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WELL LOGS ANALYSIS OF "HANNAH FIELD" OFFSHORE, NIGER DELTA.

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Abstract

A suite of wireline logs from three wells was utilized for lithology and reservoir quality evaluation in a field in Niger Delta. Lithology interpretation was done using gamma ray and resistivity logs responses. Also, well log correlation was achieved from similarity of log signatures across reservoir and non-reservoir zones. Petrophysical properties of the reservoir rocks were carried out using standard equations. The general stratigraphy is alternation of sand and shale layers which is typical of Niger delta. The sands are dirty and characterized by shale intercalations. The reservoir sands in all the wells are located at the depth interval of 8326 ft to 10596 ft. Three fluid types were identified namely gas, oil and water. Gas-water contact (GWC) occurs at the depth of 8322 ft and 9176 ft for well 1 and well 2 respectively for reservoir R1. The gas-oil contact and the oil-water contact occur at depth 9860 ft and 9911 ft respectively for R3. Computation of reservoir parameters such as net to gross, volume of shale, porosity and hydrocarbon saturation was done using standard equations. The reservoir properties have average effective porosity of 28, volume of shale of 12, net to gross sand 78 , hydrocarbon saturation 66 and permeability 21 . The petrophysical properties shows that all the reservoirs are of good quality and can be of commercial quantity.

Keywords: Well log, Petrophysical parameters, Stratigraphy, Hydrocarbon saturation, fluid type.

Introduction

Over the years, it is a widely acceptable idea that the earth is heterogenous and as a result has led to various field of study such as geophysics, geology, physics, petrophysics and others in studying and solving the earth's surface related problems. Geophysics uses various methods to study the sub surface. Some of these methods are electrical resistivity, gravity, magnetic and well logging method depending on the properties of interest. Well logging has been one of the oldest and also found useful applications in groundwater, oil and gas productions over the years as it has found initial step in oil and gas exploration. When a well drilling is finished, a decision must be made as to whether to complete the well or abandon it. Well logs often provide the data that help make the correct decision (Egbai and Aigbogun, 2012). Well logging is the most tasks for any well after drilling to determine shale volume, porosity, permeability, and water saturation (Hassan S. Naji et al.2009). The general purpose of well log analysis is to convert the raw log data into estimated quantities of oil, gas and water in a formation (Asquith and Krygowski, 2004). The first step in a log analysis is to define clean and shale baselines on the log and to identify the zones of interest clean zones with hydrocarbons (Quijada and Stewart, 2007). The interpretation of this method results enabled the estimation of reservoir properties such as porosity (Φ), permeability (K), fluid saturation, and Net Pay thickness in understanding the qualities and quantities of the reservoir formation for hydrocarbon exploration. Porosity and permeability are one of the most fundamental physical properties with respect to storage and transmission of fluids in the reservoir. Precise determination of reservoir thickness is best obtained on well logs, especially using the gamma ray and resistivity logs (Asquith, 2004). The resistivity log on the other hand, can be used for determining the nature of interstitial fluid that is, differentiating between (saline) water and hydrocarbon in the pore spaces of the reservoir rocks. Since these logs are recorded against depth, the hydrocarbon-bearing interval can be determined (Haruna et al., 2014).

Knowledge of these two properties is essential before questions concerning type of fluids, amounts of fluid, rates of fluid flow, and fluid recovery estimates can be answered. Both parameters play an important role in reservoir description (Basan et al. 1997). Continued success in the hunt for Oil and Gas reserves therefore, depends upon a thorough understanding of the subsurface geology of exploration fields, the ability to accurately predict and delineate the spatial and depth distribution of subsurface geologic facies (source rock, reservoir rock and seal) and the ability to discriminate the fluids saturating reservoirs (oil, gas or brine) and possibly quantifying such (Aminu and Olorunniwo, 2012). As hydrocarbon exploration moves into geologically and economically more challenging environments, such as deeper subsurface locations, deepwater regions, subtice in the Artic, and into geologically and stratigraphyically more complex environments, the costs of exploration is bound to be on the rise and the risks associated with field development greater (Aminu and Olorunniwo, 2012).

Therefore, the detailed estimation of the petrophysical properties has provided information on the reservoirs in the study area for hydrocarbon exploration.

Geology and Stratigraphy of the Study Area

The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta Province as defined by (Klett *et al.*, 1997). From the Eocene to the present, the delta has prograded southwest ward, forming depobelts that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km^2 Kulke (1995), a sediment volume of 500,000 km^3 (Hospers, 1965), and a sediment thickness of over 10 km in the basin depocenter (Kaplan *et al.,* 1994). The onshore portion of the Niger Delta province is delineated by the geology of southern Nigeria and southwestern Cameroon (Figure 1). The northern boundary is the Benin flank, an east-northeast trending hinge line south of the West Africa basement massif. The north-eastern 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. The province covers 300,000 km^2 and includes the geologic extent of the Tertiary Niger Delta (Akata-Agbada) Petroleum System (Michele *et al.*,1999). The Tertiary section of the Niger Delta is divided into three Formations, representing prograding depositional facies that are distinguished mostly on the basis of sand-shale ratios (Figure 2). In the Niger Delta, this sequence is modified by the numerous transgressions which have occurred from time to time, breaking the continuity of the main overall regression, and becoming stratigraphically superimposed (Short and Stauble, 1967).

Materials and Method of Study

Three vertical wells which comprised wells 1, 2 and 3 were drilled in the area of study for hydrocarbon exploration and exploitation (Figure 3). The logs covered lithology, resistivity and porosity. The lithology logs include gamma ray while deep induction log constituted the only resistivity log. The neutron, density, and sonic are the main porosity logs. All these logs were Present in all the wells except for well 3 where the density log was missing.

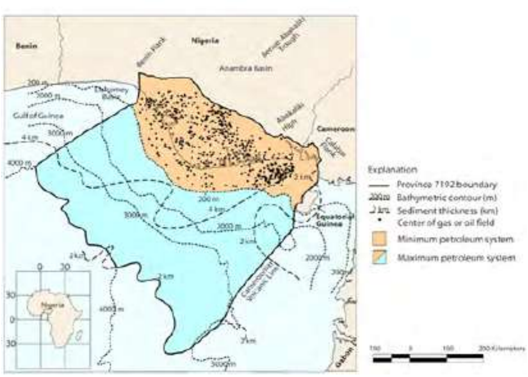

Figure 1: The Niger Delta Province (After Michele *et al.,* 1999).

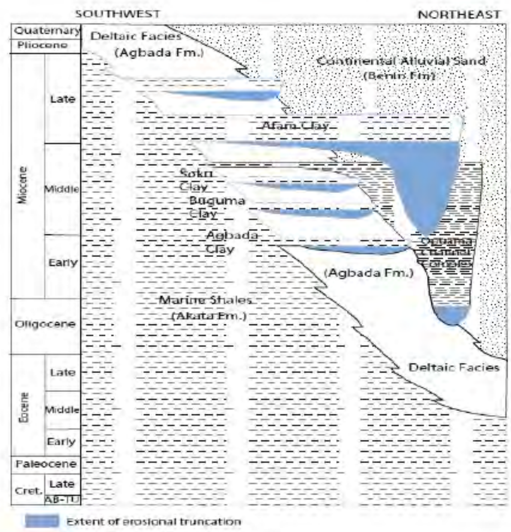

Figure 2: Stratigraphic Column of the Niger Delta. (After Doust and Omatsola, 1990)

The well log was interpreted qualitatively and quantitatively. Qualitatively, the lithology, reservoir were identified and the fluid contact was delineated while quantitatively the reservoir properties gross thickness, net thickness, volume of shale, porosity, hydrocarbon saturation, water saturation and permeability were estimated.

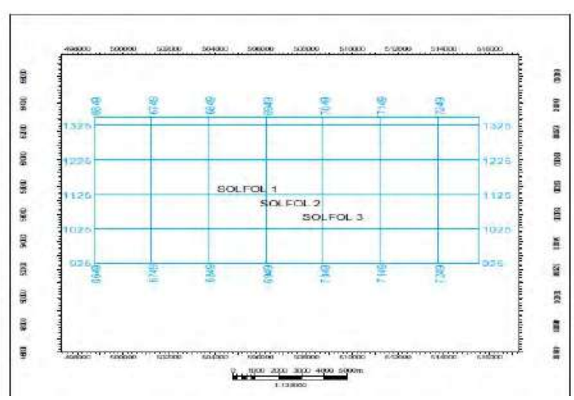

Figure 3: Base Map of the Study Location.

Results and Discussion

Lithologic Interpretation

The gamma ray log was used to delineate the lithology of the studied wells (Figure 4). Well 1 covers a depth range of 8150 ft to 9450 ft and the rock units delineated are alternation of sand and shale units. The sand units decrease in thickness with depth while the shale units increase. The sand units are dirty which comprises thin shale units within. Reservoir sand is located at a depth of 8230 ft subsea. Well 2 has a similar lithologic sequence like well 1 comprising alternation of sand and shale units. The sands are dirty comprising thin shale interbeddings. Two reservoir sands also exist at depths of 9150 ft and 9830 ft. The well covers a depth range of 9050 ft to 10350 ft sub-sea. Well 3 is similar to wells 1 and 2. The same sequence of stratification of sand and shale lithologic units exists and the studied interval is from 9150 ft to 10,850 ft subsea. The shale units are extremely thick in this well.

Well log correlation

Figure 4 depicts well correlation panel of the studied wells. The panel is composed of well 1, 2 and 3 and oriented in northwest to southeast directions. The general stratigraphy is alternation of sand and shale layers typical of Agbada formation. The sand units generally are dirty comprising of thin shale interbedding. The hydrocarbon bearing reservoirs have irregular distribution within the studied intervals.

Three (3) prospective reservoir sands were delineated across the study area namely, R1, R2, and R3 within the depth interval of 8236 ft and 10596 ft across the entire well; Sand R1 depth ranged from 8236 ft to 8368 ft for well 1, 9153 ft to 9320 ft in well 2 and 9554 ft to 9767 ft in well 3; Average thickness of reservoir R1 was 171ft with maximum thickness in well 3. R2 occurred between depth 8464 ft to 8759 ft in well 1, 9421 ft to 9526 ft in well 2 and 9984 ft to 10104 ft in well 3 though it exists only in well 3 with thickness of 120 ft. R3 ranged from 9199 ft to 9325 ft in well 1, it ranged from 9826 ft to 9939 ft in well 2, while the depth occurrence of sand C in well 3 in 10506 ft to 10596 ft. The average thickness of R4 was 102ft with maximum thickness of 113ft in well 2. From the correlation panel, R1 is observed to thin out from southeast to northwest (Figure 4).

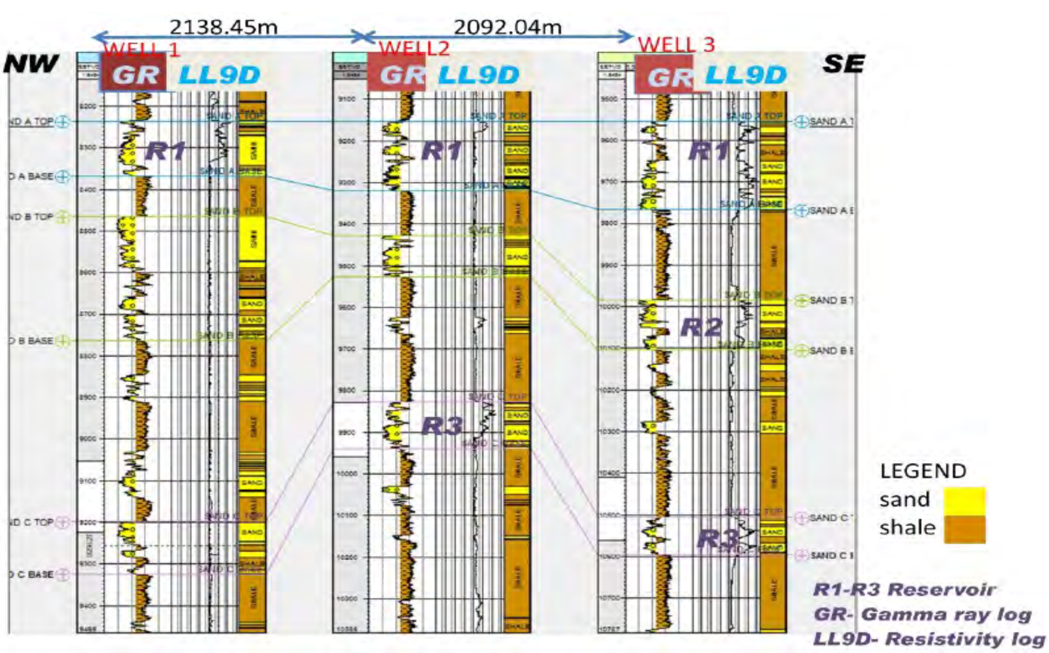

Figure 4: Well Correlation Panel of the Studied wells.

Fluid types and contacts were determined based on resistivity, neutron and density logs for reservoir R1. The presence of hydrocarbon in a formation is characterized by high resistivity while lower resistivity values indicate water. The crossplot of neutron and density logs always reveal the hydrocarbon type such that large crossover indicate gas. The presence of gas in a formation leads to decrease of neutron porosity log with a corresponding increase in density log and relatively small crossover indicates oil while smaller or no separation indicates water.

Hence, from Figure 5 two fluid types were identified namely gas and water in well 1 and well 2 for reservoir R1. The gas zone for sand A occurs between 8236ft and 8322ft in well 1 and 9153ft to 9176ft in well 2, while depth beyond this reflect the water-leg such that Gas-water contact (GWC) occurs at the depth of 8322 ft and 9176 ft for well 1 and well 2 respectively. Figure 6 shows the delineated fluid types of R3. It contain three fluids (gas, oil, and water), the gas-oil contact and the oil-water contact occur at depth 9860 ft and 9911 ft respectively.

Petrophysical analysis

The reservoir properties of wells 1, 2 and 3 were analysed and presented in Tables 1, 2 and 3 respectively. Three reservoirs located at a depth interval of 8236 ft to 10596 ft are designated as R1, R2, and R3 was mapped and analysed. Reservoir R1 (Figure 4) extends across all the wells. It is located at a depth of 8236 ft subsea in well 1. The reservoir has a gross thickness of 132 ft, net thickness 108ft, net to gross thickness 0.82, effective porosity 0.33, water saturation 18%, hydrocarbon saturation 82%, volume of shale 7.2% and permeability of 49.91md. In well 2, the reservoir is located at a depth of 9153 ft. It has a gross thickness of 167 ft, net thickness 138ft, net to gross thickness 0.83, effective porosity 0.31, water saturation 54%, hydrocarbon saturation 46%, volume of shale 8.6% and permeability 13.79md. In well 3, the reservoir is situated at a depth of 9554 ft. It has a gross thickness of 213 ft, net thickness 138ft, net to gross thickness 0.65, effective porosity 0.27, water saturation 25%, hydrocarbon saturation 75%, volume of shale 2.3% and permeability 19.68 md (Table 1). The volume of shale is low in wells 1 and 2 but high in well 3. According to Baker 1992, qualitative description of porosity, the porosity is excellent in all the wells and according to Glover, (2000); the permeability is also good in all the three wells. While hydrocarbon saturation is low in well 2 and high in well 1 and 3

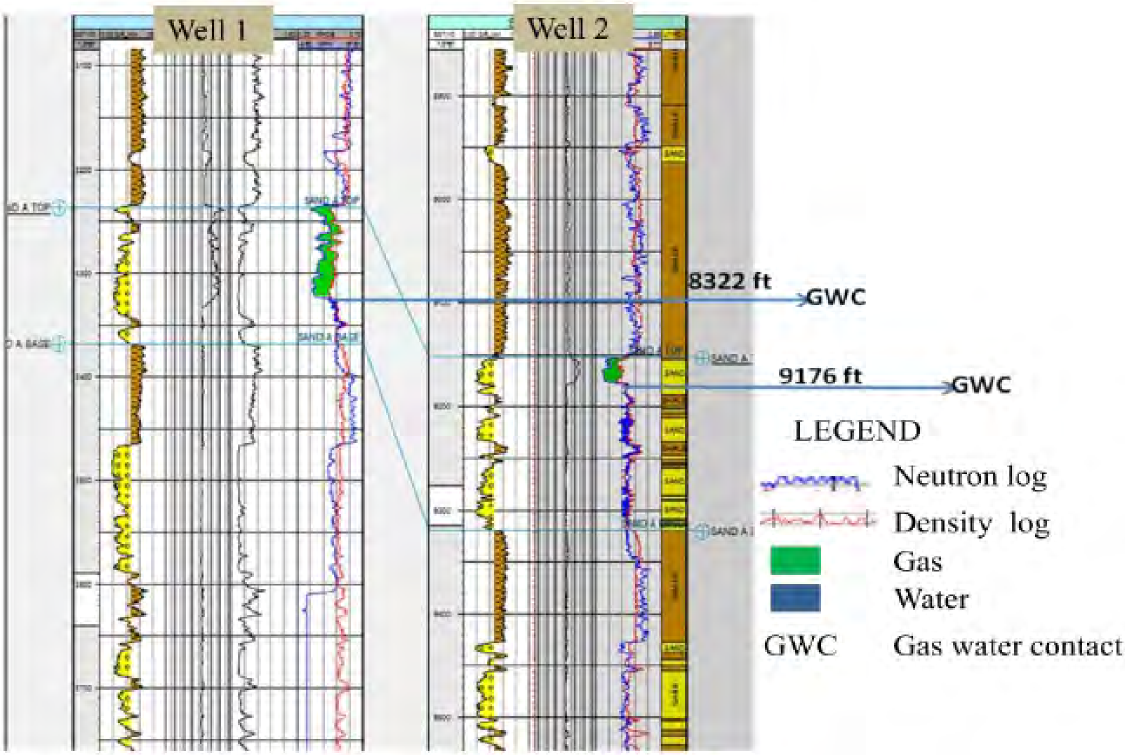

Figure 5: Delineated Fluid and their Contacts in Wells1 and 2.

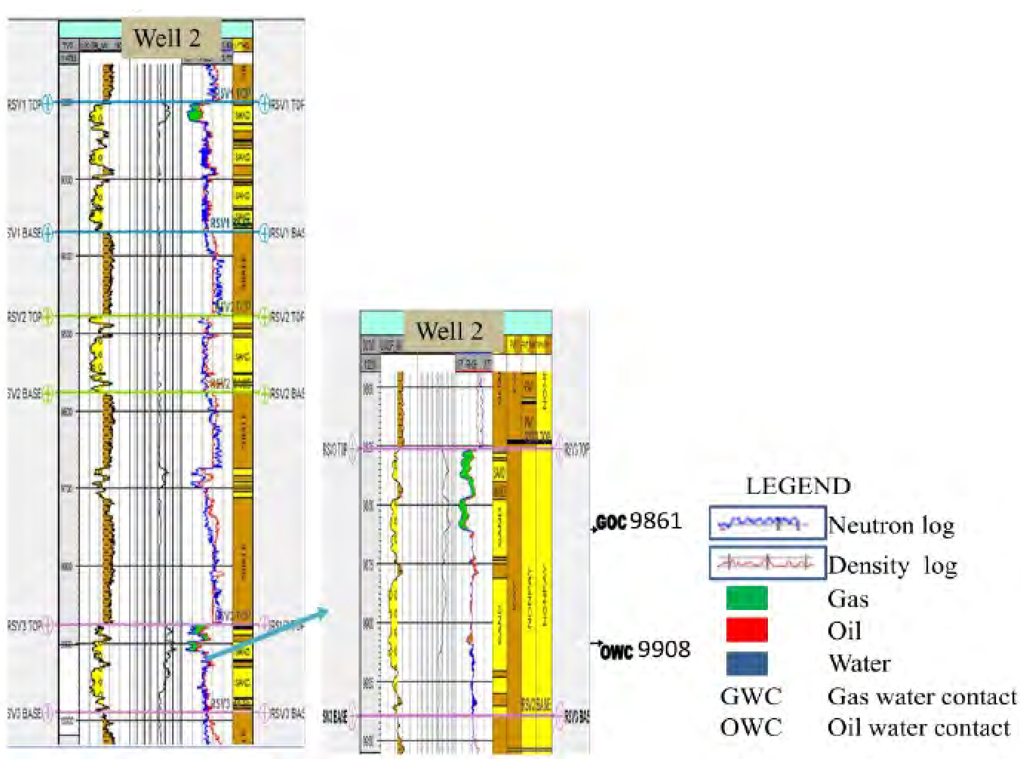

Figure 6: Delineated Fluid and their Contacts in Well 2.

Table 1: Petrophysical Parameters Obtained for Reservoir R1

Wells	Top(ft)	Base(ft)	Gross(ft)	Net(ft)	N/G	(ϕ)	Sw (%)	SH (%)	Vsh(%)	(K) md
Well 1	8236	8368	132	108	0.82	0.33	18	82	7.2	49.91
Well 2	9153	9320	167	138	0.83	0.31	54	46	8.6	13.79
Well 3	9554	9767	213	138	0.65	0.27	25	75	22.7	19.68

Where: V_{sh} - volume of shale, N/G- net to gross sand ratio, ϕ_e -effective porosity, S_w - water saturation, S_H - hydrocarbon saturation, k - permeability.

Table 2: Computed Petrophysical Parameters of Reservoir R2

Well	Top(ft)	Base(ft)	Gross(ft)	Net(ft)	N/G	(ϕ)	Sw (%)	SH (%)	Vsh (%)	(K) md
Well 3	9984	10104	120	95	0.79	0.27	21	79	8.1	23.43

V_{sh}- volume of shale, ϕ_e -effective porosity, N/G- net to gross sand ratio, S_w- water saturation, S_H - hydrocarbon saturation, k-permeability

Table 3: Computed Petrophysical Parameters of Reservoir R3

Wells	Top(ft)	Base(ft)	Gross(ft)	Net(ft)	N/G	(ϕ)	Sw (%)	SH (%)	Vsh(%)	(K) md
Well 2	9826	9939	113	92	0.81	0.26	30	70	6.7	14.65
Well 3	10506	10596	90	56	0.62	0.22	23	77	8.4	10.07

V_{sh}- volume of shale, ϕ_e -effective porosity, N/G- net to gross sand ratio, S_w-water saturation, S_H - hydrocarbon saturation, k-permeability

Reservoir 2 is situated at a depth of 9984 ft in well 3. It has a gross thickness of 120 ft, net thickness 95 ft, net to gross thickness 0.79, effective porosity 0.27, water saturation 21 %, hydrocarbon saturation 79 %, volume of shale 8.1 % and permeability 23.43 md (Table 2). The volume of shale is low, hydrocarbon saturation is high, according to Baker 1992, the effective porosity is excellent and permeability is good.

In well 2, the reservoir R3 is situated at a depth of 9826 ft. It has a gross thickness of 113 ft net thickness 92 ft, net to gross thickness 0.81, effective porosity 0.26, water saturation 30 %, hydrocarbon saturation 70 %, volume of shale 6.7 % and permeability 14.65md. In well 3 the reservoir is situated at a depth of 10506 ft. It has a gross thickness of 90 ft, net thickness 56 ft, net to gross thickness 0.62, effective porosity 0.21, water saturation 23 % hydrocarbon saturation 77 %, volume of shale 8.4 % and permeability 10.07 md (Table 3). The volume of shale is low, the hydrocarbon saturation is high in well 2 and 3, effective porosity is excellent in well 2 but good in well 3 while the permeability is good in well 2 but fair in well 3. Juhasz (1986) describes the significant impact which dispersed shale can have on producibility: "A certain amount of dispersed (pore filling) shale has a far more detrimental effect on the permeability of the sand than the same amount of shale concentrated into shale laminae between clean sand laminae. The permeability of a 33% porosity clean sand for instance would be reduced to practically zero if its pore-space is filled with shale (that is: V_{sh} -33%), but it would retain two-thirds of its permeability if this shale is present in laminations only." The low permeability values may be as result of the laminar shale present within the identified reservoir.

Conclusion

The well log analysis were carried out and analyzed both qualitatively and quantitatively. Qualitatively two lithology were delineated namely sand and shale and the sand units were correlated across the field. Three hydrocarbon bearing reservoirs were identified namely R1, R2, and R3. The hydrocarbon bearing reservoirs labelled as R1, R2 and R3 occur within a depth interval of 8236 ft to 10,596 ft subsea. The structure of the field is a multi- reservoir type. The sands of the reservoir are laminated with shale. They are probably channel deposits in origin. Reservoir (R1) has average net to gross of 0.77, porosity 0.30, water saturation 32%, hydrocarbon saturation 68%, volume of shale 13%, and permeability 28 md. Reservoir (R2) has net to gross of 0.79, porosity 0.27, water saturation 21%, hydrocarbon saturation 79 %, volume of shale 8 % and permeability 23md. Reservoir (R3) has average net to gross of 0.72, porosity 0.274, water saturation 27%, hydrocarbon saturation 73 %, volume of shale 8 % and permeability 12md. The aforementioned reservoir properties has a very good porosity, hydrocarbon saturations and high net to grosss ratio which characterized the reservoir to be of good quality except for the low permeability which may be as a result of the pore structure filled with laminar shale. therefore, the reservoirs may require stimulations in order to improve its production.

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