

Reservoir characterization and prospect identification in Onka field, offshore, Niger Delta

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ABSTRACT

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The study is focused on the use of 3D seismic, well logs and checkshots data to delineate, evaluate and characterize reservoirs relating to their hydrocarbon potentials. Four localized wells were available for this study. The study location is Onka field, offshore, Niger Delta. Well correlation and detailed petrophysical analysis was carried out along all the wells. Three reservoirs were discerned within the agbada formation. Among these delineated reservoirs, reservoir 2 occurs to be the most prolific with average gross thickness of about 49ft, net pay thickness of about 43ft, average net to gross thickness of approximately 71%, a good porosity of 20% and hydrocarbon saturation of 81% which is more blatant in well DESLA 1ST2. Seismic interpretation shows the presence of 26 faults. The faulting system corresponds with the geology of the Niger Delta. From the generated structural surface map of Reservoir 2, Fault F7 at the flank of the crest forms an antithetic fault type with both F7A and F7B. This also aligns with the mundane trapping system of the study area. It is recommended that more wells should be drilled at strategic locations to provide more data that will contribute to quality reservoir models.

1. INTRODUCTION

Data is the next oil and this also applies to oil and gas exploration as it is getting more expensive to acquire. Therefore, making judicious use of the limited data available in order to make viable decisions, has become necessary as the cost of acquiring these data is increasing with time.

Many researches have been carried out in order to have a better understanding of reservoir structures while minimizing the cost of exploration and production. Peng et al. [1] proposed a new method to tackle the quality of DST test during early evaluation stage in offshore gas reservoirs. Li et al. [2] also tried to explore reservoirs with low resistivities due to high mineralized formation water, high clay content among many other factors that might affect a reservoir formation.

The information gotten from previous nearby field are important and should contribute to whole interpretation process. However, one should also not be blind to the fact that the subsurface whose properties and structure we are trying to determine and visualize might deviate from the norm as a result of several abnormal conditions, especially in complex geological settings.

According to Adeoti and Abe et al. [3-4] among other related researches, the generation of quality reservoir models has proven for decades to be a reliable approach for the detail study of reservoir structures and its properties. Abe et al. [4] made use of seismic and distributed well log data within reservoirs using geostatic approach across the reservoirs to study and characterize them according to their qualities. However, one of the factors that determine a quality reservoir is attributed to the amount of data inputted in the process of

its generation.

This project "Reservoir Characterization and Prospect Identification in Onka Field, Offshore, Niger Delta" made use of seismic and available localized well data to get a better knowledge of the present reservoirs. In this case, we have a novel field with limited and localized well data. The results acquired from the interpretation will serve as the basis for the recommendation of developmental well locations. It will help to determine new verdant areas to acquire extended data in order to fully explore the potentials of the field.

2. MATERIALS AND METHODOLOGY

The materials available for this research are 3D seismic data and well logs suites. Litho-stratigraphic correlation was done using the available lithology log (gamma ray log) to distinguish between the two basic lithology types (i.e; sand and shale) dominant in the field according to the geology of the Niger Delta [5]. A cut off was established from the statistics of the Gamma Ray log in order to differentiate between sands with low Gamma Ray values and shales which possess high radioactive content with corresponding high Gamma Ray values. Resistivity log was used to identify the present fluid type (i.e.; formation water and/or hydrocarbon) and the hydrocarbon type was then distinguished with neutron-density crossover.

These factors were used to identify prospective reservoirs units and petrophysical analysis were carried out on them. Synthetic seismogram was generated using both sonic and density logs. Seismic to well tie was then executed to establish a relationship between seismic and well data. This

process also helps to know the events to be picked as horizons on seismic lines. Seismic interpretation, which involves the picking of faults and identified events as horizon across seismic line, was done. Taking cognizance of faults orientation, the picked horizons were interpolated to generate surface time maps which were converted to their corresponding structural depth maps with the aid of a velocity model.

3. LOCATION AND GEOLOGY OF STUDY AREA

3.1 Location of study area

The study area is geographically located offshore Niger Delta within Latitude $1^{\circ} 23' 26.357''$ and Longitude $4^{\circ} 25'$

$41.234''$. The seismic survey covers 389 In lines and 1263 Crosslines. Four wells were drilled namely DESLA1, DESLA 1ST1, DESLA 1ST2 AND DESLA 2. DESLA 1, DESLA 1ST1 and DESLA 1ST2 are drilled from same location but deviated along different path. However, DESLA 2 was drilled from different point of about 1km away from the other wells. According to the observation on well log, DESLA 2 is a dry hole with no vestiges of hydrocarbon but other wells shows evidence of hydrocarbon.

3.2 Geology of study area

Niger Delta basin is an extensional rift basin in the Niger Delta and the Gulf of Guinea on the passive continental margin near the Western coast of Nigeria [6].



Figure 1. Location of study area

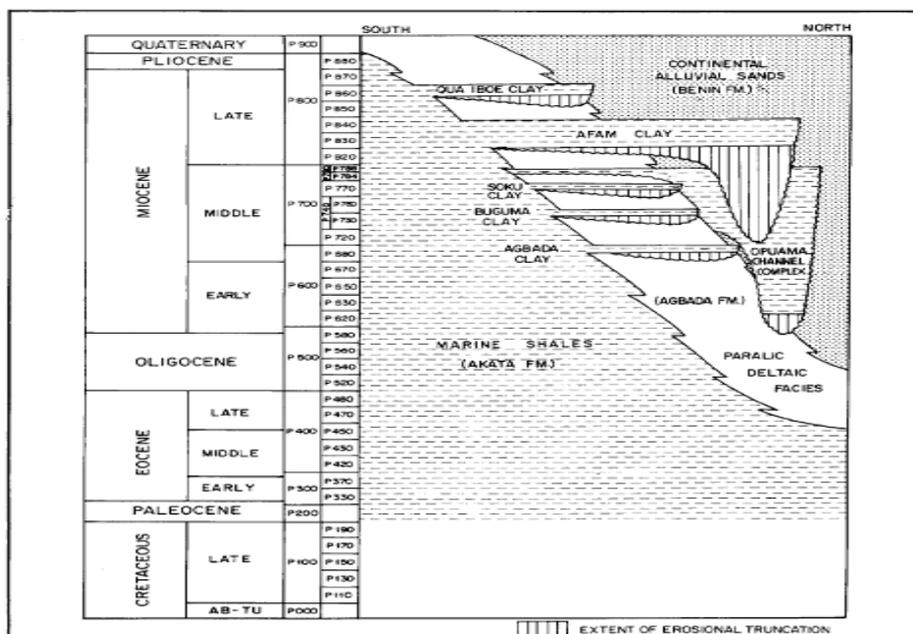


Figure 2. A stratigraphy column with the three formation present in Niger Delta [6] modified by Doust and Omatsola [13]

The clastic wedge of the Niger Delta occurs along a failed arm of a triple junction systems which was formerly emanated during the breakup that occurred between South American and African plates. This process happened in the late Jurassic [7].

The age of this basin as defined by Klett et al. [8] extends from Eocene to the present, the delta has prograded southward, forming depobelts that accounts for one of the largest regressive deltas in the world with thickness of over 10km [9], an area of some 300,000 km² [5], and a sediment volume of 500,000km³ [10]. The petroleum system of Niger Delta province is referred to as the Tertiary Niger Delta (Akata –Agbada) petroleum system [11]. The Tertiary section of the Niger Delta is divided into three lithostratigraphic formations units [12].

First, the deep-seated Akata formation with thickness of about 6,400 m at the centre of the clastic wedge. This over-pressured, ductile dark marine shale and silts (with streaks of sand of turbidite flow origin) is the potential source rock unit. The age of the Akata is from Paleocene to Recent and it grades vertically into the overlying Agbada formation [13]. The second formation is Agbada formation, it is known as the major hydrocarbon bearing unit consisting of paralic siliclastics basically sandstone with intercalations of shale. It is further overlain by the Benin formation, which is characterized by poorly sorted, medium to fine grained

radioactive sands and gravels with vestiges of shale. The structural features present in the Niger Delta which also serves as the trapping mechanisms are simple rollover structures with clay filled channel, growth faults, antithetic fault and collapsed crest.

4. PRESENTATION AND DISCUSSION OF RESULTS

4.1 Well log interpretation

The orientation of the well log correlation was from North-West to North-East. DESLA 1 is the first and only vertical well drilled in the field with total MD of 13,620ft. It cuts across the three delineated reservoirs with presence of hydrocarbon more evident in reservoir 2. DESLA1ST1 and DESLA2ST2 have total MD of 8,862ft and 8,800ft respectively. They are both wells drilled at the same location as DESLA 1 but they deviated along different paths. DESLA 2 is also a deviated well located 1172m away from the other wells with a total MD of 10,080ft. This well also cut across the three reservoirs. However, it is a dry well (i.e. no observed presence of hydrocarbon). Figure 3 and Figure 4 shows the correlation panel with the delineated reservoir unit on all the available wells.

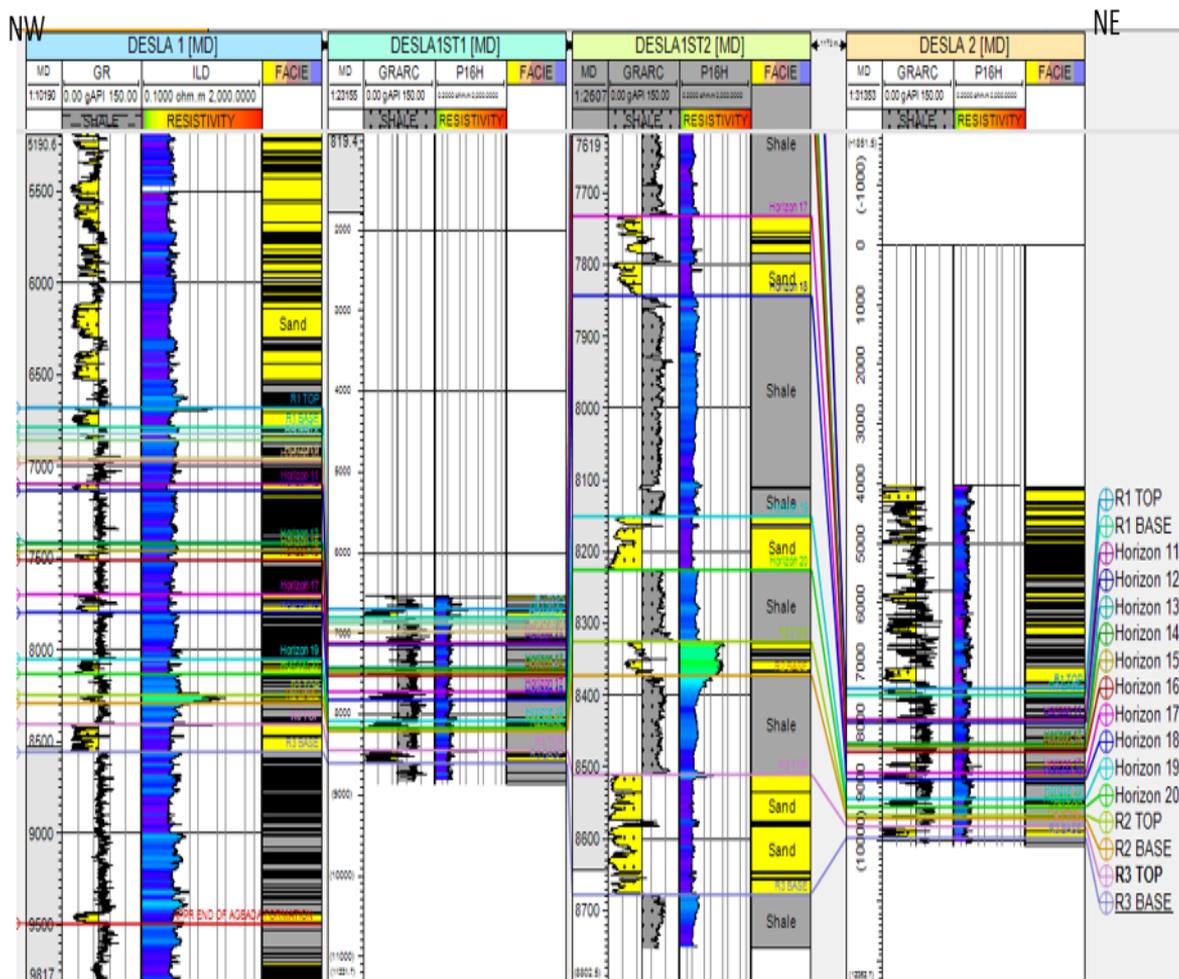


Figure 3. Well log correlation showing the some of sand units and reservoir present across the wells

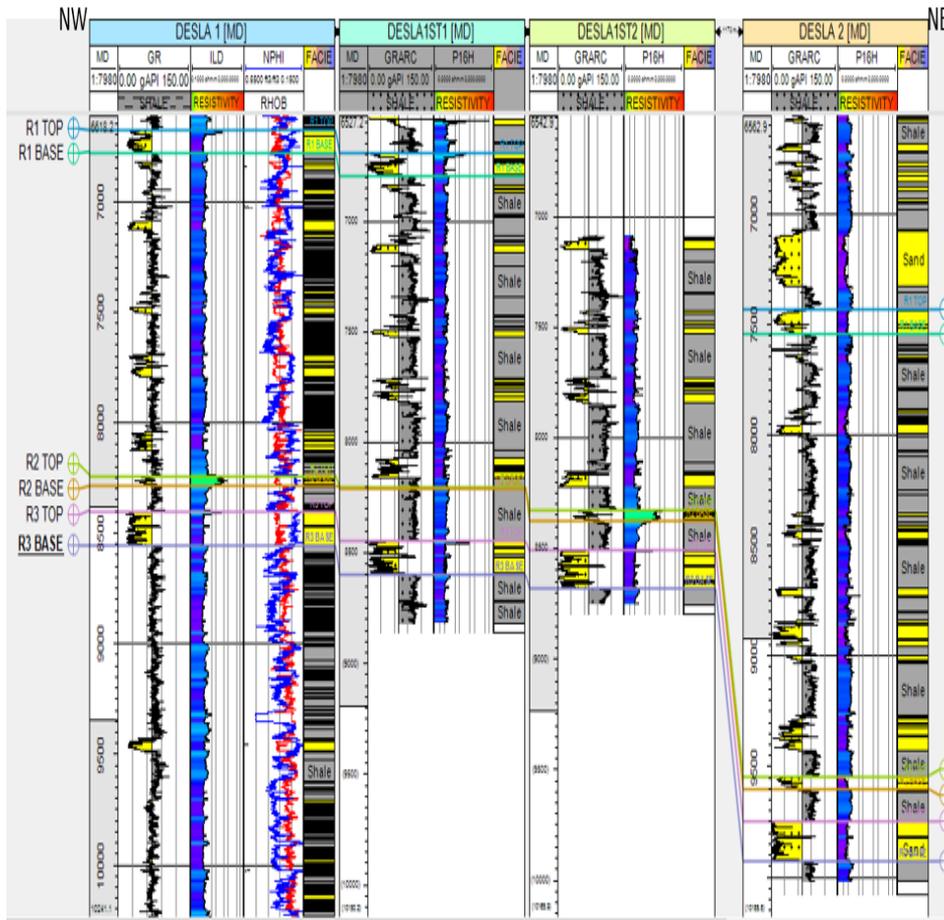


Figure 4. Well log interpretation showing the correlation of delineated reservoir across the wells

4.2 Petrophysical evaluation and analysis

4.2.1 Petrophysical evaluation and analysis of reservoir 1

The petrophysical evaluation table and charts of Reservoir 1 are displayed in Table 1 and Figure 5 respectively. This is the first encountered reservoir located within the Agbada

formation with traces of hydrocarbon. The gross thickness of this reservoir increases eastward from DESLA 1 to DESLA 2 with an average gross thickness of 104ft, an average net to gross thickness of about 84%. It has an average porosity of 26% and an average hydrocarbon saturation of 20% as evident on both DESLA 1 and DESLA1ST1.

Table 1. Petrophysical table of reservoir 1

Wells	GT (ft)	NT (ft)	NTG (%)	NP (ft)	Vsh (%)	Porosity (%)	Av Sw (%)	Av Sh (%)
Desla 1	101.9	90.5	84	17.9	16	26	79	21
Desla1ST1	102.6	90.7	87	13.9	13	35	80	20
Desla 2	108.9	99.9	84	0.0	16	27	100	0

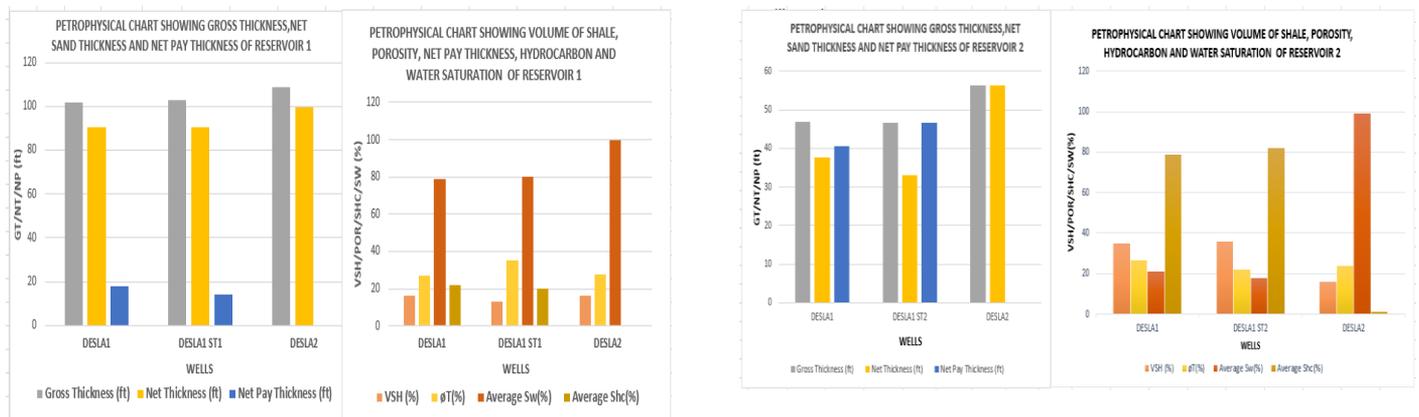


Figure 5. Petrophysical chart of Reservoir 1

Figure 6. Petrophysical chart of Reservoir 2

Table 2. Petrophysical table of Reservoir 2

Wells	GT (ft)	NT (ft)	NTG (%)	NP (ft)	Vsh (%)	Porosity (%)	Av Sw (%)	Av Sh (%)
Desla 1	46.8	37.7	65	40.6	35	27	21	79
Desla1ST1	46.7	33.0	64	46.7	36	22	18	82
Desla 2	56.4	56.4	64	0.0	16	24	99	1

4.2.2 Petrophysical evaluation and analysis of reservoir 2

Reservoir 2 is one with an average gross thickness of about 49ft with the highest of about 56ft found on well DESLA 2. It has a moderately clean unit with average net sand thickness of about 40ft and average volume of shale of about 25%. From the petrophysical evaluation as seen in Figure 6 and Table 2.

This reservoir is the most prolific hydrocarbon bearing unit when compared to the other two detected reservoirs. It has an average net pay thickness of about 43ft, an average hydrocarbon saturation of about 82% and corresponding average porosity of 23%.

4.2.3 Petrophysical evaluation and analysis of reservoir 3

Reservoir 3 is the deepest reservoir found in the field. It also saddles across the four wells with an average gross

thickness of 155ft and average volume of shale of 10% which makes it a very clean reservoir unit with little or no shale intercalations. It has a net pay thickness of about 10ft and average hydrocarbon saturation at 13% across the wells. However, the reservoir shows a 100% water saturation on DESLA 2. The petrophysical evaluation and analysis of reservoir 3 is displayed in Table 3 and Figure 7.

Reservoir 2 is observed to be the most promising reservoir. It can be seen from the chart in Figure 7 that DESLA2 have the thickest delineated unit and also have the highest sand thickness. However, DESLA1ST2 is observed to have the highest net pay, a good net to gross, a reasonable effective porosity of about 20% with the highest hydrocarbon saturation of 82% which makes it the most promising well for hydrocarbon extraction of this reservoir.

Table 3. Petrophysical table of reservoir 3

Well	GT (ft)	NT (ft)	NTG (%)	NP (ft)	Vsh (%)	Porosity (%)	Av Sw (%)	Av Sh (%)
Desla 1	154.3	146	87	12.2	13	25	84	16
Desla1ST1	149.4	136.7	88	10.5	12	36	84	16
Desla 2	166.9	167.6	92	3.4	8	39	90	10

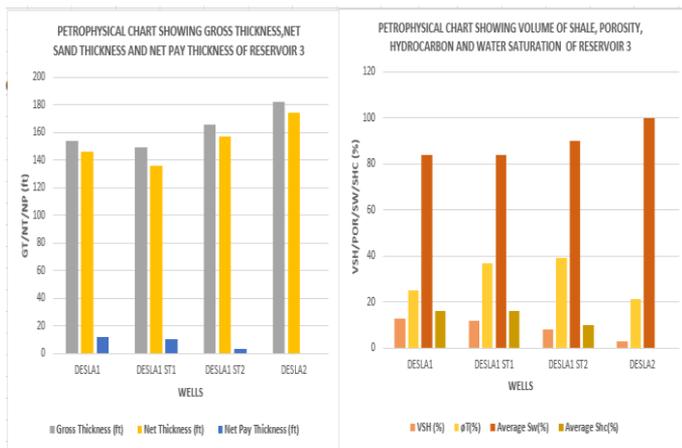


Figure 7. Petrophysical chart of Reservoir 3

4.3 Horizon and fault Interpretation

Fault interpretation was done and faults were picked on inlines across the whole seismic volume. Figure 8 shows the faults and horizons picked on a seismic section (Inline 10590). A total of 26 faults including 11 major faults and 15 minor faults were discovered. Most of the faults were observed to dip south-eastward with the exception of F15, F7 and F7B that dips in the opposite direction.

Prior to picking of horizon, the well to seismic tie was done to help match the seismic traces to synthetic seismogram and also identify the event of horizons. The event of each horizon and their approximate time of seismic is shown in Table 4 below.

Table 4. A table showing the event and corresponding seismic time of delineated reservoirs

Reservoirs	Top event	Top seismic time (ms)	Base event	Base seismic time (ms)
Reservoir 1	Trough	1788.8	Crossover	1790.5
Reservoir 2	Peak	2100.6	Trough	2109.2
Reservoir 3	Trough	2130.2	Peak	2156.8

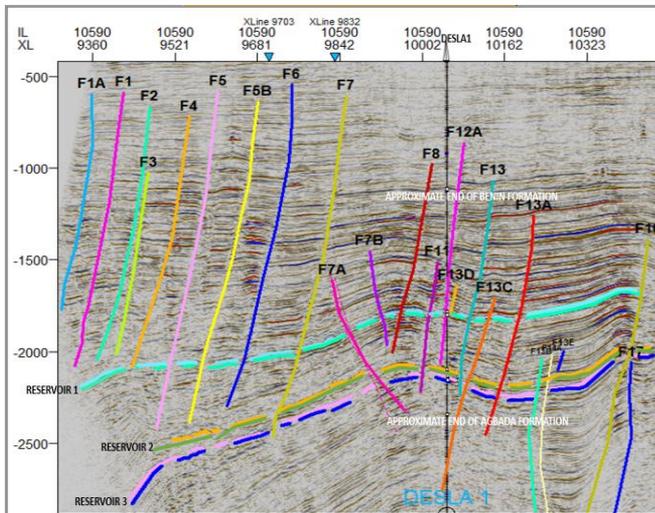


Figure 8. Seismic Interpretation showing some faults and horizons of reservoirs picked on seismic section (Inline 10590)

4.4 Structural surface interpretation

The structural surface (time) of the three reservoirs are displayed respectively in Figure 9, Figure 10 and Figure 11 respectively below.

4.4.1 Petrophysical evaluation and analysis of reservoir 1

Reservoir 1 falls within -2303.57ms and -1509.20ms on the seismic section. At the upper part of this surface, the area where the wells were concentrated. The faults F8 and F7A dips in opposite direction forming an antithetic fault located on the flank of the closure forming an enhanced anticline.

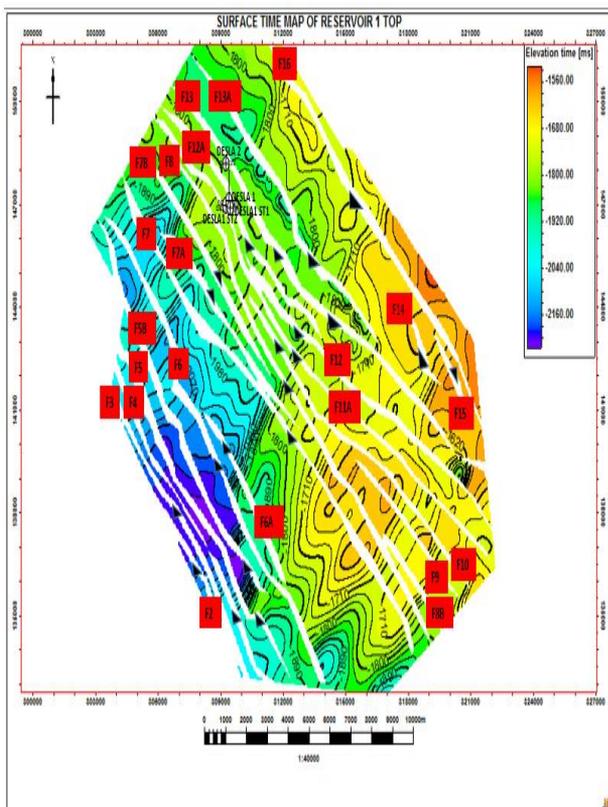


Figure 9. Surface time maps of Reservoir 1 showing the various faults that cut across it and their orientations

This is a typical hydrocarbon trap type common in the Niger Delta region. Also another major fault F16 and minor fault F15 forms an antithetic faults.

These faults might serve as a hydrocarbon trap and/or seal in terms of a fault assisted closure as seen on the far east end of the surface map in Figure 9.

Furthermore, fault F7 is also a regional fault that can deter further migration of hydrocarbon around the south-eastern closures. The latter two discussed locations are prospects for the better extraction of the hydrocarbon, therefore they should be further studied with the aid of quality reservoir models.

4.4.2 Petrophysical evaluation and analysis of reservoir 2

Reservoir 2 is the main prospect according to results generated from petrophysical evaluation and analysis. The structural surface (time) map of reservoir 2 is displayed in Figure 10. The surface (time) of reservoir 2 was picked within -1725.50ms and 3011.99ms.

The regional growth fault F16 form a fault assisted closure on the structural high at the far eastern end of this surface map. The major fault F7 can also serve as both trap and barrier for further migration of hydrocarbon as seen in the southern region of the map. This prospect might be the best location to drill developmental well for further exploitation of this promising reservoir. Furthermore, more data needs to acquired eastwards to further explore the emerging structural high.

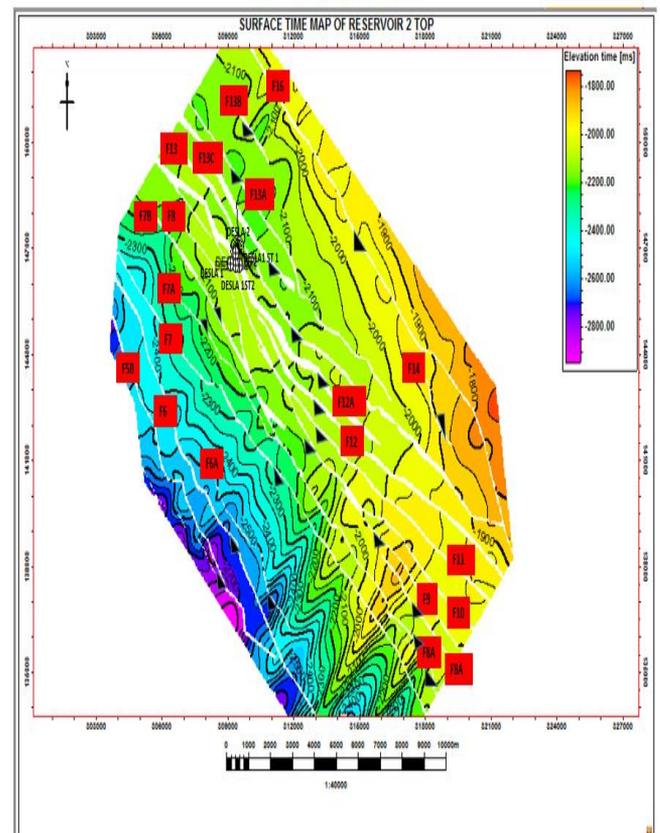


Figure 10. Surface time maps of Reservoir 2 showing the various faults that cut across it and their orientations

4.4.3 Petrophysical evaluation and analysis of reservoir 3

The last delineated and the deepest reservoir is Reservoir 3. The reservoir is very close to the previous reservoir unit. This surface (time) was picked within -1709.25ms and 3090.18ms.

The regional growth fault F16 also cut across this reservoir and form fault assisted closure on the structural high at the far eastern end of the surface map.

The major fault F7 might also serve as barrier for further migration of hydrocarbon as seen in the southern region of the map. This prospect might be a good well location to further develop this reservoir. Furthermore, more data needs to be acquired eastwards to further explore the emerging structural high. The structural surface (time) map of reservoir 3 can be seen in Figure 11 below.

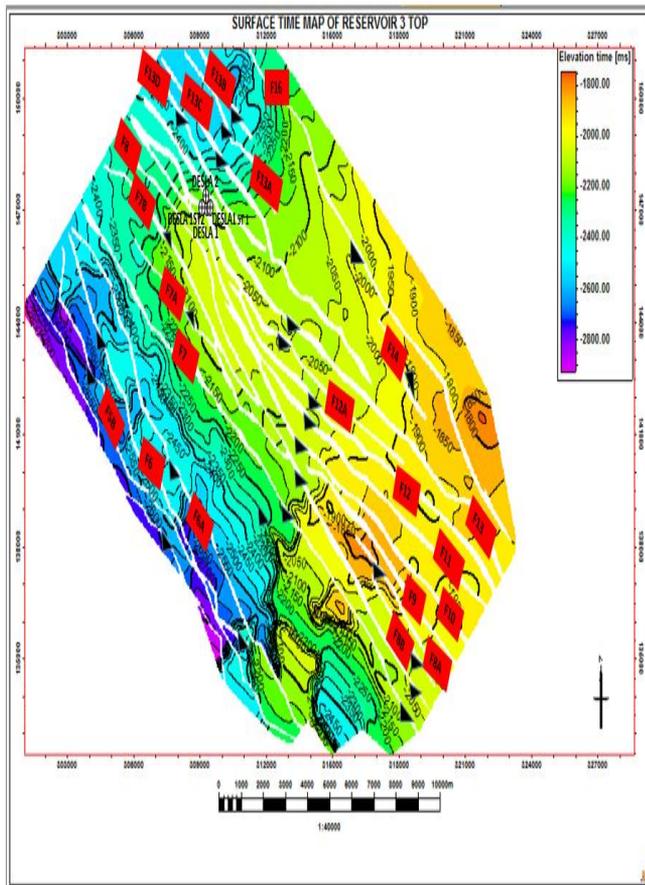


Figure 11. Surface time maps of Reservoir 3 showing the various faults that cut across it and their orientations

5. CONCLUSION

From the study, reservoir 2 is observed to be the most promising reservoir. It can be seen from the chart in Figure 6 that DESLA2 have the thickest delineated unit and also have the highest sand thickness. However, DESLA1ST2 is observed to have the highest net pay, a good net to gross, a reasonable effective porosity of about 20% with the highest hydrocarbon saturation of 82% which makes it the most promising available well for hydrocarbon extraction in this reservoir.

The prospect located at the southern part of both reservoir 2 and reservoir 3 as discussed above is a good well location that might help to enhance extraction of more economical quantity of hydrocarbon simultaneously from these close reservoirs. There is also need for an extended seismic data towards the eastern end of this study area to further evaluate and study the extent of the anticline of this area which might also be a prospective producing well location.

This study has been able to make judicious use of the limited data available to delineate and characterize reservoirs based on their hydrocarbon potential while identifying prospective well location that will enable effective extraction of the hydrocarbon in place. Furthermore, it is also recommended that more wells should be drilled at prospective location in order to provide more data that will contribute to the generation of quality reservoir models.

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NOMENCLATURE

NT	Net Thickness, ft
GT	Gross Thickness, ft
NTG	Net to Gross Thickness, %
NP	Net Pay Thickness, ft
Vsh	Volume of shale, %
Sw	Water Saturation, %
Shc	Hydrocarbon Saturation, %