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Full Length Research Paper

An appraisal of the Abura Field

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Petrophysical analysis was carried out for all the identified hydrocarbon intervals, from the four wells studied in the Abura Field using suites of geophysical well logs. From the analysis of the geological logs comprising gamma-ray, spontaneous potential, electrical resistivity, neutron and density logs, the total porosity in the hydrocarbon bearing zone was found to range from 18.0% to 28.0% and the water saturation range from 16.0 to 54.0%. Good well-to-well lithologic correlation was established across the fields studied .The researcher found that the bulk of the hydrocarbon encountered in the Niger Delta basin was found to be within a depth range of 2510.0-3887.0 m. The hydrocarbon reservoirs were found to be in the Agbada formation, which is in conformity with the geology of the Niger Delta, Nigeria. This study was carried out to find out if the petrophysical parameters computed in the field will encourage deeper drilling in the area of study.

Key words: Resistivity, Lithologic correlation, Reservoir, Hydrocarbon, Porosity, Water saturation

INTRODUCTION

The bulk of the hydrocarbon encountered in the Niger Delta, Nigeria has been mostly within a depth range of 4,000ft to 12,000ft (about 1,200m to 3,650m) since the search for oil began in 1914 (Falebita and Babalola, 2003). The industry operators, in their bid to boost the Nigeria reserves base, have over the years been encouraged to intensify their search for oil and gas through various incentives to the frontier areas. It is pertinent to note that vast upside potentials lay below the present window of exploitation undiscovered because of the limitations of the existing technology of yester years. The story has changed. High resolution 2-D, 3-D and 4-D Seismic data acquisition capability with advancement in drilling technology as well as intelligent completion strategies are facilitating ingredients that should make deep drilling an attractive option (Aigbedion, 2004).

Apart from increasing the Nigeria reserves base and meeting production targets, deep drilling in the Niger Delta may reduce the operating and capital cost since only minor expansion, if any, might be needed to upgrade the existing producing facilities. Today's technological advancement in the United state of America, United Kingdom , and China has made the present time very appropriate for the operating companies to go into deep drilling as an option for sustaining exploration activities in the Niger Delta. Increasing global energy demand requires more oil and gas production; consequently, greater challenge exists in meeting this demand especially as old reservoirs are depleted.

The challenge, as in this study, is to obtain favourable parameters that will encourage deeper drilling in the basin at minimal cost but yet meeting the Nigeria objectives of 40 billion reserve base and 4 million barrel of oil per day (BOPD) production by the year 2010.

The field of study lies in the South-West of Delta state in the Niger Delta between longitude $5^0\ 35^1$ E and $5^0\ 44^1$ N and latitude $6^o\ 42^1$ W and $5^o\ 23^1$ S. It lies within the oil prolific belt of Niger Delta.

Three major lithostratigraphic units have been recognized in the Niger Delta (Short and Stauble, 1967) (Franky and Cordy, 1967), and (Maron, 1969). These are the Akata, Agbada and Benin formations. Details of the geology of the Niger Delta have been discussed by several authors, (Schlumberger 1985, Merki 1970, Short and Stauble 1967, Reyment 1965, Otobo, 2005.)

The Benin formation, which is a loose fresh water bearing sand with occasional lignite and clay and going up to 2,286m deep with no over pressures. The Agbada formation is made up of alternation sands and shales. The sands are mostly encountered at the upper parts while shales are found mostly at the lower parts. The Agbada formation is thickest at the centre of the Delta and goes up to 457.2m. This is the seat of most oil

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Table 1. Abura Field:- Correlation Table

Well Reservoirs	1	2	3	4
	Intervals (m)	Intervals (m)	Intervals (m)	Intervals (m)
A1	2512.0 – 2522.0	2517.0 – 2531.0	2538.0 – 2545.0	2520.5 – 2542.0
A2	2680.8 – 2689.0	2678.0 – 2692.0	2650.0 – 2685.4	2647.0 – 2660.0
A3	2728.0 – 2739.0	-	-	2737.0 – 2740.0
A4	2840.5 – 2860.0	2827.0 – 2845.0	2853.5 – 2869.5	2847.0 – 2863.0
A5	3035.0 – 3060.4	3055.0 – 3060.0	2999.5 – 3081.0	3052.0 – 3075.0
A6	3195.0 – 3202.0	3172.0 – 3185.6	3180.0 – 3199.0	-
A7	-	3250.0 – 3289.0	3242.0 – 3263.5	3295.2 – 3301.0
A8	3310.0 – 3325.0	3208.0 – 3324.0	3316.4 – 3342.0	3321.0 – 3330.5
A9	3436.5 – 3442.0	3409.o – 3429.0	3417.0 – 3436.5	-
A10	3590.0 – 3697.3	3582.0 – 3600.0	3588.0 – 3595.0	3584.5 – 3591.0
A11	3678.5 – 3690.0	3669.0 – 3684.0	3691.5 – 3710.0	3680.0 – 3706.6
A12	3870 .0– 3683.0	3852.4 – 3881.0	3862.5 – 3880.0	3867.0 – 3874.0

reservoirs and center of over pressures.

Background Information of Formation Evaluation of Niger Delta Reservoir

The Abura field is situated in OML 65, about 35 km West of South-West of Warri under the Nigerian Petroleum Development Company (NPDC) in Benin. The Field consists of a NW – SE oriented roll-over structure about 11km long and 4km wide. Major reservoirs A2 – A12, out of which a total of ten were found to contain hydrocarbon.

The formations found in the Niger Delta are mostly unconsolidated sands and shale and its often not feasible to take core samples or take samples or make drill stem tests (Schlumberger, 1985). Formation evaluation is consequently based mostly on logs, with the help of sidewall samples and wire line formation tests.

THEORETICAL BACKGROUD

Saturation models are the models which relate measured resistivity to water resistivity, from which hydrocarbon content is determined. All water saturation determinations from resistivity logs in clean (Non-shaly) formations with homogenous intergranular porosity are based on Archie water saturation equation.

According to Archie (1942), water saturation equation can be written as:

$$S_w^n = FR_w / R_t \quad (1)$$

Where, n = saturation exponent which varies from 1.8 to 2.5

R_w is the formation water resistivity
R_t is the true resistivity of the formation

and

F is the formation factor.
The formation factor, F is given as

$$F = 1 / \phi^m \quad (2)$$

Where m = cementation factor

Usually in the Niger Delta, m = 1.8 (Schlumberger, 1985, Aigbedion, 2003). The range of m is between 1.7 – 1.9.

Therefore,

$$F = 1 / \phi^{1.8}$$

From equation (i) above i.e.

$$S_w^n = FR_w / R_t$$

The determination of water saturation requires the determination of R_w, R_t, and F. From the equations above n is usually taken as 2.

$$S_w^2 = F^*R_w / R_t \Rightarrow S_w = [F^* S_w / R_t]^{1/2}$$

$$= [R_0 / R_t]^{1/2}$$

Since $FR_w = R_o$

The formation factor F according to (Aigbedion, 2003) may be written as

$$F = 1 / \phi^2 \quad \text{(for carbonate rocks)}$$

Table A2. Results of Petrophysical Analysis Field: Abura.

Sand	Well Name	RESERVOIR INTERVAL (M) MD	Reservoir Inter (m) SS	Gross Sand Thickness (M)	ρ_{log} /cm^3	Net HC Sand (M)	ϕD (p.u)	ϕN	ϕ = ϕD + ϕN 2(%)	SW (%)	Fluid Contact (m)	RTE (m)	Remark
A2	1	2653.0 - 2693.0	2643.75 – 683.25	40	2.28	7.0	22.4	25.8	24.1	47.0	2657.0	9.75	ODT
	2	2650.0 - 2682.0	2640.5 – 672.5	32	2.35	9.0	16.2	17.8	17.0	25.0	2660.0	9.50	OWC
	3	2670.0 - 2695.0	2659.0 – 684.0	25	-	SHALY	-	-	-	-	-	11.0	SHALY
	4	2640.0 -2663.0	2629.0 – 652.0	23	2.34	WET	16.8	28.6	22.7	100.0	WET	19.2	WATER

Table A3. Results of Petrophysical Analysis. Field: Abura.

Sand	Well Name	Reservoir Interval (m) MD	Reservoir Inter (m) SS	Gross Sand Thickness (m)	ρ_{log} g/cm^3	Net HC Sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD +ϕN 2(%)	SW (%)	Fluid Contact(m)	RTE (m)	Remark
A3	1	2728.0 – 2733.0	2718.25 -2723.25	6	2.33	WET	19.4	29.6	24.5	100.0	-	9.75	WATER
	2	2719.0 – 2724.0	2709.5 -2714.5	5	2.37	5	17.0	29.0	23.0	29.0	2741.0	9.50	OWC
	3	2733.0 – 2742.0	2722.0 -2731.0	9	-	SHALY	-	-	-	-	-	11.0	SHALY
	4	2757.2 – 2769.0	2738.0 – 2747.0	15	2.43	10	12	33	22.5	32.0	2741.0	19.2	OWC

Table A4. Results of Petrophysical Analysis. Field: Abura.

Sand	WELL Name	Reservoir Interval (m) MD	Reservoir Inter (m) SS	Gross Sand Thickness (m)	ρ_{log} g/cm^3	Net HC Sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD +ϕN 2(%)	SW (%)	Fluid Contact (m)	RTE (m)	Remark
A4	1	2832.0 -2854.0	2822.25 -2844.25	22	2.30	7.0	18.9	32.7	25.8	33.0	2824.0	9.75	OWC
	2	2823.0 -2845.0	2813.5 – 2835.5	22	2.42	6.5	12.4	15.6	14.0	28.0	2815.6	9.50	OWC
	3	2840.0 -2870.0	2829.0 – 2859.0	30	2.25	WET	24.2	29.0	26.6	100.0	WET	11.0	WATER
	4	2823.0-2850.0	2803.8 – 2830.8	27	2.48	5.4	24.0	28.2	26.0	28.0	-	19.2	ODT

Table A5. Results of Petrophysical Analysis. Field: Abura.

Sand	Well name	Reservoir Interval (m) MD	Reservoir Inter (M) SS	Gross sand Thickness (m)	ρ_{log} g/cm^3	Net HC sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD / +ϕN2 (%)	SW (%)	Fluid contact (m)	RTE(m)	Remark
A5	1	3042.0 –3093.0	3032.25 – 3085.25	51	2.40	WET	15.2	24.8	20.0	100.0	WET	9.75	WATER
	2	3025.0 –3085.0	3015 – 3075.5	60	2.33	8.2	19.4	32.6	26.0	33.0	3018.0	9.50	ODT
	3	3046.0 – 3070.0	3035.0 – 3059.0	24	2.44	WET	12.7	23.0	17.9	100.0	WET	11.0	WATER
	4	2983.0 –3020.0	2963.8 – 3000.8	37	2.30	5.0	17.0	23.0	200	36.0	3018.0	19.2	ODT

Table A6. Results of Petrophysical Analysis Field: Abura.

Sand	Well name	Reservoir Interval (m) MD	Reservoir Inter (m) SS	Gross sand Thickness (m)	ρ_{log} g/cm^3	Net HC sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD / +ϕN 2(%)	SW s (%)	Fluid contact (m)	RTE (m)	Remark
A6	1	3169.0-3196.0	3159.25 -3186.25	27.0	2.42	WET	13.9	26.5	20.2	100.0	WET	9.75	WATER
	2	3185.0-3199.0	3175.5 – 3189.5	16.0	2.28	7.6	22.4	29.6	26.0	24.5	3208	9.50	OWC
	3	3210.0 –3215.0	3199.0- 3204.0	5.0	2.41	4.0	14.0	22.4	18.2	18.0	3208	11.0	OWC
	4	3195.0 – 3211.0	3177.8 – 3191.8	16.0	2.35	WET	18.0	27.0	18.0	100.0	WET	19.2	WATER

Table A7. Results of Petrophysical Analysis Field: Abura.

Sand	Well Name	Reservoir Interval (m) MD	Reservoir Inter (m) SS	Gross sand thickness (m)	ρ_{log} g/cm^3	Net HC SAND (m)	ϕD (p.u)	ϕN	ϕ = ϕD / +ϕN 2(%)	SW (%)	Fluid Contact (m)	RTE (m)	Remark
A7	1	3268.0– 3302.0	3258.25 – 3292.25	34.0	2.25	WET	24.2	25.8	25.0	100.0	WET	9.75	WATER
	2	3261.0 – 3280.0	3251.5 – 3270.5	19.0	2.30	WET	21.2	22.8	22.0	97.0	WET	9.50	WATER
	3	3250.0 – 3262.0	3239.0 – 3251.0	12.0	2.20	10.0	24.3	21.6	23.0	18.0	3257	11.0	GWC
	4	3238.0- 3249.0	3128.8 – 3229.8	11.0	2.35	WET	18.2	18.4	18.0	100.0	WET	19.2	WATER

Table A8. Petrophysical analysis results: Abura Field

Sand	Well name	Reservoir interval (m) MD	Reservoir Inter (m) SS	Gross sand thickness (m)	ρ_{log} g/cm^3	Net HC Sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD +ϕN 2(%)	SW (%)	Fluid contact (m)	RTE(m)	Remark
A8	1	3307.0 – 3321.0	3297.25 – 3311.25	13.0	2.30	WET	21.2	25.5	23.4	100.0	WET	9.75	WATER
	2	3315.0 – 3330.0	3305.5 – 3320.5	15.0	2.33	WET	19.4	25.0	22.2	97.0	WET	9.50	WATER
	3	3313.0 – 3333.0	3302.0 – 3322.0	20.0	2.30	WET	21.2	23.2	22.2	100.0	WET	11.0	WATER
	4	3310.0 – 3345.0	3290.8 -3325.8	35.0	2.26	WET	23.0	23.0	23.0	100.0	WET	19.2	WATER

Table A9. Petrophysical analysis results: Abura Field

Sand	Well name	Reservoir Interval (m) MD	Reservoir Inter (m) SS	Gross sand Thickness (m)	ρ_{log} g/cm^3	Net HC Sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD +ϕN 2(%)	SW (%)	Fluid contact (m)	RTE (m)	Remark
A9	1	3410.0 – 3425.0	3400.25 – 3515.5	15.0	2.39	WET	15.8	22.5	19.2	100.0	WET	9.25	WATER
	2	3408.0 – 3427.0	3398.5 – 3417.5	19.0	2.25	WET	17.6	28.0	22.8	100.0	WET	9.50	WATER
	3	3420.0 – 3441.0	3409.0 – 3430.0	21.0	2.30	WET	21.0	27.5	27.5	98.0	WET	11.0	WATER
	4	3410.0 – 3435.5	3390.8 – 3416.3	35.5	2.35	SHALY	-	-	-	-	SHALY	19.2	SHALY

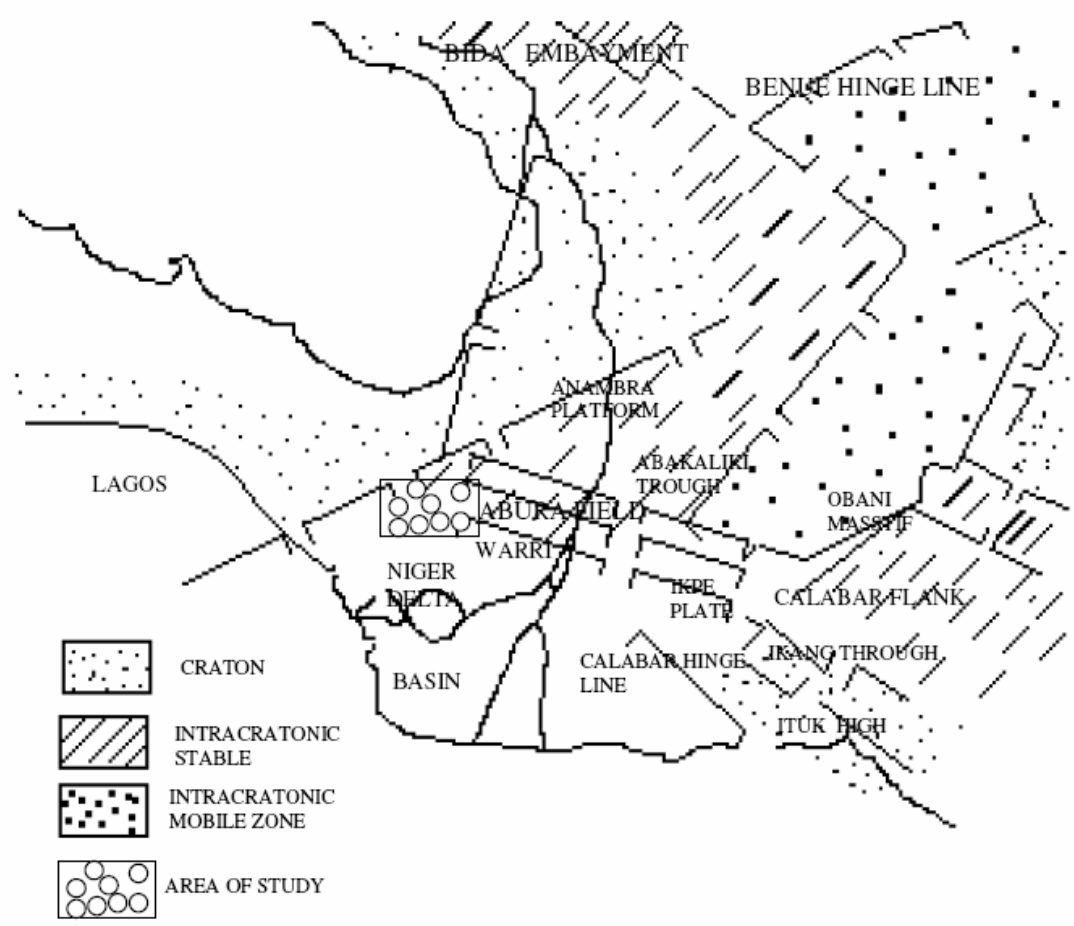

Figure 1. The map of Niger Delta showing Area of study.

$F = 0.62 / \phi^{2.15}$ (for unconsolidated sands)

and

$F = 0.81 / \phi^{2}$ (for consolidated sands)

METHODOLOGY

In this study the data acquired are suite (composite) of borehole logs from four different wells in Abura field. The logs were analysed for hydrocarbon prospect in the study area (Figure 1).

Petrophysical parameters like the lithology, fluid content, porosity, water saturation, hydrocarbon saturation and permeability were derived; from the well log data. For a thorough evaluation of a reservoir and its fluid content sufficient information is usually not obtain from a single log therefore, suite of logs are required for detailed analysis.

Well-by-Well Petrophysical analysis was carried out for the entire identified hydrocarbon intervals in the five fields studied in the Niger delta. Since the reservoir was found to contain less than 15% shale, the Archie (1942), saturation model was employed in the analysis to obtain the hydrocarbon. The Archie model is purely empirical. The density log porosity was evaluated from equation log, while the porosity from neutron was read directly from the logs.

DISCUSSION OF RESULTS

At depth interval 2657m in Abura well 1 the oil extends to the shale zone (ODT).In well 2 of the Abura field, depth intervals 2650-2682m, 2719-2324m, 2823-2845m, 3025-3085m and 3185-3199m have water saturation less than 60%. Precisely, the water saturation is between 16 and 33 percent. Oil - water contact was established at 2660m, 2741m, 2824m, and 3280m. Dept intervals 3579-3582m, 3856-3880m are shaly (Tables A2 - A12). Oil down too was observed at depth interval 3018m in sand A5 (Table A5)

In Abura well 3 , depth intervals 3210-3215m,3250-3262m, 3577-3600m, 3697-3714m, 3882-3887m were found to contain hydrocarbon with water saturation between 18 and 50%. The water saturation values are less than 60% (Water cutoff in the Niger Delta), which implies hydrocarbon saturation. From the depth intervals above, only intervals 3250-3262m and 3697-3714m are gas bearing. The neutron porosity for the interval is less than the density porosity (Tables A7 and A11). At depth

Table A10. Results of Petrophysical analysis Field: Abura

Sand	Well name	Reservoir Interval (m) MD	Reservoir Inter (m) SS	Gross sand thickness (m)	ρ_{log} g/cm^3	Net HC sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD / +ϕN 2(%)	SW (%)	Fluid contact (m)	RTE (m)	Remark
A10	1	3580.0 –3595.0	3570.25 – 3585.25	15.0	-	SHALY	-	-	-	-	SHALY	9.75	SHALY
	2	3579.0 – 3582.0	3569.5 – 3572.5	3.0	-	SHALY	-	-	-	-	SHALY	9.50	SHALY
	3	3577.0 – 3600.0	3566.0 – 3589.0	23.0	2.28	9.0	22.3	23.6	21.0	45.0	3585.0	11.0	OWC
	4	3582.0 – 3597.0	3562.8 – 3577.8	15.0	2.36	WET	17.3	18.0	18.7	100.0	WET	19.2	WATER

Table A11. Results of petrophysical analysis field: Abura

Sand	Well name	Reservoir Interval (m) MD	Reservoir inter (m) SS	Gross sand thickness (m)	ρ_{log} g/cm^3	Net HC Sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD / +ϕN 2(%)	SW (%)	Fluid contact (m)	RTE (m)	Remark
A11	1	3665.0 –3690.0	3655.25 – 3680.25	4.0	2.41	WET	14.5	26.0	20.3	100.0	WET	9.75	WATER
	2	3658.0 – 3680.0	3648.5- 3670.5	10.0	2.28	WET	22.4	28.0	25.2	100.0	WET	9.50	WATER
	3	3697.0 – 3714	3686.0 – 3703.0	17.0	2.14	100	27.6	15.0	22.0	20.0	3708.0	11.0	GWC
	4	3650.0 – 3695.0	3608.0 – 3675.8	45.0	2.42	SHALY	-	-	-	-	SHALY	19.2	SHALY

Table A12. Results of petrophysical analysis Field: Abura

Sand	Well name	Reservoir Interval (m) MD	Reservoir Inter (m) SS	Gross Sand Thickness (m)	ρ_{log} g/cm^3	Net HC sand (m)	ϕD (p.u)	ϕN	ϕ = ϕD / +ϕN2(%)	SW (%)	Fluid contact (m)	RTE (m)	Remark
A12	1	3850.0 – 3873.0	3840.25 – 3863.25	23.0	-	SHALY	-	-	-	-	-	9.75	SHALY
	2	3856.0- 3880.0	3846.5 – 3870.5	24.0	-	SHALY	-	-	-	-	-	9.50	SHALY
	3	3882.0 – 3887.0	3871.0 –3876.0	5.0	2.30	5.0	17.8	18.9	18.5	50.0	3885.0	11.0	OWC
	4	3860.0 – 3885.0	3840.8 – 3865.8	25.0	2.4	SHALY	-	-	-	-	-	19.2	SHALY

intervals 2840-2870m, 3046-3070m, 3120-3140m, 3313-3333m, 3420-3441m, water saturation is 100%. Gas - water contact was established at 3257 and 3708m, why all water was established at 3208, and 3885m. Depth intervals 2670 - 2695m and 2733-2742m are shaly.

In Abura well 4, depth intervals 2757-2769m, 2823-2830m, and 2983 - 3020m, water saturation (Sw) values are less than 60%, precisely between 28 and 36% and since porosity from the neutron log is not less than porosity from the density log, this shows an oil bearing zone (Tables A3-A5).

At dept intervals 2663m, 3195-3211m, 3238-3249, 3310-3345m, 3582-3597m, water saturation is greater than 60% the zone may be water bearing.

The analysis of the GR, resistivity, and porosity logs showed that the overall lithology is an alternating sequence of sands and shale's, which conform to the standard lithological variations in Agbada formation of the Niger Delta basin. Of the three lithostratigraphic unit recognized in the Niger Delta, only the top two were penetrated by the wells studied in Abura field.

The units penetrated are the continental Benin sands, and the paralic Agbada sands and shales. These units and their boundaries were delineated using well log data. It is believe that the Akata shale was not penetrated by any of the wells. All hydrocarbon reservoirs in the Abura field occur within the formation. From the analysis of the data, the bulk of the hydrocarbon is within the depth range of (2510.0 – 3887.0m).

The total porosity in the hydrocarbon bearing zones was found to range from 18.0 to 28.0% and the water saturation ranges fro 16.0 to 54.0%. Good well-to-well lithologic correlation has been established across the field (Table 1).

CONCLUSION

The four wells studied have indicated the presence of hydrocarbon reservoir with varying thickness, lateral extents and fluid contents. All the identified prospective zones occur within the Agbada formation. study.

This article reveals that the bulk of hydrocarbon encountered in the area of study is within a depth range of 2511-3887m using well log data. This is incontradition to the study carried out by Falebita and Babalola, 2003, that the depth of hydrocarbon accumulation in the Niger delta is between 1200-3650m.The present study further reveals that the favourable parameters obtained from the area of study will encourage deeper drilling in the Niger Delta Basin in order to meet the Nigeria objectives of 40 billion reserve base and 4 million barrel of oil per day by the year 2010. Today's technological advancement has made the present time very appropriate for the operating companies to go into deeper drilling (recommended in this study) as an option for sustaining exploration activities in the Niger Delta.

The porosity (Neutron and Density) log responses are better defined as seen in this study, in thick clean sand formations as against thin marginal pay sands. This petrophysical measurements, consequently have proved to be effective too and potential for reserves / production addiction and recommended fro use in the Niger Delta lithological setting. Since log data are highly interpretive and thus liable to subjectivity, it is strongly suggested that convectional cores be taken and thoroughly analysed to confirm all pertinent log derived information.

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