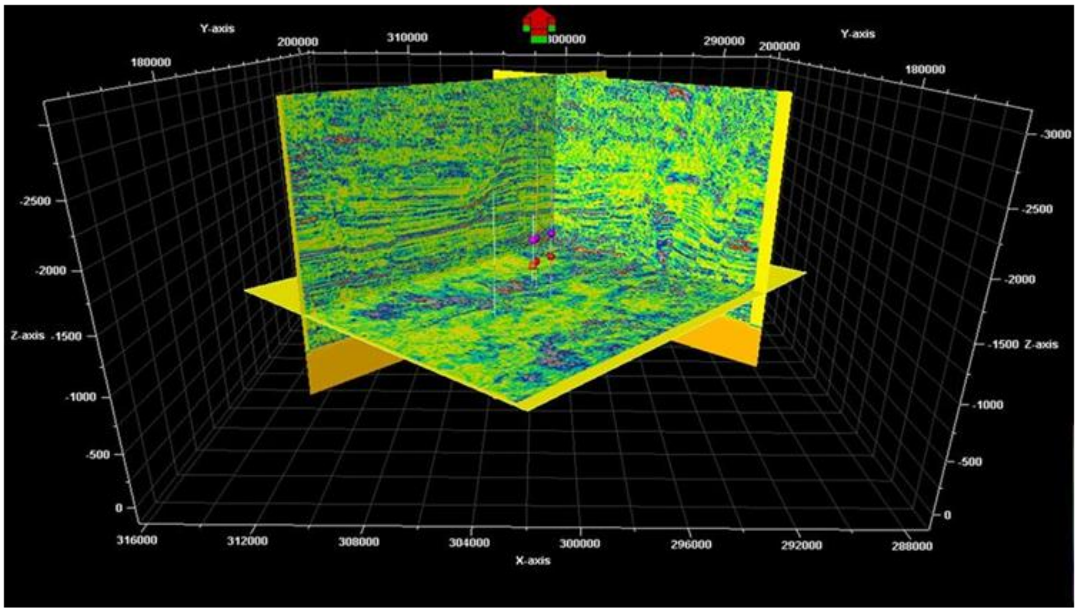

Figure 5 3D seismic view (Inline, Xline and Z components) and wells.

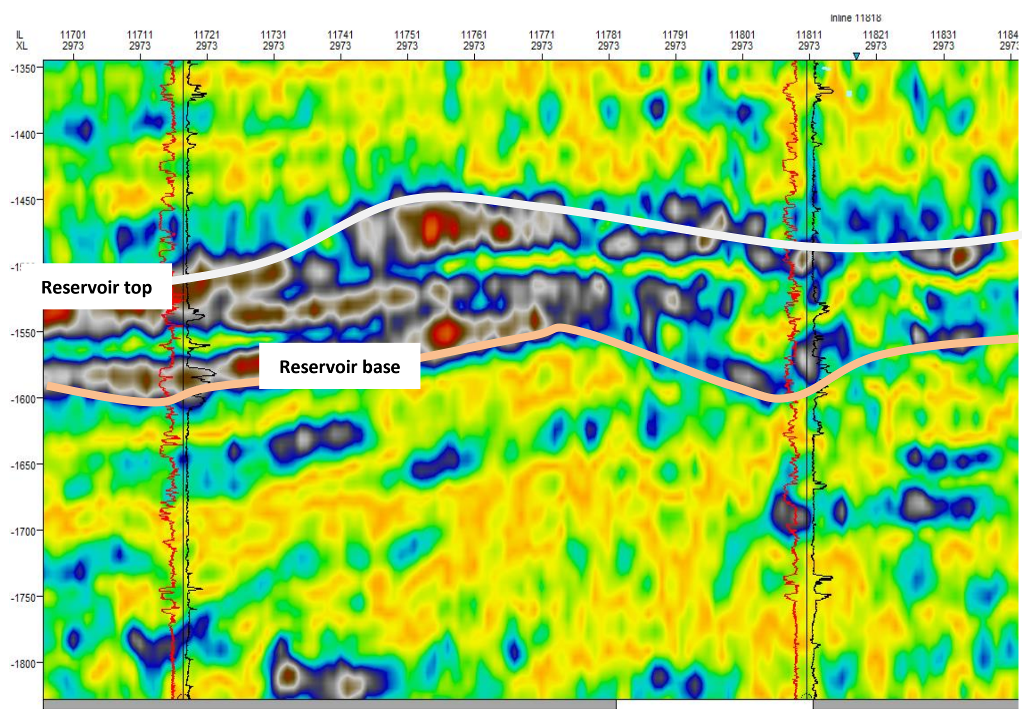

Figure 6 Tying of wells to seismic using checkshot data.

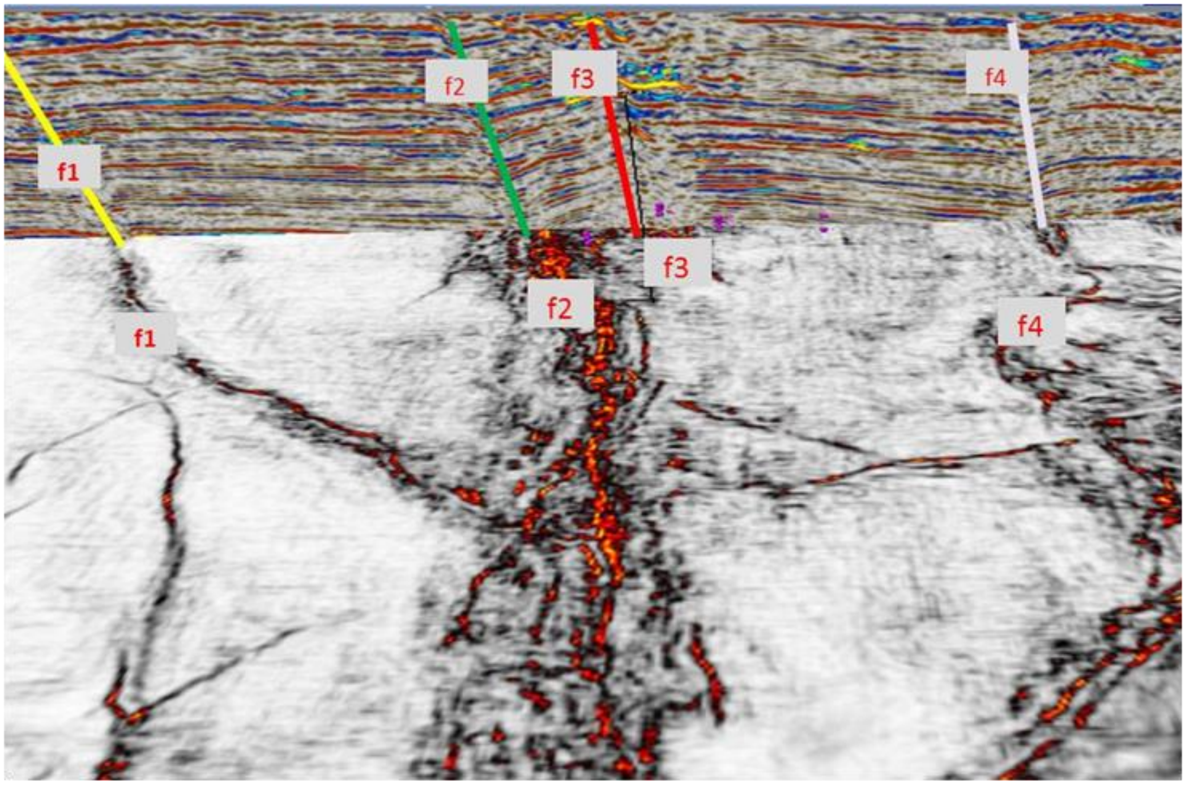

Figure 7 Faults mapping using Variance attributes

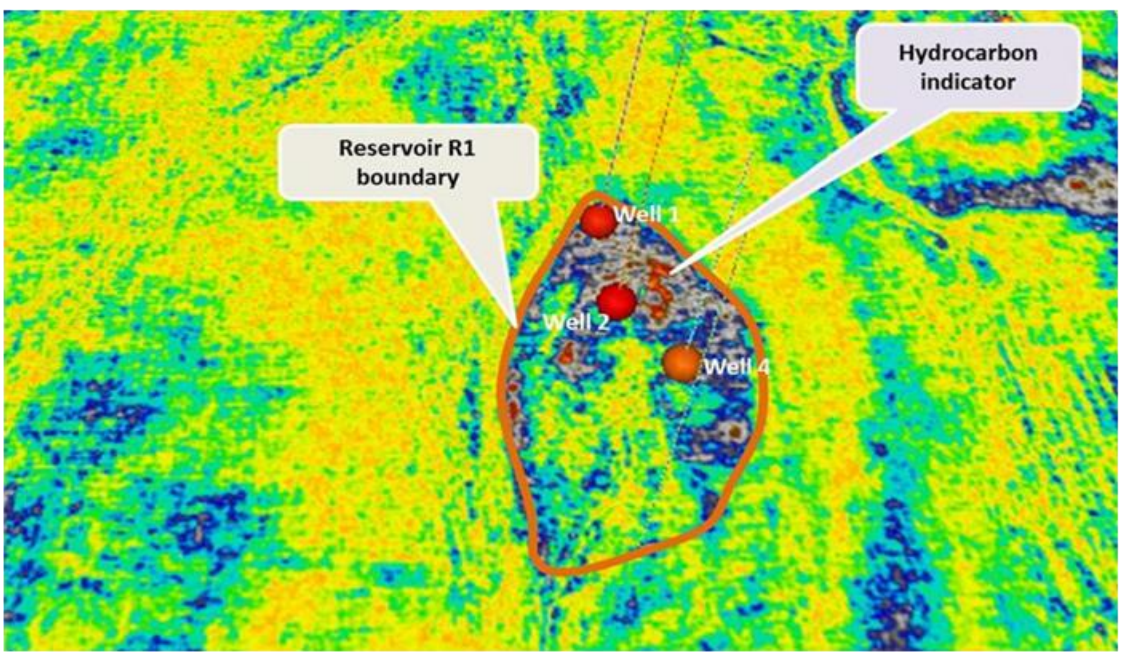

Figure 8 Reservoir R1 area extent mapping using Envelope extraction slice at 1350ms.

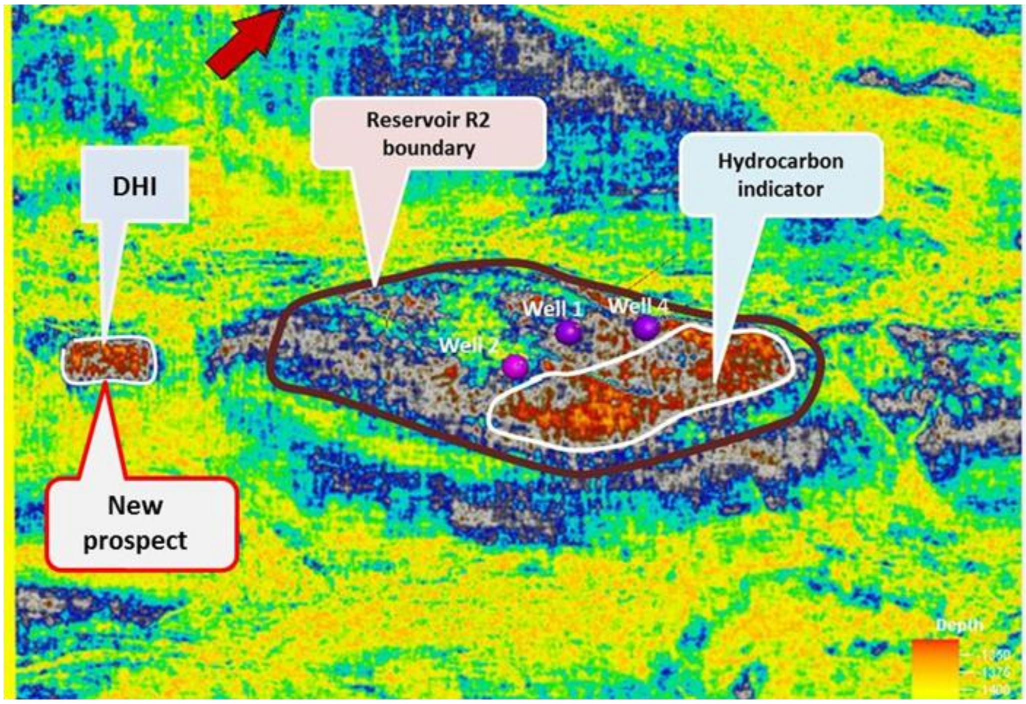

Figure 9 Reservoir R2 area extent mapping using Envelope extraction slice at 1500ms.

4. Conclusion

The strength of well log properties crossplot cannot be overemphasized, not only to distinguish the lithology base on these well log parameter values but also to determine the variation in the values of the petrophysical parameters across the well. The facies analysis using well log properties crossplot shows that there are variations in lithology between sand and shale under constant values of log parameters. For instance density –nuetron crossplot revealed that sand has low density (1.6–2.2 g/cc) compare with shale density (2.2-2.6 gm/cc). Lithostratigraphy analysis confirmed that Agbada formation of Niger Delta is of intercalation of sand and shale. Most importantly, the analysis suggests that acoustic impedance can not be perfectly used as lithology tools or to discriminate lithology, because it is possible for two or more facies to have the same acoustic impedance.

Petrophysical analysis show two oil Reservoirs with average gross thickness of 105m, net pay thickness of 57m, N/G of 0.54, density porosity of 0.28, oil saturation 0.66 and V_{shale} of 0.06. These petrophysical properties estimated show that the field of study is a prolific oil field.

This study also confirmed that seismic attributes are useful as direct hydrocarbon indicator, to identify hydrocarbon prospect(s) directly on seismic section without the consent of well logs, in mapping of faults and to map the lateral extent of the reservoirs. I recommend that a developmental well should be drilled to confirm the suspected prospect.

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