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Evaluation Of Petrophysical Properties of a Field in Deep Off Shore Niger Delta, Nigeria.

*Osaji, AdaobiGloria[1], Chiazor, FortuneIjeoma[2], Patta, Anthony Lenata[3]
[1,3] *Centre for Petroleum Geosciences, University of Port Harcourt, Nigeria*
[2] *Department of Geology, University of Port Harcourt, Nigeria*
**Corresponding Author*

Abstract
This study involves petrophysical reservoir analysis of four wells SAJI-001, SAJI 004-ST1, SAJI 003-ST1, SAJI-005 using composite well logs. The suite of well logs consists of gamma ray, resistivity, neutron and density log. The conventional methods of well log qualitative and quantitative interpretation were adopted. The main lithology obtained from the gamma ray logs are sands and shale. Four reservoirs were identified and correlated across the four wells. The petrophysical analysis finding result indicates that the average shale 0.08 to 0.23 (Frac), total porosity 0.22 to 0.28 (Frac), effective porosity 0.20 to 0.22 (Frac), permeability 117.5 to 180.32 (mD) and water saturation 0.29 to 0.46 (Frac) and the finding indicates that the reservoir rocks are very good in quality.

Keywords: *Petrophysical, Reservoir, Lithology, Wells and Correlated.*

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I. INTRODUCTION

The Niger Delta Basin is an economically significant and complex geological region extending from Nigeria to the Gulf of Guinea. It develops because of swift deposition of sediments without effective sediment dewatering (Iheaturu et al., 2022:Nnurum et al., 2024). Because of swift deposition, different types of sediments co-occur very commonly in the form of sediment intercalation. The research regarding those petrophysical characteristics and interaction between different fluids i.e., gases, liquid hydrocarbons, and aqueous solutions is very crucial to reservoir characterization (El Din et al., 2011).

The knowledge regarding the geological aspects in the petroleum reservoirs should be understood in order to evaluate the petroleum reservoirs' geological characteristics to store hydrocarbons. A three-dimensional pore link in the rock leads to the effective storage and discharge of fluids in a reservoir. Due to the requirement to form an opinion regarding the storage capacity and ability to convey reservoir rocks, porosity and permeability are fundamental physical characteristics. Proper development and management ability to forecast future performance require effective awareness and relationship with reservoir fluids about such characteristics. Core analysis based on petrophysical data in petroleum and gas operations matters because it provides an insitu reservoir characterization that provides crucial information used in supporting reservoir quality and maximum strategy in hydrocarbon recovery. Investment and economic recovery applicability in the process of hydrocarbon recovery and drilling and field development plans are informed by such an assessment (Osurinde et al., 2019).

However, the reservoir is controlled by the depositional environmentin a fluvial system, the reservoir will be described to consist of the overbank deposits and the sands in the channel and they will be high in horizontal and in-lateral heterogeneity (Reading, 1996). While marine environments will form gigantic continuous sand bodies (turbidites).

The rock core samples from the formations are recovered and tested in a laboratory and the laboratory tests the rock core samples and analyses the rock core samples' physical and chemical characteristics according to the process to apply core petrophysical and lithological data analysis. It provides the data on the fluid saturation, porosity, and permeability (Nnurum et al., 2021) among other reservoir characteristics. One among many types of sediments, exists where the reservoir characteristics change laterally in the same formation layer. The reservoir characteristics changes with depth. The reservoir characteristics in the context of space refer to changes in the characteristics between different places such as between formations or between different layers while temporal variations in rock properties exist where reservoir characteristics change with time due to injection, production, or natural causes.

Quantification of the capacity of the rock to store and allow fluids to permeate will be the foundation upon which reservoir simulation and production predictions will be achievedNnurum et al., 2021). Improved methods and techniques will allow us to process meaningful information from data in the subsurface with accuracy to high levels. The awareness gained in lithology discrimination has resulted from the quest to find an economic hydrocarbon reservoir and the requirement to have clear awareness of the petrophysical and lithological characteristics that will allow effectiveproduction of hydrocarbon.

The objective of this study is to integrate the petrophysical and lithological properties of reservoir rocksin deep offshore Niger Delta sedimentary basin. The X Field is a deepwater offshore field spudded and made up of four main wells. The X Field is Nigeria's largest deepwater oil field. The field was developed with subsea wells tied back to a floating production, storage and offloading (FPSO) vessel.

II. LOCATION OF THE STUDY AREA

The study area is located within the offshore area of Niger delta, Nigeria between latitude
04° 30' 00"N to 05° 30' 00" N and Longitude 05° 00' 00"E to 06° 30' 00"E. The Niger Delta region Nigeria is presented in Figure 1.

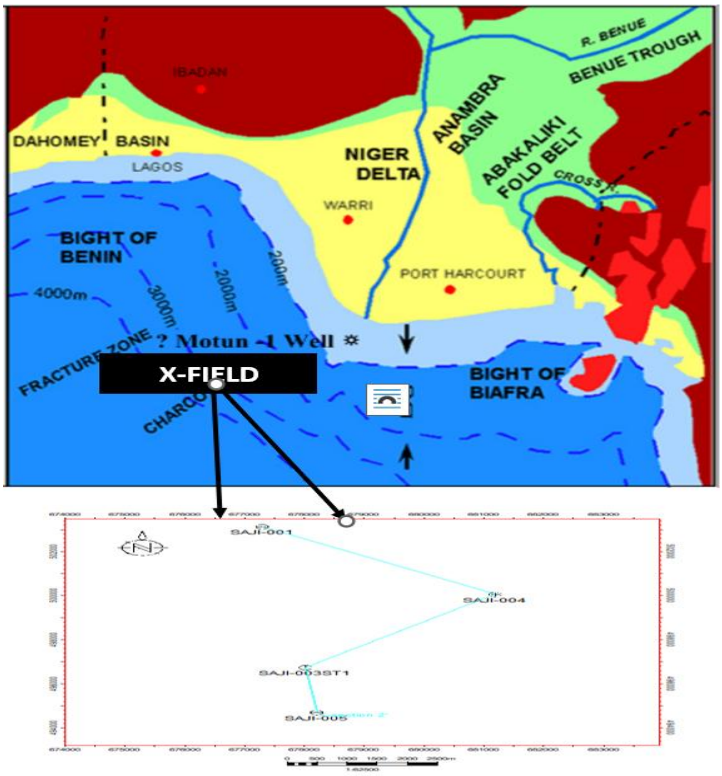


Figure 1: Location and Base map of the study Area (Ogbahon & Afolabi, 2020)

III. GEOLOGY OF THE NIGER DELTA

The Niger Delta sedimentary basin is made up of three lithostratigraphy (Fig 2). They are Akata Formation, Agbada Formation, and Benin Formation.

THE AKATA FORMATION

Akata Formation is a significant geologic unit in the Niger Delta basin because it is the main source rock. It is a constituent of the Tertiary Niger Delta (Akata-Agbada) Petroleum System and is one of the principal hydrocarbon producers in the region (Doust & Omatsola, 1990). Its appearance is dark Gray, uniform shale with a thin interbedded turbidite sand and silt (Ekweozor & Daukoru, 1994). The Akata Formation, since Paleocene to the present, was deposited under low sea level conditions where terrestrial material is deposited into deep-water environments Kulke, (1995).

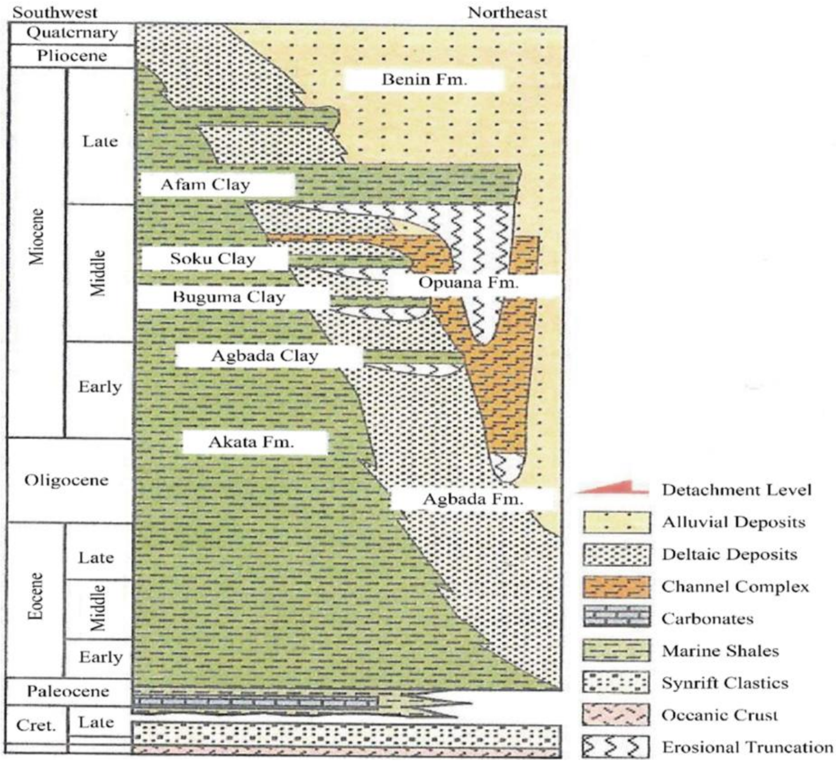


Figure 2: Stratigraphic column showing the three formations of Niger delta (Whiteman, 1982).

THE AGABADA FORMATION

The Agbada Formation, deposited during the Eocene through the recent times, represents a significant geologic unit of the Niger Delta Basin. The formation is the main petroleum-containing formation of the delta and very significant in regional hydrocarbon production. Agbada Formation is characterized by interbedding shale and sandstone sequences, which are over 3,700 meters thick and correspond to delta-front and delta-topset facies. Agbada Formation is made up of sandstones that form primary reservoirs and shales that form seals. Depositional cycles of the formation vary from 15 to 100 meters, with transgressive marine sands and fluvio-deltaic deposits forming its characteristic stratigraphy. These repeated sedimentation patterns are a sign of differential subsidence and sediment supply. Agbada Formation has a thickness of 10,000 to 15,000 feet and is structurally variable and depositional positions (Short & Stauble, 1967).

THE BENIN FORMATION

The Benin Formation largely consists of coarse- to medium-grained sandstones with occasional intercalations of shales and clays. The sands are virtually unconsolidated, highly porous, and permeable, making them very good aquifers for drinking groundwater. The absence of faunal content in the formation prevents easy dating; however, geological studies reveal that deposition occurred from the Late Eocene to the Recent (Short & Stauble, 1967). The Benin Formation has a depositional environment that is continental in nature, comprising sediments deposited under alluvial and deltaic plain conditions. The environments are dominated by complex interactions of fluvial, deltaic, and coastal processes, which resulted in a heterogeneous lithological composition. The stratigraphy is characterized by thick sand sequences with interbedded thinner layers of clay and shale. The confining layers for groundwater are provided by the shale and clay layers, rendering the formation hydro geologically more valuable (Reijers, 2011). The sedimentological complexity of the formation reflects the variation in sediment supply and energy of deposition. Poorly cemented sandstones of the Benin Formation often contain feldspar and quartz as major minerals. Their friability accounts for their good aquifer properties, and occasional clay interbeds, which act as aquitards, provide natural protection against groundwater reservoir contamination. The Benin Formation is the principal aquifer system in much of the Niger Delta Basin.

IV. STRUCTURAL AND TECTONIC EVOLUTION OF THE NIGER DELTA BASIN

Tectonic frameworks which act along the west coast of equatorial Africa influence the structural evolution and tectonics of the Niger Delta Basin. The framework itself is determined by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic Ocean. Such fracture zone ridges divide the margin into distinct basins and form the boundary faults of the Cretaceous Benue-Abakaliki Trough in Nigeria. The

Benue-Abakaliki Trough, an important structural feature, extends extremely deep within the West African shield and is a failed arm of a rift triple junction related to the opening of the South Atlantic. Rifting in this part started in the Late Jurassic, going through into the Middle Cretaceous (Lehner & De Ruiter, 1977). The structural representations of tectonic activities are so very complicated and range from shale diapirs to rollover anticlines, from collapsed growth-fault crests to back-to-back fault systems as well as steeply dipping, closely spaced flank faults (Figure 3).

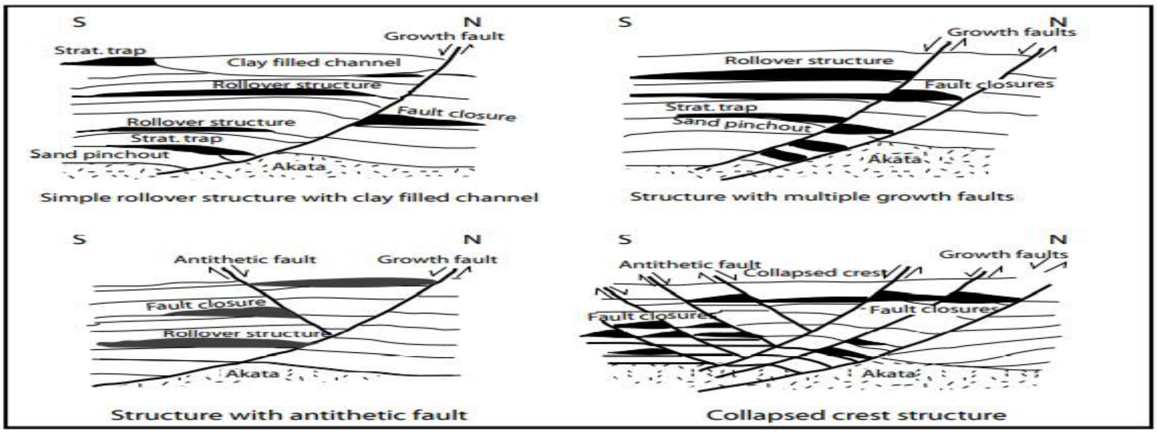


Figure 3: Example of Niger Delta oil field structure and associated trap types (Doust & Omatsola, 1990; Stacher, 1995).

These all combine to define a particular structural identity of the Niger Delta (Evamy et al., 1978). The schematic seismic section from the Niger Delta continental slope and rise, which shows the incidences of gravity-driven tectonics on sediments in the distal parts of the depobelt (Stacher 1995). These distal tectonic features are crucial for today's understanding of sedimentary deformation and hydrocarbon distribution within the basin.

Thus, the structural evolution of the Niger Delta illustrates the interplay between tectonic processes and sedimentary processes. The affirmative initial rifting during the Late Jurassic and Cretaceous created the most general structural framework of the basin, while later gravity tectonism proved to exercise internal deformation.

V. MATERIALS AND METHODS

DATA SET

The Petrophysical analysis carried out in this study was conducted using suite of well logs for four wells. The suite of well logs is made of gamma ray log, neutron log, density log and resistivity log.Petrophysical analysis deals with systematic procedures for interpreting well log data in order to obtain reservoir properties. The research designed is to evaluate the petrophysical properties of a field in deep off shore Niger delta. The research steps employed are shown in (Figure 4).

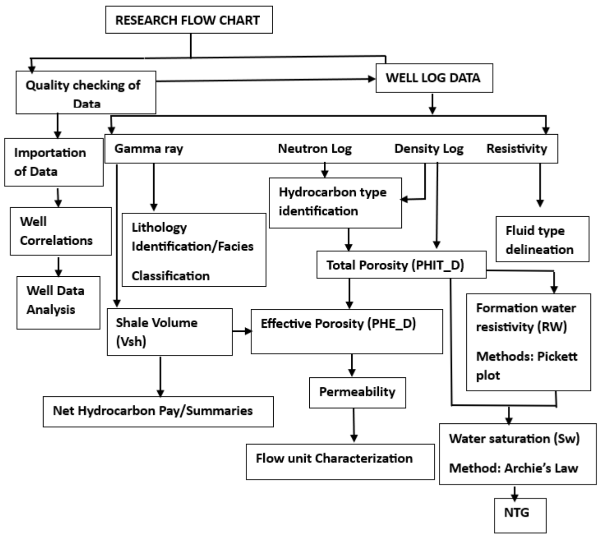


Figure 4: Well data and logs suite utilized in the present study

Lithology Identification: The gamma ray, density, and neutron logs helped identify lithological units and correlate with core information.
Shale Volume Calculation (Vsh): This was estimated from gamma ray logs for the quantity of shale within the reservoir. 3.1

$Vsh(IGR) = \frac{GR_{logSignal} - GR_{CleanRock}}{GR_{Shale} - GR_{Clean\,rock}}$ 1

$VSHLarinovTertiaryRocks = (0.083(2^{3.71*IGR}$ - 1) 2

Vshale was estimated using GR
The GR method involved the application of Larinov tertiary rock. The method was preferred due to IGR correction in areas of radioactive sand
Lithology Petrology: Core samples were intensively petrologically investigated in order to determine the mineral composition and the texture, which define the reservoir quality.

Petrophysical Property Estimation
Total Porosity Φt (PHIT_D): Porosity would be estimated using the density log data to provide a measure of the total pore volume in the reservoir rock.
Total Porosity was calculated from density log:
PHIT = (*pma – pb*)/ (*pma -pfl*) 3
Where:
PHIT = total porosity
Pma = matrix density
Pb = bulk density
Pfl = fluid density
Effective Porosity Φeff (PHE_D): Effective porosity was calculated to establish the connected pore volumes that allow for fluid flow.
Effective Porosity was calculated using the formula:
PHIE = PHIT*(1 –VSH) 4
Where:
PHIE = effective porosity
PHIT = total porosity
VSH= volume of shale
Permeability: Permeability was estimated from core and well log data, which provides details regarding the ease with which fluids can pass through the reservoir.
Permeability was estimated using the formula:
K =$28.67e^{0.251\emptyset}$ 5
K = Permeability
∅ = porosity
e = exponential
Perm (K) decreases exponentially with Porosity across all the wells as lithologies transit between Sand and Shale
Water Saturation (Sw): Water saturation has been determined using Archie's Law, which approximates water saturation from resistivity and porosity data.
Water saturation was estimated using Indonesian shale. This is because Archie is too optimistic in shaly-sand zones. Therefore, results from Indonesian shale were preferred in those zones.
Resistivity of water is an important input in Sw estimation due to Rw data sparsity, Pickett plot of each reservoir was made and used to determine water resistivity (Rw).

$$SW_{\text{Indonesia}} = \left\{ \frac{\sqrt{\frac{1}{Rt}}}{\left(\frac{Vsh^{(1-0.5Vsh)}}{\sqrt{Rsh}}\right) + \sqrt{\frac{\phi_e^m}{a.Rw}}} \right\}^{(2/n)}$$ 6

Net-to-Gross Ratio (NTG)

Net-to-Gross (NTG) ratio is a significant reservoir assessment parameter that approximates the percent of net reservoir rock (i.e., the permeable and porous rock that can hold and transmit hydrocarbons) relative to the entire volume of rock (gross rock).

VI. RESULTS AND DISCUSSION

Identified Lithology and Reservoir Sands

Lithology was inferred from the behaviour of the gamma ray logs. Shale and sandstone were the major lithologies inferred from the well log. When the gamma ray log deflects towards right-hand side it has been considered to have high radioactive element which is an indication for shale lithology.When the deflection is towards left-hand side it is considered an indication of low radioactive element which is interpreted as sand stone lithology. The sand stone zone of high resistivity is designated as high hydrocarbon bearing zone. The sand stone is designated by yellow colour while shale zone is designated black colour. as shown in (Figure 5).

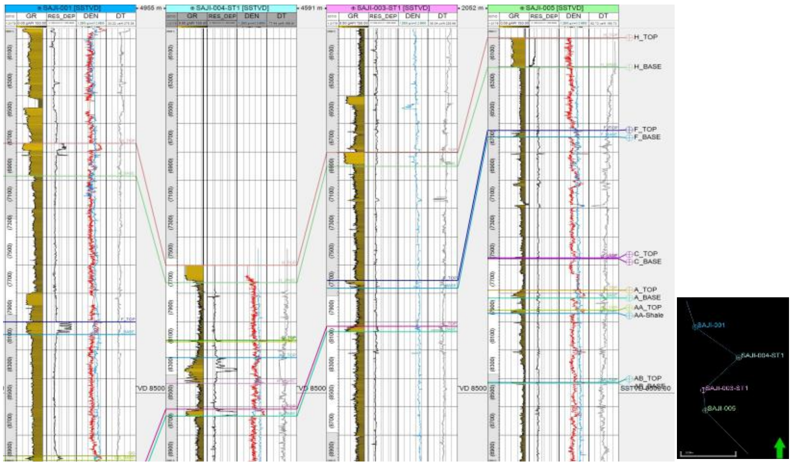


Figure 5: Well logs of SAJI-001, SAJI-004 ST1 SAJI-003 ST1, and SAJI-005

Computed Petrophysical properties from well logs

The computed petrophysical properties for the various identified reservoirs are shown in

Table 1. Petrophysical analysis revealed that effective porosity is between 0.05 – 0.28 (frac), Gross 14.50-7050.64 (ft), Net 14.50-231.50 (ft), Net to Gross 0.77-0.99 (frac), Average volume of shale 0.08-0.23 (frac), Average total Porosity 0.13-0.31 (frac)Average permeability between 3.11 – 1308.27(mD) and contains water saturation of 0.11 – 0.79 (frac).

The petrophysical parameters computed for the four wells SAJI 001, 003-ST1, 004-ST1 and SAJI-005 are also shown in log forms (Figure:6 – Figure:32).

Table 1: Petrophysical Sums and Averages

	Well	Zones	Top	Bottom	Gross (ft)	Net (ft)	Net to Gross	Av_Shale Volume (ft3/ft3)	Av_Porosity (ft3/ft3)	Av_Water Saturation (ft3/ft3)	Av_PHIE_D	Av_PERM_WR
1	SAJI-001	H_TOP	6819.00	7050.64	231.64	231.50	0.98	0.23	0.28	0.46	0.22	180.32
2	SAJI-001	F_TOP	8080.32	8169.79	89.47	89.29	0.98	0.18	0.28	0.11	0.24	253.14
3	SAJI-001	GG	9026.74	9058.89	32.15	29.89	0.93	0.30	0.25	0.31	0.18	92.37
4	SAJI-001	E_TOP	9242.82	9299.14	56.32	56.14	0.98	0.15	0.21	0.16	0.18	91.89
5	SAJI-001	A_TOP	9982.03	10080.58	98.55	79.00	0.80	0.27	0.19	0.43	0.13	39.28
6	SAJI-003-ST1	H_TOP	6881.78	7230.16	348.38	337.16	0.97	0.24	0.27	0.79	0.23	188.35
7	SAJI-003-ST1	F_TOP	7788.31	7842.65	54.34	42.15	0.78	0.17	0.26	0.41	0.24	248.66
8	SAJI-003-ST1	E_TOP	8111.17	8150.06	38.89	36.56	0.94	0.08	0.24	0.40	0.23	200.07
9	SAJI-003-ST1	ED_TOP	9339.51	9378.20	38.69	38.20	0.99	0.12	0.29	0.08	0.27	468.72
10	SAJI-003-ST1	D_TOP	9549.55	9568.44	18.89	18.44	0.98	0.08	0.05	0.26	0.05	0.76
11	SAJI-004-ST1	H_TOP	7680.96	7788.73	107.77	107.23	0.99	0.02	0.09	1.00	0.09	3.11
12	SAJI-004-ST1	G_TOP	8211.08	8220.39	9.31	8.89	0.96	0.15	0.33	0.36	0.33	920.36
13	SAJI-004-ST1	F_TOP	8338.54	8508.54	170.00	167.54	0.99	0.15	0.23	0.32	0.20	109.75
14	SAJI-004-ST1	E_TOP	8695.79	8745.79	50.00	47.79	0.96	0.07	0.31	0.15	0.30	572.92
15	SAJI-004-ST1	D_TOP	9657.44	9688.55	31.11	31.05	0.99	0.04	0.25	0.17	0.24	216.41
16	SAJI-004-ST1	A_TOP	9782.25	9797.81	15.56	13.81	0.89	0.14	0.23	0.64	0.20	105.21
17	SAJI-004-ST1	AA_TOP	10748.20	10762.20	14.00	13.70	0.98	0.06	0.24	0.24	0.24	227.24
18	SAJI-004-ST1	AB_TOP	10818.10	10826.20	8.10	6.20	0.77	0.22	0.24	0.22	0.21	146.83
19	SAJI-005	H_TOP	6252.08	6282.82	30.74	30.32	0.99	0.00	0.31	0.93	0.31	581.78
20	SAJI-005	F_TOP	6728.54	6774.63	46.09	45.63	0.99	0.09	0.29	0.35	0.28	385.27
21	SAJI-005	E_TOP	6893.51	6897.59	4.08	3.59	0.88	0.00	0.36	0.20	0.36	1308.27
22	SAJI-005	D_TOP	7104.06	7119.99	15.93	15.49	0.97	0.03	0.30	0.25	0.30	516.53
23	SAJI-005	C_TOP	7628.67	7633.98	5.31	4.98	0.94	0.00	0.25	0.61	0.25	245.49
24	SAJI-005	A_TOP	7882.30	7912.30	30.00	29.80	0.99	0.06	0.26	0.72	0.25	248.71
25	SAJI-005	Ac_TOP	10022.40	10030.20	7.80	7.70	0.99	0.02	0.32	0.40	0.32	669.08
26	SAJI-005	Ad_TOP	10230.60	10312.40	81.80	81.40	0.99	0.01	0.30	0.18	0.30	546.97
27	SAJI-005	Ae_TOP	11040.00	11054.50	14.50	14.50	0.99	0.08	0.22	0.29	0.20	117.5

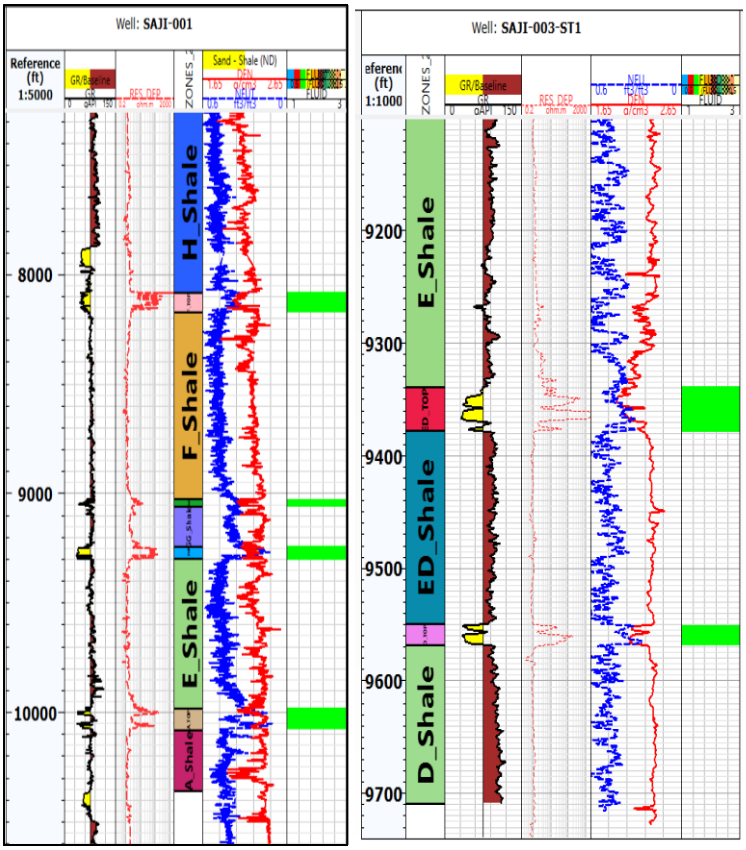


Figure 6: Fluid Distribution

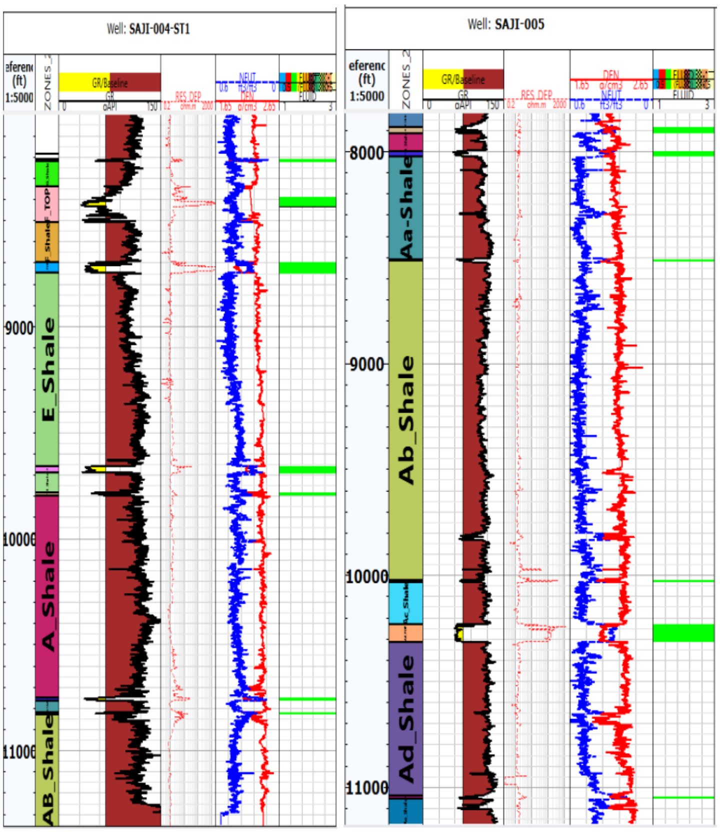
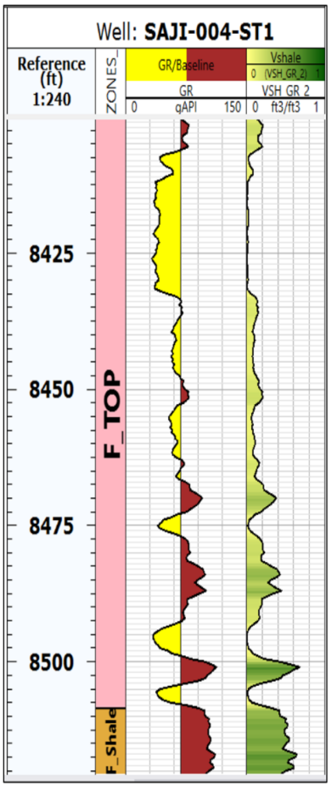


Figure 7: Fluid Distribution



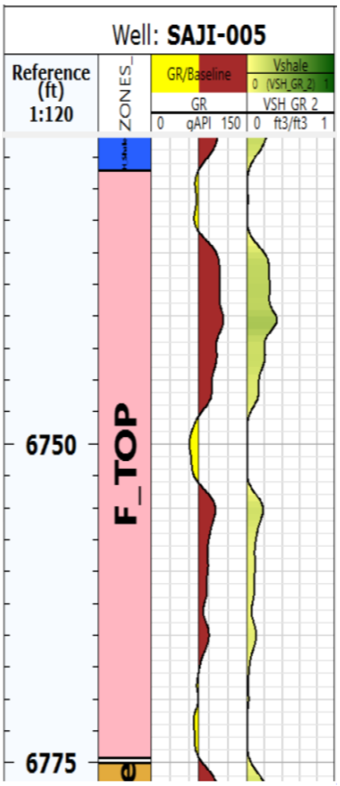
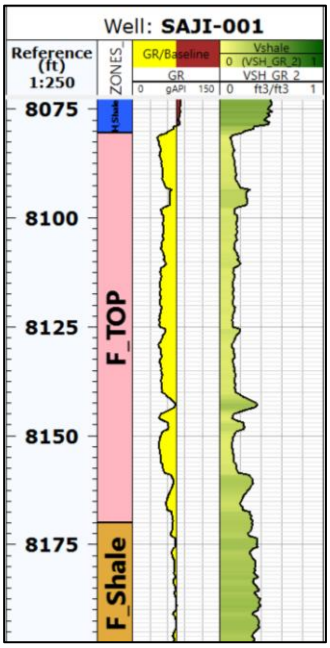


Figure 8: Volume of Shale



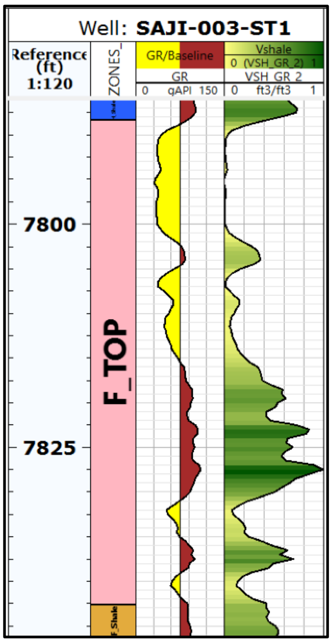


Figure 9: Volume of Shale

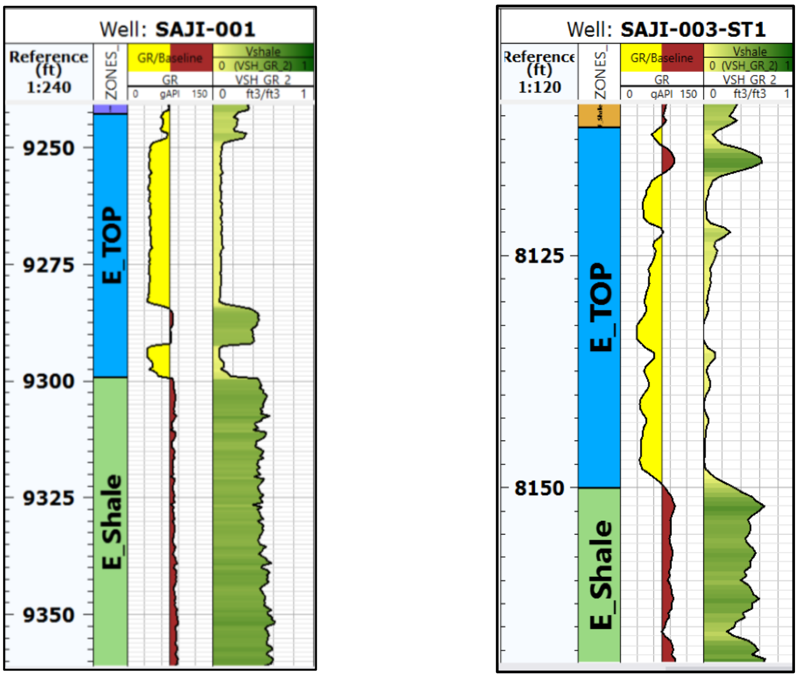


Figure 10: Volume of Shale

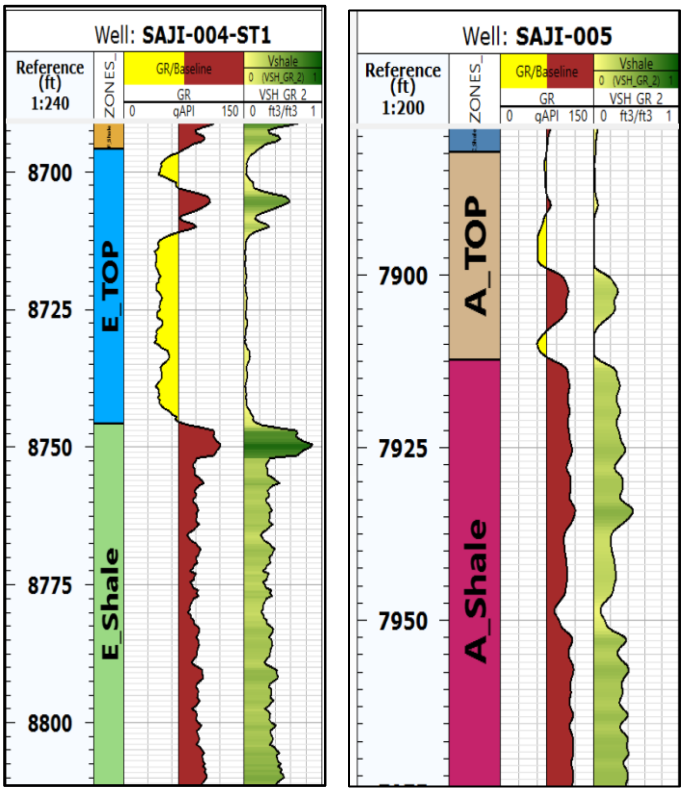


Figure 11: Volume of Shale

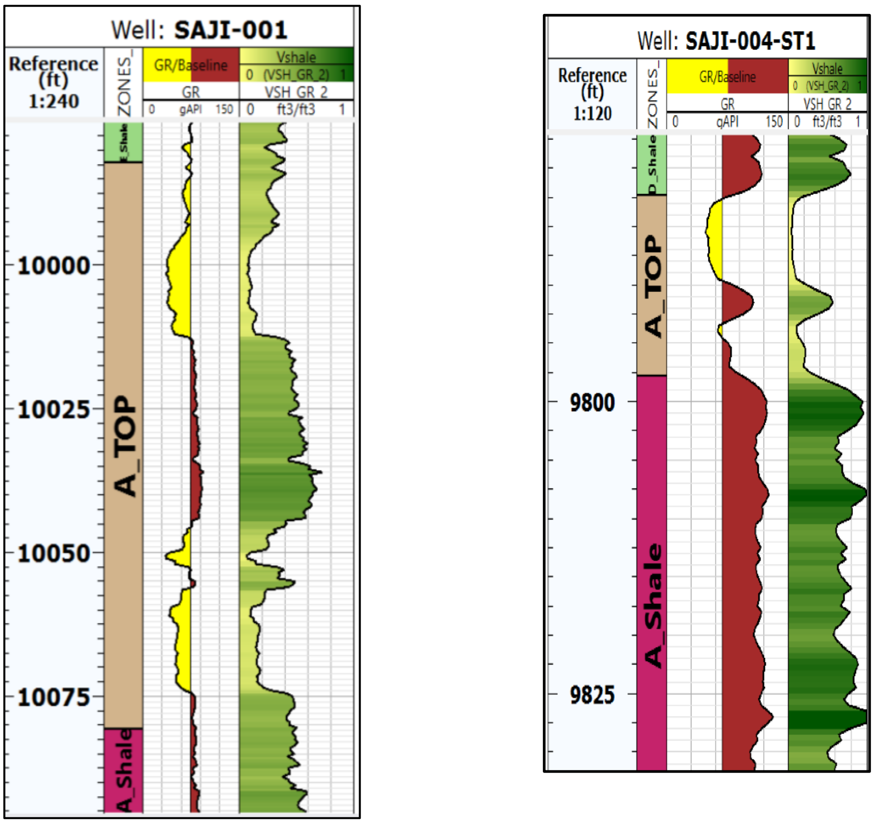


Figure 12: Volume of Shale

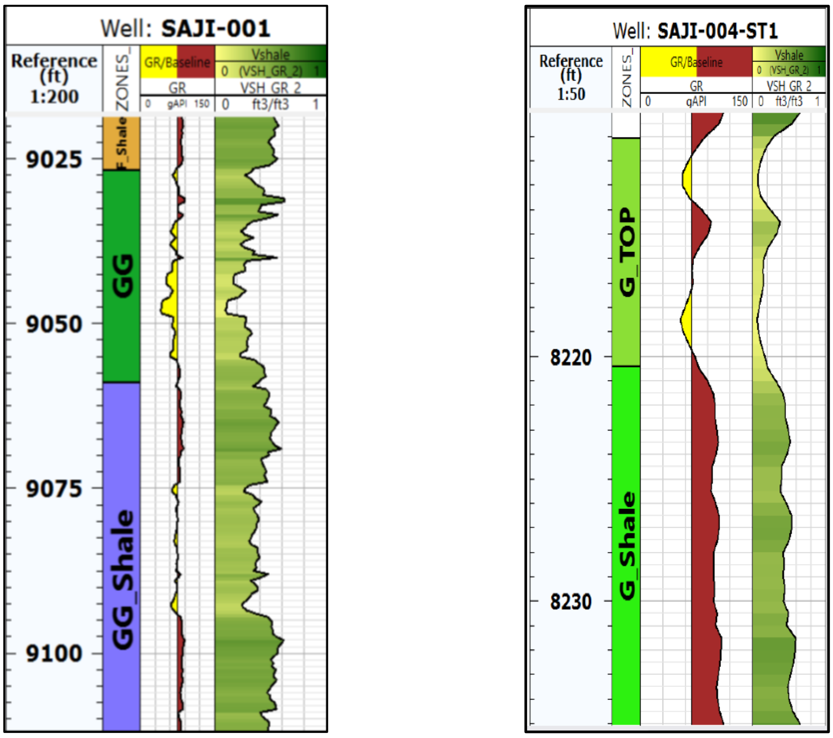


Figure 13: Volume of Shale

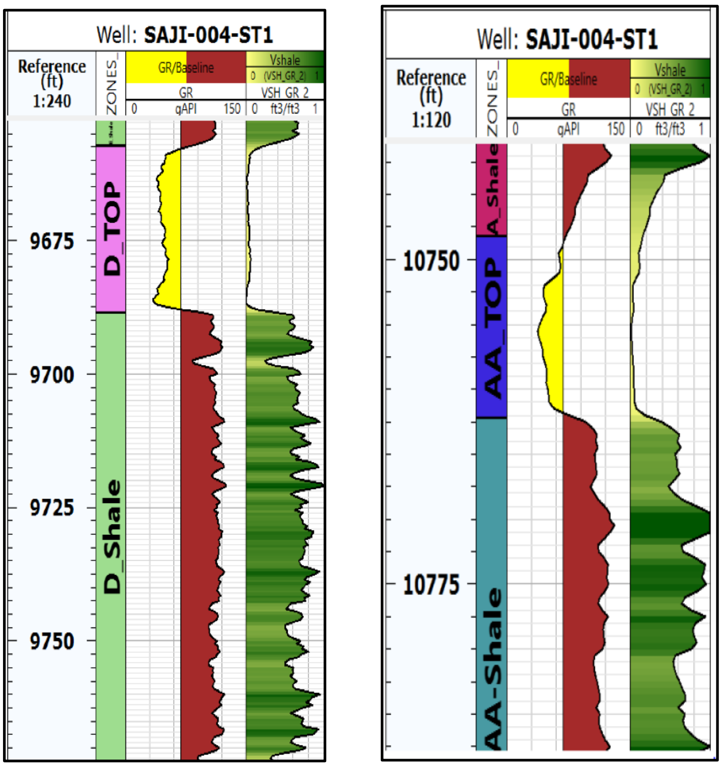


Figure 14: Volume of Shale

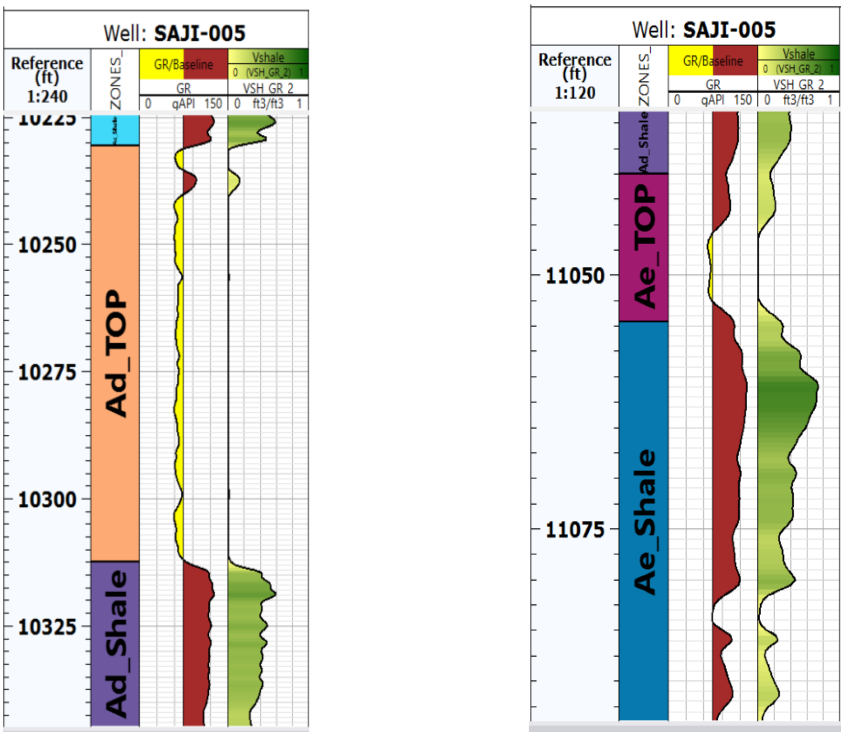


Figure 15: Volume of Shale

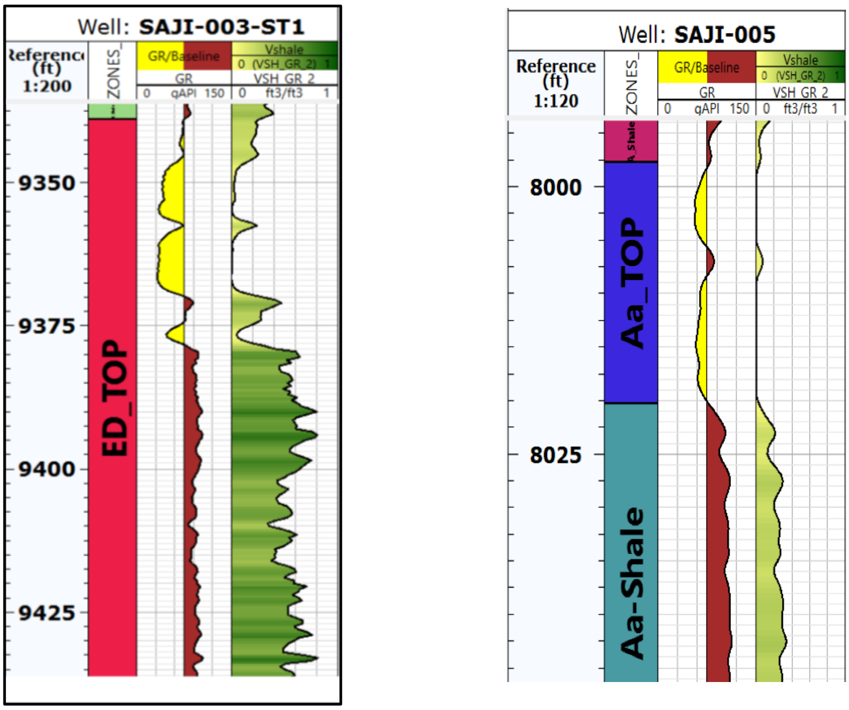


Figure 16: Volume of Shale

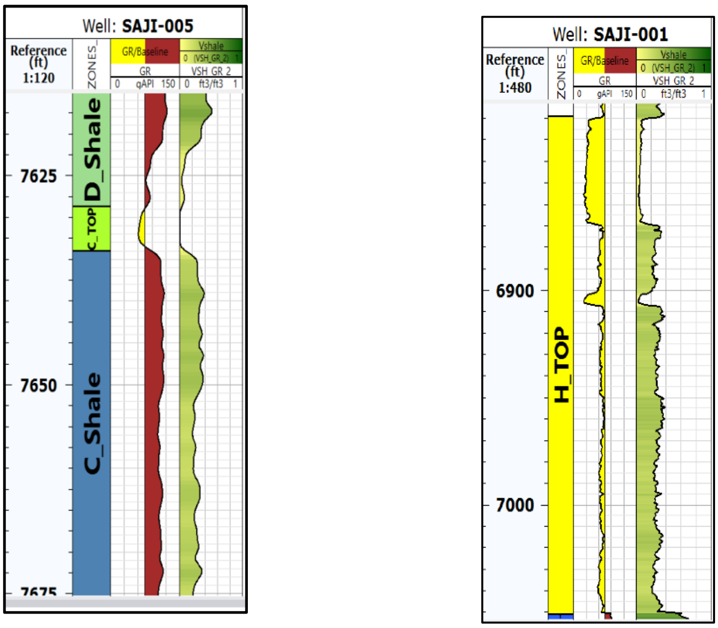


Figure 17: Volume of Shale

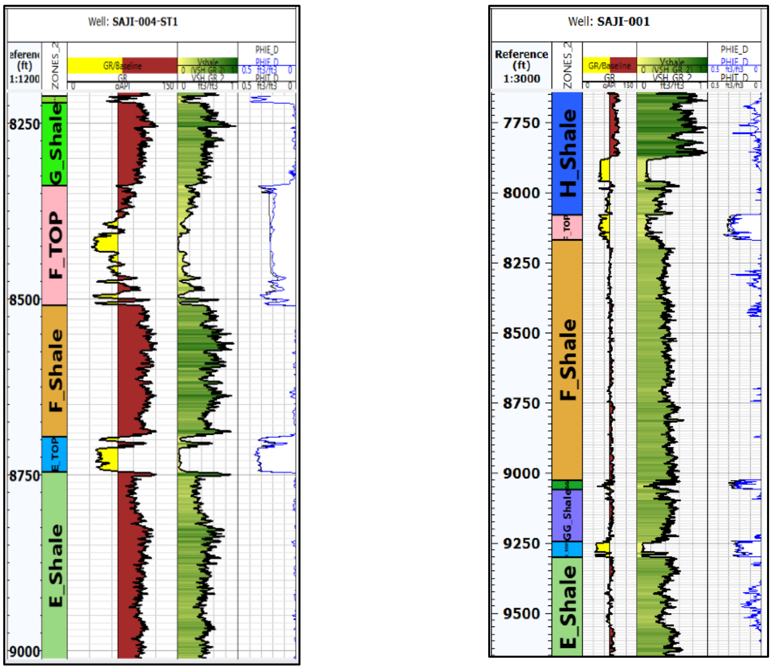


Figure 18: Effective Porosity

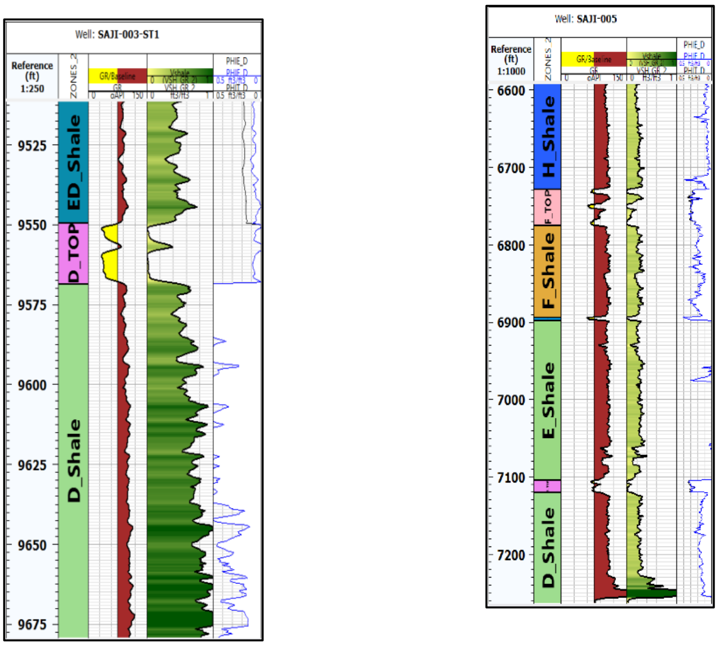


Figure 19: Effective Porosity

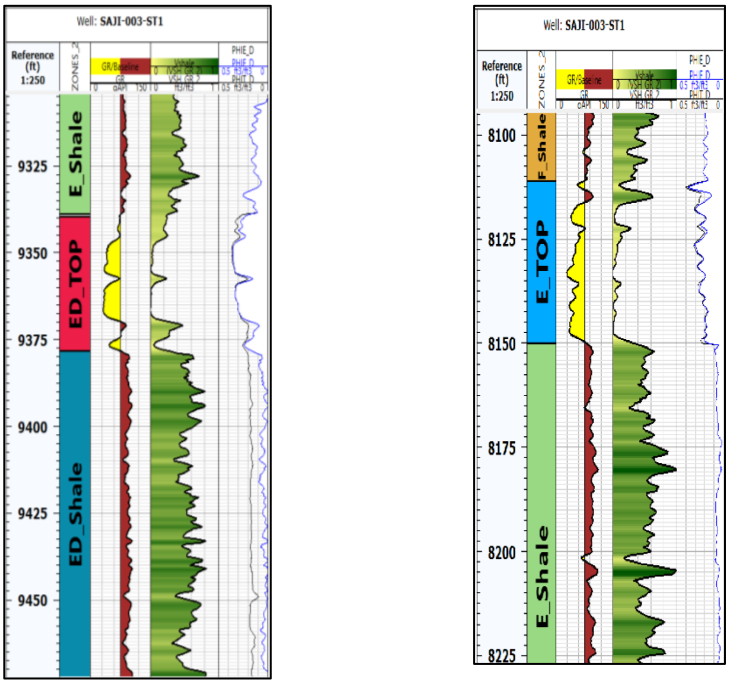


Figure 20: Effective Porosity

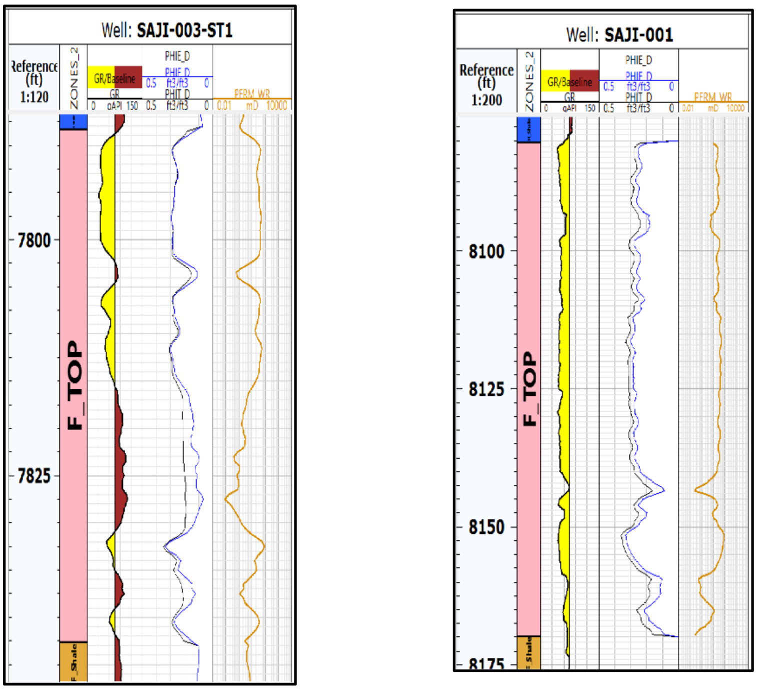


Figure 21: Permeability

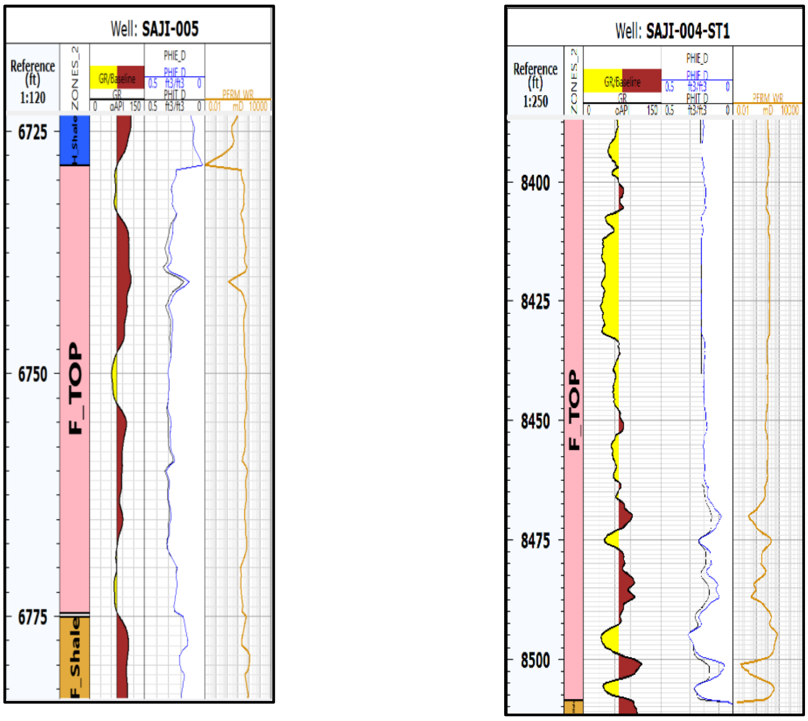
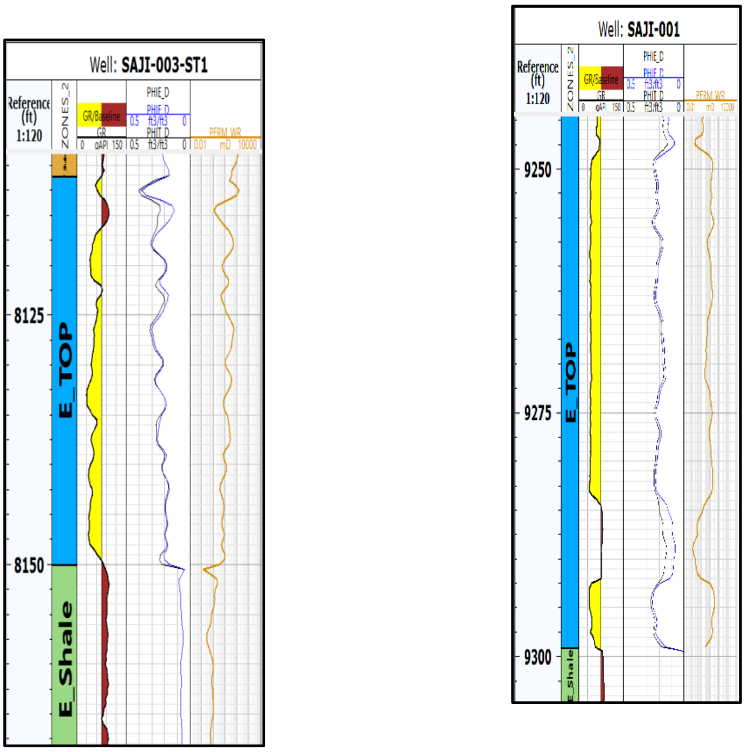


Figure 22: Permeability



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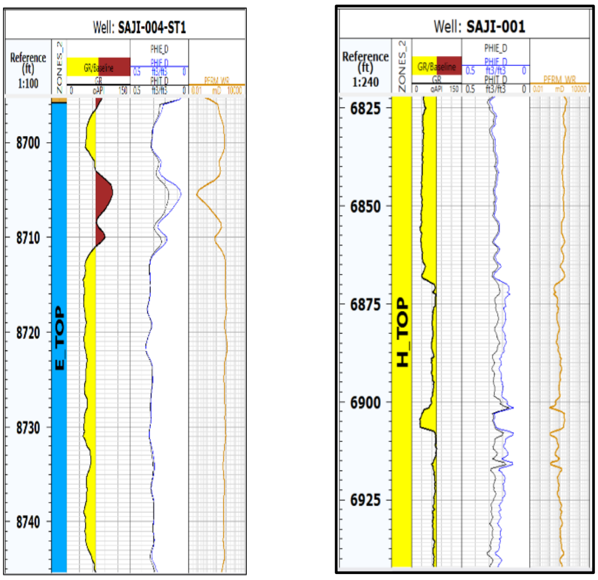

Figure 24: Permeability

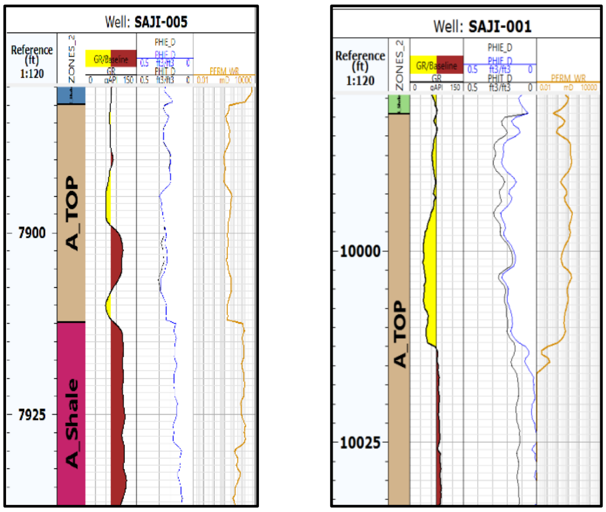

Figure 25: Permeability

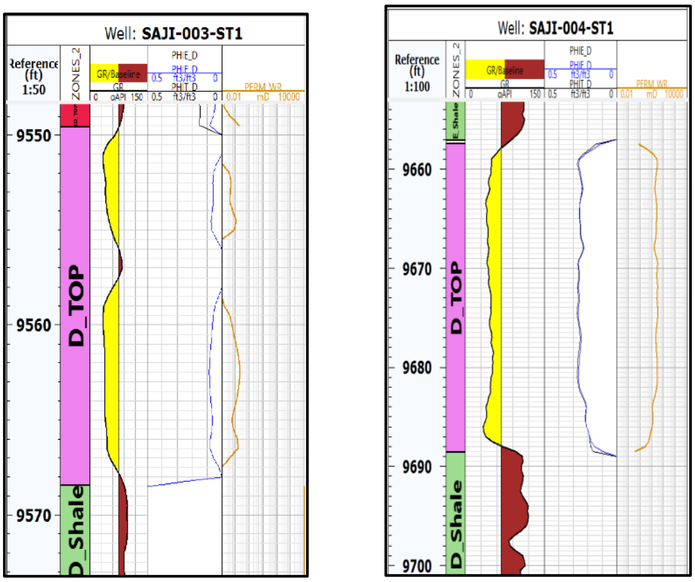

Figure 26: Permeability

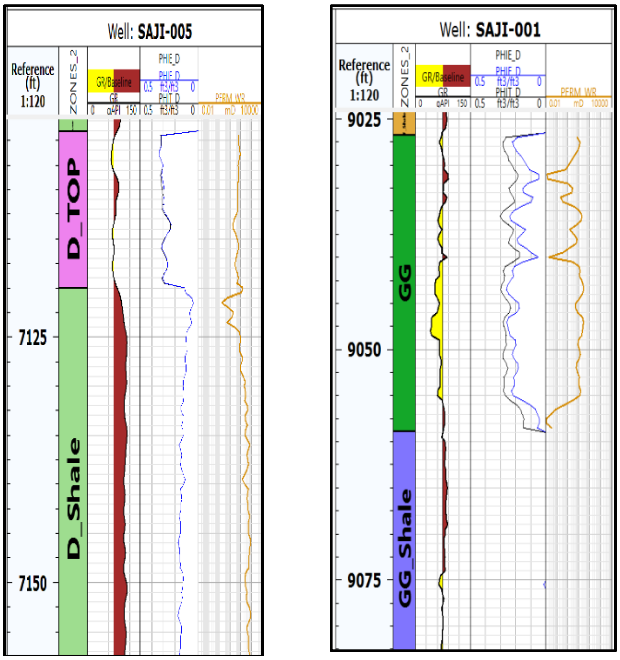

Figure 27: Permeability

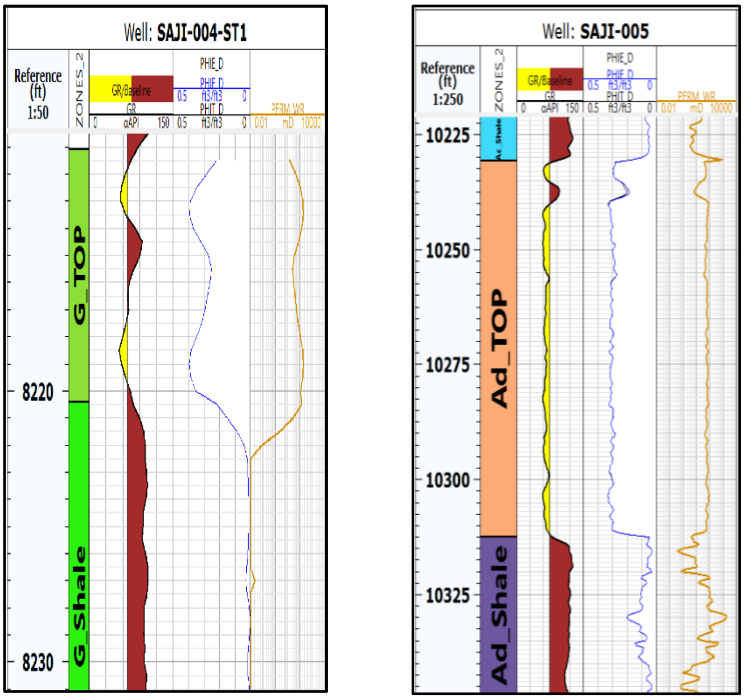

Figure 28: Permeability

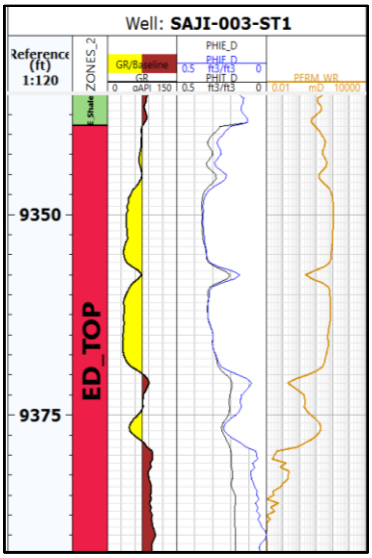

Figure 29: Permeability

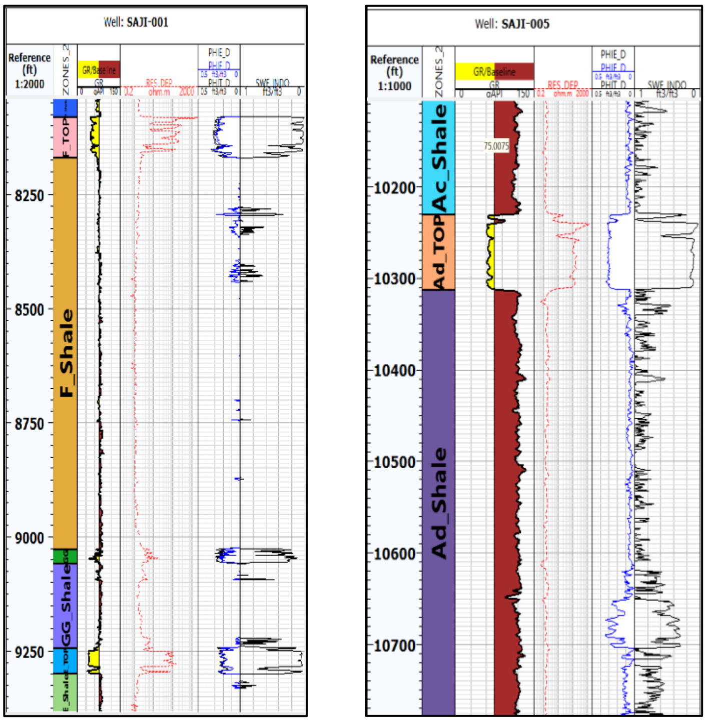

Figure 30: Water Saturation

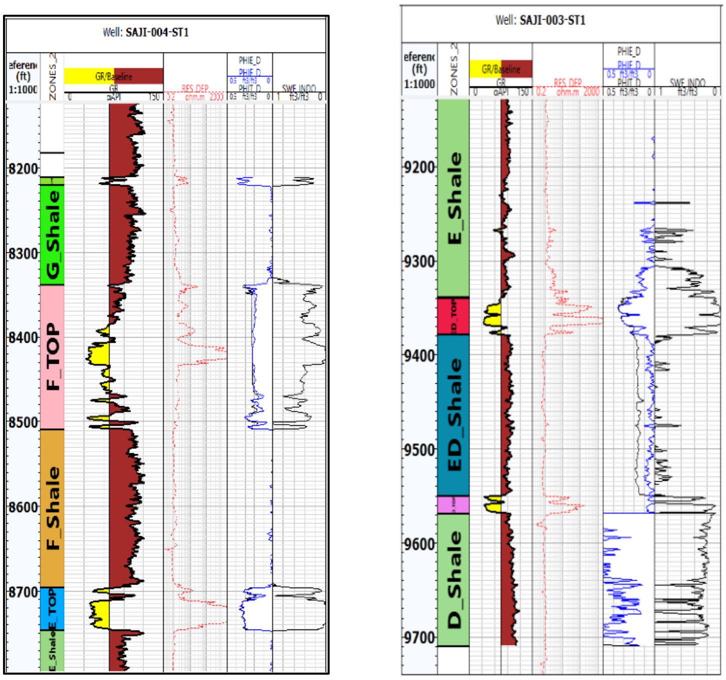

Figure 31: Water Saturation

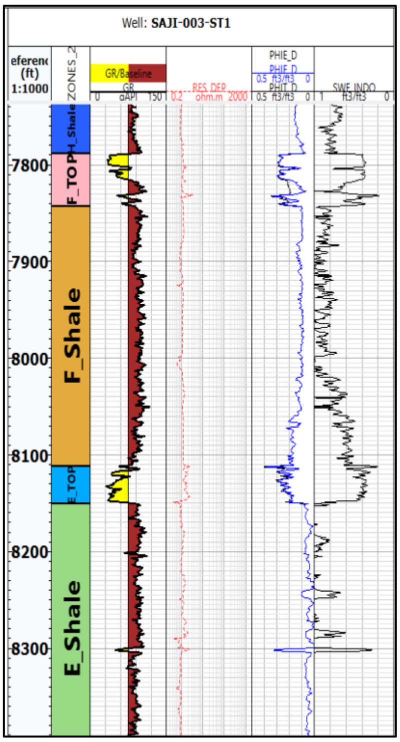

Figure 32: Water Saturation

VII. DISCUSSION OF RESULTS

The lithologies identified from the well logs are mainly sand and shale.

The sand and shale are alternated which is an indication of the Agbada formation within the Niger Delta. Four reservoirs were delineated and were correlated across the four wells used in this study. Petrophysical analysis of the zones of interest in the four (4) wells indicate very low shale volume, an indication of reservoir having very good quality sand and little shale. Total and effective porosity result is >20% which categorized the reservoir sand as very good thus inferring the sand zones are highly porous and good for the trapping of fluids. The permeability range in the zones of interest are excellent to very good and therefore fluid flow within the reservoir units will be effortless. From the water saturation it can be inferred that most of the reservoir has good hydrocarbon potential.

VIII. CONCLUSION

The petrophysical analysis carried out for the X field shows that the four reservoirs identified in the study area using suite of well logs have good hydrocarbon potential. According to the computed petrophysical parameters, the reservoirs exhibit good permeability (1308.27mD), high total effective porosity (0.28 and 0.22 frac, respectively) and low shale volume

(0.08-0.23 frac). The presence of reservoir sands with outstanding hydrocarbon storage and flow potential is confirmed by the well log. Significant hydrocarbon saturation across all zones is indicated by water saturation levels. The x field reservoirs have favourable characteristics for the production and accumulation of hydrocarbons, according to the integrated petrophysical analysis. For reservoir management and field development planning in the study area, these results offer a solid basis.

REFERENCES

[1]. Doust, H., & Omatsola, E. (1990). Niger Delta. In J. D. Edwards & P. A. Santo Grossi (Eds.), *Divergent/passive margin basins* (Vol. 48, pp. 201–238). American Association of Petroleum Geologists.

[2]. Ekweozor, C. M., & Daukoru, E. M. (1994). Northern delta depobelt portion of the Akata-Agbada petroleum system, Niger Delta, Nigeria. In B. Magoon & W. G. Dow (Eds.), The Petroleum System: From Source to Trap (Vol. 60, pp. 599-614). American Association of Petroleum Geologists Memoir.

[3]. El Din, S. Serag, Dernaika, M. R., and M. Z. Kalam. (2011) "The Impact of Heterogeneity on Laboratory Petrophysical Measurements." Paper presented at the SPE Reservoir Characterization and Simulation Conference and Exhibition, Abu Dhabi, UAE, Doi: https://doi.org/10.2118/147950-MS 1-12

[4]. Evamy, B. D., Haremboure, J., Kamerling, P., Knaap, W. A., Molloy, F. A., & Rowlands, P. H. (1978). Hydrocarbon habitat of the Tertiary Niger Delta. *American Association of Petroleum Geologists Bulletin*, 62(1), 1-39.

[5]. Iheaturu, T. C., Ideozu, R. U., Abrakasa, S. & Jones. A. E. (2022). Sequence Stratigraphy and Tectonic Framework of the Gabo Field, Niger Delta, Nigeria. *Scientia Africana*, 21(3), 19-36

[6]. Kulke, H. (1995). Sedimentation and tectonics in the Niger Delta. *American Association of Petroleum Geologists Bulletin*, 79(11), 1563-1580.
[7]. Lehner, P., & De Ruiter, P. A. C. (1977). Structural history of Atlantic margin of Africa. *AAPG Bulletin*, *61*(7), 961-981.
[8]. Osunrinde. T.O, Iloka .C, Yawale A. 2019 Field developmental plan analysis: a case study of 'x' reservoir. Journal of Petroleum Exploration and Production Technology vol. 9, 2185–2203 https://doi.org/10.1007/s13202-019-0622-0
[9]. Reijers, T. J. A. (2011). Stratigraphy and sedimentology of the Niger Delta. Geologos, 17(3), 133–162.
[10]. Short, K. C., & Stäuble, A. J. (1967). Outline of geology of Niger Delta. *AAPG bulletin*, *51*(5), 761-779.
[11]. Stacher, P. (1995). Present understanding of the Niger Delta hydrocarbon habitat. In *Geology of deltas* (pp. 257-267).
[12]. Nnurum, E. U., Tse, A. C., Ugwueze, C. U., & Chiazor, F. I. (2024). Multicriteria evaluations for sand production potentials: a case study from a producing oil field in the Niger Delta Basin (Nigeria). *Scientia Africana,* 23(3), 341-354.
[13]. Nnurum, E. U., Ugwueze, C. U., Tse, A. C.,&Udom, G. J. (2021) Soil Gradation Distribution across Port Harcourt, South-eastern Nigeria.*International Journal of Research in Engineering and Science (IJRES).* 9(11): 25-33.
[14]. Nnurum, E. U., Ugwueze, C. U., Tse, A. C., & Udom, G. J. (2021). Spatial distribution of Soil Permeability across Port Harcourt Area, Southeastern Nigeria. *Journal of Scientific and Engineering Research,* 8 (10), 84 - 93