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Research paper

Petrophysical analysis of "explorer" wells using well log and core data(a case study of "explorer" field, offshore Niger Delta, Nigeria)

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Abstract

Reservoir characterization involves computing various petrophysical parameters and defining them in terms of their quantity and quality so as to ascertain the yield of the reservoir. Petrophysical well log and core data were integrated to analyze the reservoir characteristics of Explorer field, Offshore, Niger Delta using three wells. The study entails determination of the lithology, shale volume (Vsh), porosity (Φ), permeability (K), fluid saturation and cross plotting of petrophysical and core values at specific intervals to know their level of correlation. The analysis identified twelve hydrocarbon-bearing reservoir from three different wells. Average permeability value of the reservoir is 20, 0140md while porosity value range between 18% to 39%. Fluid type defined in the reservoirs on the basis of neutron/density log signature were basically water, oil and gas, low water saturation values ranging from 2.9% to 46% in Explorer wells indicate high hydrocarbon saturation. The Pearson Correlation Coefficient and Regression Equation gave a significant relationship between petrophysical derived data and core data. Scatter plot of petrophysical gamma ray values versus core gamma ray values gave an approximate linear relationship with correlation coefficient values of 0.6642, 0.9831 and 0.3261. Crossplot of petrophysical density values and core density values revealed that there is a strong linear relationship between the two data set with correlation coefficient values of 0.7581, 0.9872 and 0.3557, and the regression equation confirmed the relationship between the two data set. Also the scatter plot of petrophysical porosity density values versus core porosity density values revealed a strong linear relationship between the two data set with correlation coefficient values of 0.7608 and 0.9849, the regression equation confirmed this also. Crossplot of petrophysical porosity density values versus core porosity density values in Well 3 gave a very weak correlation coefficient values of 0.3261 and 0.3557 with a negative slope. The petrophysical properties of the reservoirs in Explorer Well showed that they contain hydrocarbon in commercial quantity and the cross plot of the petrophysical and core values showed direct relationship in most of the wells.

Keywords:*Petrophysics; Correlation; Regression; Niger Delta; Reservoirs; Characterization; Hydrocarbon and Saturation.*

1. Introduction

Hydrocarbon accumulations have been found to mostly occur in pore spaces of reservoir rocks. Therefore, to have an idea of the commerciality of a new accumulation or reservoir, some basic petrophysical parameters such as porosity, permeability, hydrocarbon saturation,and thickness etc., needs to be evaluated. These parameters can be inferred from various well logs. Adaeze,et al.(2012) presented their results from the evaluation of petrophysical properties of "Uzek"well, Niger delta using well log and core data with a view to understand their effects on the reservoirs hydrocarbon prospect and oil productivity of the field. They were also able to reveal similarity in the porosity values of well log and core data using the pearson correlation coefficient and regression equations (Adaeze et a., 2012).
Evaluating the distribution of these petrophysical parameters throughout the formation, knowing fully that well logs data cannot give a precise and unequivocal information about a reservoir, which have direct impact on the reservoir parameters estimated, therefore coredata is use to complement this in other to enhance accurate estimation of reservoir properties and the eventual hydrocarbon in place.

1.1. Aim and objectives of the research

The aim of this work is to analyze the petrophysical parameters of the wells in "Explorer" field using well log data and core data.
with the following objectives:

- Estimate reservoir properties using petrophysical parameters (porosity, permeability, water saturation, net/gross, hydrocarbon in place, net pay etc.)
- Compare well log parameters and core data parameters using crossplot
- Give a quantitative and qualitative interpretation of the reservoirs in "Explorer" field.

1.2. Study location

The area of study, ‘Explorer field’, lies in the Gulf of Guinea 120 kilometers from the coast of Nigeria and belongs to Shell Nigeria Exploration and Production Company SNEPCo. The new name (“EXPLORER’’), given to the field and wells are only valid for the purpose of this project. Figure 1 below, map of Niger Delta showing the study area.

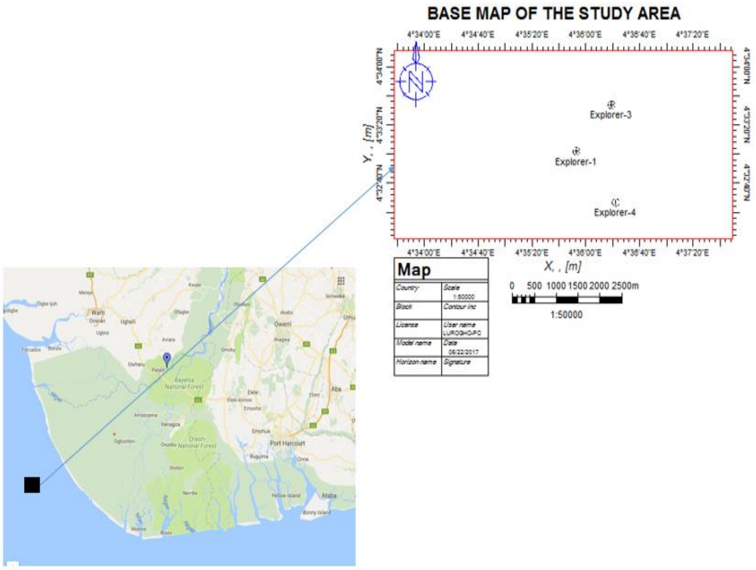

Fig. 1: Location and Base Map of EXPLORER Field Showing Location of the Wells

2. Geology of the study area

The Niger Delta covers an area of about 7500km^2.It is a large acute delta situated in the Gulf of Guinea. From the Eocene to the present, the delta has prograded southwestward, 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. Its stratigraphy has been described in detail by (Short and Stauble, 1967) and (Frankl and Cordy, 1967) of which they recognized three lithostratigraphic units i.e. the Benin, Agbada and Akata Formations (Figure2).

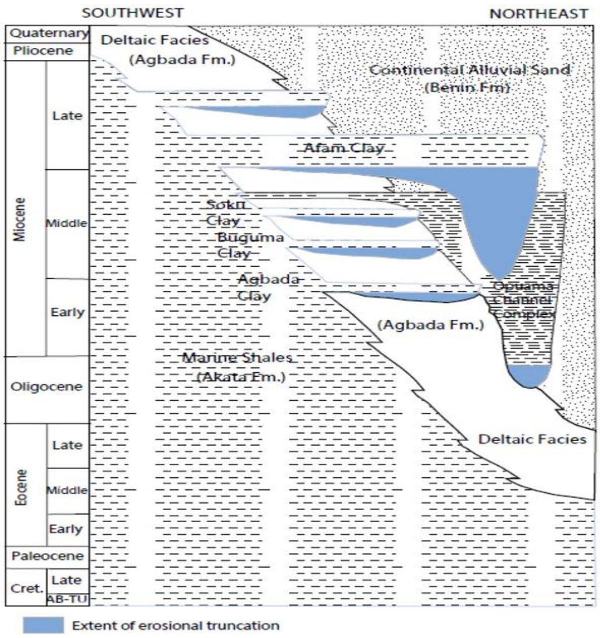

Fig. 2: Stratigraphic Column Showing the Three Formations of the Niger Delta (Modified After Doust and Omatsola, 1990).

The Benin Formation is a continental Eocene to Recent deposit of alluvial i.e. up to 2000m thick, the uppermost and youngest rock stratigraphic unit, while the Agbada Formation is a paralic sequence that is characterized by the alternation of sand bodies and shale layers. It is also associated with synsedimentary growth faulting and as well contains the bulk of the known oil accumulation in the Niger Delta. The Akata formation is the lowest unit at the base of the delta. It is of marine origin and is composed of thick shale sequences (potential source rock), turbidite sand (potential reservoirs in deep water), and minor amounts of clay and silt. The Akata formation is under compacted in much of the delta (Avovbo, 1978). The growth faults in the Niger Delta according to (Weber, 1987) are considered to be the major migration conduit and leading factor controlling the hydrocarbon distribution pattern in the Niger Delta. Most known traps in Niger Delta fields are structural although stratigraphic traps are not uncommon.

3. Material and methods

Geophysical well log interpretation and core description were done on the wells of Explorer field, concise qualitative and quantitative evaluation were done on the well by first identifying the sand and shale using the gamma ray log, and next compare zones of sandstone with the corresponding resistivity log by identifying sandstone to be of high resistivity and shale to be of low resistivity, the porosity log was then used in identifying the fluid contact. By using empirical petrophysical formula, the petrophysical values were computed which enables in differentiating the oil bearing reservoir from water bearing reservoir (Figure 3), the porosity log also confirms the nature of the reservoir. The core data in excel format were then compared with the computed petrophysical values using excel software, at depth where all the core data corroborated with the petrophysical values, crossplot was done and comparison was done using statistical approach.

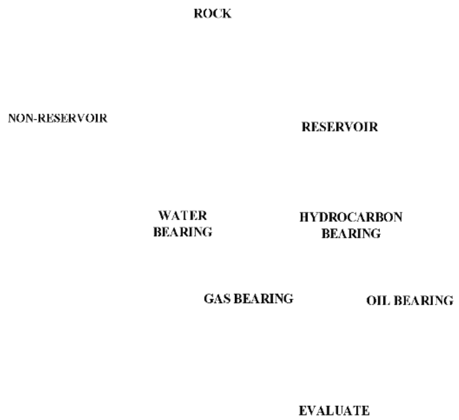

Fig. 3: Workflow for Petrophysics Analysis.

3.1. Shale volume estimation

Shale volume (Vsh) was calculated using the formula in equation (1) which uses values from the gamma ray (GR) in equation (2)

$$V_{sh} = 0.083\ [2^{(3.7 \times I_{GR})} - 1.0 \qquad (1)$$

$$I_{GR} = \frac{\text{GR log} - \text{GRmin}}{\text{GRmax} - \text{GRmin}} \qquad (2)$$

In equation (2), I_{GR} is the gamma ray index, GR log is the picked log value while GR minimum and GR maximum indicate values picked in the sand and shale base lines respectively.

3.2. Determination of porosity

Porosity, $Ø_{DEN}$ is defined as the percentage of voids to the total volume of rock. This parameter is determined by substituting the bulk density readings obtained from the formation density log within each reservoir into equation (3)

$$Ø_{DEN} = \left(\frac{\rho ma - \rho b}{\rho ma - \rho f}\right) \qquad (3)$$

and where ℓ_{ma}, $\ell_{b\ and}$ ℓ_f are matrix density, formation bulk density and fluid density respectively.

3.3. Calculation of water saturation

To calculate water saturation, Sw of uninvaded zone, the method used requires a water resistivity Rw value at formation temperature calculated from the porosity and resistivity logs within clean water zone, using the Ro method given by the following equation

$$S_w = \left(F \times \frac{R_w}{R_t}\right)^{1/n} \qquad (4)$$

Where, F: Formation Factor, R_w: Formation water resistivity at formation temperature, R_t: True formation resistivity, n: Saturation exponent. This was given to be 2. 0.

3.4. Determination of hydrocarbon saturation

Hydrocarbon Saturation, Sh is the percentage of pore volume in a formation occupied by hydrocarbon. It can bedetermined by subtracting the value obtained for water saturation from 100% i.e.

$$Sh = (100 - SW)\ \% \qquad (5)$$

3.5. Calculation of permeability

Permeability, K is the property of a rock to transmit fluids. For each identified reservoir permeability, K is calculated using equation 6

$$K^{1/2} = \frac{250 \times \varnothing^3}{Sw\ irr} \qquad (6)$$

Where Swiris the irreducible water saturation

Table 1: Porosity and Permeability Values for Reservoirs Qualitative Description (Adapted from Rider, 1986)

Qualitative Evaluation of Porosity	
Percentage Porosity (%)	***Qualitative Description***
0 - 5	Negligible
5 - 10	Poor
15 - 20	Good
20 – 30	Very Good
> 30	Excellent
Qualitative Evaluation of Permeability	
Average K_Value (md)	***Qualitative Description***
< 10.5	Poor to fair
15 – 50	Moderate
50 – 250	Good
250 – 1000	Very Good
> 1000	Excellent

4. Results and discussion

The results and discussion obtained from this work are coined around the properties that define a reservoir as being either prolific or not. These parameters are computed, using empirical petrophysical equations. The subsurface lithologies were mapped first by using gamma ray log which indicate low signature for sand and high for shale. Through lithology identification, reservoir sands were marked throughout the wells. After identifying the sands, resistivity logs were then used to indicate the fluid type that occurred in a reservoir. Petrophysical parameters such as porosity (ϕ), permeability (k), Volume of shale (V_{sh}), Water saturation (S_w), Hydrocarbon saturation (S_h), Irreducible water saturation (S_{wirr}) etc. were calculated and the results presented in form of graphs and tables.

Based on the qualitative and quantitative interpretations, twelve (12) reservoirs sand were identified throughout three (3) wells. The well correlation panel of the wells studied is shown in Figure 4, but well Explorer 2 was not having information within the interval analysed. The depth (m) interval and thickness of the reservoir is shown in Table 2

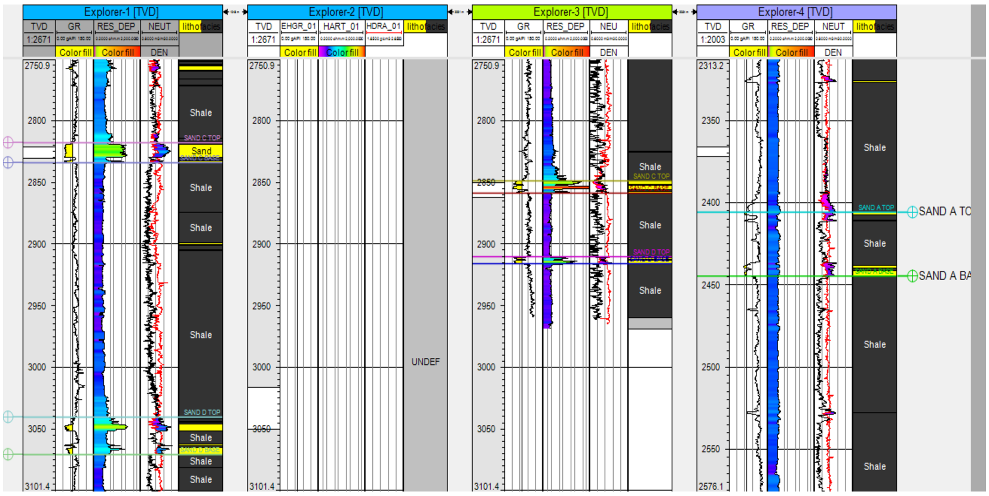

Fig. 4: Log Responses to the Explorer Sandstone Lithology.

Table 2: Depth Intervals (M)

WELL	SAND A(m)	SAND B(m)	SAND C(m)	SAND D(m)	SAND E(m)
EXPLORER 1 Thickness	2077.14-2104.94(27.8)	2462.78-2487.52(24.71)	2817.80-2834.75(16.95)	3040.39-3070.78(30.39)	3611.20-3641.62(30.42)
EXPLORER 3 Thickness	1784.47-1820.52(36.05)	2098.20-2122.14(23.94)	2845.78-2858.01(12.23)	2909.94-2915.56(5.62)	
EXPLORER 4 Thickness	2401.83-2444.60(42.77)	3038.59-3057.11(18.52)	3118.41-3143.54(25.13)		

4.1. Reservoir data discussion

The main target of petrophysical analysis is the determination of the hydrocarbon saturation of each reservoir across the wells alongside with other petrophysical data.

WELL 1 RESERVOIR A

Reservoir A for well 1 (Figure 5) is hydrocarbon reservoir. The reservoir is within depths of 2077.14m to 2104.94m (Table 2) with NTG of 100% and volume of shale (V_{sh}) value of 2%, while the hydrocarbon saturation (S_h) is 78% with porosity (ϕ) value of 30% which indicate that the reservoir is excellent, an absolute permeability (K) of 10,149.8md is gotten. These petrophysical parameters computed indicate that the reservoir contains only oil.

WELL 1 RESERVOIR B

Reservoir B for well 1 (Figure 6) is hydrocarbon reservoir. The reservoir is within depths of 462.78m to 2487.52m (Table 2) with NTG of 96.9% and volume of shale (V_{sh}) value of 9%, while the hydrocarbon saturation (S_h) is 88.7% with porosity (ϕ) value of 39% which indicate the reservoir is excellent with an absolute permeability (K) of 8,333.3md is gotten. All the petrophysical parameters computed and also the cross plot of the neutron density log indicate that the reservoir is oil. This reservoir is thus expected to be productive when put into production.

WELL 1 RESERVOIR C

Reservoir C for well 1 (Figure 6) is hydrocarbon reservoir. The reservoir is within depths of 2817.80m to 2834.75m (Table 2) with NTG of 82% and volume of shale (V_{sh}) value of 3%, while the hydrocarbon saturation (S_h) is 87% with porosity (ϕ) value of 34% which indicate the reservoir is excellent with an absolute permeability (K) of 26,820.6md is gotten. All the petrophysical parameters computed indicate that the reservoir contains only oil and thus is prolific.

WELL 1 RESERVOIR D

Reservoir D for well 1 (Figure 7) is hydrocarbon reservoir. The reservoir is within depths of 3040.39m to 3070.78m (Table 2) with NTG of 71% and volume of shale (V_{sh}) value of 2.9%, while the hydrocarbon saturation (S_h) is 89% with porosity (ϕ) value of 28% which indicate that the reservoir is excellent with an absolute permeability (K) of 6,146.56md is gotten. All the petrophysical parameters computed indicate that the reservoir contains only oil and is recommended for production

WELL 1 RESERVOIR E

Reservoir E for well 1(Figure 8) is hydrocarbon bearing reservoir. The reservoir is within depths of 3611.20m to 3641.62m (Table 2) with NTG of 76.1% and volume of shale (V_{sh}) value of 4.6%, while the hydrocarbon saturation (S_h) is 56% with porosity (ϕ) value of 18% which indicate excellent reservoir with an absolute permeability (K) of 27,509md is gotten.

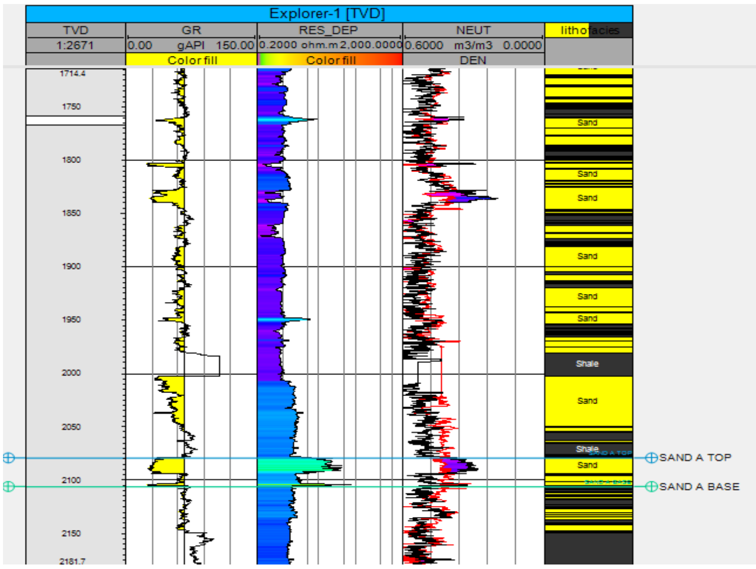

Fig. 5: Well 1 Reservoir A.

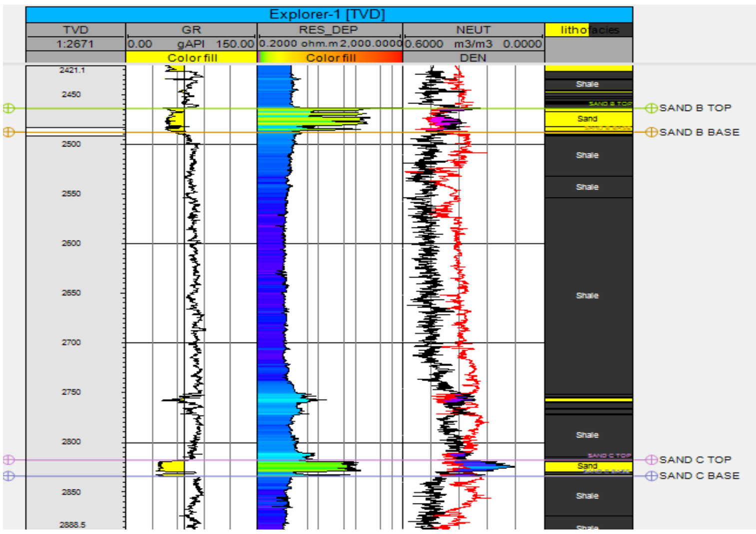

Fig. 6: Well 1 Reservoir B and C.

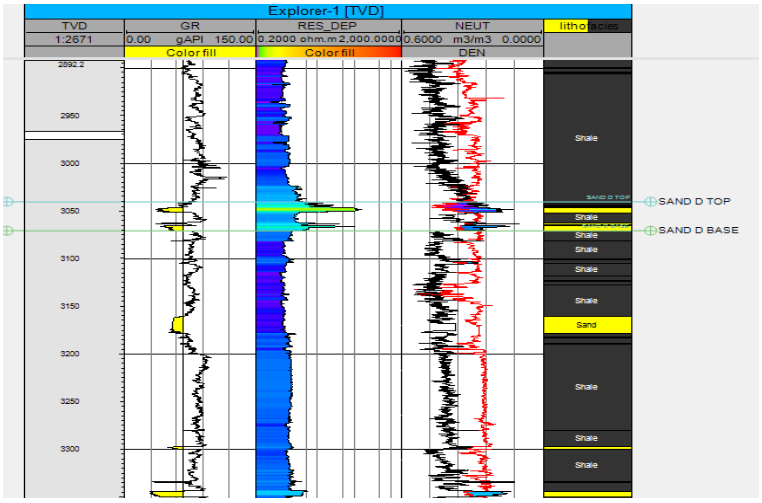

Fig. 7: Well 1 Reservoir D.

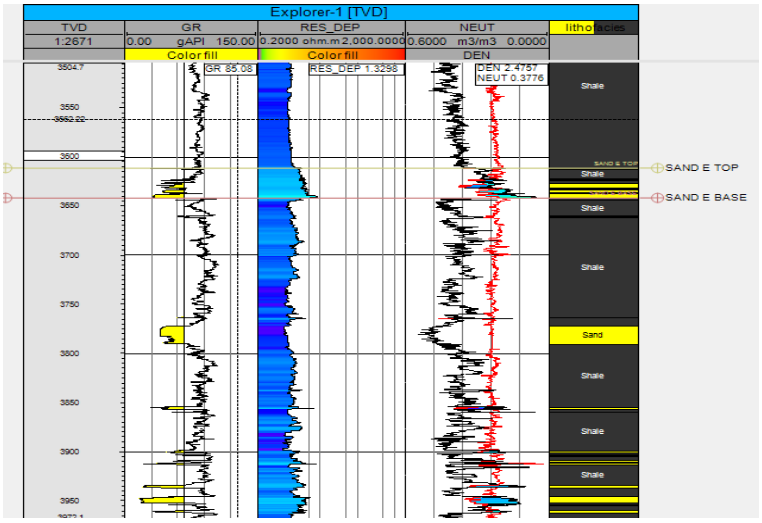

Fig. 8: Well 1 Reservoir E.

Table 3: Computed Petrophysical Parameters for Well 1

EXPLORER 1 PARAMETERS	RESERVOIRS SAND A	SAND B	SAND C	SAND D	SAND E
NET/GROSS(%)	100	96.9	82	71	76.1
I_{GR}	0.147	0.29	0.15	0.12	0.17
V_{sh} (%)	2	9	3	2.9	4.6
S_w (%)	22.4	11.3	13	11	44
S_h (%)	78	88.7	87	89	56
ϕ(%)	30	39	34	28	18
K(md)	10,149.8	8,333.3	26820.6	6,146.56	27,509

WELL 3 RESERVOIR A

Reservoir A for well 3 (Figure 9) is hydrocarbon reservoir. The reservoir is within depths of 1784.47m to 1820.52m (Table 2) with NTG of 58% and volume of shale (V_{sh}) value of 6.1%, while the hydrocarbon saturation (S_h) is 55% with porosity (ϕ) value of 28% which indicate the reservoir is excellent with an absolute permeability (K) of 6146.56md is gotten. All the petrophysical parameters computed indicate that the reservoir is water bearing.

WELL 3 RESERVOIR B

Reservoir B for well 3 (Figure 9) is hydrocarbon reservoir. The reservoir is within depths of 2081.79m to 2122.14m (Table 2) with NTG of 87% and volume of shale (V_{sh}) value of 34%, while the hydrocarbon saturation (S_h) is 54% with porosity (ϕ) value of 35% which indicate the reservoir is excellent with an absolute permeability (K) of 31914md.3 is gotten. All the petrophysical parameters computed indicate that the reservoir contains both oil and water, and the oil is not prolific.

WELL 3 RESERVOIR C

Reservoir C for well 3 (Figure 10) is hydrocarbon reservoir. The reservoir is within depths of 2845.78m to 2858.01m (Table 2 with NTG of 92% and volume of shale (V_{sh}) value of 0.9%, while the hydrocarbon saturation (S_h) is 98% with porosity (ϕ) value of 20% which indicate the reservoir is excellent with an absolute permeability (K) of 400 is gotten. All the petrophysical parameters computed indicate that the reservoir contains only oil and is prolific, thus the reservoir can be put into production.

WELL 3 RESERVOIR D

Reservoir D for well 3 (Figure 10) is hydrocarbon reservoir. The reservoir is within depths of 2909.94m to 2915.56m (Table 2) with NTG of 70% and volume of shale (V_{sh}) value of 6.1%, while the hydrocarbon saturation (S_h) is 94% with porosity (ϕ) value of 33% which indicate the reservoir is excellent with an absolute permeability (K) of 22421.3md is gotten. All the petrophysical parameters computed indicate that the reservoir contains only oil and is prolific.

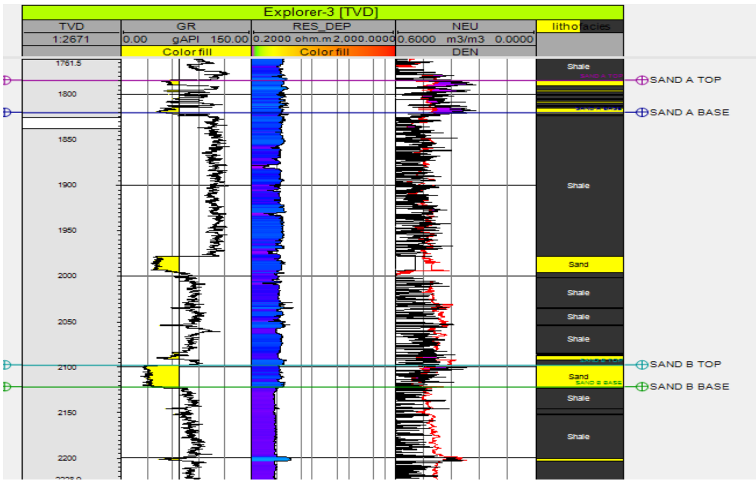

Fig. 9: Well 3 Reservoir A and B.

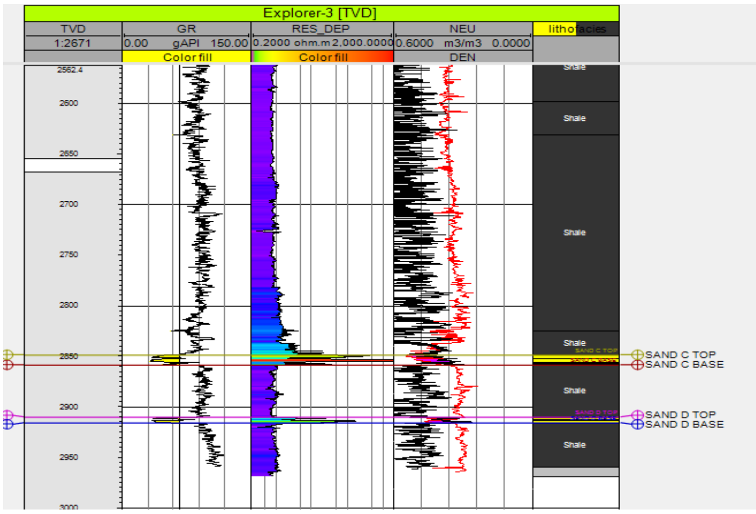

Fig. 10: Well 3 Reservoir C and D.

Table 4: Computed Petrophysical Parameters for Well 3

EXPLORER 3 PARAMETERS	RESERVOIRS SAND A	SAND B	SAND C	SAND D
NET/GROSS(%)	58	87	92	70
I_{GR}	0.214	0.637	0.04	0.22
V_{sh} (%)	6	3.4	9	6.1
S_w (%)	45	46	1.4	6.1
S_h (%)	55	54	98	94
ϕ(%)	28	35	20	33
K(md)	6,146.56	31,914.3	400	22,421.3

WELL 4 RESERVOIR A

Reservoir A for well 4 (Figure 11) is hydrocarbon reservoir. The reservoir is within depths of 2401.83m to 2444.60m (Table 2) with NTG of 35% and volume of shale (V_{sh}) value of 86%, while the hydrocarbon saturation (S_h) is 32% with porosity (ϕ) value of 33% which indicate the reservoir is excellent with an absolute permeability (K) of 21.3md is gotten. All the petrophysical parameters computed indicate that the reservoir contains water as the hydrocarbon saturation is very low.

WELL 4 RESERVOIR B

Reservoir B for well 4 (Figure 12) is hydrocarbon reservoir. The reservoir is within depths of 3038.59m to 3057.11m (Table 2) with NTG of 21% and volume of shale (V_{sh}) value of 1.5%, while the hydrocarbon saturation (S_h) is 85% with porosity (ϕ) value of 26% which indicate the reservoir is excellent with an absolute permeability (K) of 3016.8md is gotten. All the petrophysical parameters computed indicate that thereservoir contains only oil in small quantity.

WELL 4 RESERVOIR C

Reservoir C for well 4 (Figure 12) is hydrocarbon reservoir. The reservoir is within depths of 3118.41m to 3143.54m (Table 2) with NTG of 95% and volume of shale (V_{sh}) value of 4%, while the hydrocarbon saturation (S_h) is 97% with porosity (ϕ) value of 24% which indicate the reservoir is excellent with an absolute permeability (K) of 1866.24md is gotten. All the petrophysical parameters computed indicate that the reservoir contains gas only and also the crossplot of the neutron-density curve give vivid evidence, as excellent porosity and permeability value also confirm this, thus it is recommended that the reservoir is put on production.

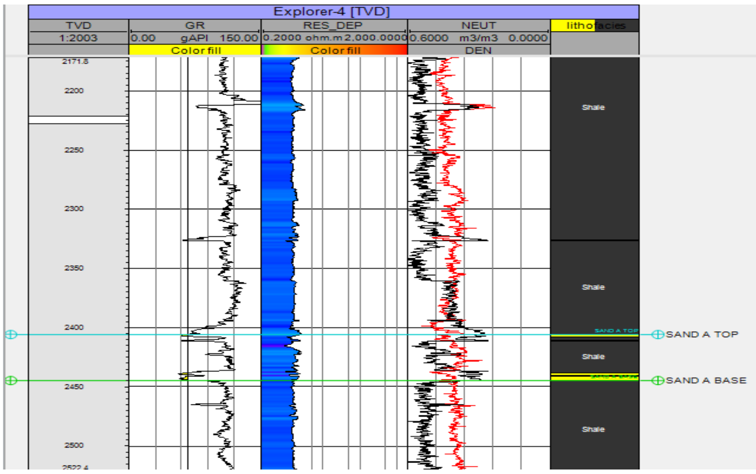

Fig. 11: Well 4 Reservoir A.

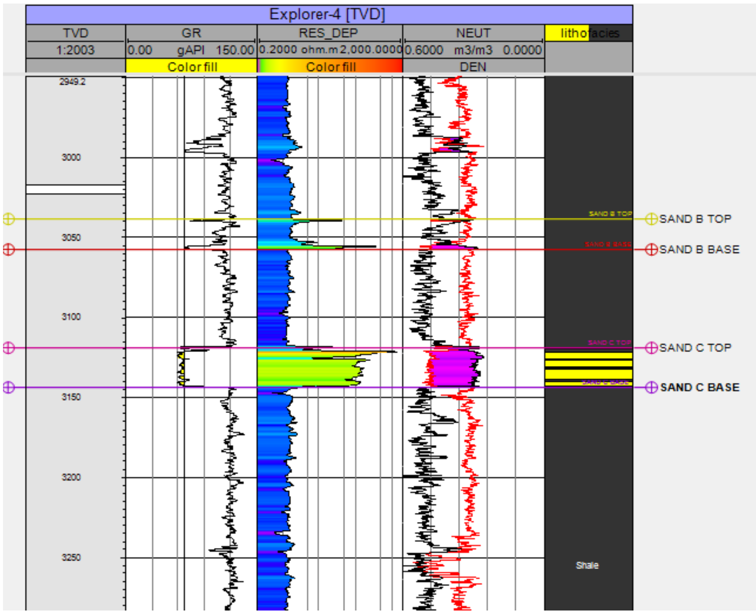

Fig. 12: Well 4 Reservoir B and C.

Table 5: Computed Petrophysical Parameters for Well 4

EXPLORER 4 PARAMETERS	RESERVOIRS SAND A	SAND B	SAND C
NET/GROSS(%)	35	21	95
I_{GR}	0.95	0.065	0.15
V_{sh} (%)	86	1.5	4
S_w (%)	68	15	2.9
S_h (%)	32	85	97
ϕ(%)	33	26	24
K(md)	22,421.3	3,016.8	1,866.24

4.2.Comparison of core values with wireline values

Petrophysical result values were compared with the core data using Pearson correlation coefficient and regression equation.

4.2.1. Comparison of petrophysical gamma ray data and core gamma ray data

The core analysis gamma ray values and the petrophysical log gamma ray values of the Explorer wells studied revealed a significant similarity in the gamma ray values determined by the two different methods. The petrophysical log gamma ray values and the core analysis gamma ray values of the reservoirs in Explorer well were plotted as a scatter diagram (Figures 13,14, and 15). They show approximate linear relationship between the two variables. Though well 4 gives an inverse relationship between the two data set. The correlation coefficient r values of 0.6642, 0.9831 and 0.3261 were obtained for well 1 (reservoir B), well 3 (which cover reservoir C and D) and well 4 (which include reservoir B and C) respectively, for well 1 a fairly strong linear relationship was observed, while well 3 give very strong linear relationship, well 4 indicate a very weak relationship. A linear regression equation of y= 0.5911x + 21.141, y= 0.9701x + 1.2692 and y= -0.9466x + 195.45 were also computed for the petrophysical log gamma ray values and core analysis gamma ray value in well 1 (reservoir B), well 3 (reservoir C and D) and well 4 (reservoir B and C) respectively, and were used to fit a regression line to the set of points (Figures 13,14 and 15). The inverse relationship between the two data set for well 4 account for the negative slope, which also leads to the weak correlation coefficient.

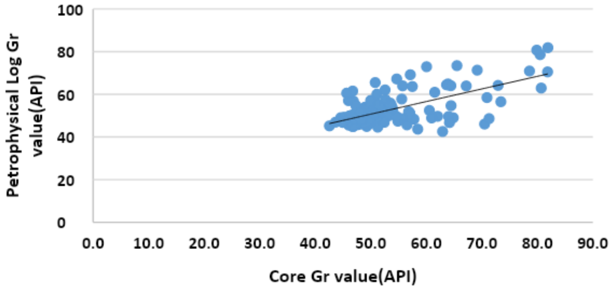

Fig. 13:GR Petrophysical Log Data Versus GR Core Data for Well 1 Reservoir B.

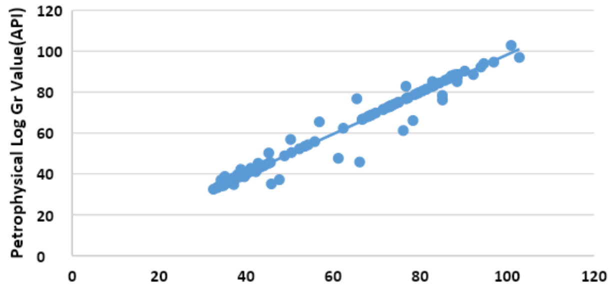

Fig. 14:GR Petrophysical Log Data Versus GR Core Data for Well 3 Reservoir C and D.

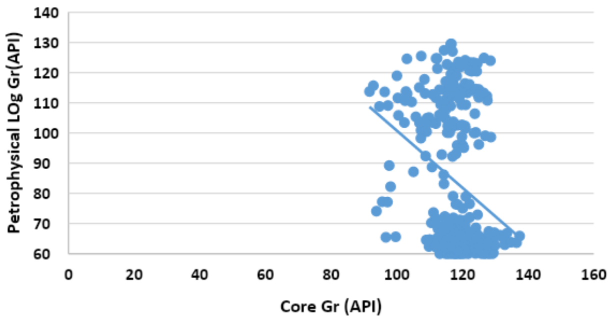

Fig. 15:GR Petrophysical Log Data Versus GR Core Data for Well 4 Reservoir B and C.

4.2.2. Comparison of petrophysical density data and core density data

The core analysis density values and the petrophysical log density values of the Explorer well studied. It revealed a significant similarity in the density values determined by the two different methods. The petrophysical log density values and the core analysis density values of the reservoirs in Explorer well were plotted as a scatter diagram (Figures 16,17 and 18). They show approximate linear relationship between the two variables except for well 4 which cut across two reservoir (reservoir B and C), and this have an inverse relationship. The correlation coefficient r values of 0.7581, 0.9872 and 0.3557 were obtained for well 1 (reservoir B), well 3 (reservoir C and D) which is a very strong correlation coefficient and well 4 (reservoir B and C) which give a weak correlation coefficient respectively. A linear regression equation of $y= 0.6994x + 0.6239$, $y= 0.9729x + 0.0565$ and $y= -1.3679x + 5.0427$ were also computed for the petrophysical log density values and core analysis density value in well 1 (reservoir B), well 3 (reservoir C and D) and well 4 (reservoir B and C) respectively, and were used to fit a regression line to the set of points (Figures 16,17 and 18). The negative slope obtained from the well 4 is as a result of the inverse relationship between the data set and this in turn account for the weak correlation coefficient.

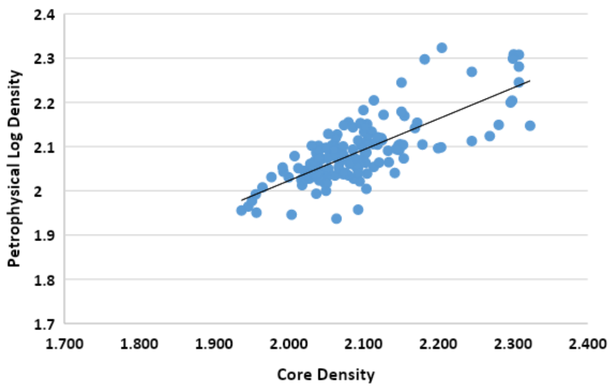

Fig. 16: Density Petrophysical Log Data Versus Density Core Data for Well 1 Reservoir B.

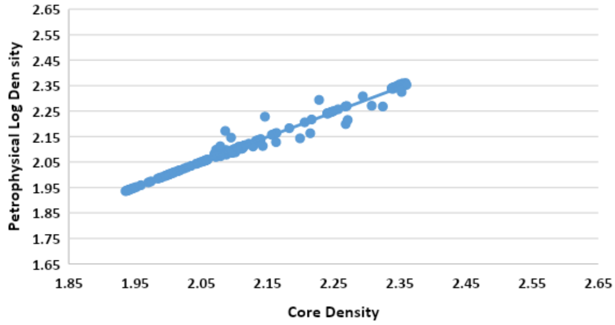

Fig. 17: Density Petrophysical Log Data Versus Density Core Data for Well 3 Reservoir C and D.

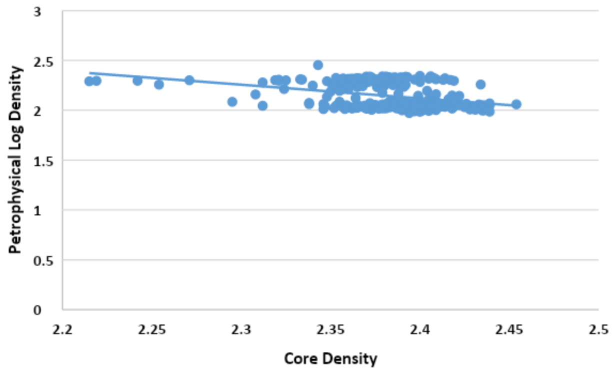

Fig. 18: Density Petrophysical Log Data Versus Density Core Data for Well 4 Reservoir B and C.

4.2.3. Comparison of petrophysical porosity density data and core porosity density data

The core analysis porosity density values and the petrophysical log porosity density values of the Explorer well studied. It revealed a significant similarity in the porosity density values determined by the two different methods. The petrophysical log porosity density values and the core analysis porosity density values of the reservoirs in Explorer well were plotted as a scatter diagram (Figures 19 and 20). They show approximate linear relationship between the two variables. The correlation coefficient r values of 0.7608 and 0.9849 where obtained for Well 1 (reservoir B) and Well 3 (reservoir C and D) respectively, indicating a strong linear relationship. A linear regression equation of $y= 0.7462x + 9.4592$ and $y= 0.7917x + 3.3984$ were also computed for the petrophysical log porosity density values and core analysis porosity density value in well 1 (reservoir B) and well 3 (Reservoir C and D) respectively, and were used to fit a regression line to the set of points (Figures 19 and 20).

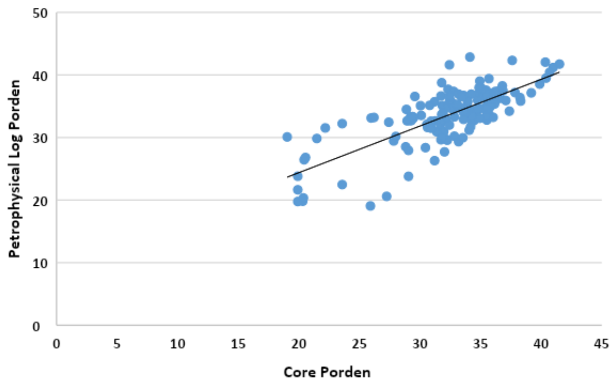

Fig. 19: Porden Petrophysical Log Data Versus Porden Core Data for Well 1 Reservoir B.

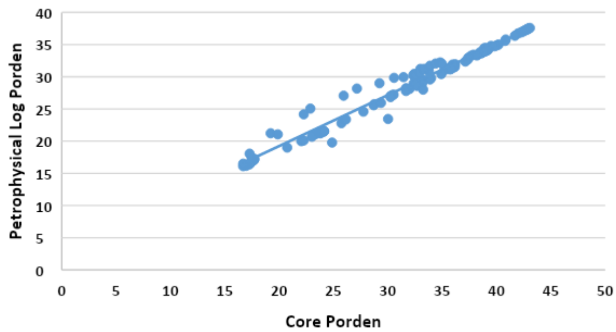

Fig. 20: Porden Petrophysical Log Data Versus Porden Core Data for Well 3 Reservoir C and D.

4.3.Analysis of petrophysical parameter estimation

Net/gross ratio was used to define the proportion of the intervals that were considered to be reservoirs and it aided in the understanding of the formation, this ratio reflects overall quality of a particular zone in question and no minding its thickness. Figures 21 – 25 shows the histogram of the various parameters that were plotted to show their pictorial variation within the interval that was studied. These intervals indicated areas/units where sand deposition is concentrated, and where better reservoir quality is to be found with variations in the quality of sand. In attempting to distinguish net reservoirs and net pay intervals in the reservoir found in Explorer well, cut-offs were used and zones which are porous and permeable were easily identified. Gamma ray, resistivity, neutron and density logs were used as indirect indicators of permeability of the Explorer well reservoirs because core is generally of limited extent and could not be relied on to define all net reservoir zones, hence, reliance was placed on the wire line log data due to the fact that it indicated the presence of fluid invasion by mud filtrate. Low gamma ray reading indicated low shale content and higher permeability, while high neutron density porosity indicated high permeability.

The average water saturation revealed the proportion of void space occupied by water in the Explorer well reservoirs based on the calculations made, and it showed that water saturation of the reservoirs are low except for Sand A well 4 which is 68% thus, high hydrocarbon saturation and high hydrocarbon production.

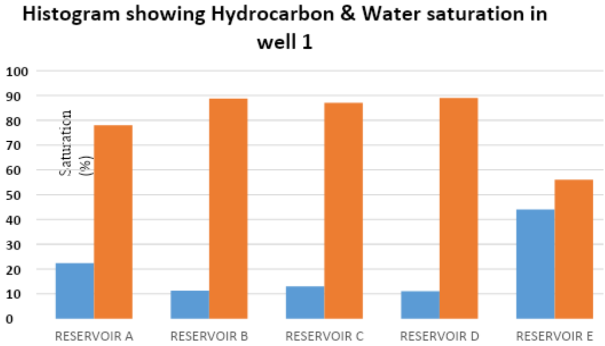

Fig. 21: Histogram Showing Hydrocarbon and Water Saturation in Well 1.

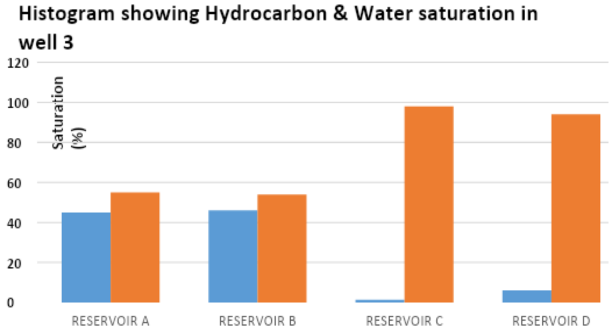

Fig. 22: Histogram Showing Hydrocarbon and Water Saturation in Well 3.

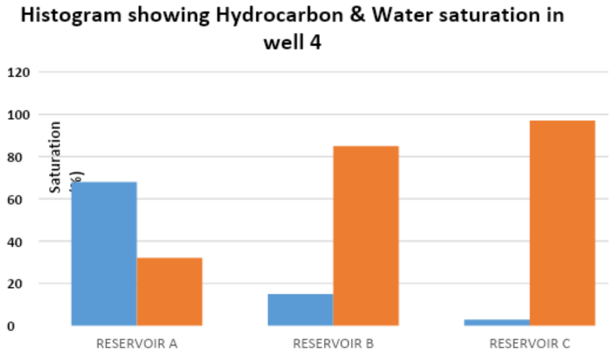

Fig. 23: Histogram Showing Hydrocarbon and Water Saturation in Well 4.

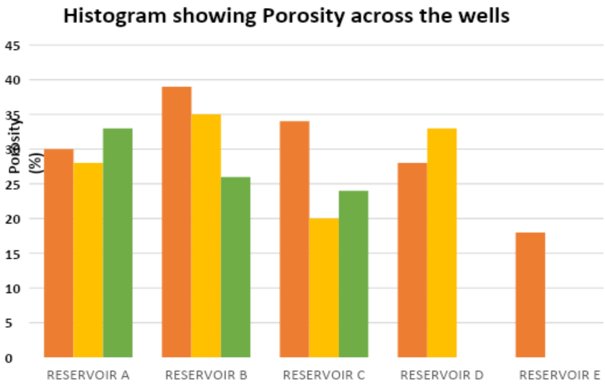

Fig. 24: Histogram Showing Porosity Across Well 1, 3 and 4.

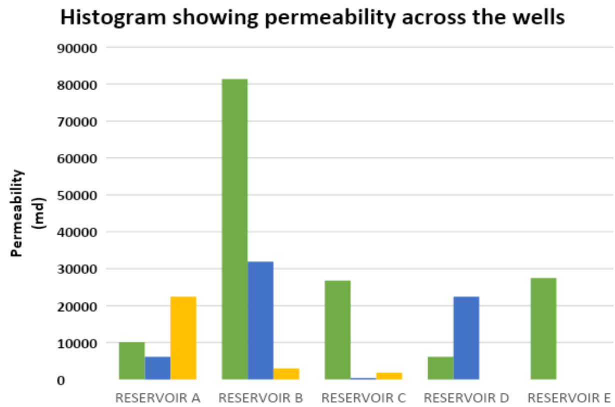

Fig. 25: Histogram Showing Permeability Across Well 1, 3 and 4.

4.4. Analysis of cross plots

Cross plots were done to show the relationship between log calculated values against those derived from core analysis data. The gamma ray log values were plotted against the core gamma ray values and this gives a direct relationship between the two data set except for the reservoir in well 4 which gives an inverse relationship between the two data, the inverse relationship is inferred to be as a result of the core gamma ray data which might have loss its physical and chemical properties during analysis in the laboratory. The density log values were plotted against density core values, this plot shows that there is a consistent, straight line relationship between the two, except for the reservoir in well 4 where both the two data set gives an inverse relationship which is said to be due to laboratory analysis of the core data. Each log shows the volume of shale in its own way. Through the straight line region, changes in porosity typically involve changes in shale content. However, in the very clean sandstones there are variations in porosity which do not involve shale and the relationship between the two logs changes. The sands in the Explorer well reservoirs is oil filled, except for a particular reservoir in well 4 (reservoir C) which is gas filled.

5. Conclusion

Average k value of the reservoir is 20, 0140md while ϕ value ranges between 18% to 39%. Fluid type defined were basically water, oil and gas, low Sw indicate high Sh. The Pearson Correlation Coefficient and Regression Equation gave a significant relationship between petrophysical derived data and core data. Scatter plot of petrophysical gamma ray values versus core gamma ray values gave an approximate linear relationship with correlation coefficient values of 0.6642. Crossplot of petrophysical density values and core density values revealed that there is a strong linear relationship between the two data set with correlation coefficient values of 0.7581. scatter plot of petrophysical porosity density values versus core porosity density values revealed a strong linear relationship between the two data set with correlation coefficient values of 0.7608. These result reveals that the reservoir formation in has the capacity to produce economically when place on production, although some of the reservoir formations in the field, will be more prolific than others.

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