# Utilizing Mud-logging as a Tool for Exploration: A Case Study, Kushi-20 Oil Well in Niger Delta Region, Nigeria.

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## ABSTRACT

Mud-logging as exploration tool involves the acquisition of samples from the shale shaker for quantitative and qualitative analysis to detect hydrocarbon presence. At the Kushi–20 well, mud-logging was done using water-base and oil-base mud to give lithological break down and hydrocarbon shows of the well. Conclusively, mud-logging as a relevant tool in the oil and gas well drilling was stressed and was recommended for use in drilling exploratory, development and appraisal wells since it provides relevant information about the hydrocarbon content of the well and the sub-surface formation.

(Keywords: flame, shale, hydrocarbon, petroleum, exploration)

## INTRODUCTION

Mud-logging is a continuous analysis of the cuttings and drilling fluid to ascertain oil and gas presence or absence coming from the formation penetrated by the drilling bit and also formation depth drilled or the oil and gas bearing formation. The practice of mud-logging tries to record, identify, and evaluate the lithology, drilling parameter, and hydrocarbon shows. The data obtained by the mud logger is presented in the form of various logs as driller's log, or the cuttings log or show evaluation log. The mud logger takes this data, correlates it with data from other wells, and ascertains whether commercial quantities of hydrocarbons may be produced by the well.

The mud logger, in addition, monitors the well bore for stability to prevent blowouts or kicks while making sure that data is forwarded to the right people at the right time.

Four important areas of mud logging such as penetration rate and lag, gas detection, formation evaluation, sample collection, and show evaluation must be understood for us to comprehend all of the information available (Aahestand, 1996).

## THEORY

The practice of mud-logging tries to record, identify, and evaluate the litho-logy, drilling parameter and hydrocarbon shows. The data obtained by the mud logger is presented in the form of various logs as driller's log, or the cuttings log or show evaluation log.. It is the most commonly used indicator of the porosity of a formation. A source of high-velocity gamma radiation is pressed against the side of the borehole and the rays are emitted directly into the formation. The log often measures the amount of back scattering of the gamma radiation through collisions with the electrodes in the rock.

The rebuilding is, thus related to the true electron density, which in turn is inversely related to the porosity.

$$\varphi = \frac{\rho_m - \rho_b}{\rho_m - \rho_f} \quad \textbf{(1)}$$

Where
$\varphi$ = Porosity,
$\rho_m$ = apparent matrix,
$\rho_b$ = bulk density
$\rho_f$ = mud filtrate density in g/cm$^3$.

Archie (1950), defined petrophysics as the physics of individual rocks in relations to their petrology, and this offers a viable tool in oil exploration. Some of the essential petrophysical parameters needed to evaluate a reservoir include porosity, lithology, and reservoir thickness, water saturation, index of oil morability, hydrocarbon saturation bulk oil volume, etc. (Schlumberger,1974)

Porosity is the percentage of voids in a given volume of rock. It is the pore volume per unit volume of formation. It is the most important attribute of a reservoir rock because it determines the amount of fluid it can hold. Id the rock type and its matrix density are known, the porosity can be calculated from the bulk density as:

$$\varphi = \frac{\rho_{matrix - \rho_{bulk}}}{\rho_{matrix - \rho_{fluid}}} \qquad \textbf{(2)}$$

For the purpose of this study, porosity will be determined as an arithmetic average of the density porosity (φ B) and the neutron porosity (φ N).

$$\varphi B = \frac{\rho_{ma - \rho_b}}{\rho_{ma} - \rho_f} \qquad \textbf{(3)}$$

Where

$\rho_{ma}$ =matrix density

$\rho_f$ = fluid

(Rene Langer, 1991) gave the following values

$\rho_{ma}$ = 2.65g/cm$^3$ for sand stones

$\rho_{ma}$ = 2.71g/cm$^3$ for limestone

$\rho_{ma}$ = 2.87g/cm$^3$ for dolomite

Archie (1942), proposed the formula: a/ $\varphi^m$

Where,
F=formation factor
M=Cementation factor
a = Constant
φ =Porosity

Values of a and n are constant for different lithologies and in the case of Niger Delta, they are generally taken as 0.62 and 2.15, respectively (Bariod, 1995).

Water saturation is the percentage of pore volume in a rock, which is occupied by the formation waters and is given as:

$$S_w = \frac{\left(\frac{a}{\varphi^m} \cdot \frac{R_W}{R_t}\right)^{\frac{1}{2}}}{\sqrt{\frac{FW}{R_t}}} \qquad \textbf{(4)}$$

Where,
$S_w$ =water saturation
N= saturation
Fw $=R_o$ when the formation is 100% ater saturated
$Sw^n = R_o/R_t$

$$S_w = \sqrt{\frac{R_o}{R_t}} = \sqrt{\frac{Fw}{R_t}} \qquad \textbf{(5)}$$

The flushed zone water saturated is the amount od water in the zone affected by mud invasion. Schlumberger (1974) derivd the expression for Sxo as:

$$S_{xo} = S_w^{\ 1/5} \qquad \textbf{(6)}$$

Where

$$S_w = \frac{\left(\frac{R_{xo}}{R_t}\right)^{\frac{5}{8}}}{\frac{R_{mt}}{R_w}} = \sqrt{\frac{Fw}{R_t}}$$

Hydrocarbon saturation is the fraction of the pore volume filled with hydrocarbons. It is estimated between water saturation and gas unity. The oil gas (hydrocarbon saturation) can be expressed as:

$$S_h = 1 - S_w \qquad \textbf{(7)}$$

If the water saturation of a reservoir is 100%, it implies hydrocarbon absent.

The residual hydrocarbon saturation ($S_{hr}$) is the amount of hydrocarbon left in the flushed zone after the water saturation has been determined. Mathematically,

$$S_{hr} = 1 – S_{xo} \qquad \textbf{(8)}$$

Where,
$S_{xo}$ = water saturation of the flushed zone index of oil movability is defined as the ratio of water saturation to the flushed zone water saturation ($S_{xo}$).

$$1.0M - \frac{S_w}{S_{xo}} \quad \textbf{(9)}$$

Conventionally, 1.0.M is 1 or approximately so, it implies that no hydrocarbon have been flushed by the invasion where as movable hydrocarbon are indicated when 1.0.M < 0.7.

When 1.0.M > 0.7, it indicates immovable hydrocarbon.( Bariod, 1989).

The bulk volume oil (B.V.O) is the percentage of the expressed mathematically as:

B.V.O = ($S_{xo}$-$S_w$) φ

If B.V.O = 1 or within its range, it implies that the volume of the reservoir with immovable hydrocarbon is very minimal.

Therefore, the resistively of the formation water (Rw) for Koko well two was determined, using the formula below:

$$SP = k\log\frac{R_{mf}}{R_w} \quad \textbf{(10)}$$

$$SP = -k\log\frac{R_{mf}}{Sp} \quad \textbf{(11)}$$

Where,
Sp = voltage difference between shale and sand stone in millivolt.
K = a constant, for Nacl solutions, K = 71 at $25^oC$ or ($77^oF$).
$R_{mf}$ = resistively of mud filtrate in $R_{m.}$
$R_w$ = resistively of formation water in $R_{m.}$

## STRATIGRAPHY OF THE STUDIED AREA

The Niger Delta occur at the southern end of Nigeria bordering the Atlantic Ocean and extends from about longitude 3o.9 E and latitude $4^{o.}$30' – $5^o$.20'N. The proto-delta developed in the northern part of the basin during the capanian transgression and ended with the poleocene transgression.

It has been suggested that the formation of the modern delta basin which enhanced and controlled the development of the present day Niger delta, developed by rift faulting during the Precambrian. Sedimentological and funal data suggest that the modern Niger delta has a configuration similar to that of the past.(Molua and Ujuanbi,2006)

## METHODOLOGY / MATERIALS

The project was carried out at Kushi-20 well in Ekere Local Government Area of Bayelsa State, Nigeria. A mud-logging unit is a skid mounted caravan containing both acquisition / application computers and instruments for the purpose of well surveillance while drilling for oil and gas.

Mud-logging unit is a small laboratory mounted on a drilling rig as described by the petroleum engineer. A typical mud-logging unit can be grouped into three sections:

i) The sensors
ii) The computers and equipment section
iii) The geological section.

## Results And Analysis

The main analysis carried out by the mud-logging engineers in Kushi – 20 includes, the lithological and gas analysis. In the lithological analysis, the location was studied and properly scrutinized for their shale sand content together with accessory minerals. Lagged samples were taken and examined using the following procedures:

- A portion of the sample collected was put in two wet bags.
- The sample left was washed with mesh sieve of 120mm at the bottom and 80mm on top, oil base mud drill cuttings washed with special liquid detergent while water base mud drill cuttings were washed with fresh water.
- Part of the washed sample was dried in an oven with regulated temperature, 60 $\pm$ $5^0$ c. The dried samples were stored in labeled envelops.
- While the remaining portion was use for various lithological tests. The investigated properties including the grain size, texture, porosity, sorting etc. for sand, and hardness, color, density, shape and fractures for shales.

The very soft clayed shale encountered in the location was studied and when exposed to water, the sticky shales tend to swell (see Figure 1)

In gas analysis, the detector and chromatography were used. The detectors employed were the flame ionizing detector (FID) and thermal catalytic combustion (TCC). The flame ionizing detector is usually interconnected with total hydrocarbon analyzer (THA) for better analysis.

The total hydrocarbon analyzer records the total units of drill gas and these total units might include the following components: Methane ($C_1$), Ethane ($C_2$), Propane ($C_3$), Normal butane ($NC_4$) and Pentane ($C_5$). The gas analysis for Kushi – 20 is as shown in Table 1.

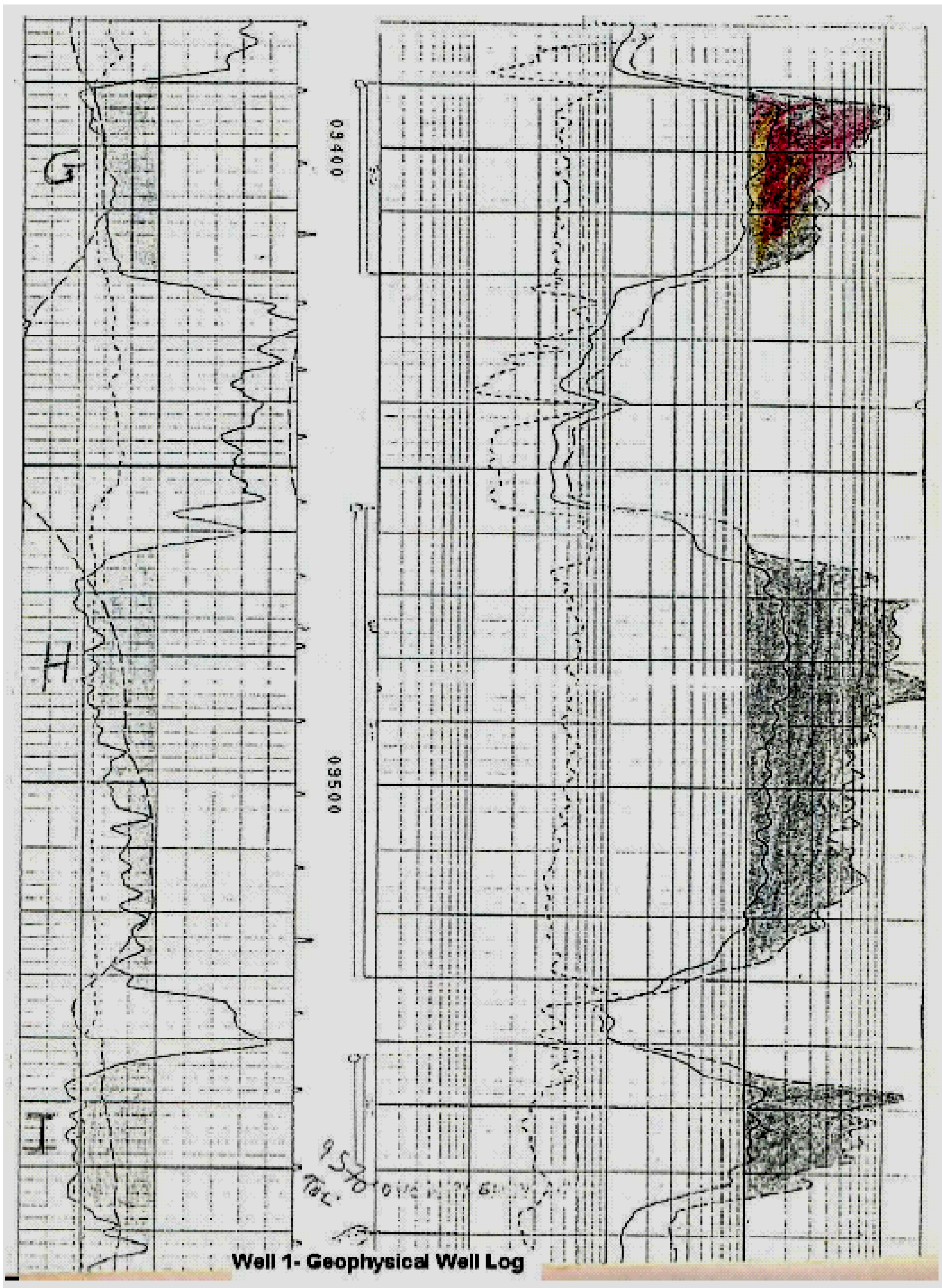


**Figure 1:** Geophysical well log (source SPDC, 1994).

**Table 1:** Comparative Gas Analysis.

| DEPTH | GAS READING (UNIT) | $C_1$ (PPM) | $C_2$ (PPM) |
|---|---|---|---|
| 7750 | 9 | 962 | - |
| 8172 | 11 | 1550 | - |
| 8294 | 165 | 24100 | 6561 |
| 8876 | 512 | 72400 | 20081 |
| 9180 | 919 | 140455 | 39474 |
| 9636 | 340 | 51529 | 14239 |

Comparative gas analysis of locations maximum units of gas recorded in kushi – 20 was 1941 units.

## CONCLUSION

Mud-logging is of great importance in exploratory well drilling. It involves the collection of samples (cuttings) from the shale shaker and a quantitative and qualitative analysis of the sample to confirm hydrocarbon presence and gives the desired information for a prospective reservoir.

Consequent upon the comparative study on the two type of mud used for Kushi – 20 well. It was discovered that:

- Fewer days was spent on drilling, reaming and tacking troublesome formation with the oil base mud used.
- Less number of bits was used will oil base mud in the well.
- Less twist spot was encountered with the oil base mud.
- Cost is less when drilling with oil base mud compared to water base mud but in times of serves loss, spillage while using oil base mud, cost will be very high and longer days will be spent.

To this end, the tremendous role of mud logging in the oil and gas industry cannot be over emphasized in that without it, completion of a dry well would result. Thus all the money, effort and time spent would have amounted to complete waste if mud-logging as an exploration tool were not available.

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