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Evaluation of Petrophysical Properties of a Reservoir in Kolo Creek Field, Niger Delta, Using Well Log Analysis.

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ABSTRACT

The main petrophysical parameters needed for the evaluation of a reservoir are porosity, permeability, hydrocarbon saturation, thickness and area. Other parameters such as the reservoir geometry, formation temperature & pressure and Lithology, can play vital roles in the evaluation, completion and production of the reservoir. In the study area which is within the Kolo Creek field in the Niger Delta, the method adopted for the evaluation utilized gamma ray logs to differentiate potentially porous and permeable reservoir rock (sands, sandstones and siltstones) from non-permeable clays and shales. Also, neutron and density log combination, were used principally to delineate porous formations, determine the porosity as well as differentiate gas and oil zones. Resistivity logs were used to assess water and hydrocarbon saturations. The quantitative analytical data show average porosity values in the three wells (X, Y and Z) as 16.44%, 16.38% and 17.48%, respectively. Also observable results indicate that wells X, and Z have high hydrocarbon saturation values of 70.18%, 81.46 % and 78.38%, respectively and average water saturation values of 38.27%, 18.55% and 21.62%, respectively. The three wells (X, Y, and Z) have good average permeability values of 326.58md, 274.85md and 310.38Md, respectively. Directly deriving from their petrophysical attributes, it may be inferred that the hydrocarbon producibility of the three wells are of commercial value.

(I) INTRODUCTION

The development of geophysical logging tools and techniques in petrophysical interpretation has primarily been focused and directed toward assessing a particular target zone. In petroleum applications, this means determining the amount of oil and gas that is contained in the formation. This is further refined by detailed seismic interpretation to provide a concept of a potential reservoir.

To achieve this goal, physical properties of the rock have to be measured which include porosity, water saturation and permeability, etc. Unfortunately, no tool can give these results. Therefore, tool combinations that will measure porosity and original hydrocarbon in place have been developed for various geologic targets. This is achieved by logging operation with logging tools which are designed to measure formation properties through electrical, nuclear, acoustic, and other means which are lowered on a cable or wireline down the borehole. The cable or the wireline down the borehole provides the conduit for the transmission of electric data between the tool and the surface control where the recording equipment is situated.

This study is carried out to evaluate the reservoir properties of Kolo Creek using the petrophysical parameters such at porosity, fluid saturation, and permeability, etc. A combination of well logs was used to enhance accuracy and better results.

Determining insitu porosity was done by the use of three “porosity” tools, and for a resistivity tools. Those porosity tools that were used normally are the density, resistivity, and neutron porosity tools. We would examine in detail, later on how values from these logs can be converted into porosity units for the formation that is being examined.

A second basic parameter determined for insitu porosity is the saturation of the formation with water and hydrocarbon. As it turns out, what is determined directly from logs is the water saturation. From the knowledge that 100 percent minus the water saturation (i.e. 100% - Sw) gives us the hydrocabon saturation. In other words, we have 20 percent water saturation and 80 percent hydrocarbon saturation.

Using the porosity log plus a resistivity log, water saturation can be calculated through the basic Archie equation, (Archie, 1942). The estimation of volumetric reducibility of hydrocarbon reserves is one of the most important aspects in petroleum exploitation.

Specially, knowledge of reserves is pertinent for decision making on the exploitation and development of a reservoir, evaluation of the result of an exploration programme and financing of the development, among others. The method/approach of estimation adopted depends on the availability of data.

Location and Geology of the study area

The Kolo field is situated in the Niger-Delta area of Nigeria. The Kolo field is one of the northern most fields in the Niger-Delta located within Greater Ughelli Depobelt. The precise locations are concealed because of the proprietary reasons. The tectonic frame work of the Delta suggests that the sediments were deposited in a parallic environment in a close proximity to paleographic basement highs to the north (the Onitsha high) and east (the Abakaliki high). (Doust, H.and Omatsola, E.1982.)

This Paleogeographic position has affected the sediment and possibly the structural setting of the field and has resulted in complex reservoir geometry's with rapid sand variation. The sands can be roughly be subdivided into two types: predominantly shore face or predominantly (tidal) channel. Shore face sand bodies are elongated along the growth faults direction, while channel type sands run north- south perpendicular to the growth faults, and seem to cross the major growth fault. The general structure is that of an elongated rollover anticline bounded to the north and south by two major growth faults. Although the general structure remains same, both the orientation of the axis of the rollover anticline and the position of the crest of the reservoir vary at the different reservoir levels.

Figure 1: Location Map of Study Area

(II) AIMS OF THE TUDY.

The main aim of well log interpretation was the evaluation of the potential producibility of porous and permeable formations encountered by the drill. Here, the computed values of the porosities and fluid saturation could be used for the estimation of total reserves and to determine if the accumulation is commercial. The fluid types are also distinguishable.

(III) METHODOLOGY

ELECTRIC LOGGING PRINCIPLES/APPLICATION

For many scientific and economic aims, laboratory data of high precision and reliability, for both the fluids and the rocks that contain them are necessary. For the petroleum geologist and the drillers such data cannot be acquired quickly enough or cheaply enough to be useful. The operators in the oil fields needed a method by which the fundamental properties of the rocks and their fluid contents could be quickly and reliably determined in the subsurface.

The requirement was achieved by the electric well log. Some of the electric logs and their principles/application that were used in this project work are as follows.

SPONTANEOUS POTENTIAL LOG

The SP curve is a recording versus depth of the difference between the electrical potential of a movable electrode in a borehole and the electrical potential of a fixed surface electrode. It records the electrical potential (voltage) produced by the interaction of formation connate water, conductive drilling fluid and certain ion selective rocks e.g., (shale). It is a recording of naturally occurring physical phenomena in in-situ rocks. The SP log is the single curve on the left side of the electrical log.

Technique: The SP in a well is measured by lowering a single electrode into the uncased hole and immersing a second electrode known as the surface electrode into the mud pot. If the mud pit is so deep, and channel can be immersed along it (i.e., in a small hole on the surface filled with drilling mud). The source of the potential is the difference in electromotive force between the fluid in the drilling mud and the fluid, if any, in the pores of the rock. This potential difference creates an electrochemical cell, which produces a current. The spontaneous potential electrode measures the Potential difference in millivolts (mv) with respect to a reference electrode at infinity.

The SP curve cannot be recorded in holes filled with nonconductive muds because such muds do not provide electrical continuity between the sp electrode and the formation.

APPLICATION AND INTERPRETATION

- Readings of the SP curves are negative to the left, positive to right depending on the relative salinities of the formation of the formation water and of the mud filtrate.
- If the formation water salinity is greater than the mud filtrate salinity, then deflection is to the right.
- If the formation water salinity is less than the mud filtrate salinity, then the deflection is to the right.
- In the normal circumstance in which the drilling mud is fresh than the formation water, high negative readings or “kick” to the left are given by porous rocks especially porous sands.
- Salt water in porous rocks gives higher readings than fresh water, if the mud is fresh and not salty.
- High positive readings towards the right are given by dense limestones, shales and evaporites.
- The SP curve is worthless if the drilling mud is salty.
- Continuous line deflecting towards the right side of the log depicts the shale base line.
- Positive deflections are usually observed in fresh water bearing formations.
- If the salinities of the mud filtrate and formation water are similar, there is no spontaneous potential or current flow and hence no SP deflection opposite a permeable bed.
- The slope of the SP curve at any level is proportional to the intensity of SP or currents in the borehole mud at that level.
- The shape of the SP curve and the amplitude of the deflection opposite a permeable bed depends on

1. Thickness, hi and true resistivity Rt, of the permeable bed.
2. Resistivity, Rxo and diameter d, of the zone contaminated by mud filtrateinvasion.
3. Resistivity, Rs of the adjacent shale formation.
4. Resisitivity, Rm, of the mud and diameter h of the borehole.

- In sum, the SP curve reflects the lithology of the rock, its fluid content,indirectly its porosity.

IMPORTANCE

- To differentiate potentially porous and permeable reservoir rocks (sandstone, limestone, and dolomite) from non permeable clays and shales.
- To delineate the top and bottom of beds i.e. bed boundaries and permit bed correlation.
- Gives a qualitative indication of bed saliness.
- Permits the determination of formation water resistivity, Rw. termination of depositional environment.

(IV) RESULTS AND INTERPRETATION

EVALUATION/QUANTITATIVE INTERPRETATION OF PETROPHYSICAL PROPERTIES OF A RESERVOIR IN KOLO CREEK FIELD.

The major objectives were to compute the petrophysical parameters used in evaluating the reservoir, and they include y Resistivity of formation water, Rw

True resistivity, Rt

Porosity, ф

Formation factor, f

Water saturation, Sw

Hydrocarbon saturation, Sh.

Permeability, K.

In defining the lithologies, the gamma ray log was used to delineate permeable sandstone strata, which is a possible reservoir from impermeable horizon which may be shale. This is because the gamma ray is shale indicator, owning to its deflections. The resistivity log was used to access hydrocarbon zones or targets for example if we have a very high resistivity, it implies that something of very low conductivity has contributed to that, which may be oil or gas, although according to Schlumberger 1989, resistivity high than 1000 0hm-meter are common in impervious very low porosity e.g. evaporite formations.

More light was put onto the former generation using resistivity by observing the little crossover and stacking on top of each of the neutron and density logs on those reservoir levels.

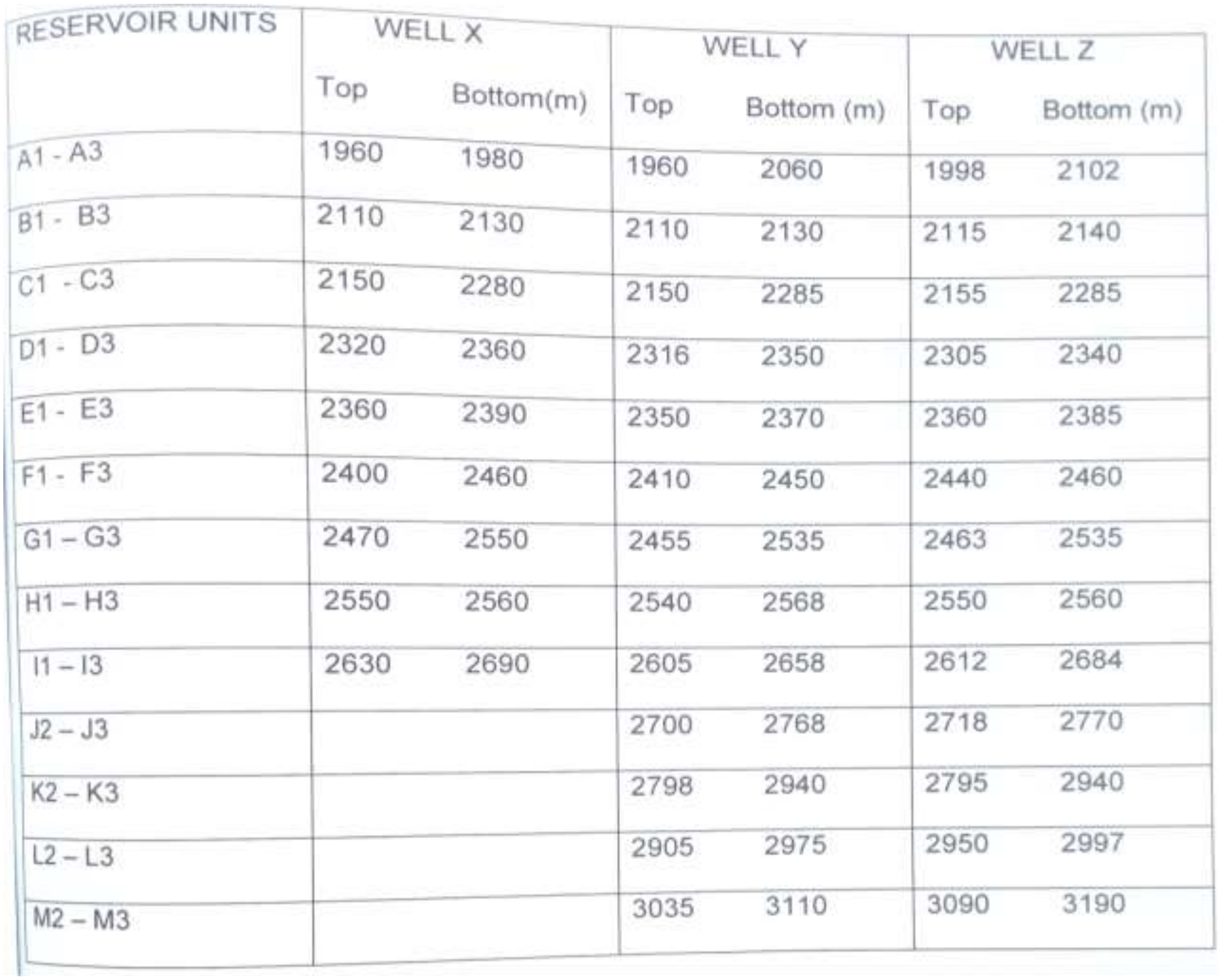
However, using all the log applications outlined in the previous chapter, the data were deduced from the convectional log suites of 3 different wells in Kolo Creek field.

The readings were taking across the reservoir units of the 3 wells, at various depths based on the correlation using shale resistivity as a marker to ascertain the lateral continuity of reservoirs.

A total of 35 reservoir units were achieved in all the 3 wells. Well X, 9 reservoir units were evaluated. Well Y, 13 reservoir units were evaluated and finally well Z, 13 reservoir units were also evaluated (Table 1).

Fig.(3, 4 and 5) show a plot of Porosity, Permeability and Hydrocarbon saturation versus depth across wells X,Y and Z in Kolo Creek field.

Table 1: Reservoir Units of the Well of Kolo Field



RESERVOIR UNITS	WELL X		WELL Y		WELL Z	
	Top	Bottom(m)	Top	Bottom (m)	Top	Bottom (m)
A1 - A3	1960	1980	1960	2060	1998	2102
B1 - B3	2110	2130	2110	2130	2115	2140
C1 - C3	2150	2280	2150	2285	2155	2285
D1 - D3	2320	2360	2316	2350	2305	2340
E1 - E3	2360	2390	2350	2370	2360	2385
F1 - F3	2400	2460	2410	2450	2440	2460
G1 – G3	2470	2550	2455	2535	2463	2535
H1 – H3	2550	2560	2540	2568	2550	2560
I1 – I3	2630	2690	2605	2658	2612	2684
J2 – J3			2700	2768	2718	2770
K2 – K3			2798	2940	2795	2940
L2 – L3			2905	2975	2950	2997
M2 – M3			3035	3110	3090	3190

In computing the petrophysical parameters such as the porosity, water saturation and

Permeability which were the major objectives of this project research work, the equations 1 to 20 outlined were applied.

CALCULATION

Tables 1, 2, and 3 Show the Formation Evaluation of wells X, Y and Z, respectively in Kolo Creek field.

POROSITY ϕ

The porosity of the various reservoir units in wells X, Y and Z was achieved by the formula

$$\phi = \frac{Pma-Pb}{Pma-Pf}$$

Where pma =Density of matrix

= 2.65g/cm3 for sandstone

Pf = Density of fluid = 1.0g/cm3

pb = Bulk density of formation read from the Density log.

WATER SATURATION

The water saturation of wells X, Y and Z was achieved by using Archie's equation

$$Sw^n = \frac{FR_w}{Rt} \text{ ....Eqn.13}$$

Where n is saturation exponent.

= 1.8 for Niger-Delta correlation

Rt = True resistivity of formation read from resistivity log.

F = formation factor

$$F = \frac{1}{\Phi^2} \text{ Eqn.14}$$

Rw is resistivity of formation water in the reservoir formation. The average calculated value for each of the 3 different wells are 0.06 ohm-m, 0.07 ohm-m and 0.06 ohm-m respectively across clean water bearing for wells X, Y and Z in the oil field.

R_W = R_0Eqn.15

F

Ro is the resistivity of formation at 100% water saturation.

Therefore Hydrocarbon saturation

Shc = 1 — Sw —-Eqn.16

Where Shc = hydrocarbon saturation

Sw = water saturation.

PERMEABILITY

The permeability of wells X, Y and Z was achieved using Morris and Biggs equation.

Timur Equation

Kmd = $O.136\phi^{4.4}$ -Eqn.17

$Swirr^3$

Morris and Biggs

Kmd = $C\o^3$

$Swirr^3$

Where C is a constant as follows

Gas: 80

Oil: 250

K= $\o^3$*250

Swirr

Where 0 = Porosity

Swirr = Irreducible water Saturation.

But $Swirr = \sqrt{\frac{F}{2000}}$ Eqn. 20

F= Formation Factor

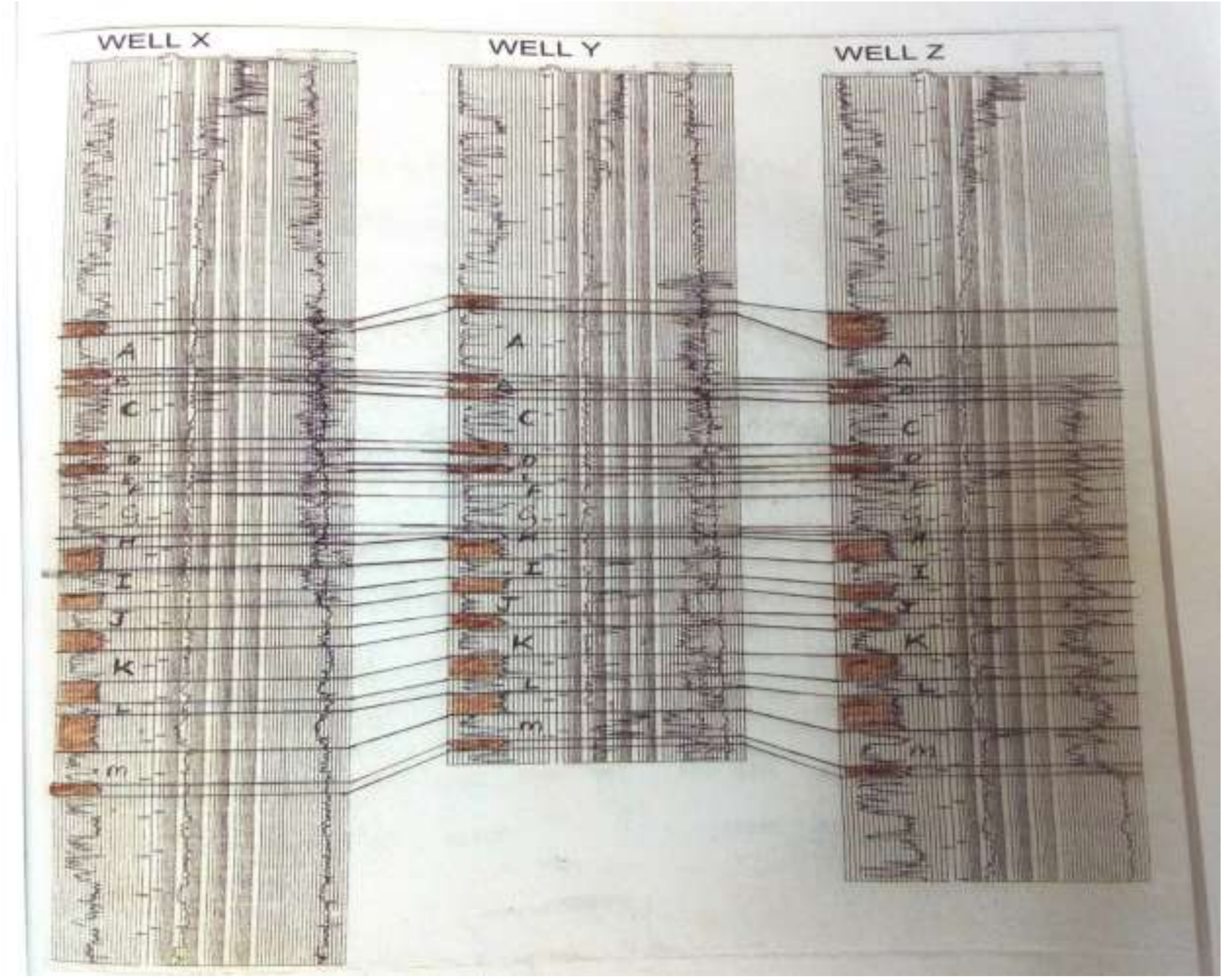
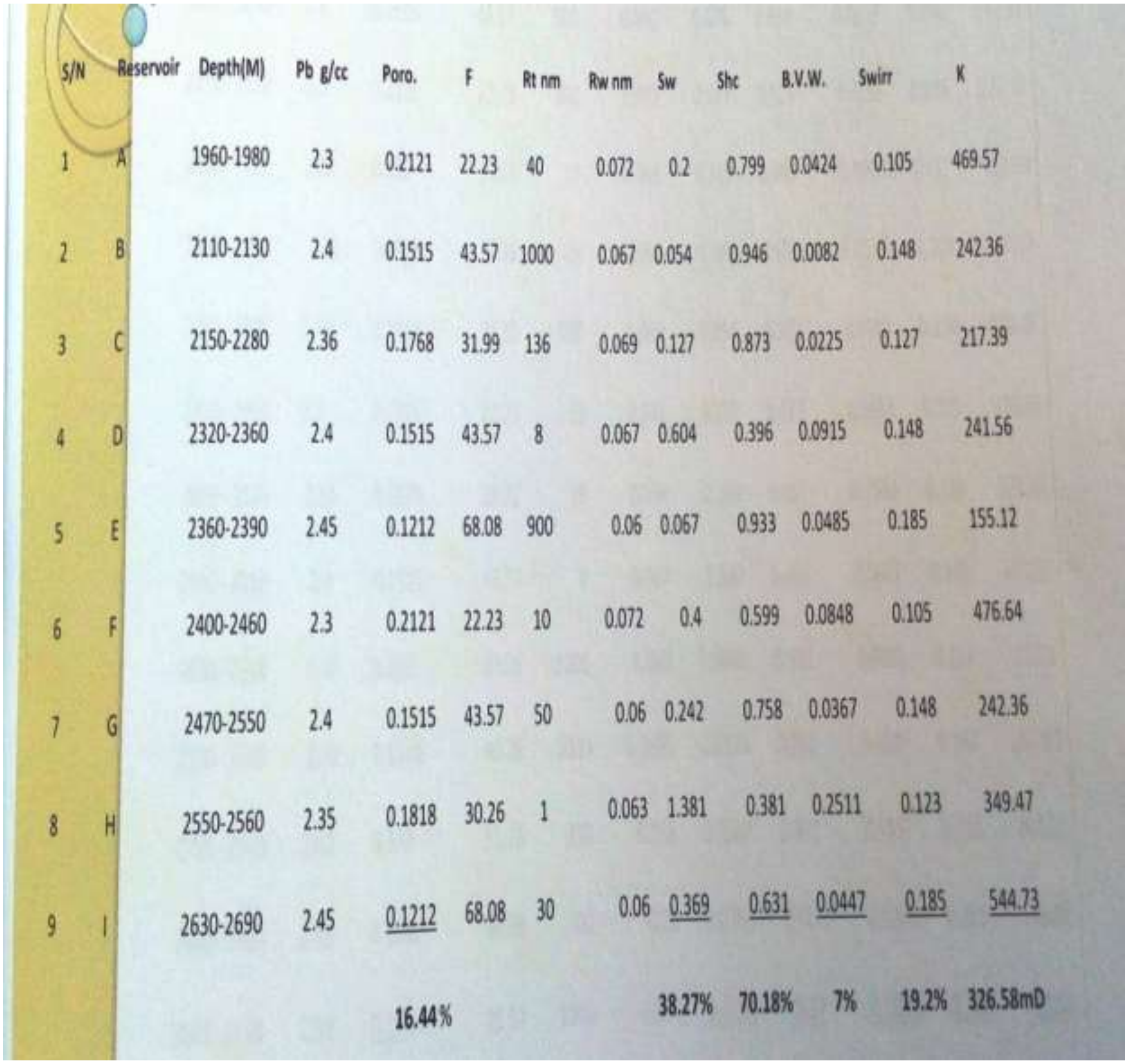


Figure 2: Log Suite of Well X,Y and Z showing Correlation

Table 2: Formation Evaluation of Well X



S/N	Reservoir	Depth(M)	Pb g/cc	Poro.	F	Rt nm	Rw nm	Sw	Shc	B.V.W.	Swirr	K
1	A	1960-1980	2.3	0.2121	22.23	40	0.072	0.2	0.799	0.0424	0.105	469.57
2	B	2110-2130	2.4	0.1515	43.57	1000	0.067	0.054	0.946	0.0082	0.148	242.36
3	C	2150-2280	2.36	0.1768	31.99	136	0.069	0.127	0.873	0.0225	0.127	217.39
4	D	2320-2360	2.4	0.1515	43.57	8	0.067	0.604	0.396	0.0915	0.148	241.56
5	E	2360-2390	2.45	0.1212	68.08	900	0.06	0.067	0.933	0.0485	0.185	155.12
6	F	2400-2460	2.3	0.2121	22.23	10	0.072	0.4	0.599	0.0848	0.105	476.64
7	G	2470-2550	2.4	0.1515	43.57	50	0.06	0.242	0.758	0.0367	0.148	242.36
8	H	2550-2560	2.35	0.1818	30.26	1	0.063	1.381	0.381	0.2511	0.123	349.47
9	I	2630-2690	2.45	0.1212	68.08	30	0.06	0.369	0.631	0.0447	0.185	544.73
				16.44%				38.27%	70.18%	7%	19.2%	326.58mD

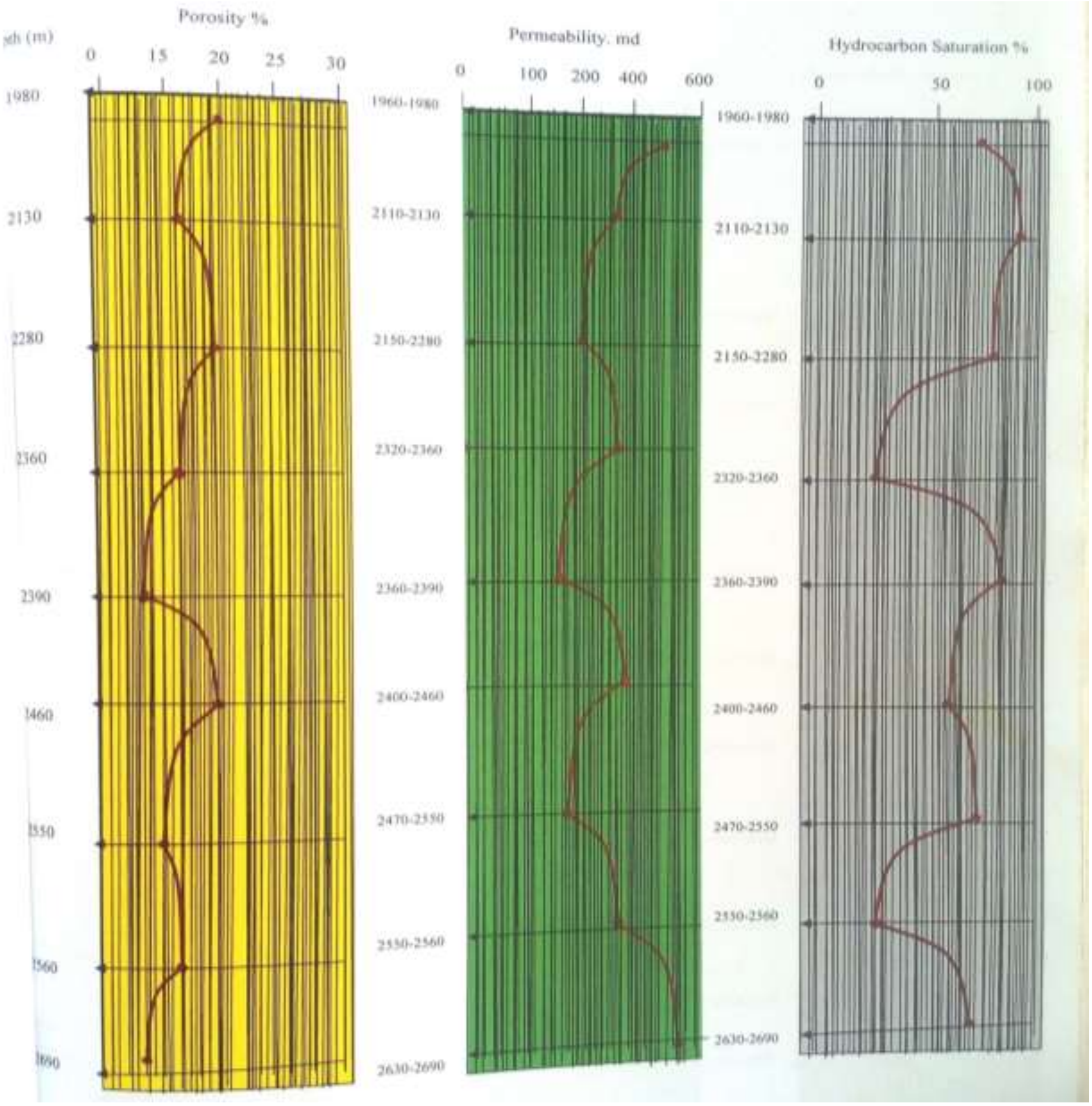


Fig 3: Plot of Porosity, Permeability and Hydrocarbon Saturation versus depth, Well X

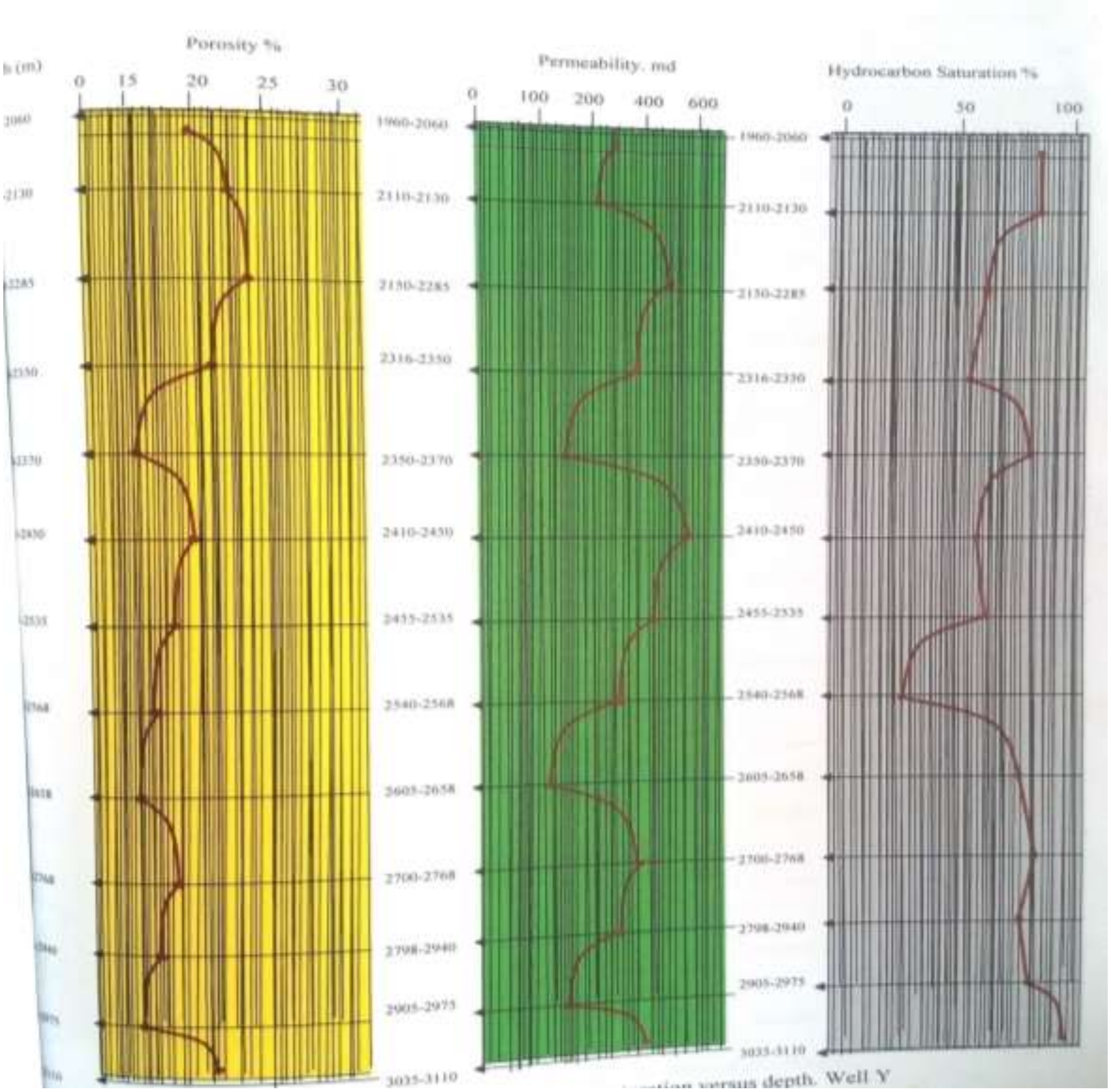


Fig 4: Plot of Porosity, Permeability and Hydrocarbon Saturation versus depth, Well Y.

(V) DISCUSSIONS

Porosity and permeability are greatly influenced by some diagenetic effects as one goes down the well. For instance, porosity tends to decrease with depth due to compaction. The effect of compaction on the porosity of sandstone formation is limited because of its elastic nature; whereas in shale formation, the porosity decreases greatly with compaction. This is the main reason why the primary migration in source rocks (sandstone, dolomite and limestone) is affected by cementation, presence of clay minerals and facies changes, which in turn decrease the porosity. Porosity is dependent on grain shape, grain packing, grain sorting, overburden and compaction, cementation and clay content.

In the studied area of Kolo Creek field, the average porosity values in the three wells (X Y and Z) are 16.44%, 16.38% and 17.48%, respectively. Also the average permeability values are 326.58md, 274.85md and

There exists a natural efficient water drive in many of the Kolo reservoirs which was attributable to the high sand/shale ratio.

The relationship between porosity and permeability indicates that the size of the connecting pore-throats controls the effectiveness of porosity toward permeability. At higher porosity values, pore-throat size is the dominant control on permeability. Porosity has a greater impact on permeability as the hydraulic radius and the porosity of the rock decrease.

Therefore, the inter-relationship of reservoir porosity, permeability, thickness and lateral distribution determines reservoir system

For a better and more accurate porosity evaluation using wireline petrophysical logs, more than one porosity tool is recommended for the computation of average porosity values. Also, well log data should not be the only reliable information to ascertain porosity values rather other geological

310.38md, respectively. These figures are based on the quantitative analyses of the Prospective reservoirs. The prospective reservoirs are mainly consolidated sands which tend to exhibit heterogeneity. This heterogeneity may be as a result of facies variation and the nature of the environment of deposition. Though the porosity and permeability vary within the formation.

quality.

Although this research is preliminary, the ability of hydrocarbons to be produced seems to be linked to a combination of pore-throat size and fluid properties. When comparing rocks with the same permeability but different porosities, rocks with lower porosity are better reservoirs because the pore- throats are larger, and therefore will have higher relative permeability to hydrocarbons. The more viscous the fluid, the larger the pore-throats must be to recover the hydrocarbons. Based on the results of these petrophysical properties, the following I recommendations are made:

approach such as mud logging and core analysis should be utilized to compliment well log data.

The volumetric producible hydrocarbon reserves should be computed to know whether the zones will be economically viable and of commercial target.

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