# ASSESSMENT OF ENVIRONMENT OF DEPOSITION AND RESERVOIR QUALITY OF WELL TMG C-2 IN THE WESTERN NIGER DELTA

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## ABSTRACT

***This research revealed the reservoir quality and the nature of the depositional Environment of the study location in order to have an accurate field development and reservoir update. The objectives are to interpret logs of gamma ray, porosity and permeability, to determine depositional environments from the log motifs, identify reservoir sands, reservoir depth and thickness. Based on the log responses (signatures) of the well that shows the funnel and bell shapes, the major two sand bodies B and C studied in the well TMG-C2 were deposited in shallow marine environments. Sand B was deposited in Fluvial, shoreface and tidal environments. Fluvial environments occurred towards the western portion of the field capping a shoreface environment at the bottom of the well. Sand C was deposited in shoreface and tidal environment (shallow marine environment). Predominantly shoreface environment was capped with minor tidal channel. Tidal environment occurred at the bottom edge of the well capping shoreface. The average effective porosity ranges between 18.64% to 20.8% and permeability between 226.5 to 300.5 millidarcy, which shows that the sands have moderate to good reservoir quality. The facies and the reservoir quality model, show a good sand development with better porosity and permeability while area with poor sand development have lower reservoir quality. The effective porosity and permeability variation suggest possible changes in depositional processes such as change from laminar to turbulent flow and change in sediment source leading to variation in sorting and porosity.***

**Keywords:** *Reservoir Sands, Well logs, Porosity, Permeability, River Channels*

## INTRODUCTION

The Niger Delta is an oil province of Nigeria located on the West Africa continental margin popularly called the Gulf of Guinea. The Niger Delta lies between Latitude 4°N and 7°N and Longitude 3°E and 9°E, in the South-South geo-political region of Nigeria. The Cenozic Niger Delta is situated at the intersection of the Benue Trough and the South Atlantic Ocean where a triple junction developed during the separation of the south America and Africa within the late Jurassic (Obaje, 2009). The Niger Delta basin is one of the sedimentary basins formed by the rift faulting of the Nigeria Precambrian rock. The Niger delta is important because of its hydrocarbon resources, which started to evolve in Eocene period and deposition is still ongoing offshore. The development of the delta depended on the interplay between supply and subsidence, large amount of data from several thousands of drilled wells have led to a considerable understanding of the regional geology and stratigraphy of the delta. Information has been published on petroleum geology and sedimentology (Short and Stauble, 1967, Weber and Daukoru, 1975) and biostratigraphic (Ozumba 1995 and 1997, Adeniran 1997) provided a detailed benthic foraminifer's biostratigraphy and described the four zones from the late early Miocene to the Pliocene. (Adeniran, 1997) delineated six zones supporting planktic foraminifera from Oligocene to Pliocene from the western Niger Delta. The stratigraphy, Sedimentology, structural configuration and paleo environent during which the reservoir rocks accumulated are studies by various workers. These include (Short and Stauble, 1967; Weber, 1971; Weber and Daukoru, 1975; Evamy *et al*; 1978; Rider; 2002; Selley, 1978 and many others). Tinker, 1996 defined reservoir characterization as the quantification, integration, reduction and analysis of geological, petrochemical, seismic and engineering data. However, increase, knowledge of reservoir characterization and architecture is provided by integration of a large number of well data. The goal of this study is to provide a better understanding of the distribution of reservoir properties (porosity, permeability), A better understanding of the Lithofacies (A mappable subdivision of a stratigraphic unit that can be distinguished by its lithofacies,texture, mineralogy, grain size, and the depositional environment that produced it.) and the depositional environment and other features that distinguishes it from rocks. Depositional facies may consist of one or few lithofacies spread through its body (Omoboh and Odigi, 2020**).** Reservoir is a subsurface rock that has permeability and effective porosity which contains commercially exploitable quantity of hydrocarbon. Reservoir characteristics involves the determination of the physical properties of reservoir (Ability to store and transmit fluid) units and change in their distribution throughout the reservoir. The physical properties include the porosity, permeability and fluid saturation. In reservoir characterization process, computer-generated well data is used to identify the depositional environment. In this research work, it includes the evaluation of reservoir rock in Niger Delta. Reservoir characterization integrates all available data to define the geometry, distribution of physical parameters and flow properties such as porosity, permeability and fluid saturations (Omoboriowo, *et al*, 2012).

## LOCATION OF THE STUDY AREA

The study area of the well “TMG C-2” is located within the Niger delta basin which is situated on the equatorial West African continental margin at the Gulf of Guinea which is between latitudes 4° and 7°N and longitudes 3° and 9°E (Figure 1).

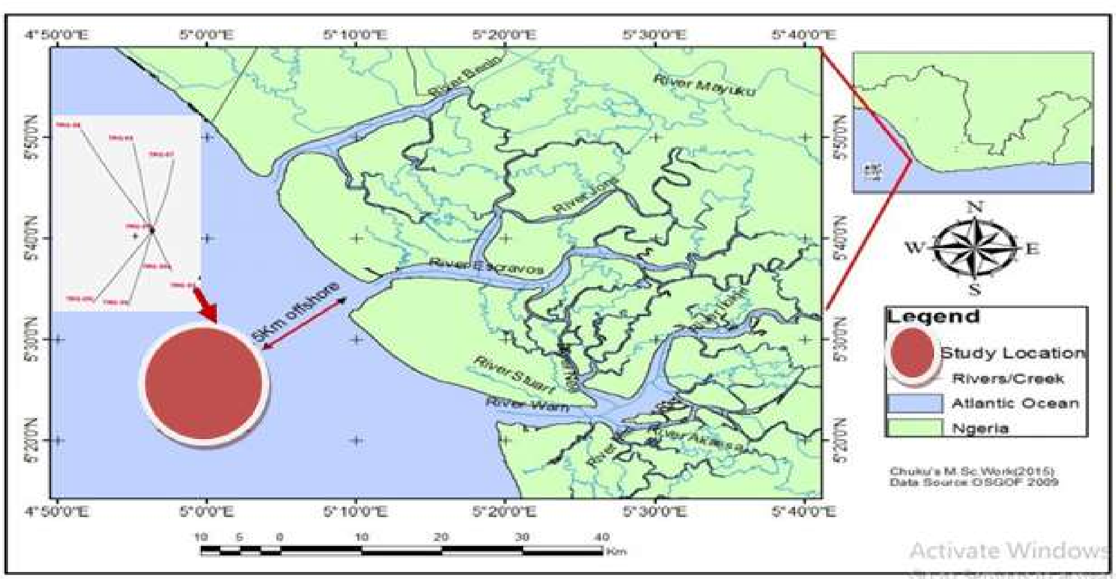


**Figure 1:** Location Map of the Study Location 15km offshore Western Niger Delta Nigeria (modified after Chuku and Ibe 2015)

## MATERIALS AND METHODS

### MATERIALS

The data set for this research was provided by Department of Petroleum Resources (DPR).

i. Samples: Well logs of well TMG C-2 [ Gamma ray Log; Permeability Log; Porosity Log]
ii. Base map showing the structural elements and locations of well (figure 1).
iii. Software used: Petrel software

### METHODS

A well log was used after quality check for the study. Lithologic types were determined from the application of log principles. Log response variation trend, showing shape especially in Gamma Ray was interpreted for various environment of deposition. The permeability and porosity of the reservoir were determined. From this and the relative position of the sand to other facies - shale, the depositional environment of the sands was interpreted. The facies model was generated using petrel software. The reservoir quality (porosity) of the sands was determined from permeability and porosity logs. A comparison was made between the lithofacies model and the reservoir quality model to examine probable cause of variation in reservoir quality.

### Lithodologic Description from Well-Logs Signatures

Lithology according to Oxford Dictionary can be defined as the study of the general physical characteristics of rocks. Lithology is the description of a rock physical characteristics (color, texture, grain size and composition) visible at outcrop, in hand or core samples, or with low magnification microscopy.

Gamma ray logging is a method used to measure naturally occurring gamma radiation for characterization of rocks or sediments in boreholes. It is sometimes used in mineral exploration and water-well drilling, but most commonly for formation evaluation in oil and gas well drilling. The difference in radioactivity amongst shales and sandstones allows the gamma ray tool to distinguish between shales and non-shales. The gamma ray log ranges from 6.49-169.11 API (American Petroleum Institute) units. If the signature reads more towards 6.49 (i.e., towards the left) the lithology indicates a Sandy lithology and also a reservoir when the signatures tend towards 169.11 (i.e., towards the right) then it indicates a shaly lithology. Signatures shapes indicates different structures but the resolution of the log presents limits us to only attempt the identification of the lithology Gamma ray of well TMGC-2 were used to interpret their lithologies.

### Interpretation of Environment of Deposition Using Gamma Ray Log Signatures.

The repetitive nature of the funnel shape suggests dominants of progradation with minor transgression which may be related to local change in base level, or change in sediment supplied. These features are produced by shoreline processes such as transportation, deposition from bedload with minor suspension deposition and slight tidal current effects the generation of minor bell shape especially toward the eastern portion.

Bell shape refers to upward decrease in grain size with corresponding decrease in sand content which represent a decrease in depositional energy over time - retrogradation sedimentation (Figure 2).

### Precaution Measures Taken Prior To Data Interpetation from the Well Log

**Data Quality Check**.

Data quality check was carried out by highlighting the following from the well log given. The following values were;

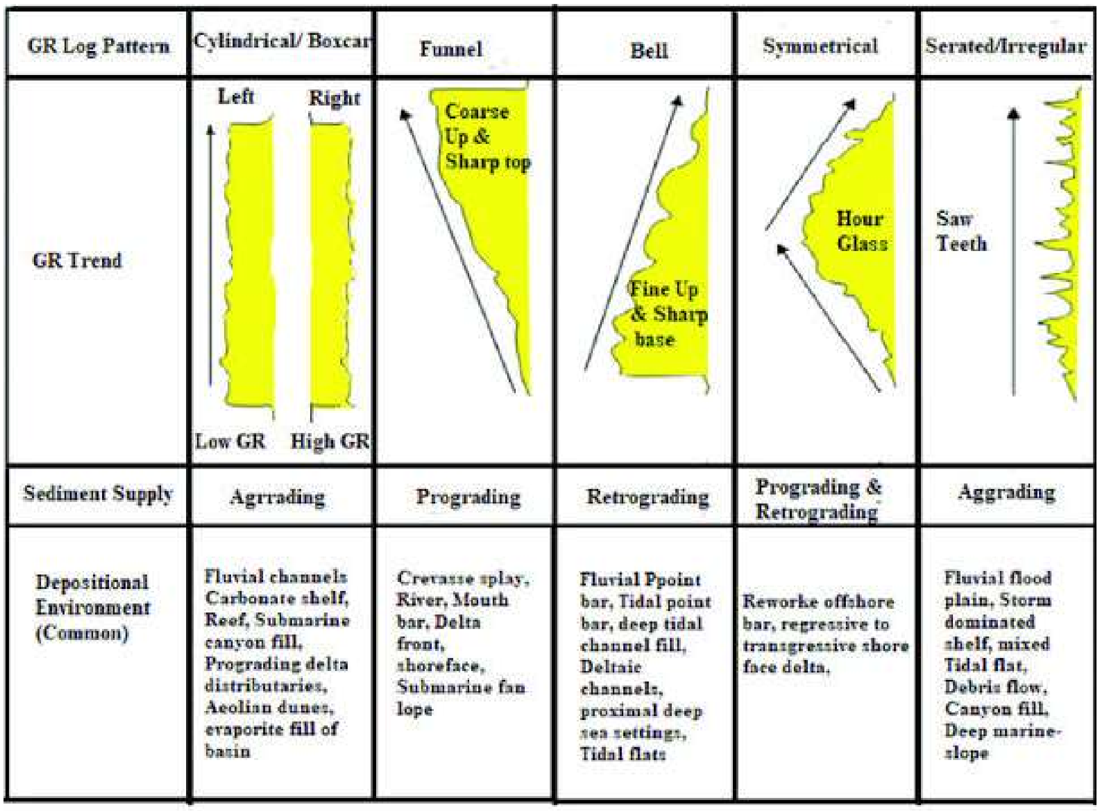


**Figure 2:** Description of depositional environment using gamma ray log (Adapted after Emery and Myers 1996)

The Gamma Ray of the well given

i. The Porosity of the well given

ii. The Permeability of the well given

iii. Total Depth of the well given

**PROCEDURES**

The main type of software used in carrying out the analysis is the Petrel Software. The data given are saved in a particular format known as the (LAS), The Petrel is also a type of software that was used to carry out the well analysis but before analysis was carried out, Data quality check was carried on the Petrel, after opening the computer software then click on Home and click on the import buffer, it brought out the data inventory to import the data given into the software. Petrel accept data saved in (LAS) format, so there was little or no need for data quality check because the necessary information has been checked using the Petrel software. Dominant Sand suggests deposition from bedload transport with minor alternation from suspension fall out. The suspension load fall-out may be related to tidal influence which generates temporary increase in water depth thereby lowering the energy of transportation and deposition of suspension materials.

**RESULTS AND DISCUSSIONS**

**Lithologic Interpretation of Well TMG C-2**

The lithology of well TMG C-2 is made up of Shale and Sand (reservoir). A Lithostratigraphic description indicates that the environment is mostly shale/clay which is yellow in color. The Lithology of well log is dominated by the shale which really exists between the depths of 1950ft- 2282.5ft, deep down in the well there was alteration of shale and sand in different percentage composition in per depth basis. Shale is the most in the well log(figure 3), however the shaliness shows maybe a source rock but this cannot be approved as a source rock until a well detailed geochemistry analysis is carried out. The use of gamma ray well log description helped in determining the formation type. The gamma ray logs showed dominant shale/clay (in yellow). The permeability and porosity log show the reservoir (Sand) and shapes.

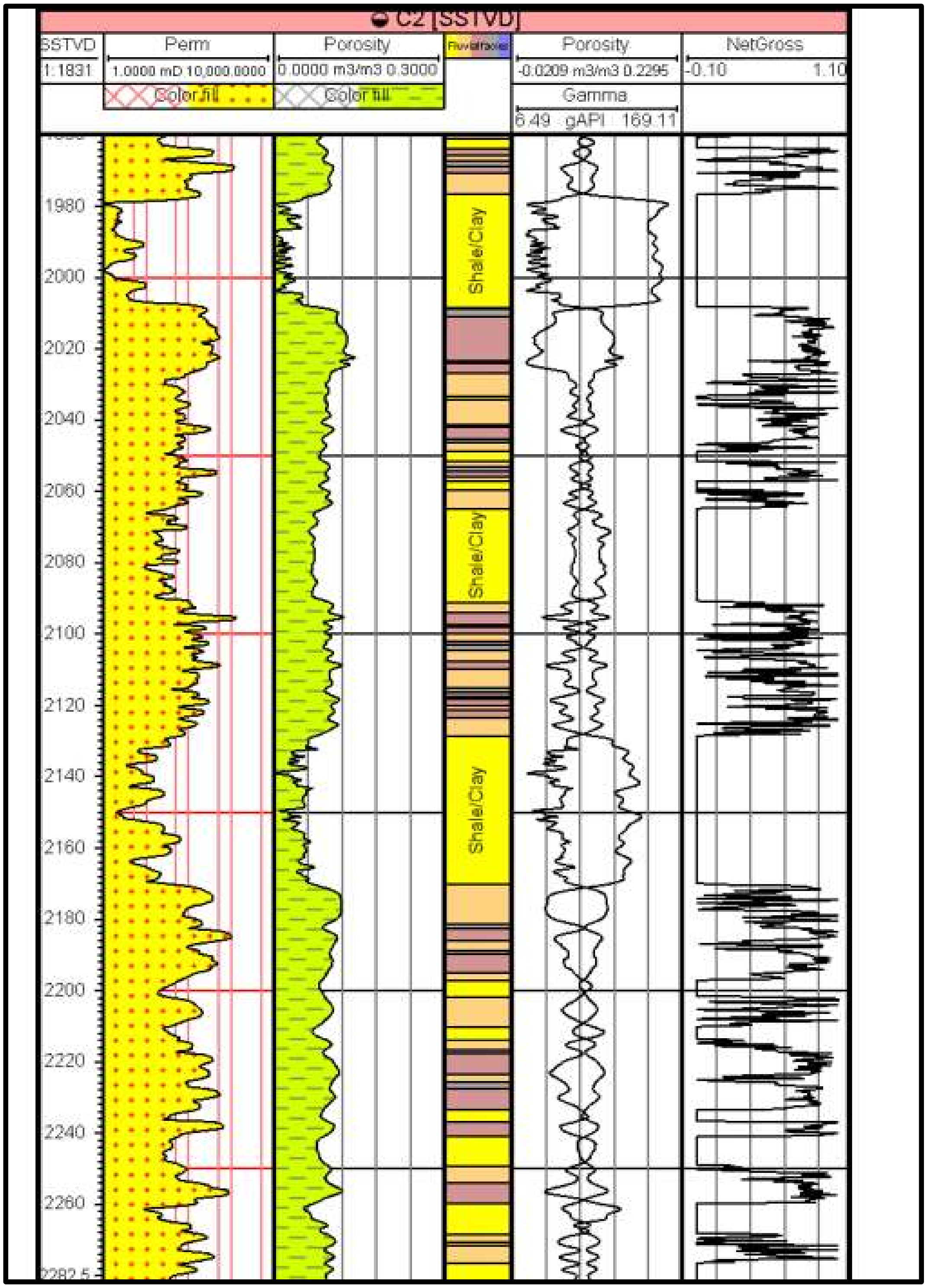


**Figure 3:** Lithologic description of the study area with Petrel software

**DEPOSITIONAL ENVIRONMENT FEATURES OF WELL TMG-C2.**

**Gradational base, funnel shape and bell shape** (figure 4).

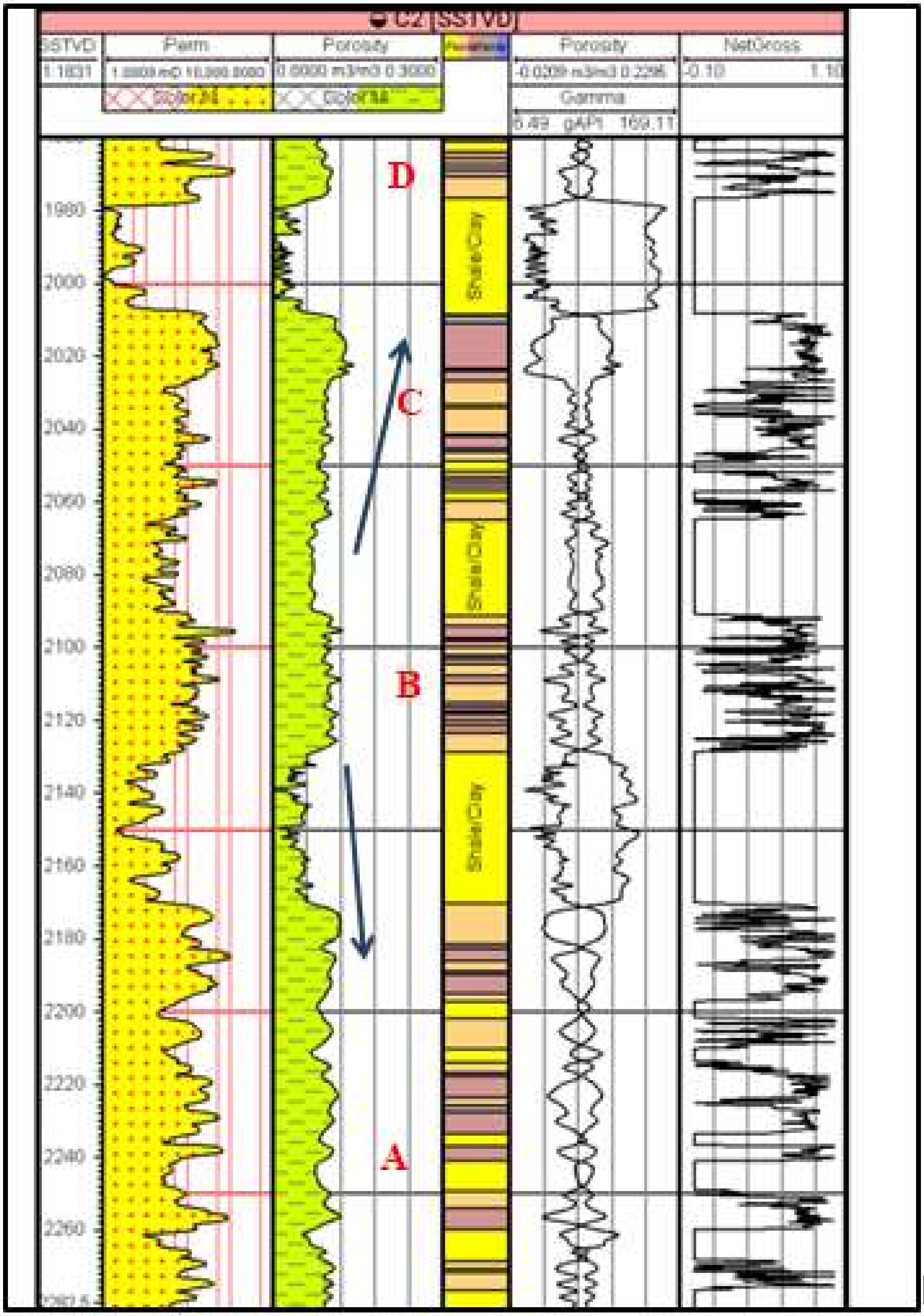


**Figure 4:** Gradational base, funnel shape, followed by bell shape of sand C reflecting an initial upward increase in grain size followed by an upward decrease in grain size.

**Relative position of Sand to Shale facies (figure 5).**

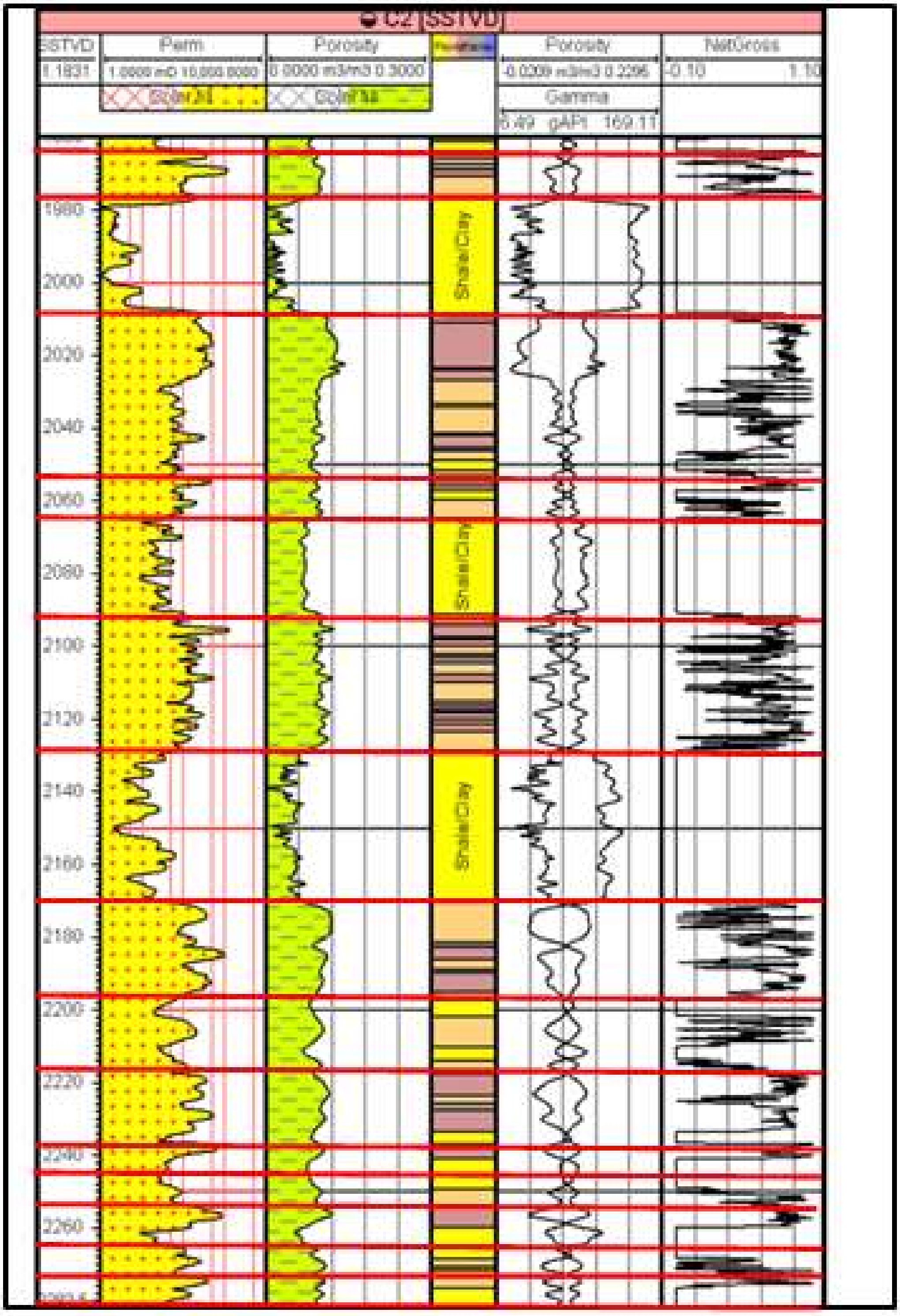


**Figure 5:** Relative position of Sand to Shale facies, (sandwiched between Shale/Clay), help define its environment of deposition.

**Log shape signatures;** Gradational base, funnel shape capped by bell shape that signifies shoreface capped with fluvial deposit (figure 6).

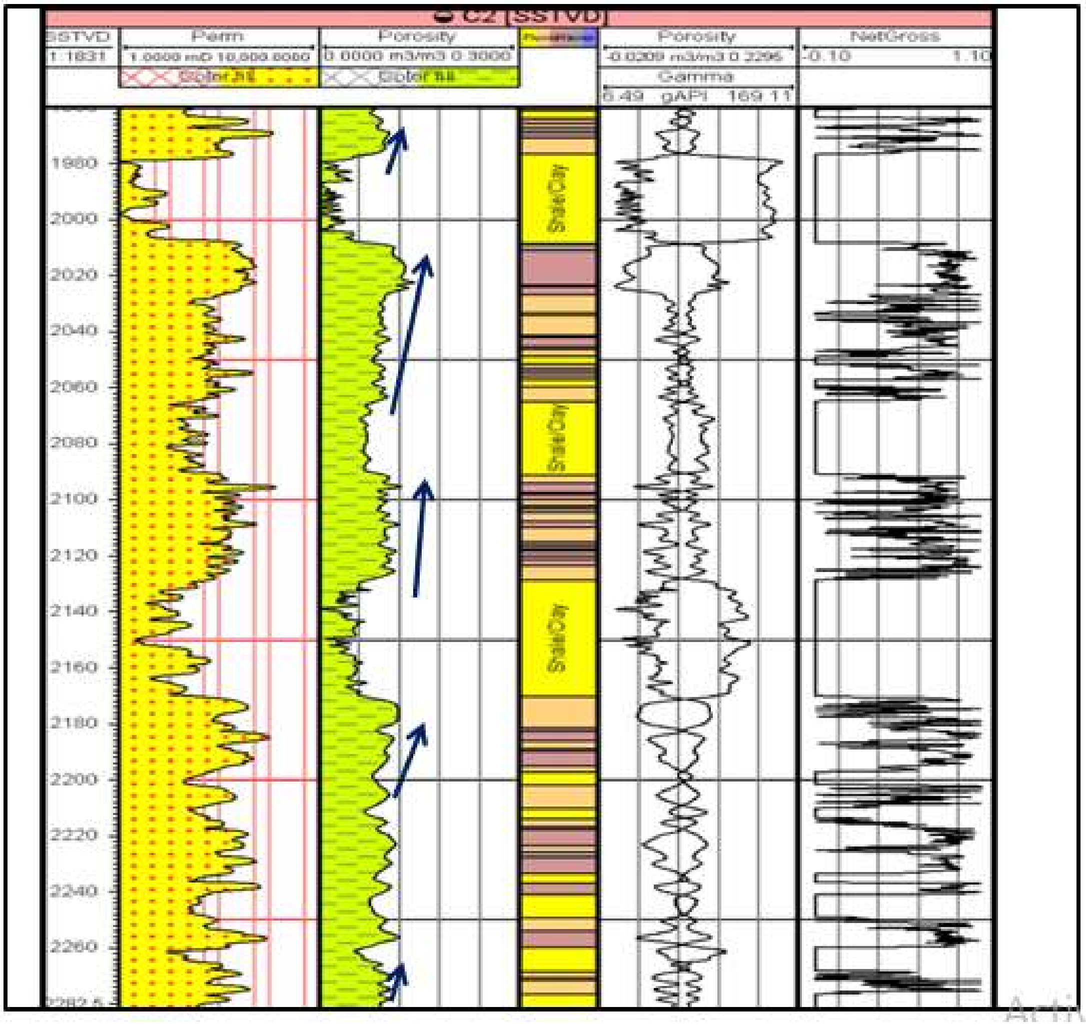


**Figure 6:** Gradational base, funnel shape capped by bell shape signifying shoreface capped with fluvial deposit.

Weber 1971, suggested that one of the major criteria used in identifying depositional environment of sand bodies in the Niger Delta basin is their grain size distribution and was reflected by the gamma ray log shape and trend.

From the above features: nature of upper contacts and lower contacts, relative position of Sand to Shale facies, better Sand development in the upper section of the facies model(figure 6), log shape trend (funnel capped with bell shape); the sand was interpreted to be from shallow marine environment: a shoreface capped with fluvial facies and tidal facies. The tidal channels was inferred based on the serrated nature of the bell shape.

**Depositional processes Features of Sand C**.

From the log signature in the well (figure 7), facies are seen to be made more of Sand with laminations of Shales, which have a gradational base, repeated funnel shape, it implies repeated upward increase in grain size, overall upward decrease in Shale/Clay content.

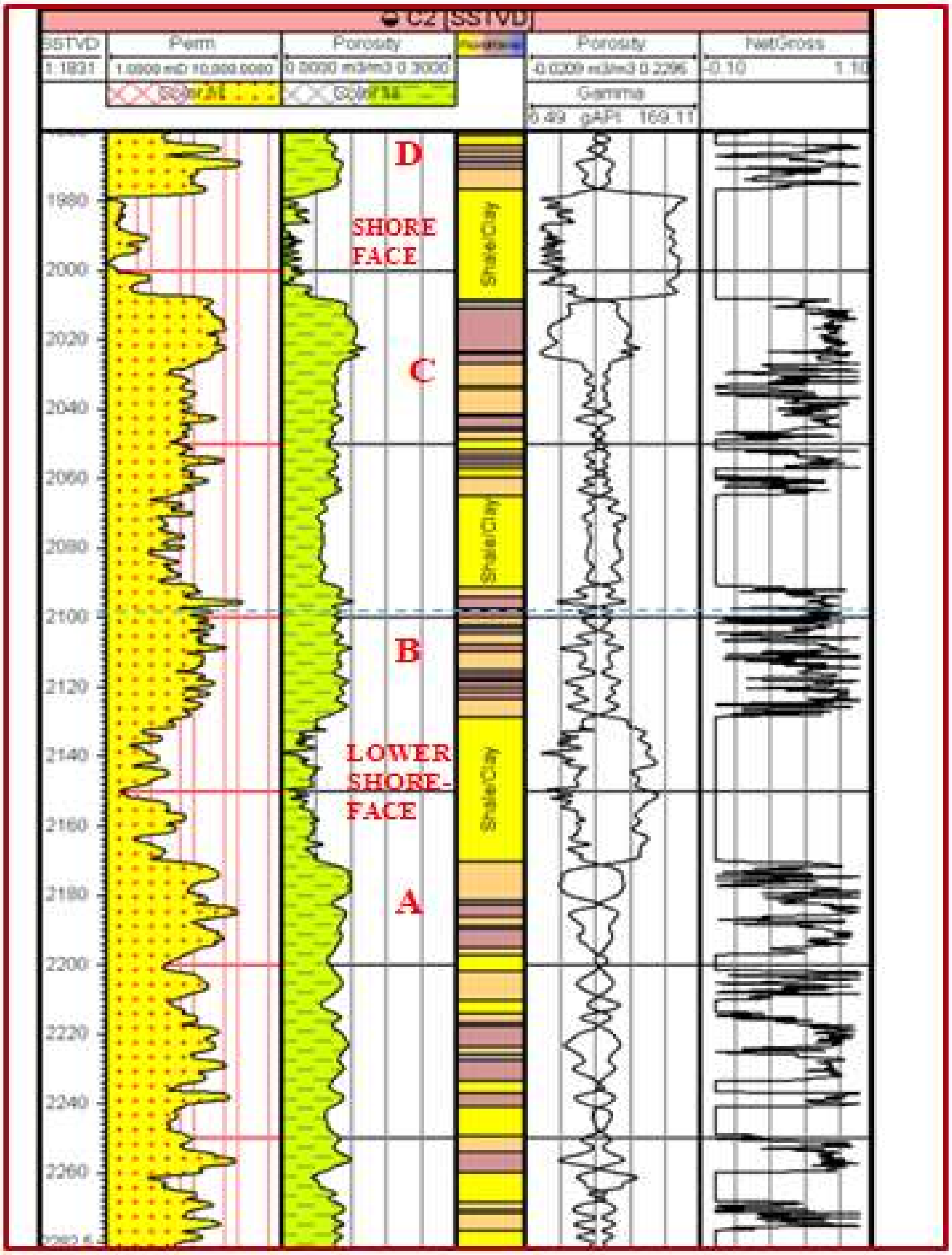


**Figure 7:** Grain size variation of sand C with nature of upper / lower contacts produced by depositional Processes.

The dominance of Sand suggests deposition from bedload transport with minor alternation from suspension fall out. The suspension load fall-out may be related to tidal influence which generates temporary increase in water depth thereby lowering the energy of transportation and deposition of suspension materials. Funnel shape refers to upward increase in grain size with corresponding decrease in clay content which represents an increase in depositional energy over time - a progradation sedimentation. The repetitive nature of the funnel shape suggests dominance of progradation with minor transgression which may be related to local change in base level, or change in sediment supply. These features are produced by shoreline processes such as transportation, deposition from bedload with minor suspension deposition and little tidal current effects generating the minor bell shape.

**Depositional Environment features of Sand.**

The following features were used to infer the depositional environment of sand with multiple funnel shape of sand with gradational base reflecting repetitive upward increase in grain size (figure 8).

**A. Multiple funnel shape with gradational base.**

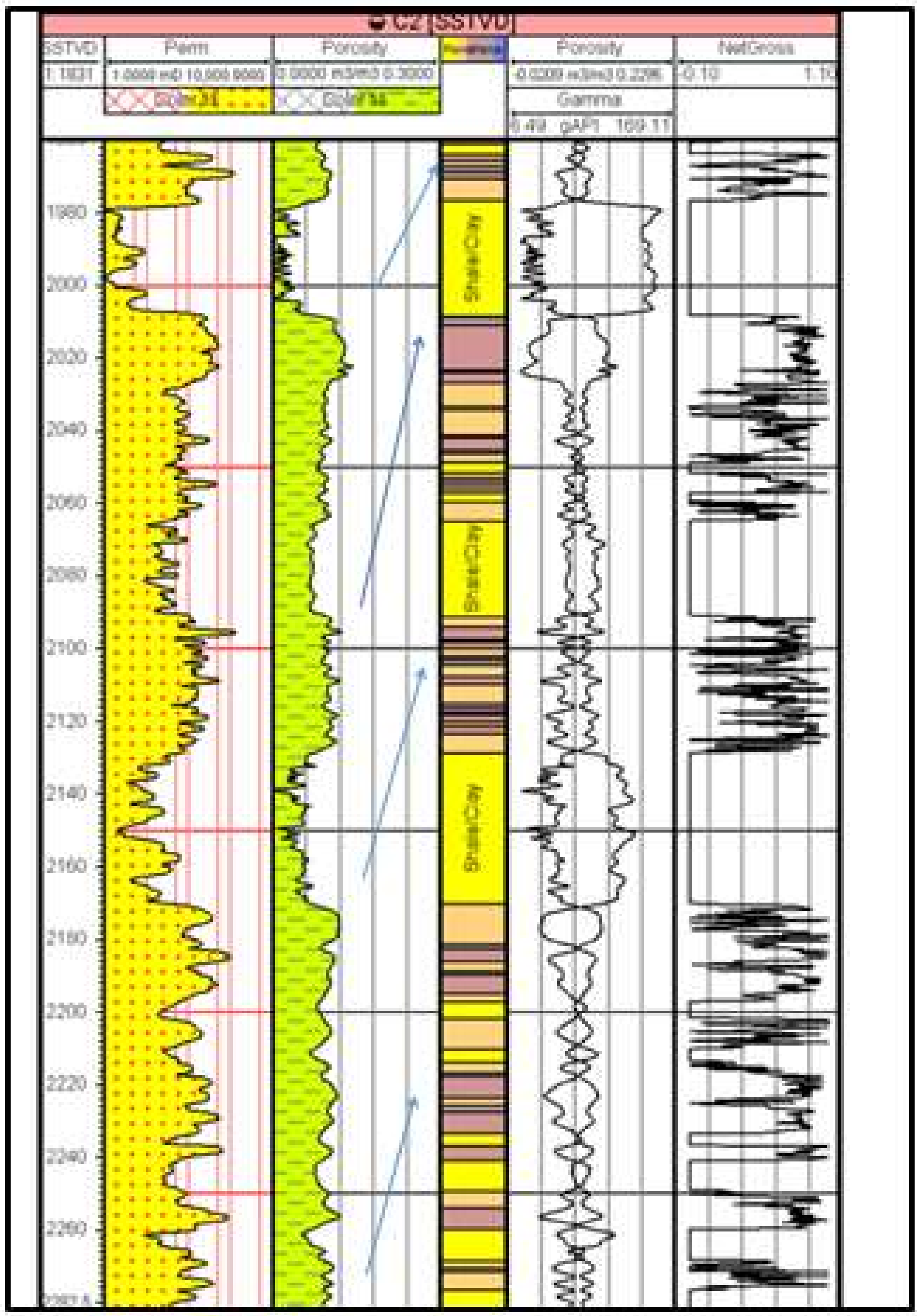


**Figure 8:** Multiple funnel shape of sand with gradational base reflecting repetitive upward increase in grain size

**B.** Position of the sand in relation to other lithologies (facies) (figure 9).

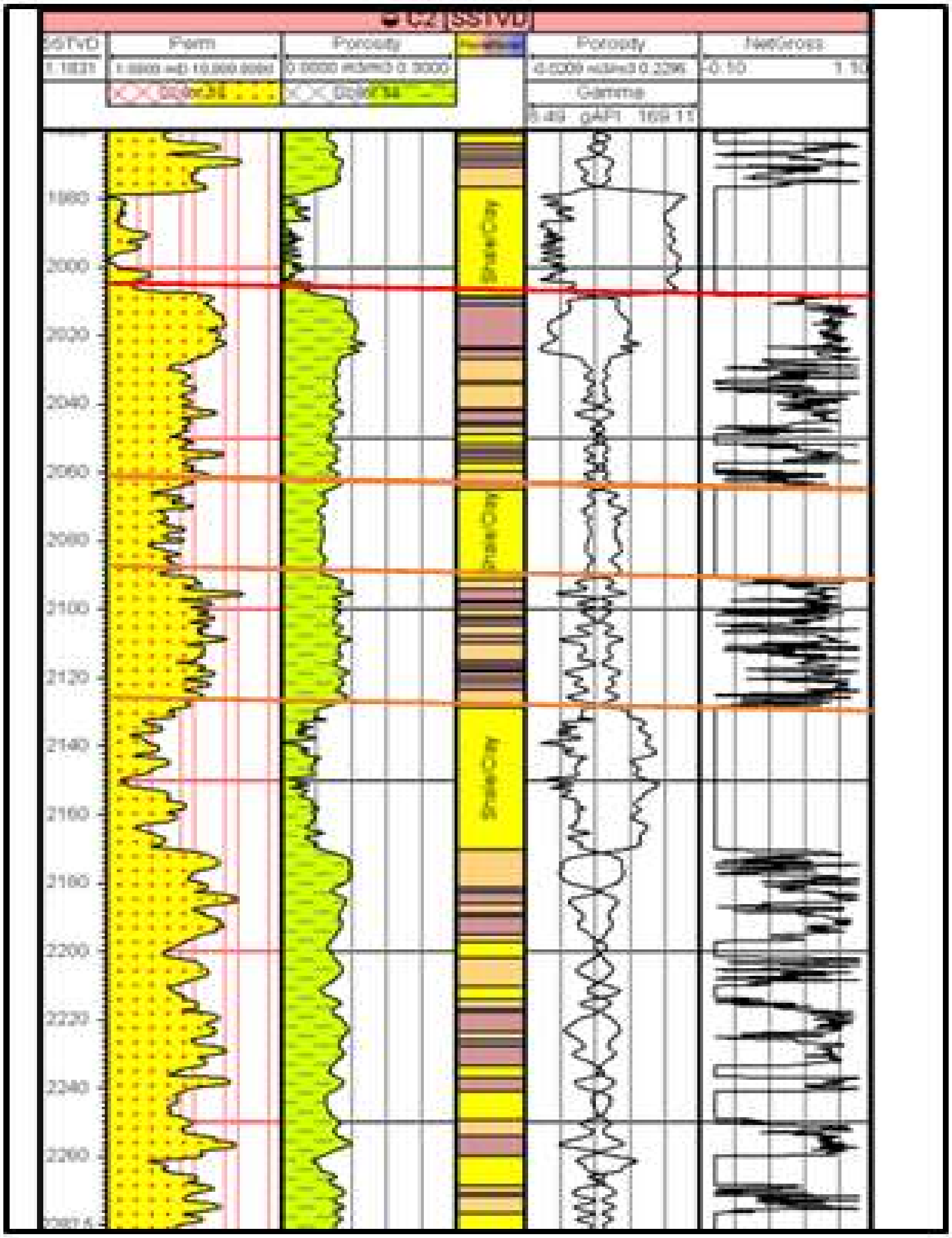


**Figure 9:** Position of sand facies (lying between marine shale)

**RESERVOIR QUALITY OF WELL TMG C-2.**

The porosity and permeability of the sands is shown below:

**Table 1: Porosity and Permeability of sand C**

| **Sand Body** | | | |
|---|---|---|---|
| Well Name and Depth (m) | Average Total Porosity (%) | Average Effective Porosity (%) | Average Permeability (milidarcy) |
| Southward direction | | | |
| Well C2 (2010ft) | 29.9 | 20.8 | 300.5 Top |

The base map of the field showing the wells position is shown in (Figure 1)From figure 1 and table 1, the average reservoir quality of the sand was seen to decrease. Reflecting decrease in grain size and thus depositional energy in this direction. Although the change in reservoir quality from the well is more rapid, this might not be unrelated to the shallow depth of the sand at the well top position or probable increase in diagenetic processes in the field.The reservoir quality show lesser reduction than expected, this may be attributed to probable early porosity preservation processes which occur at shallow depth such as clay mineral coating of grains which inhibit later diagenetic processes such as quartz overgrowth (Godwin, et al, 2021). The average reservoir quality variation of the field, is the direction of the depositional axis of the sand, which shows an uneven variation. The effective porosity which already removed the unconnected pore spaces of clay minerals found in shale shows that diagenetic processes of compaction and cementation might have affected the reservoir to various decrees and at different scale. It also suggests that depositional processes might have varied in strength and sediments properties might have changed during the deposition of the sand. Since the depositional axis is from northwest to southeast,the reservoir quality is expected to be highest in the position of sand (figure 8) because of the higher energy of deposition there and least in position of shale due to the expected lower energy of deposition there, but this was not so as the reservoir quality was highest in the position of lower shale in the well which although also closer to the sand and least in the position of sand. This could be attributed to effect of uneven sorting of the reservoir, or supply of sediments with different textural properties such as roundness and angularity or diagenetic processes which altered the reservoir quality in the well positions since shale effect have been removed.

The relative increase in the reservoir quality in the position of sand might be attributed to better sorting of the reservoir in that area due to change from turbulent to laminar flow, or porosity enhancing diagenetic processes such as pressure dissolution or local absence of elements needed for the precipitation of cements in pore spaces which would have reduced porosity in that area (Godwin, et al, 2021).From table 2 and figure 8 below, the average reservoir quality of the sand was seen to increase from the bottom to top. This may be related to increase in wave current / tidal activity which approaches from the south enhancing the sorting of the reservoir and thus its quality. It may also be related to lack of serious diagenetic cementation processes affecting the reservoir or homogenous composition and good fabric which preserve the original porosity and permeability. Looking at the reservoir from the top to the bottom direction - approximate depositional axis, there is a general decrease though not uniform, but in the position of the well top; there was a marked increase from 17.84% in well reservoir A to 20.4% in B position.

**Table 2:** Sand B reservoir quality

| **Sand Body** | | | |
|---|---|---|---|
| Well Name and Depth (m) | Average Total Porosity (%) | Average Effective Porosity (%) | Average Permeability ( milidarcy) |
| Southward direction | | | |
| Well C2 (2090ft) | 20.67 | 18.64 | 226.5 Bottom |

This shows that the reservoir quality tends to follow the depositional axis, probably due to porosity preservation processes of diagenesis such as dissolution of liable grains and leaching or probable overpressure around the well. The petrophysical log of the sand is shown in (figure 10). It confirms the environment of deposition to be of shoreface where depositional mechanism allows for an upward increase in reservoir quality.

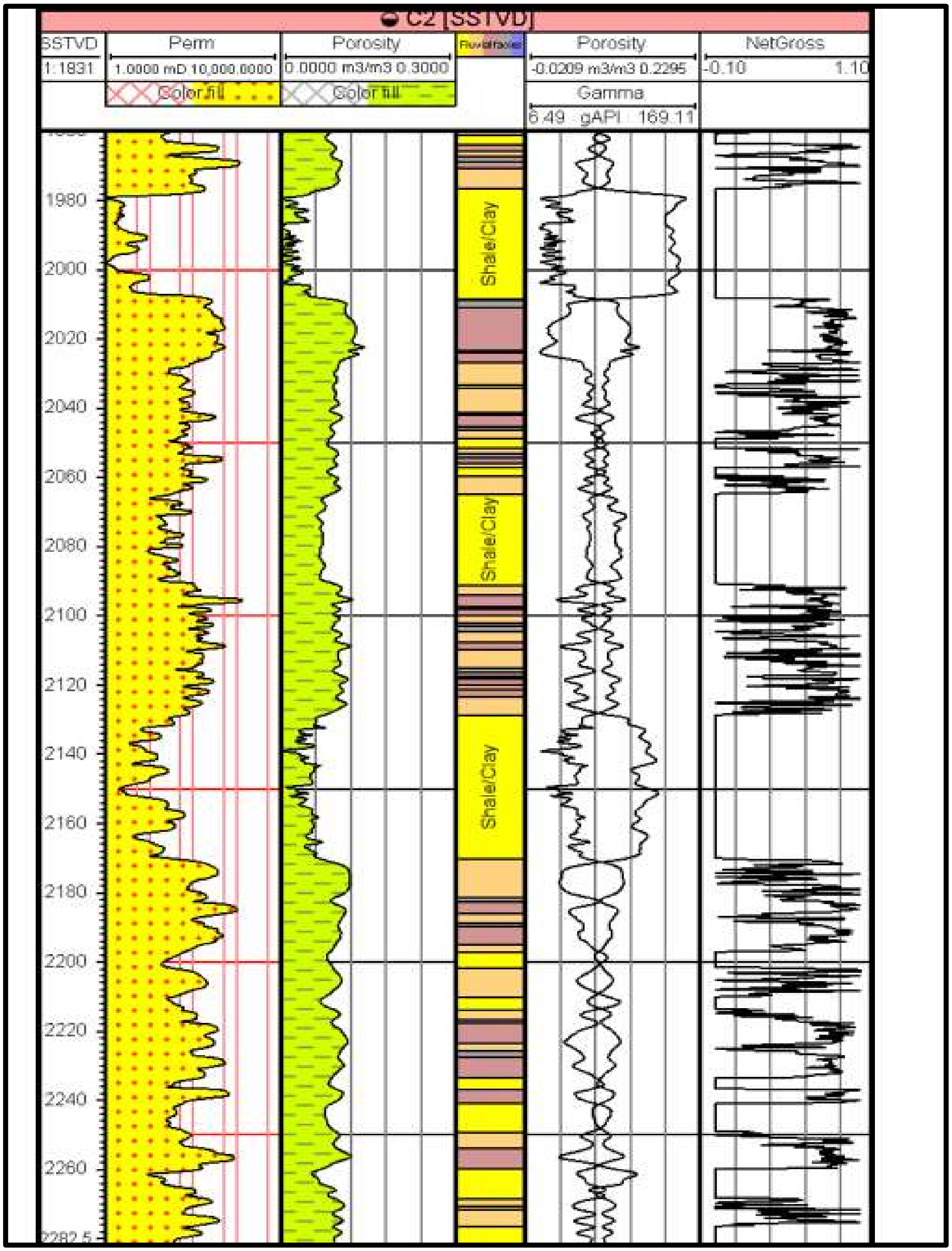


**Figure 10:** Petrophysical log showing variation in reservoir quality

## CONCLUSION

The facies model of the sands and their corresponding reservoir qualities at different depths have been analyzed. From the facies, effective porosity and permeability models of sand A and B, figure 8 to 9, it can be seen that the reservoir quality increases upwards and decreases downwards following the facies (lithofacies) pattern. This temporal distribution of the facies and quality confirm the reservoir to be of shallow marine environment where progradation is taking place allowing coarser sediments with good reservoir quality to overlie finer sediments with poor reservoir quality deposited in low energy areas. The facies models of sand B with its corresponding reservoir qualities models (porosity and permeability), show that its reservoir quality was controlled by depositional fabric: area with good sand development have good reservoir quality. The depositional processes in a shallow marine shoreface / mouth bar environment, allow the porosity and thus permeability to increase downward within the reservoir due to increasing grain size downwards. This is seen from the porosity and permeability model of sand B which are better developed in the lower section than the lower part.

Where both the facies and the reservoir qualities are well developed from the bottom to the top, the few isolated poor textural and thus poor reservoir qualities sediments (silt and clay), may reflect localized change in sediment supply, reduction in slope of the depositional surface, reduction in the quantities of water transporting the sediment and bed roughness, all of which reduce transport velocity thereby causing deposition of fines. The reverse is also true for the upper part of the reservoir, figures where there are isolated good textural and reservoir qualities development in areas where fines, are expected to produce poor reservoir qualities. Such good textural development might result from localized catastrophic events such as shock or storm induced turbidity current that flow into the fine sediment.

The sand A and B of well TMG-C2, Niger Delta Basin was deposited in the shoreline to shallow marine environment: shoreface overlain with fluvial channel to the bottom and tidal channel to the top. The sand B was deposited in a shoreface environment with tidal effect generating minor tidal channel toward the top portion. The highest porosity values occur in area with fluvial and shoreface environments suggesting the combined effects of higher grain size of the channel with wave effect on the shoreface creating better sorting. Higher grain size and good sorting will produce better porosity and permeability. Their reservoir qualities increase upward following the facies pattern suggesting that reservoir quality was controlled primarily by depositional processes and thus environment of deposition. The reservoir quality varies aerially and temporally suggesting probable variation in depositional processes such as change from turbulent to laminar flows, change in composition and textural properties of deposited sediment or varying degree of diagenetic processes.

## RECOMMENDATION

This study suggests that reservoir quality is mainly controlled by processes in depositional environment and for accurate field development and reserve update, a reservoir characterization should be carried out in all other wells in the study area.

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