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Petrophysical Evaluation of Etu Field Coastal Swamp I Depobelt Niger Delta, Nigeria

Akaerue Emmanuel I.[1], Okon Ita A.[2] and Austin C. Okonkwo[3]

[1]Geophysics Unit, Department of Physics, University of Calabar, P.M.B 1115.Cross River State, Nigeria

[2]Ministry of water Resources, P.O.Box 1177, Calabar, Cross River State, Nigeria.

[3]Department of Geology and Mining, Enugu State University of Sciences and Technology, Enugu, Nigeria.

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ABSTRACT

Etu field is located along the proximal margin of the Coastal Swamp I depobelt, a subbasin within the Niger Delta clastic wedge formed by margin collapse into underlying undercompacted shale. A Petrophysical framework evaluation for Etu field was constructed by combining data from Seven (7) Well Logs within hundreds of meters thick, define layers of reservoirs and sealing strata formed during episodic progradational and retrogradation of deltaic shorelines. The quality of the reservoirs are moderate to good and in some distal reservoirs, they are excellent. The average porosity values are approximately the same, but have variation in permeability which could be as a result of compaction of older reservoirs on the proximal part of the field. A total of thirty seven (37) reservoirs between 3000-4500 (m) were demonstrated. Sixteen (16) of the reservoirs are oil bearing, Six (6) are gas bearing while Fourteen (14) are water saturated.

Introduction

Rock physics is the science of measuring rock properties and establishing the relationship between these properties. Petrophysics is a viable tool for detection and evaluation of hydrocarbon bearing layers. One of the fundamental properties of a reservoir rock is porosity. However, for a rock to be an effective reservoir, it must have good pore interconnectivity. The main physical parameters needed to evaluate a reservoir are porosity, hydrocarbon saturation, permeable bed thickness, and permeability etc. These parameters may be derived or interred from electrical, nuclear, and acoustic Logs, which can be translated to qualitative information of depth/thickness of productive intervals, to distinguish between oil, gas and water in reservoir.

Location of the Study Area

The Etu field is situated in OML-XYZ, in the swamp region of the Niger Delta, Nigeria (Figure 1).

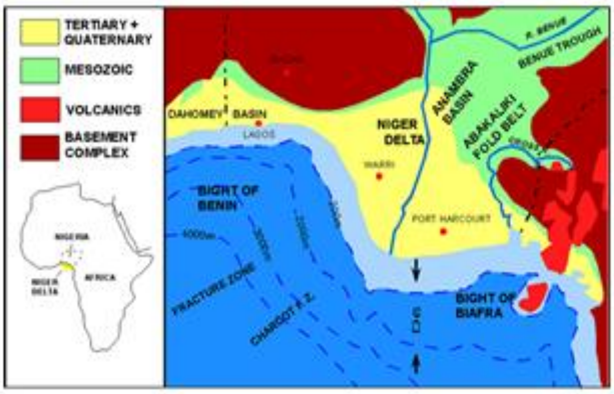

Figure 1. Index Map Niger Delta And the offshore Nigeria.

The first discovery was made in 1975 by Etu well-1 which found some 264 ft NGS and 307 ft NOS in 11 intervals. There are 7 completed drainage points in 4 wells all producing under primary recovery technique.Total cumulative oil production as at 1-12-2005 is 3.9 MMstb. The seven wells studied are exploration wells situated in the Gulf of Guinea and extend throughout the Niger Delta Province as defined by Klett and others (1997). 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 with an area of some 300,000 km^2 (Kulke, 1995), a sediment volume of 500,000 km^3 (Hospers, 1971), and a sediment thickness of over 10 km in the basin depocenter.

Stratigraphy of Niger Delta

The stratigraphy of the Niger Delta is divided into three diachronous units of Eocene to Recent age that form a major regressive cycle. The uppermost unit, the Benin Formation, comprises continental/fluviatile and backswamp deposits up to 2500m thick. These are underlain by the Agbada Formation of paralic, brackish to marine, coastal and fluvio-marine deposits, organized into coarsening upwards 'offlap' cycles (Short,K.C and Stauble A.J, 1967). The underlying Akata Formation comprises up to 6500m of marine pro-delta clays. Shales of the Akata Formation are overpressured and have deformed in response to delta progradation. These shales facilitate regional decollement for updip extension and downdip compression. Shales of the Akata Fm constitute a world-class source rock (Ekweozor,C.M and Daukoru 1994).

Tele:
E-mail address: akaerueemmanuel@gmail.com

Structure

The Etu structure is a large collapsed crest rollover anticline trending east-west. Bounded to the north by the major XX boundary fault, it forms part of the larger Baristo structural trend. The hydrocarbons found at shallow depths are trapped against the southern-most antithetic fault while at deep levels, the hydrocarbons are dip closed in footwall of this same antithetic fault.

Methods and Materials

Seismic

The Etu 2D survey was acquired as part of the Wemboo 2D seismic survey in 1972 and 3D survey was carried out in 1996. A total of 180 km^2 and 100 km^2 of 15 fold data with a 25 x 25m bin spacing were acquired for the Etu 3D survey. The C.10 and D5.0 reservoir sands are two of the 9 key horizons mapped in the Etu 3D seismic survey. They constitute the two main reservoirs in the Etu field and account for 73% of the currently booked STOIIP volumes. Both sands are oil bearing in all wells, which penetrate the intervals with the exception of Etu -1. Identification of the C.10 and D5.0 seismic markers corresponding to their near tops was carried out using all wells that penetrated the sands. Synthetic seismograms generated for Etu wells -2, -3, -4 and -5, were used in well-to-seismic calibration. The near top of the C.10 reservoir sand correlates to the peak of a medium to high amplitude. This is a low to medium frequent maximum (soft kick) seismic loop with good lateral continuity in the field area..

Identification of Reservoir Rocks

To discriminate potential reservoir rock from non permeable rock, gamma ray logs (GR) was used. The GR logs measure the natural radioactivity in formation and can be used for identifying lithologies and for correlating zones. Shale – free/sandstones and carbonates have low concentrations of radio-active material and give low GR readings. As content increases, the gamma ray log response also increases because of the concentration of radioactive material in shale.

For a quick look evaluation the following steps were followed:

- A sand line was constructed by reading the average GR level of thick clean sands (sands with lowest. GR) and was called the sand line. Also a GR level in thick shale beds was identified. This reading was assumed to represent 100% shale and called shale line
- A near vertical line was drawn in the middle between the shale line and the sand line (cut-off line) about 65- 69.5 API values.
- All intervals where the GR log is on the left of this cut-off line were assumed to be potential reservoir.(Figure.2)

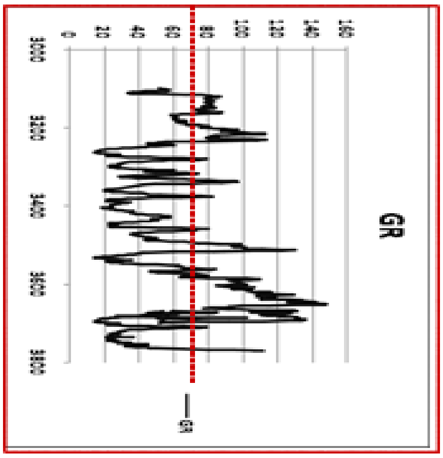

Figure 2. schematic presentation of gamma ray log, showing the cut-off line (red dotted line)

Determination of Shale Volume

The Niger Delta productive sands are found intercalated with shales. Thus presence of shale or clay minerals in a reservoir can cause erroneous values for water saturation and porosity derived from logs. Hilchie (1978) noted that the most significant effect of shale in a formation is to reduce the resistivity contrast between oil or gas and water. He further suggested that for shale to significantly affect log- derived water saturation, shale content must be greater than 10 – 15%.

There is therefore need to correct for the presence of shale in Niger Delta reservoirs.

The first step in shaly sand analysis is to determine the volume of shale.

The Gamma Ray Index was first calculated as:

$$I_{GR} = \frac{GR\ log - GR\ min}{GR\ max - GR\ min} \quad (1)$$

The Shale Volume was then calculated using the (Larionov, 1969) nonlinear response method.

$$V_{sh} = 0.083.\ (2^{3.7 \times I_{GR}} - 1) \quad (2)$$

(For tertiary unconsolidated rocks).

Where: GR_{log} = GR reading from the log.

GR_{min} = GR log reading in clean sandstone

GR_{max} = GR log reading in shale zone.

I_{GR} = Gamma ray index.

V_{sh} = volume of shale.

Evaluating Porosity

Porosity is the ratio of voids to the total volume of rock in percentage, and is usually designated by the Greek letter phi, Φ

$$\text{Porosity, } \Phi = \frac{\text{Volume of pores}}{\text{Total volume of rock}} \quad (3)$$

This is usually called the total porosity, but the effective porosity is a function of interconnected void spaces and is most useful in characterizing a reservoir. Consequently, in this project effective porosity will be used.

Density Porosity

The reservoir porosity calculated from the density data for this project was done with this formula.

$$\Phi_D = \frac{P_{ma} - P_b}{P_{Ma} - P_{fl}} \quad (4)$$

Where

Φ_D = Density porosity

P_{Ma} = Matrix density (2.64g/cm^3 for sandstones).

P_b = Formation bulk density (from wire-log).

P_{Fl} = Fluid density (1.0g/cm^3).

Average Neutron Density Porosity

$$\Phi_A = \frac{(\Phi_D + \Phi_N)}{2} \quad (5)$$

Where:

Φ_A = Average porosity.

Φ_N = Neutron porosity (from logs).

Φ_D = Density porosity.

Effective Porosity

The average porosity is corrected for shale effects to give effective porosity.

$$\Phi_E = \Phi_A \times (1 - V_{sh}). \quad (6)$$

Where:

ΦE = Effective porosity.

Vsh = Shale volume.

Φ_A = Average porosity.

In general, field appraisal classifications of reservoir porosity are;

Percentage / Decimal

5% - 10% = 0.5 – 0.10 = poor.

10% - 20% = 0.10 – 0.20 = good.

Above 20% = above 0.020 = very good.

Resistivity of Formation Water (Rw)

The resistivity of water was determined in this project using the pickets plot. Figure3.

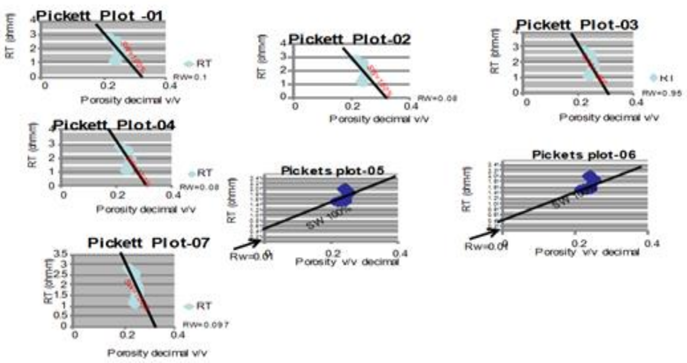

Figure 3. Determination of Rw from a Pickett plot. A linear scale plot.

The value ranges between 0.01 – 10Ωm. A clean water bearing reservoir was identified for each well and porosity Φ was plotted against uninvaded zone resistivity RT on a double logarithmic plot (pickets plot).A best fit line was drawn through the point; the intersection point of this best fit line on the resistivity axis will be the value of the Rw

Determination of the Water Saturation (Sw)

The amount of pore volume in a rock that is occupied by formation water is referred to as water saturation. The pores of the formation may be filled with gas, oil or water and the sum of the saturation of all the fluids in the formation must total 100%.

Archie's equation (1942) was used to estimate Sw

$$Sw = \left\{\frac{a \times Rw}{RT \times \Phi^m}\right\}^{1/} \quad (7)$$

Where:

Sw = water saturation (in v/v decimal or percentage).

Rw = is the resistively of formation water.

RT = Uninvaded zone resistivity from deep formation resistivity.

Φ = Porosity of the zone.

a = Tortousity factor = (0.81) or local correction factor

m = is cementation factor = 2.

n = is the saturation exponent = 2.

Flushed Zone Water Saturation

Flushed zone water saturation was determined using Archie's equation, but two variables were changed, mud filtrate resistivity (Rmf) given at the log header in place of formation water resistivity (Rw) and flushed zone resistivity (R_{xo})

$$S_{xo} = \left\{\frac{a \times Rmf}{R_{xo} \times \Phi^m}\right\}^{1/n}. \quad (8)$$

Sxo = Flushed zone water saturation.

Rmf = Resistivity of the mud filtrate

R_{xo} = Invaded zone resistivity determined (from the shallow resistivity log).

Φ = Formation porosity determined from the neutron and density.

a = 0.81.

m =2

n = 2.

Determination of Hydrocarbon Saturation

The Hydrocarbon saturation is the fraction of reservoirs pore volume occupied by hydrocarbons.

$$Sh = 1 - Sw. \quad (9).$$

Where:

Sh = hydrocarbon saturation

Sw = water saturation.

Determination of Bulk Volume Water (Bvw)

The proportion of water in the total formation is referred to as bulk volume water. It can be used as an indicator that the formation is at irreducible water saturation. It is a product of the formations water saturation and porosity. When a formation is at irreducible water saturation (Swirr), values of the Bvw calculated over a range of depths in a formation are constant or very close to constant. Water in the uninvaded zone (Sw) does not move because it is held on grains by capillary pressure. Therefore hydrocarbon production from a zone at irreducible water saturation should be water free (Morris and Biggs, 1967).Thus Bvw increases with decreasing grain size.

$$Bvw = Sw \times \Phi \quad (10).$$

Where:

Bvw = Bulk volume water.

Sw = Water saturation.

Φ = Porosity.

Determination of Permeability (k)

Permeability is the ease of a rock to transmit fluids and is controlled by the size of the pore throat. It is measured in Darcy's (or milidarcy md). The Wyllie & Rose (1950) log derived permeability equation was used. It is valid for estimating permeability in formations at irreducible water saturation (Schlumberger, 1985).Then values gotten are compared to values of nearby producing wells of the same formation.

$$k = \left[\frac{250 \times \Phi^3}{Swirr}\right] \quad (11)$$

Where:

k =log derived permeability

Swirr = Irreducible water saturation.

Φ= Porosity of the zone.

Reservoir permeability's may be loosely described as follows:

Very low: $k < 1$ md

Low = 1 md $< k <$ 10md.

Fair: 10md $< k <$ 50md.

Average: 50md $< k <$ 200md.

Excellent: $k >$ 500md.

Reservoir permeability varies widely, from 0.001md for tight gas sand in East Texas to 4000md for unconsolidated sands in the Niger Delta.

Determinations of the Movable Hydrocarbon Index (Mhi)

The ratio of water saturation (Sw) to flushed zone water saturation (S_{xo}) gives the amount of hydrocarbons which have been moved by the invasion process. The ratio is referred as the moveable hydrocarbon index. This provides an estimate of the producibility of oil.

$$Sw/Sxo = \left\{\frac{R_{xo}/Rt}{R_{mf}/Rw}\right\}^{1/2} \quad (12)$$

If the ratio Sw/S_{xo} is equal to or greater than 1.0, then hydrocarbon were not moved during invasion. This is true regardless of whether or not a formation contain hydrocarbons. Whenever the ratio is less than 0.7 for sandstones, the moveable hydrocarbon is indicated (Schlumberger, 1972).

Identifying the Hydrocarbon Bearing and Water Bearing Layers (OWC)

Hydrocarbon and water bearing layers can be easily delineated using resistivity log. From Archie's equation (1942). Rt increases when the water is replaced by oil with porosity and lithology remaining constant.

$$R_T = \frac{Rw}{\Phi^m S_w^n} \quad (13)$$

Rt increases when porosity (Φ) decreases or density increases with lithology and Sw constant.

Water bearing intervals was outlined by low resistivity and tram lining between density and resistivity. The density decreases when the water is replaced by oil in the formation with the same porosity, thus the hydrocarbon bearing intervals was not only characterized by high resistivity but often by an anti-correction between the density and the resistivity logs.

Distinguish Between Oil and Gas. (OGC).

Gas or light hydrocarbons within the zone of investigation of the Density or Neutron devices causes the apparent porosity from density log to increase and the Neutron log to decrease. On a Density-Neutron plot, this results in a shift (from the liquid-filled point of the same porosity) upward and to the left, almost parallel to the iso- porosity lines. This implies that Density and Neutron logs in a crossplot will be shifted in opposite directions in a hydrocarbon bearing zones. Thus zones with large density-neutron separation are identified as gas bearing zones and zones with small separation as oil bearing zones.

Results and Discussions

Etu- Well 01

Six major reservoirs intervals A1-A6 were delineated for this well as showed in figure 4.

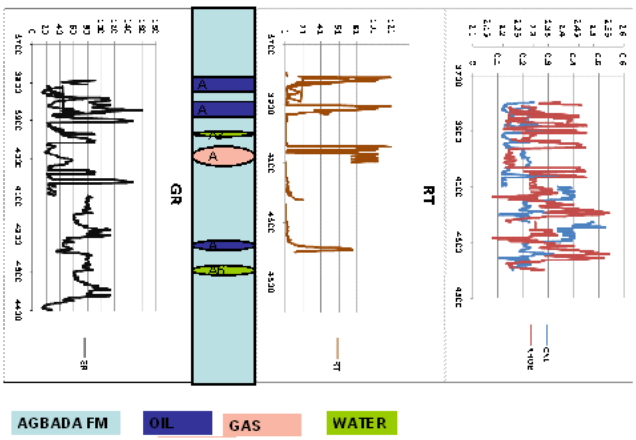

Figure 4. Schematic presentation of petrophysical interpretation of-01.

The Petrophysical properties are summaries in Table 2.The reservoirs sands have average net thickness which range from 9 –56m.A good value that highlight an excellent sand development with a low value of Vshale (0.01 – 0.03 v/v decimal).These reservoirs interval are of clean sand and its porosity (Φ), permeability (k) and values are excellent to allow free flow of fluid. Reservoirs A_1 A_2, A_4 and A_5 have high resistivity (R_t) which are greater than R_o values, and also low water saturation which are invariably good indication that they have high hydrocarbon saturation (60 – 92%).The hydrocarbons in reservoirs A1, A2, A5 could be oil with the tracking together of the density and neutron log signatures while the reservoirs A4 could be gas with the negative crossing of the neutron and density logs. Reservoirs A3 and A6 have low resistivity (R_t) values (3 – 8 ohms) approximately equal to R_o with high water saturation values (95 – 85%). This could be an evidence of water filled pores. Using gamma ray log a cut of value of 65 API was determined while the resistivity of the formation water Rw was determined from the Pickett plot.

Etu – Well 02.

Six major reservoirs intervals B_1 - B_6 were delineated for this well as shown in (Figure5).Average porosity values obtained ranges from 20 – 25%.

The reservoirs are clean sand shown by their V-shale values of 0.02 – 0.05 v/v decimal. Reservoir B_1 has low average resistivity values of 56.7 ohm – m at 3105 – 3200m; this reduces to an average of 3.70 ohm – m at depths below 3105m suggesting that the fluid content in the intervals below this depth is water. This infers an oil-water (OWC) at that point.

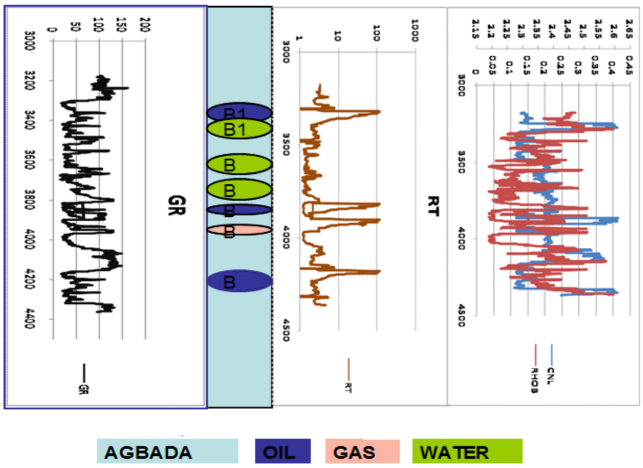

Figure 5. Schematic presentation of petrophysical interpretation of Etu-02.

The Petrophysical properties are summarized in Table 3.

Table 3. Summary of the Petrophysical Results for Etu-02.

Reservoir Intervals	Net Sand Count (m)	Average Porosity (%)	Average Resistivity (ohm)	Average Vshale(v/v) Decimal	Average MHI	Average Permeability (md)	Average Water Saturation (%)	Fluid Type
B 1a 3106-3200	95	25	86.7	0.04	0.46	3237	25	OIL
B 1b 3200-3210	10	22	3.7	0.03	0.54	14.1	68	WATER
B2 3248-3268	7	22	4.1	0.04	0.52	13.5	65	WATER
B3 3263-3279	16	25	3.91	0.05	0.53	18.1	67	WATER
B4 3316-3326	10	24	109.5	0.04	0.44	2674.4	21	OIL
B5 3460-3466	16	23	120	0.02	0.47	3574.1	20	GAS
B6 3473-3482	9	20	81	0.05	0.49	2311	15	OIL

The low average resistivity values and high water saturation of B_2, B_3,and B_6 are indications that the fluid content could be water. Reservoirs B_4, B_5 and B_6 could be hydrocarbon as indicated by their high average resistivity values and low water saturation. The tracking together of the density and neutron log signatures in reservoir B_4 and B_5 could be oil indicator. Whereas the separation of the neutron log and density log signatures crossplot in reservoir B5 could be gas.

Etu – Well 03.

Four major Reservoirs intervals C_1 – C_4 were delineated for this well as showed in figure 6.

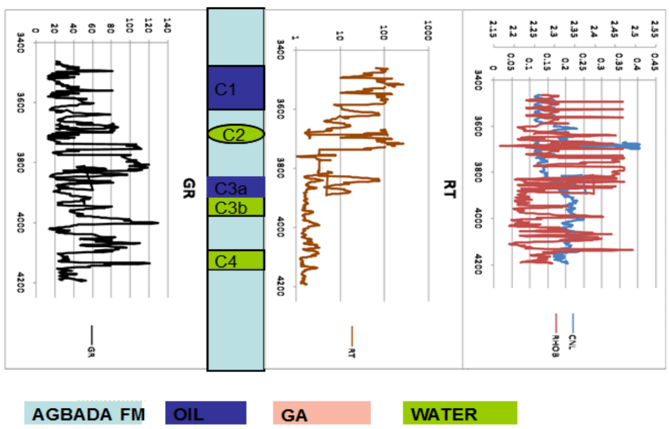

Figure 6. Schematic presentation of petrophysical interpretation of Etu-03.

The Petrophysical properties are summarize in Table 4.The reservoirs are well developed with good thickness ranging from 12 – 51m.There porosityΦ, permeability k and moveable Hydrocarbon index MHI values, are excellent to allow free flow of fluids.

Table 4. Summary of the Petrophysical Results for Etu-Well 03.

Reservoir Intervals (m)	Net Sand Count (m)	Average Porosity (%)	Average Resistivity (ohm)	Average Vshale (v/v)	Average MHI	Average Permeability (md)	Average Water Saturation (%)	Fluid Type
C1 3463-3585	126	20	90	0.29	0.4	618	21	OIL
C2 3590-3677	87	26	4.1	0.34	0.51	13.4	86	WATER
C 3a 3696-3737	43	23	81	0.04	0.49	1718	18	OIL
C 3b 3755-3773	18	18	3.1	0.04	0.41	12.68	67	WATER
C4 4100-4145	45	21	2.5	0.04	0.39	18.1	80	WATER

Reservoirs C_1 and C_3 show evidence of hydrocarbon saturation as the total resistivity (R_T) value are greater than the R_o values. Below 3969m depth in reservoir C_3,could be water Reservoir as indicated by high water saturation values 69% marking the oil – water contact (OWC). Also Reservoir C_2 and C_4 could be water as indicated by high water saturation and R_t approximately equal to R_o. ($R_T = R_o$).

Etu – Well 04.

Seven major reservoirs intervals $D_1 - D_7$ were delineated for this well as showed in figure 7.

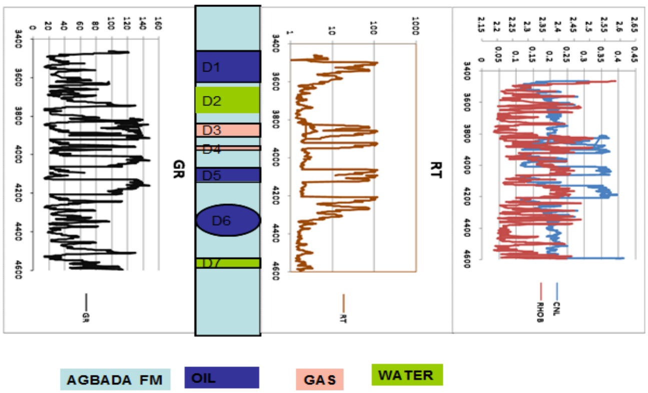

Figure 7. Schematic presentation of petrophysical interpretation of Etu-04.

A cut off values of 67.5 API were determined. The Petrophysical properties are summaries in Table 5

Table 5. Summary of the petrophysical results for Etu-well 04.

Reservoir Intervals (m)	Net Sand Count (m)	Average Porosity(%)	Average Resistivity (ohm)	Average Vshale (v/v) Decimal	Average MHI	Average Permeability (md)	Average Water Saturation (%)	Fluid Type
D1 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OIL
D2 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	WATER
D3 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	GAS
D4 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	GAS
D5 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OIL
D6 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OIL
D7 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	WATER

Reservoirs D_1, D_2 . D_3, D_4, D_5, could be hydrocarbon as indicated by their high resistivity R_t and low water saturation Sw .Reservoir D_5 & D_4 could be gas considering the neutron and density log separation while reservoirs D_2 and D_7could be water as evident from their low resistivity and high water saturation values.

Etu – Well 05.

Seven major Reservoirs intervals E_1 - E_7 with average net sand ranging 7 – 76m thick were delineated Figure.8

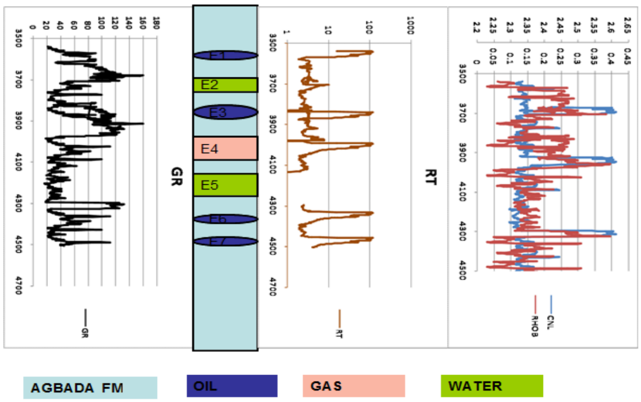

Figure 8. schemat presentation of petrophysical interpretation of Etu-05.

The Petrophysical properties are summarized in Table6

Table 6. Summary of the Petrophysical Results of Etu-Well 05.

Reservoir Intervals	Net Sand Count(m)	Average Porosity(%)	Average Resistivity(ohm-m)	Average Vshale (v/v)	Average MHI	Average Permeability (md)	Average Water Saturation (%)	Fluid Type
E1 3617-3800	83	25	110	0.08	0.46	2813	18	OIL
E2 3700-3750	50	20	2.2	0.05	0.38	20	85	WATER
E3 3800-3876	75	20	120	0.04	0.36	3145	20	OIL
E4 4088-4095	7	25	120	0.03	0.34	3456	18	GAS
E5 4200-4300	100	18	3.2	0.05	0.47	18	87	WATER
E6 4400-4445	45	21	95	0.08	0.34	2815	20	OIL
E7 4608-4630	21	25	98	0.04	0.35	1916	21	OIL

The Pickett plot aided in the determination of the resistivity of the formation water. The indication of high resistivity R_t, ($R_t > R_o$) and low water saturation about 18% of Reservoirs E_1 , E_3, E_4, E_6 and E_7 could be probably Hydrocarbon reservoirs. The negative separation of neutron and density log signatures distinct in reservoir E_4 could be an indication of gas filled reservoir (figure 8). Reservoirs E_2 and E_5 could be water filled as indicated by high water saturation values.

Etu – Well 06.

Four reservoirs F_1 - F_4 with average net sand ranging 7 – 25m thick were delineated. The Petrophysical properties are summarized in Table 7.

Table 7. Summary of the Petrophysical Results for Etu-Well 06.

Reservoir Intervals (m)	Net Sand Count (m)	Average Porosity (%)	Average Resistivity (ohm-m)	Average Vshale (v/v) Decimal	Average MHI	Average Permeability (md)	Average Water Saturation (%)	Fluid Type
F1 3220-3300	80	26	87	0.023	0.44	2084.8	18	GAS
F2 3400-3500	100	18	5.6	0.04	0.56	2.5	70	WATER
F3 3514-3558	44	20	4.6	0.03	0.55	15.8	67	WATER
F4 3710-3800	90	19	128.5	0.035	0.55	2971	24	OIL

The Average resistivity values for F2 and F_3 is 5.7 ohm-m and 5.6 ohm-m with water saturation values are 65% and 46% respectively, suggesting water as the fluid content. Reservoir F_1 & F_4 with a high resistivity value of 128.5 ohm-m and low water saturation of 24% could suggest hydrocarbon.

The Neutron – density crossplot showed that reservoir FI contain gas figure 9.

The average MHI values of 0.56 and 2971.5 md of permeability in reservoir F_1 & F_4 suggest good fluid moveability.

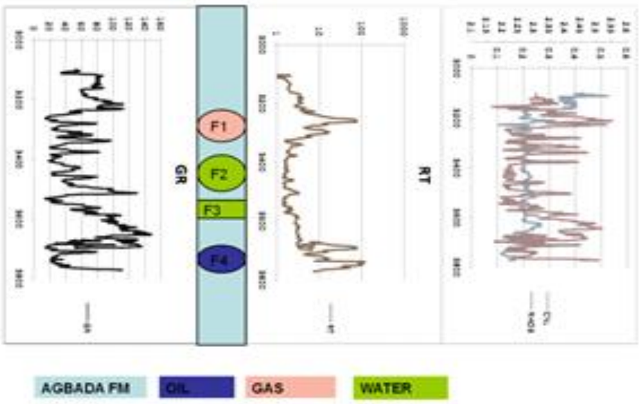

Figure 9. Schematic presentation of petrophysical interpretation of Etu-06.

Etu – Well 07.

Table 8. Summary of Petrophysical Results for Etu-Well 07.

Reservoir Intervals (m)	Net Sand Count (m)	Average Porosity (%)	Average Resistivity (ohm-m)	Average Vshale (v/v) Decimal	Average MHI	Average Permeability (md)	Average Water Saturation (%)	Fluid Type
G1 3753-3800	47	25	4.1	0.029	0.55	19	85	WATER
G2 3910-3953	43	25	3.4	0.220	0.51	21	75	WATER
G3 3988-4060	52	24	80	0.024	0.56	2888	17	GAS
G4 4150-4200	50	20	3.2	0.20	0.50	21	65	WATER

Four reservoirs G_1 - G_4 were delineated with good sand sedimentation. Average Net sand ranging 7 – 70m thick.

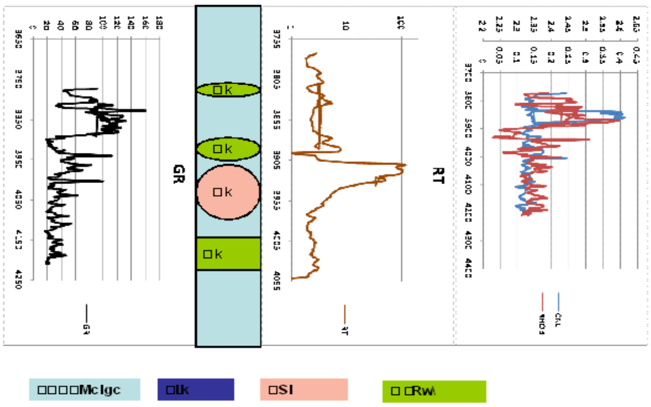

Figure 10. Schematic presentation of petrophysical interpretation of Etu-07.

The Petrophysical properties are summarize in Table 8. Reservoir G_3 with high resistivity value 80 ohm-m and low water saturation of 17% suggests a hydrocarbon filled reservoir. The neutron density cross plot showed that G_3 could contain gas Figure 10. Average resistivity values of $G1_,$ G_2 and G3 are 8.1, 4.5 and 3.2 ohm-m and water saturation are 85, 75 and 65% respectively suggest reservoir filled water.

Conclusion

The quality of the reservoirs in the Etu Field Niger delta are moderate to good and in some distal reservoirs, they are excellent. The average porosity values are approximately the same, but have variations in permeability which could be as a result of compaction of the older reservoirs on the proximal part of the field. The escalator regression sedimentation model of the Niger Delta makes it clear that younger sediments are found in the distal part of the basin with pronounced thickness greater than that on the proximal part. Compaction initiates early in the older rocks of proximal facies and grades down basinward. So the geometric properties (porosity and permeability) are bound to vary relatively. A total of seven wells have been drilled into the Etu structure encountering thirty seven (37) reservoirs between 3000-4500m. Sixteen (16) of the reservoirs are oil bearing, six (6) are gas bearing while fourteen (14) are water saturated, that is, water bearing reservoirs. The hydrocarbon found at the shallow depths are trapped against the southernmost antithetic fault while at deep levels hydrocarbons are dip closed in footwall of this same antithetic fault.

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