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Reservoir Characterization of "G900" Sandstones Using Wireline Logs and Cores in Development Planning of Gabo Field, Onshore Niger Delta.

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Abstract: *Wireline logs and cores are analysed to evaluate the quality of reservoir "G900" of Gabo field as insight for reservoir production optimization planning. "G900" have very good intergranular porosity and excellent permeability with the main reservoir fluid content as oil and water. "G900" sands are cleaner towards the North indicating relatively higher play potential. This clay rich subarkosic to arkosic sandstones is rich in quartz and albite with grain size that is fine to coarse, dominantly poorly sorted, platykurtic to mesokurtic with symmetrical to fine skewness.. It is a stacked interval of near shore deposits within deltaic sequences that is rich in ripples and cross stratifications. Effective reservoir development plan of "G900" is achieved by combining this result with seismic, well test, production data and other geological information to reduce uncertainties, reveal "G900" lateral extent, compartmentalization, complexities, and fluid quantity for improved production forecast.*
Key Words: *Mineralogy, Reservoir, Porosity, Permeability, Water Saturation*

I. Introduction

The reservoir is a key element within a petroleum system. Morse (1994) and North (1985) definition of a reservoir is integrated to define a reservoir as a storage space within a trap that can accommodate, transmit and produce significant volume of fluids. The basic properties of interest in a reservoir are porosity and permeability. Textural parameters such as grain size, sphericity, roundness, sorting, packing, percentage of matrix and cement influence the porosity and permeability of detrital rocks (Serra, 1985).

Reservoir characterization is a process for quantitatively assigning reservoir properties, recognizing geological information and uncertainties in spatial variability (Lake and Carroll, 1986). Reservoir characterization is essential for planning appropriately sealed reservoir management plan (Fowler et al., 1999). The quality of sandstone reservoirs is a function of source area, the depositional process and the paleo-environment of deposition.The sources of sediments within the Niger Delta are from the uplifted hinterlands which is crystalline basement complex. The Niger Delta displays concentric arrangement of terrestrial and transitional depositional environments that can be broadly categorized into continental deltaic top facies (Benin Formation), paralic facies (Agbada Formation) and prodeltaic facies (Akata Formation) based on studies by Avbovbo (1978), Doust and Omatsola (1990). Each of this facies is characterised by varieties of individual depositional facies. The hydrocarbon reservoir zone is found in the Agbada Formation and its porosities are of excellent quality between 28% and 32% while the permeability's are in Darcie's (Schlumberger, 1985).

The objective of this study is to evaluate the quality of reservoir "G900" in Gabo Field using well logs and core information which encompassed data from sidewall core description, grain size analyses and mineral composition. The results of this study will serve as a guide in developing preliminary plan for this "G900" production optimisation and management.

Study Area And Regional Geologic Setting

Gabo field is located onshore Niger Delta which is situated between latitude 3^0N and 6^0N and longitude 5^0E and 8^0E. The Niger delta regional geologic setting is shown in figure 1.

II. Methodology

- Evaluation of petrophysical parameters such as porosity (φ), water saturation (S_w), hydrocarbon saturation (S_h), permeability (k)and volume of shale (V_{sh})from well logs using Asquith and Gibson (1982).Porosity is calculated from density log valuesusing equation (1).

$$\varphi_{\mathrm{DEN}} = \left(\frac{\rho_{ma}-\rho_b}{\rho_{ma}-\rho_f}\right) (1)$$

Where $\rho_{ma}$is density of formation matrix, ρ_f is density of drilling fluids and ρ_b is bulk density measure from the density log.

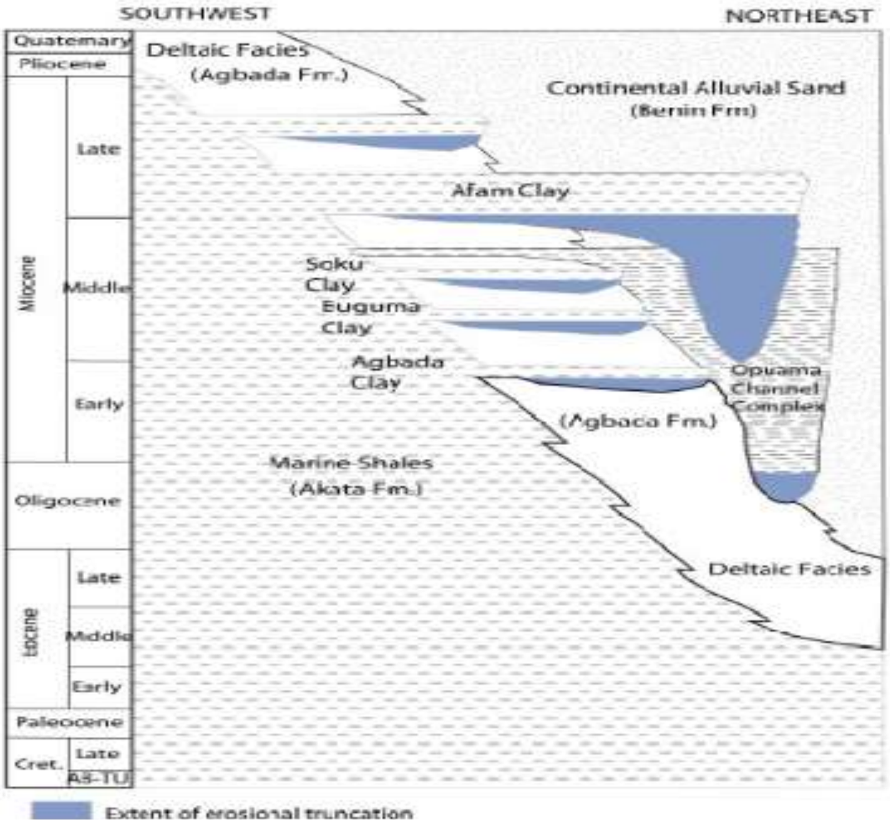


Figure 1: Stratigraphic Column Showing the Three Formations of the Niger Delta (Doust and Omatsola, 1990).

Water saturation is computed using equation (2)

$$S_w = \sqrt{\frac{0.62 \times R_w}{\varphi 2.15 \times R_t}} (2)$$

Where R_w is resistivity of formation water and $R_t$is true resistivity of the formation.

The relationship between hydrocarbons to water saturation is shown in equation (3).

$$S_h = 1 - S_w (3)$$

Permeability (k) within an oil zone is

$$k = \left[\frac{250 \times \varphi^3}{S_{wirr}}\right]^2 (4)$$

In a gas zones, permeability is calculated using equation (5).

$$k = \left[\frac{79 \times \varphi^3}{S_{wirr}}\right]^2 (5)$$

Where S_{wirr} is irreducible water saturation.

The volume of shale (V_{sh}) is calculated from gamma-ray log values by:

$$V_{sh} = 0.083 \times \left[2^{(\mathbf{3.7xI_{GR}})} - \mathbf{1}\right] (6)$$

Gamma-ray index (I_{GR}) is computed by:

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} (7)$$

- Grain size analysis to definesediment nomenclature and determine the degree of uniformity, skewness and kurtosis of sediments within the reservoirs using Folk (2003).The uniformity of sorting of sediments is calculated using inclusive graphic standard deviation (σ_1) given by:

$$\sigma_1 = \frac{\phi_{85}-\phi_{16}}{4} + \frac{\phi_{95}-\phi_5}{6.6} \quad (8)$$

This formula includes 90% of the distribution and its best for overall measure of sorting (Folks, 2003).

The measure of skewness is determined using inclusive graphic skewness (SK_1).

$$SK_1 = \frac{\phi 16+\phi 84-2\phi 50}{2(\phi 84-\phi 16)} + \frac{\phi 5+\phi 95-2\phi 50}{2(\phi 95-\phi 5)} \quad (9)$$

The SK_1 value obtained is recorded with either a positive (+) or negative (-) sign. Analysis of SK_1 is made using Folks (2003).

Kurtosis (K_G) is measured using:

$$K_G = \frac{\phi 95-\phi 5}{2.44(\phi 75-\phi 25)} \quad (10)$$

K_G is interpreted using Folks (2003).

- Reservoir sands classification by mineral composition using Folks (2003) QFR_F Plot.

III. Results And Discussions

Petrophysics

Reservoir "G900" for each well is evaluated independently and results are presented in Table 1. Generally, porosity of "G900" is very goodsince it is greater than 20% based on North (1985) porosity classification and volume of shale infers sand dominance.

Table 1: Average petrophysical values of reservoir "G900" across wells.

Petrophysical Parameter	**RESERVOIR "G900" ACROSS WELLS IN GABO FIELD**				
	GABO 20	**GABO 13**	**GABO 12**	**GABO 11**	**GABO 10**
Depth Interval (m)	2515 – 2610	2465 – 2560	2460 – 2555	2465 – 2560	2435 – 2530
NPHI (%)	21.5	20.5	22.9	36.2	22
V_{sh}(%)	3.5	3.2	5.1	7	2.6
φ_{DEN}(%)	30.5	29.2	29.5	25.3	32
S_w(%)	33.6	40.5	45.2	100	19.6
k (darcies)	5492	613	2702	Not Applicable	4850
Gross thickness G (m)	95	95	95	95	95
Net thickness N (m)	7	55	40	Negligible	84
N/G (%)	7.4	58	42	Negligible	88.4
OWC (m)	2522	2523	2526	Not Applicable	2523

The reservoir fluid content is oil and water dominantly, with little or very negligible gas. The oil water contact in the study area is found within 2522m and 2526m. The reservoir net to gross ratio (N/G) varies though with excellent permeability.

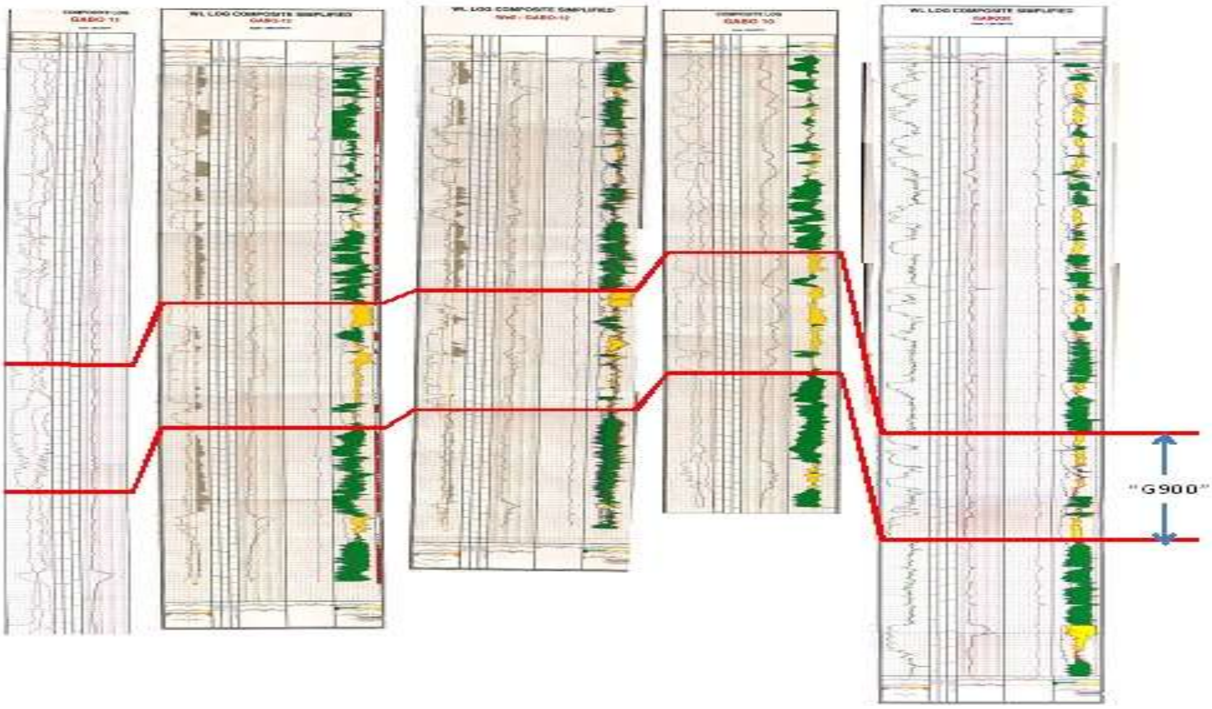


Figure 2: Reservoir "G900" wireline log correlation.

"G900" percentage volume of shale indicates that the direction of fining is towards the South and the potential direction of play favours drilling towards the North.

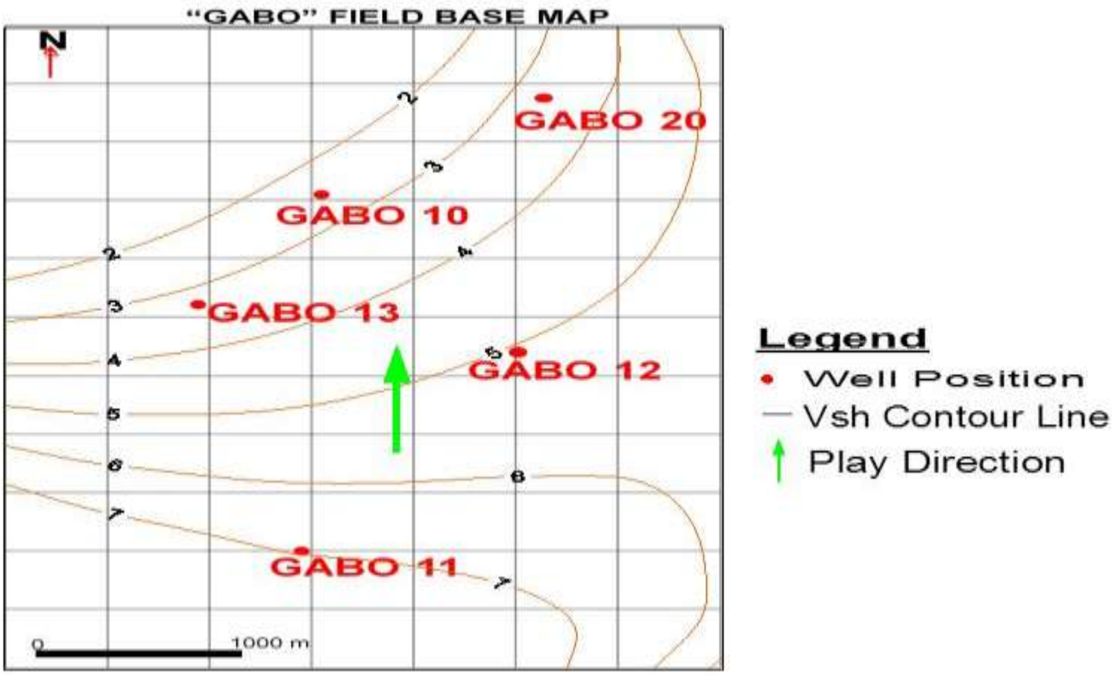


Figure 3: "Gabo" Field base map of study area showing well positions and percentage volume of shale contours for reservoir "G900" showing potential direction of Play represented by green arrow.

Mineralogy

Reservoirs "G900" shows varying composition in minerals as shown in Table 2. "G900" reservoir sand are classified assubarkose to arkose in nature using QFR_F plot by Folks (2003). This implies that the reservoirs provenance may be dominantly granitic.

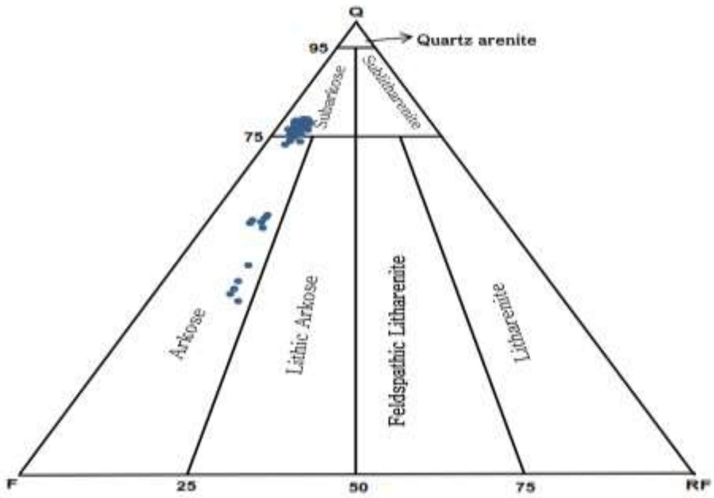
Table 2: Reservoir "G900" mineral composition

Minerals	**CompositionalRange (%)**
Quartz	57 – 92
Albite	0.7 – 8
Microcline	2 – 17
Calcite	0 –0.5
Siderite	0 – 3
Pyrite	0 – 0.8
Kaolinite	0.5 – 17 (Dominantly <2)
Muscovite	0
Illite + Mica	0.1 –3.5
Other minerals	0.1 – 0.4

This subarkosic and arkosic sand are composed of quartz and albite (Plagioclase feldspar), as major minerals with kaolinite presence. The pore filling kaolinite are authigenic and may have been derived from diagenesis of feldspars. They is minor presence of pore bridging illite. This affects "G900" permeability and porosity which is dominantly intergranular and have been influenced by diagenesis..

Grain size analysis

Grain size distribution ranges from very fine sandstones to very coarse-grained sandstones. The resrvoir sandstones sediments composition is classified using the gravel-sand-mud plot.The inclusive graphic standard deviation (σ_1) of "G900" ranges from 1.017 to 1.181 and this implies that sediments are poorly sorted using Folks (2003).The inclusive graphic skewness (SK_1).of the reservoirs in Gabo field ranges from 0.055 to 0.159. Consequently, reservoir "G900" sediments skewness is nearly symmetrical to fine using Folks (2003). In addition, they are platykurtic to mesokurtic since the kurtosis value ranges from 0.869 to 0.94.



Q-pole: All types of quartz (but not chert)

F-pole: All single feldspars (K or Na, Ca), plus granite and gneiss fragment (Plutonic and course grained, deep crustal rock).

R_F: All other fine-grained rock fragment (Supracrustal), chert, slate, schists, volcanic, limestone, sandstone, shale etc.

Figure 4: Reservoir sand classification based on mineralogy using QFR_F Plot (Folks, 2003).

GABO 20 Lithologic Core Description

At 2597m to 2597.9m core depths (2599.9m to 2600.8m log depths) reservoir "G900" sediments shows stacked interval of fine to medium-grained sandstones, slightly coarsening upwards, with shale drapes and local current ripples. In addition, *Ophiomorpha* burrows presence which is indicative of near-shore environment. At 2597.90m to 2599.12m core depths (2600.8m to 2602.02m log depths), sediments arestacked sandstones of very coarse to coarse grains with trough cross-bedding, megaripples, local disgenetic siderite nodules andscarce quartz granules. At 2599.12m to 2599.5m core depths (2602.02m to 2602.4m log depths), reservoir "G900" sediments shows fine to medium-grainedsandstone, slightly fining upwards with shale drapes.

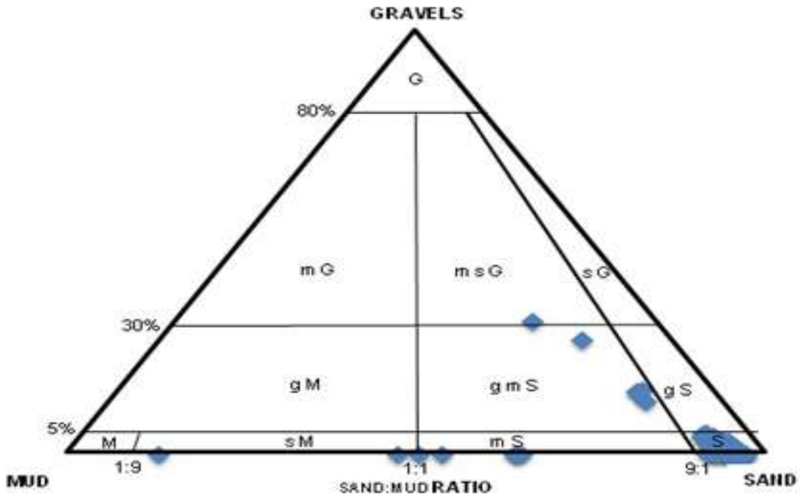
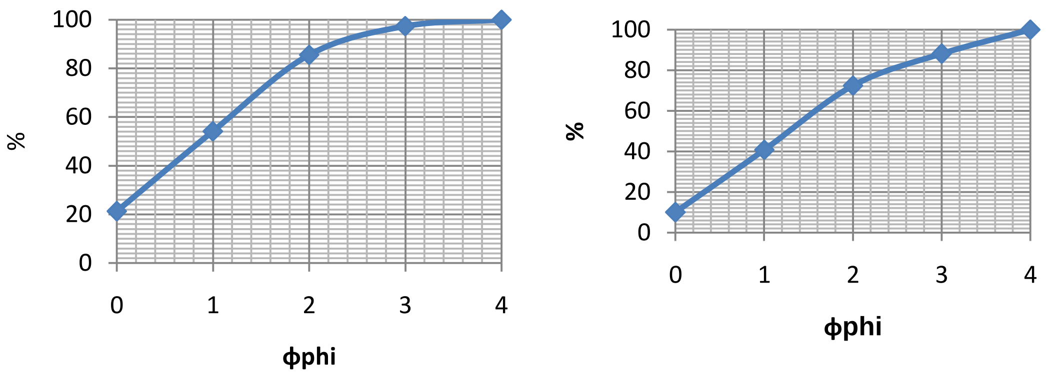


Figure 5: Gabo Field reservoirs grain size classification using Gravel-Sand-Mud Plot, modified from Folks (2003). (sM –Sandy mud; mS – Muddy sand; gmS – Gravelly muddy sand; msG – Muddy sandy gravel; S – Slightly gravelly sand)

At the base, sediments are medium-grained sandstone with planar cross-bedding which infers sediment migration.At 2599.5m to 2599.75m core depths (2602.4m to 2602.65m log depths), "G900" is clean, well sorted fine to medium-grained sandstone with scarce coarser grains at top and base but no structures. At 2599.75m to 2599.95m core depths (2602.65m to 2603m log depths), sediments are unsorted, medium to very coarse-grained sandstones with planar cross bedding and occasional siderite nodules.



(a) (b)

Figure 6 (a and b): Graphical representation of the grain size distribution of reservoirs in Gabo Field.

At 2599.95m to 2600.1m core depth (2602.85m to 2603m log depths),they are fine to medium-grained sandstones with megaripples and shale drapes. At 2600.1m to 2614.03m core depths (2605.4m to 2616.93m log depths) are stacked intervals of poorly sorted fine to very coarse-grained sandstones that are fining upwards. Fine grained sandstones are rich in shale drapes while medium to coarse grained sandstone have planar to tough cross bedding, megaripples and abundant scarce quartz granule.The fining upwards sandstones with very erosives base infer channel fill deposited.Presence of ripples and cross stratification reflects bar migration.

IV. Conclusion

Evaluation of reservoir "G900" show very good porosities and fluid content to be dominantly oil and water with excellent permeabilities derived from wireline logs. The major mineral component is quartz and albite with appreciable microcline. Authigenic clayminerals are present which may be derived from the alteration of mainly feldspars due to diagenesis or other factors prevelent in the paleo-depositional environment. This clay rich arkosic reservoir "G900" is poorly sorted with sandstone grains that have nearly symetrical to fine skewness and intergranular porosity.

Reservoir "G900" sediments shows stacked alternating intervals of fine to very coarse-grained sandstones that are dominantly fine upwards channel fill deposits. Fine-grained sandstones are rich in shale drapes, local current ripples and some *Ophiomorpha* burrows. Medium to very coarse-grained sediments are dominantly unsorted to poorly sorted with planar to trough crossbeddings, megaripples, local diagenetic siderite nodules and abundant scarce quartz granule. Consequently, reservoir "G900" is a typical near-shore deposits within deltaic sub-environment sequence. This study describes reservoir "G900" to have a better reservoir quality towards the North using the percentage volume of shales derived from wireline logs but due to the limited number of wireline logs and core data, more information is required to reduce reservoir uncertainties in net thickness, fluid quantity, fluid type and complexities. Subsequently, combining this study results with production data, seismic, well test and other geological information will minimisethis uncertainties in reservoir "G900" description and in turn, improve production forecast towards achieving an effective developmental plan.

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