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FORMATION EVALUATION AND INTERPRETATION OFDEPOSITIONAL ENVIRONMENT;A CASE STUDY OF Y-FIELD IN NIGER DELTA

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Abstract

There is a need to assess a well for its production viability under complex conditions. Each reservoir has a unique environment and they need to be explored and understood using a range of measurements taken from inside the well. To do this, formation evaluation is needed at the exploration and production stages. This is done to ascertain whether or not economic reserves of hydrocarbon are present and, if they are, to determine the most economical and efficient way to extract them. This will improve decisions for subsequent drilling.The available data for the characterization of the Reservoirs in Y-Field includes well logs for eight wells, 3D seismic and check shot data. The well logs were interpreted with using Interactive Petrophysics v3.6 and the location of the wells was interpreted using IHS Kingdom Suite 2017. The well logs were first interpreted to determine the various lithologies (sand and shale), reservoir thickness and stratigraphic relationship. Petrophysical parameters such as volume of shale, porosity, water saturation, hydrocarbon saturation, bulk volume water and permeability using appropriate formulas.Six reservoir sand (Reservoir 1, Reservoir 2, Reservoir 3, Reservoir 4,Reservoir 5 and Reservoir 6) were delineated. The Petrophysical

analysis of Well 1, Well 2, Well 3, Well 4, Well 5 and Well 6 gives an insight of the probability of fluid in the wells and its economic viability for extraction.It was delineated from this study that the wells had different top and bottom for each reservoir unit. Also, it was estimated as well that the permeability of the wells were not homogenous and this is as a result of different sedimentation processes that took place in the formation of the Niger Delta. The depositional environments of the reservoirs were observed manually to be cylindrical and funnel shaped. This shows aggradation and coarsening up of sediments, which is a typical characteristic of the Niger Delta.

1. INTRODUCTION

There are 3 main types of rocks that exist in the earth, Igneous Metamorphic and Sedimentary Rocks. For this study we will concentrate on the Sedimentary rocks and also look into the subsurface where most of our hydrocarbons are generated and trapped.Stratigraphic interpretation of seismic data requires that the seismic information be expressed in geologic terms. A strict geological view of the earth is developed from subsurface observations, the guiding principles of geologic evolution, and subsurface information from boreholes. (Oladunjoye, 1999).

Afuye (2013), said there are incessant subsurface uncertainties and challenges of geological reservoir models and erroneous interpretations often associated with the already identified reservoir in the Niger Delta.Therefore there is need for re-assessment and identification of these reservoirs and their potential hydrocarbon reserves prior to production, by the utilizing of 3D reservoir modelling approach in order to reduce and document in great details the reservoir uncertainties which are: the reservoir architecture/geometry, the spatial distribution of the associated facies of depositional environment, the petrographic properties (examples are porosity distribution, permeability distribution and fluid saturation distributions), the reserve estimates and provision of input for the reservoir fluid flow pattern. (Afuye, 2013).

The 3D Static reservoir Modelling focuses on the integration of the well log data, 3D seismic and sequence stratigraphic principles can be used to constrain the static reservoir model. Integrating seismic data with well-logs enhance higher degree of reliability particularly in stratigraphic situations that were previously difficult to interpret. Stratigraphic significance is only where seismic data is tied to well logs. The wave shape of the seismic reflection can be related to a stratigraphic and also show how it extends.

Stratigraphic conclusions from seismic data depends on the data being sufficiently free from noise so that the seismic response is predominantly that of sediments. (Oladunjoye,1999).When there is poor data quality either in the seismic or well log data as well as practical onshore and offshore problems all contribute to poor well to seismic matching. These limitations are caused as a result of seismic reflections being unable to show the accurate image changes of the subsurface properties. Improved well to seismic data can be achieved through the following: Migration, Common Mid-Point (CMP) gather, bulk shifting, editing, deconvolution good acquisition and processing of seismic data coupled with good interpretation skills.

This research work helps to locate faults and traps with the use of seismic modelling and matching them to the appropriate well logs in order to be able locate wells, reservoir volumetric estimate and production to some degree of certainty.Nigeria as a country, its economy is heavily dependent on the oil sector. Due to increase in population which is directly related to high energy demand, decline in production activities has impacted on supply disruptions, hence, the necessity of increasing reserves and optimizing production of existing field.

However, geoscientist have to work much harder today to discover economics reservoir. Searching for hard-to-find stratigraphic and structural traps is very common as we examine mature zones to undercover missed hydrocarbon. In modern times, simply relying on the full-stacked amplitude response as a direct hydrocarbon indicator is not enough; typically, advanced reservoir characterization technique and seismic attributes analysis are needed to evaluate a reservoir properly.The aim of the research is to identify probable zone of hydrocarbon across the study area and determine the depositional environment of the study area.

The objectives of this research entail the following:Identification of various lithological unit. Correlation of well logs to obtain a lateral continuity of the formation. Identification of potential fluid bearing formation and the types of fluid content. Interpretation of the depositional environment of such potential fluid bearing formations. Calculation of petrophysical parameters such as Porosity, fluid saturation and permeability.

The scope of study includes involves correlation of the logs and further interpretation in terms of lithology, hydrocarbon occurrence, petrophysics and depositional environment.Three sets of logs were used which include:Correlation log: Gamma ray logs, Resistivity log: Deep resistivity RES DEEP and Porosity logs: Density and Neutron logs.

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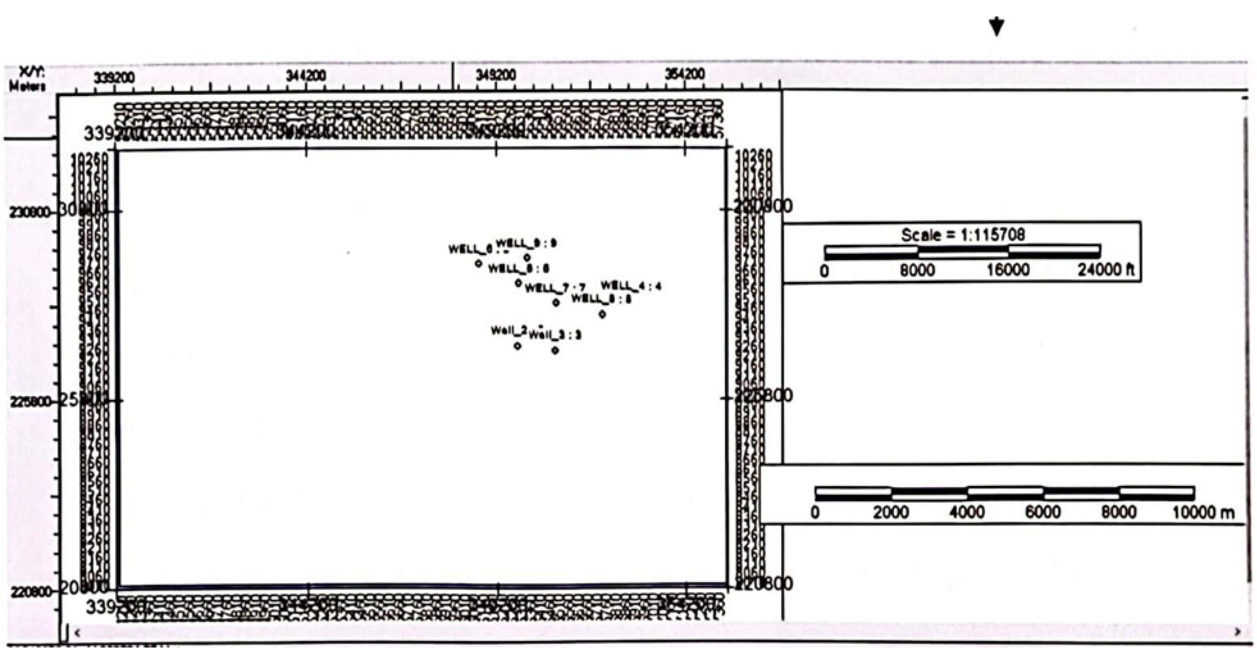
2. METHODOLOGY

2.1Location of Study Area

The study area is located on latitude 339266.50 to 355291.50 on x coordinate, and latitude 220874.50 to232399.50 on y coordinate on the world coordinate.



x348076.21.Y:232734.55 Meters

Figure 1: Base map of the area.

2.2**Data used and Interpretation**

The materials used for this study include,

1. 3D Seismic data (Soft)
2. One Check-shot survey data (soft)
3. Digital wireline log data (Soft)

2.2.1 **3-D Seismic Data**

The field is fully covered by fair to good 3-D Seismic data, though the resolution of the data is bad at the deeper levels.

2.2.2 **Check-shot Data**

One Check-shot velocity data was available. This could not be shared and used in establishing Seismic to well tie for horizon interpretation for all the wells, because the wells are at varying depth.

2.2.3**Well Log Data**

Log data are available for all the four wells in the field. The data is generally of good quality. The log types used for quantitative analysis in this study are the gamma ray, resistivity, density and neutron logs. The SP and gamma ray logs were mainly used for lithology identification.

2.3. **Software Employed**

IHS (Markit) Kingdom suite was employed in mapping the wells and Interactive Petrophysics

(IP) was used for the petrophysical analysis.

2.4. **Well Logging**

Well logging was developed by the Schlumberger brothers (1978) in France. Geophysical borehole logging, also known as downhole geophysical surveying or wire-line logging, is used to derive further information about the sequence of rocks penetrated by a borehole. Well log is a continuous record of measurement made in borehole respond to variation in some physical properties of rocks through which the bore hole is drilled. Of particular value is the ability to define the depth to geological interfaces or beds that have a characteristic geophysical signature, to provide a means of correlating geological information between boreholes and to obtain information on the in-situ properties of the wall rock.

In practice the most useful and widely-applied methods are based on electrical resistivity, electromagnetic induction, self-potential, natural and induced radioactivity, sonic velocity, temperature, gravity and magnetic logging. In addition, several other types of subsurface geophysical measurements may be taken in a borehole environment. Of these, perhaps the most important and widely used is vertical seismic profiling. The instrumentation necessary for borehole logging is housed in a cylindrical metal tube known as a sonde. Sondes are suspended in the borehole from an armored multicore cable. They are lowered to the base of the section of the hole to be logged, and logging is carried out as the sonde is winched back up through the section. Logging data are commonly recorded on a paper strip chart and also on magnetic tape in analogue or digital form for subsequent computer processing.

2.5**Petrophysical Analysis**

This is the study of the physical and chemical properties of rock and the fluid present in them. petrophysical log interpretation is one of the most useful and important tools available to a petroleum geologist. Petrophysicist uses rock properties and relationship to identify, quantify and evaluate hydrocarbon reservoir, source rock and seals. Well log data are used for corelating zones of interest and also defining physical rock characteristics such as lithology, porosity, pore geometry, permeability and fluid typing. Zone parameters such as depth, thickness, and reserves can also be estimated.

2.6**Types of Well Logs**

There several geophysical well logs that typically measure natural electrical currents, electrical resistivity, sonic velocity, and a variety of radioactive parameters, to derive information like density, porosity, permeability, composition of fluids and lithology. These logs are explained below.

2.6.1 **Gamma Ray Logs**

Gamma ray log measures radioactivity originating within a few decimeters of the borehole. Because of the statistical nature of gamma-ray emissions, a recording time of several seconds is necessary to obtain a reasonable count, so the sensitivity of the log depends on the count time and the speed with which the hole is logged. Measurements can be made in open and cased wells. Gamma ray logs are used for lithology identification which is a basis for well correlation. Bed boundaries and shale content evaluation can also be evaluated using gamma ray log.

2.6.2 **Formation Density Logs**

The formation density log is a porosity log that measures electron density of a formation. Two separate density values are used by density log: the bulk density (ROHB) and the matrix density (Pma). Dense formations absorb many gamma rays, while low-density formations absorb fewer. Thus, high-count rates at the detectors indicate low-density formations, whereas low count rates at the detectors indicate high-density formations. Therefore, scattered gamma rays reaching the detector are an indication of formation density.

The most frequently used scales are a range of 2.0 to 3.0 gm/cc or 1.95 to 2.95 gm/cc across two tracks. A density derived porosity curve is sometimes present in tracks #2 and #3 along with the bulk density (Rb).

2.6.3 **Neutron Log**

The Neutron Log is primarily used to evaluate formation porosity, but the fact that it is really just a hydrogen detector should always be kept in mind. It is used to detect gas in certain situations, exploiting the lower hydrogen density, or hydrogen index. The Neutron Log can be summarized as the continuous measurement of the induced radiation produced by the bombardment of that formation with a neutron source contained in the logging tool which sources emit fast neutrons that are eventually slowed by collisions with hydrogen atoms until they are captured (think of a billiard ball metaphor where the similar size of the particles is a factor). The capture results in the emission of a secondary gamma ray; some tools, especially older ones, detect the capture gamma ray (neutron-gamma log). Other tools detect intermediate (epithermal) neutrons or slow (thermal) neutrons (both referred to as neutron-neutron logs).

2.6.4 **Density/Neutron Overlays**

Both the density and neutron tools determine the porosity of a reservoir, but do this by measuring different quantities. The density tool measures the bulk density, while the neutron measures the hydrogen density. For this season, both tools respond differently to some pore fluids and lithologies. It is standard practice to plot both logs in one track, using a scale such that both logs overlay a water bearing limestone. Using these scales, the logs will separate uniquely in other lithologies and pore fluids. For example, in gas bearing reservoirs, the recorded neutron porosity is lower and the bulk chemistry is reduced compared with the responses in a similar water/oil bearing formation (Figure 2). These effects can be significant depending on the gas saturation in the invaded zone. The resulting separation with neutron on the right hand and density on the left is called a gas separation. Shales have inverted effect (shale separation). Due to the clay bound water, which is chemically attached to the clay particles, the neutron tool records high porosity, whereas in reality no effective porosity is present.

Neutron Porosity

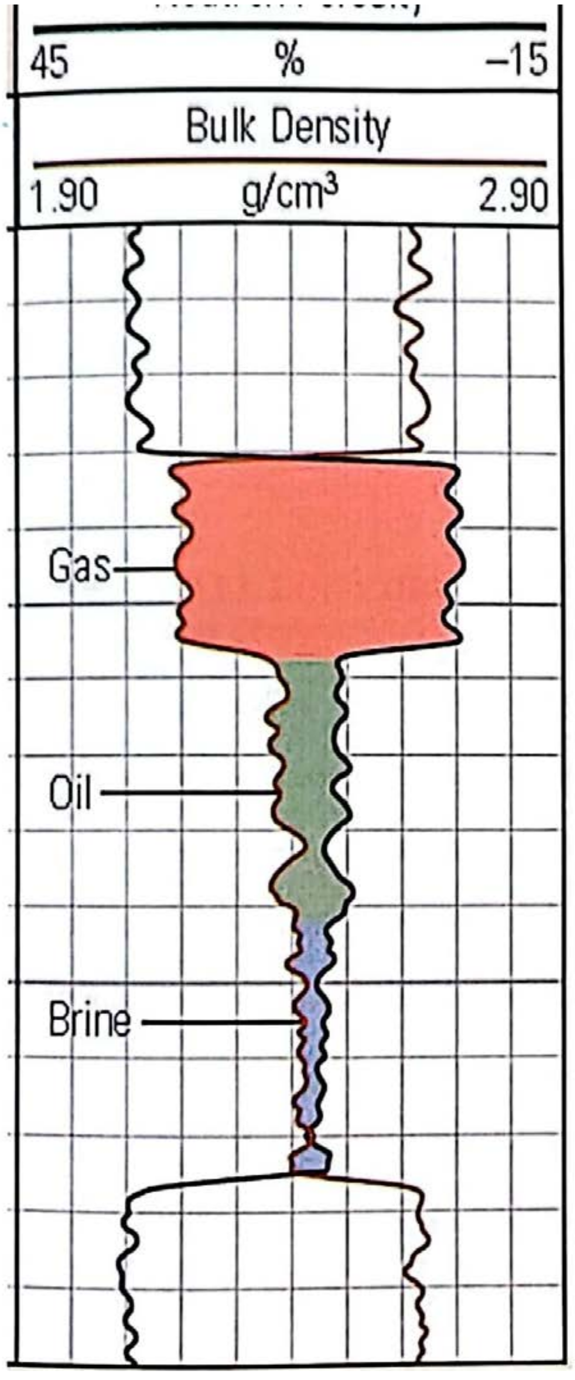


Figure 2: Fluid type from Neutron-Density overlay.

2.6.5 **Resistivity Logs**

Resistivity logs measures the electric properties of the formation. Resistivity is the inverse of conductivity. The ability to conduct electric current depends upon: the volume of water, the temperature of the formation, the salinity of the formation. Resistivity logs measure the ability of rocks to conduct electrical current and are scaled in units of ohm-m. Resistivity logs are mainly use for hydrocarbon delineation and also for identifying permeable zones. This log can also be used for water saturation estimation.

2.7**Well Log Correlation**

The process of correlation of log units in a stratigraphic sequence involves the use of various parameter, such as fossil content, lithologic facies, etc in mapping the lateral continuity and equivalence of these unit. However, this can also be achieved by using gamma ray log singly or in combination with some other logs that is descriptive of the characteristics of individual beds within a given stratigraphic sequence. The gamma ray log and the resistivity log were used to correlate lithologic unit across four wells in this study.

The maker bed is first identified and correlated. Marker beds are lithological units that are laterally extensive and visible in most part of the well. Once the maker beds have been established, the member of the stratigraphic sequence can then be correlated with respect to the trend of the marker beds. Well correlation is of particular importance because it allows for the deduction of the presence of fault and geological structures intersecting the wells.

2.8. Petrophysical Interpretation

The log data (in LAS format) of all the 6 wells namely Well 1, Well 2, Well 3, Well 4, Well 5 and Well 6 were loaded into Interactive Petrophysics and used to generate curves. Gamma Ray curve was placed in track 1; Resistivity (Micro resistivity, Shallow, Medium and deep) curves were placed in track 2 while Density and Neutron were placed in track 3. Both qualitative interpretation and quantitative interpretation was carried out.

2.8.1 Qualitative Interpretation of Logs

Permeable zones (sands) were differentiated from non-permeable zones using GR and Neutron/Density logs. The gamma and resistivity logs characteristics were employed in the correlation analysis. Based on this, tops and bases of hydrocarbon sand units were delineated in all the six wells. Hydrocarbon-bearing intervals were discriminated from water-bearing intervals using the resistivity logs (especially deep resistivity). Fluid Contacts (OWC/ODT) were therefore inferred from resistivity logs. Fluid typing (oil, gas or water) was done using Neutron/ Density logs. Since the area of interest of this project work is in the hydrocarbon bearing sandstones. Twelve hydrocarbon bearing sandstone beds ere successively mapped and their respective tops and base was mapped. But for this study the first six sandstone beds were used.

2.8.2 Fluid Distribution and Delineation

An integrated approach was used to establish fluid contacts. Fluid contacts seen by wells were taken as the actual contacts in the reservoirs. The contacts in the wells were identified using the logs (resistivity and density-neutron), and delineated by log correlation.

2.8.3 Quantitative Interpretation

The well log data were used for quantifying rock properties in S.M.T. Kingdom software.

2.8.3.1 Porosity Determination

Total porosity was estimated majorly from density logs using a matrix density and fluid density.

The effective porosity was then deduced by introducing shale volume into the equation. Equations1, 2 and 3 below were used in the computation.

$$ØT = (\rho ma - \rho B)/(\rho ma - \rho f) \quad 1.0$$

$$ØTsh = (\rho ma - \rho sh)/(\rho ma - \rho f) \quad 2.0$$

$$ØE = ØT - (ØTsh * VSH) \quad 3.0$$

Where $\boldsymbol{\rho ma}$ is the Matrix Bulk density,

$\boldsymbol{\rho sh}$ is the Shale Bulk density,

pf is the fluid density (density log reading in 100% water),

PB is the Bulk density (density log reading in the zone of interest),

VSH is the Volume of shale,

ΦT is the Total porosity in the zone of interest,

ΦTsh is the Total porosity in shale,

ΦE is the Effective porosity in the zone of interest.

Table 1: Common values of matrix density (pma) are given below: -

Rock type	Matrix density(g/cm)
Sand/sandstone	2.65
Limestone	2.71
Dolomite	2.87
Anhydrite	2.98

2.8.3.2 **Water Saturation Determination**

Water saturation was estimated from Archie's and Modified Simandoux equations. In order to estimate water saturation from any of the methods, Formation water resistivity (Rw) and formation resistivity (Rt) needs to be estimated. Therefore, Sw (Archie's equation) was then estimated using the Rw, Rt and Φ; local correction factor or tortuosity factor (a) of 1 was assumed; saturation exponent (n) of 2 was also assumed; and cementation exponent (m) of 1.80-1.82. Equation 4 was used for computation.

$$SW = \left(\frac{a * R_w}{R_t * \phi_t^m} \right)^{\frac{1}{n}} \text{(Archie's equation)} \qquad 4.0$$

Note that Sh = 1 - Sw

Where Sw is the Water saturation,

Sh is the hydrocarbon saturation,

a is the tortuosity factor,

n is the saturation exponent,

m is the cementation exponent,

Φ is the porosity and

Rw is the formation water resistivity,

Rt is the formation resistivity

Since the Niger Delta consists mainly of sandstone reservoirs,2.65g/cm3 was used forthis work.

From the combination of both neutron and density logs, a combination porosity is derived which is more accurate. The method used is the root mean square formula given as: -

$$\Phi N.D = \sqrt{(\Phi N^2 . \Phi D^2)/2} \qquad 5.0$$

Where $\Phi N.D$ is also represented as ΦT and is the true porosity

Porosity derived from neutron log

ΦD= porosity derived from density log

Water saturation (Sw) and Hydrocarbon saturation (Sh): -

Water saturation (Sw) is the fraction (or percentage) of the pore volume of the reservoir that is filled with water. It is generally assumed, unless otherwise known that the pore volume not filled with water is filled with hydrocarbon. Determining water and hydrocarbon saturation is one of the basic objectives of well logging. This could be determined mathematically or by using appropriate charts.

The first step to determine water saturation is to calculate the resistivity of the formation water (Rw) in water saturated zone (below the OWC).

Thus, we assume that Sw=100%=1 and

Rw=Φ2.R1/a 6.0

Where a is a constant and is equal to 0.81

After calculating for Rw, the value is substituted in the formula.

$$Sw = \sqrt{\frac{a.\,Rw}{\Phi 2.\,Rt}} \quad 7.0$$

In a hydrocarbon bearing zone.

From the water saturation, we can calculate for hydrocarbon saturation (Sh) using the formula:

S_h=1-S_w 8.0

Hydrocarbon in place: -

This is a product of the porosity, Φ and hydrocarbon saturation, Sh.

Formation factor: -

This was calculated using the formula

$$\mathbf{F = a/\Phi^2} \quad 9.0$$

Where a=0.81

Irreducible water saturation (Swirr): -

In a water wet formation, there is always a certain amount of water held in the pores by capillary force. This water cannot be displaced by oil at pressures encountered in the formations, so the water saturation never reaches zero. This value of water saturation is called irreducible water saturation (Swirr) and is given by:

$$Swirr = \sqrt{F/2000} \quad 10.0$$

Where F= formation factor

Bulk Volume of Water

The bulk volume of water (BVW) is the percentage of the total rock that is occupied by water.

$$BVW=S_w*Ø \quad 11.0$$

Permeability

This is the property of a rock that has to transmit fluids. It is related to porosity but not always dependent upon it and it is controlled by the size of the connecting passages between pores. It is measured in Darcies and represented with the symbol K.

$$K=[250*(Ø^3/Swirr)]^2 \quad 12.0$$

NET TO GROSS

This calculated by subtracting the volume of shale from 1 (where 1.0 =100% sand content).

$$NTG=1 - V_{sh} \quad 13.0$$

2.9. **Interpretation of Depositional Environments**

Manual interpretation of lithology from well logs should be undertaken using all the logsregistered. Composite log (correlation, resistivity and porosity logs) were used in theinterpretation of lithology and lithofacies. The final lithology may appear on this composite plotor, may be transferred to a document with only the logs used for correlation to avoid overclustering.

Interpretation involves both horizontal and vertical routine checks. The horizontal routine considers all the logs available for a particular well. It entails: -

1.The visual inspection of the logs for the formation of interest on a correlation log, GR for example and then a continuous horizontal observation for similar characteristic. Where all the logs corroborate the same interpretation, the lithology is noted.

2. Although the horizontal routine is the basis for any lithological interpretation, individual logs should also be examined vertically for trends, baselines or absolute values. For gamma ray log, a shale baseline can be drawn. This used to delineate sand-shale sequences in relatively simple lithologic zones (e.g Niger Delta).

Density-neutron combination when plotted on a compatible scale can be excellent indicators of lithology as well as fluid content and type. Thus, a certain amount of preparation of the compositeplot in the vertical sense can aid in the horizontal routines. On a basis of log shapes anddiagnostic log patterns, the depositional environments were inferred.

3.1**Results and Discussion**

All interpretation and analysis have been carried out on a 3D seismic data with inline range of 8,000 to 10,300 and cross line range of 54,200 to 57,400. Eight wells were given in the well log data (Well 1, Well 2, Well 3, Well 4, Well 5, Well 6, Well 7 and Well 8) and 6 six were used for this project because Well 7 and Well 8 were far from the other well.

3.2**Well Log Correlation**

Thirteen reservoirs sands were mapped and correlated across the six wells but only six sands were studied for this project Figure 3 and 4. The correlation show that the reservoirs are laterally continuous and bounded by correlatable shale units.

3.3 **Reservoir Properties**

Reservoir properties (especially porosity, water saturation and hydrocarbon saturation) are moderately good. The porosity, permeability, water saturation and hydrocarbon saturation vary across the wells.

3.3.1 **Hydrocarbon Reservoir Unit One**

This reservoir unit was mapped across the six wells. Well 1, Well 2, Well 3, Well 4, Well 5 and Well 6 all contain this reservoir unit at different depth and thickness, Figure 3 and 4.

Well 1 Well 2 Well 3
Well 2

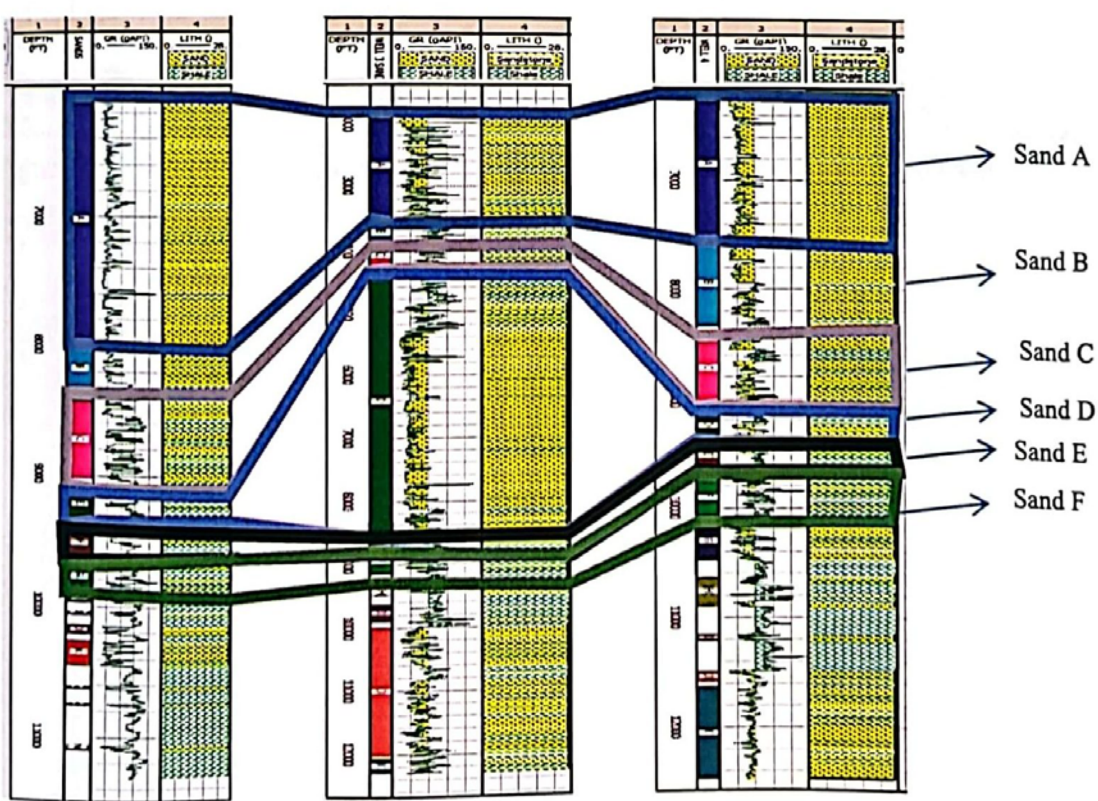


Figure 3: Cross-sectional view of the Mapped Reservoir Sands across Wells 1-3

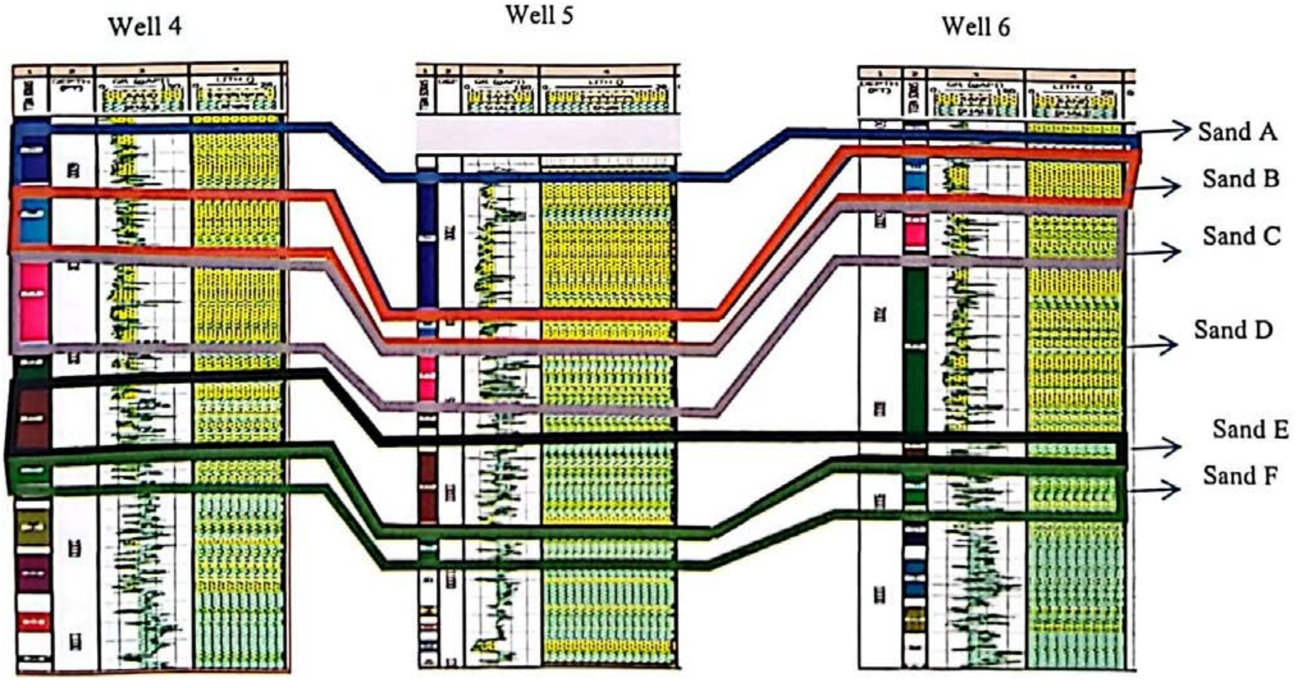


Figure 4: Cross-sectional view of the Mapped Reservoir Sands across Wells 4-6

Table 2: Tabular Presentation of the Results and Interpretation of Reservoir unit One.

Well Name/Properties	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Formation Top(ft) TVD	6070.00	1804.50	6161.50	5413.39	6234.00	4921.26
Formation Bottom(ft)TVD	7977.00	3567.50	7533.00	6128.40	7889.50	5085.80
Gross Thickness(m)	1907.00	1763.00	1371.50	715.01	1655.50	164.54
Net Thickness(m)	1754.25	-	968.71	0.00	1653.50	69.79
Net/Gross	0.920		0.706	-	0.999	0.424
Phi(Φ)	0.292		0.297		0.306	0.392
(Φe)	0.2424		0.0342		0.2944	0.3610
Water Saturation(Sw)	1.000		0.115	-	0.091	0.155
Vsh	0.170		0.042		0.038	0.079
Sh		1.000	0.885	1.000	0.909	0.845
Swirr	0.0689		0.0678		0.0660	0.0515
BVW	0.2424		0.0039		0.0268	0.0560
K	0.1260		0.1443		0.1707	0.8336

The sand unit is found in Well 1 at a near depth of 6070.00ft (Marker Top) and its base is found at depth 7977.00ft with gross thickness of 1907.00m (thick). The Net thickness is 1754.25m and the permeability is 0.1260 (relatively low).

At Well 2, this reservoir unit was discovered to exist at depth 1804.50ft (Maker top) and bounded at the base at depth 3567.0ft (Maker base). The bed thickness is estimated to be 1763.00m (considerably thick). No resistivity value was recorded at this depth for the well, hence the fluid cannot be determined.

Reservoir unit in Well 3 was found at depth 6161.50ft (Maker top) and the base found at 7533.00ft (Marker base). Net thickness of 968.71m and it has a permeability of 0.1443.

At Well 4, the same reservoir unit was discovered to exist at depth is found 5413.39ft (Maker top) and bounded at the base at depth 6128.40ft. The net thickness is estimated to be 968.71m. The well has no permeability and cannot transmit fluid.

Reservoir unit in Well 5 was found at depth 6234.00ft (Maker top) and the base found at 7889.50ft (Marker base). Net thickness of 1653.50m and it has a permeability of 0.1707.

At Well 6, the same reservoir unit was discovered to exist at depth is found 4921.26ft(Maker top) and bounded at the base at depth 5085.80ft. The net thickness is estimated to be 69.79m. The well has permeability of 0.8336 and can transmit fluid more than the other wells.

3.3.2 **Hydrocarbon Reservoir Unit Two**

The sand unit is found in Well 1 at a near depth of 7997.50ft (Marker Top) and its base is found at depth 8356.00ft with gross thickness of 358.50m (thick). The Net thickness is 250.50m and the permeability is 0.0471 (relatively low).

At Well 2, this reservoir unit was discovered to exist at depth 3617.50ft (Maker top) and bounded at the base at depth 3880ft (Maker base). The bed thickness is estimated to be 1754.25m (considerably thick). There is no Permeability value.

Reservoir unit in Well 3 was found at depth 7551.50ft (Maker top) and the base found at 8338.0ft (Marker base). Net thickness of 786.5m and it has a permeability of 0.0083.

At Well 4, the same reservoir unit was discovered to exist at depth is found 6143.3ft (Maker top) and bounded at the base at depth 6781.9ft. The net thickness is estimated to be 630.76m. The well has permeability of 0.2107.

Reservoir unit in Well 5 was found at depth 7930.00ft (Maker top) and the base found at 8217.50ft (Marker base). Net thickness of 287.50m and it has a permeability of 0.3243. (moderately permeable)

At Well 6, the same reservoir unit was discovered to exist at depth is found 5170.80f(Maker top) and bounded at the base at depth 5682.30ft. The net thickness is estimated to be 510.00m. The well has permeability of 0.6800 and can transmit fluid more than the other wells.

Table 3: Tabular Presentation of the Results and Interpretation of Reservoir unit Two.

Well Name /Properties	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Formation Top(ft) TVD	7997.50	3617.50	7551.50	6143.30	7930.00	5170.80
Formation Bottom(ft) TVD	8356.00	3880.00	8338.00	6781.90	8217.50	5682.30
Gross Thickness(m)	358.50	262.50	786.50	638.60	287.50	511.50
Net Thickness(m)	250.50	-	786.50	630.76	287.50	510.00
Net/Gross	0.920	-	1.000	0.988	1.000	0.997
Phi	0.250	-	0.273	0.316	0.296	0.379
(Φe)	0.1875		0.2580	0.0275	0.2806	0.3673
Water Saturation (Sw)	1.000		0.141	0.087	0.109	0.0700
Vsh	0.250		0.055	0.050	0.052	0.0310
Sh		1.000	0.859	0.913	0.891	0.930
Swirr	0.2546		0.0737	0.0637	0.0678	0.0529
BVW	0.1875		0.0364	0.0024	0.0306	0.0257
K	0.0471		0.0083	0.2107	0.3243	0.6800

3.3.3 **Hydrocarbon Reservoir Unit Three**

The sand unit is found in Well 1 at a near depth of 8422.00ft (Marker Top) and its base is found at depth 9030.50ft. The Net thickness is 386.00m and the permeability is 0.0127 (relatively low).

At Well 2, this reservoir unit was discovered to exist at depth 3927.50ft (Maker top) and bounded at the base at depth 4283.00ft (Maker base). The Net thickness is 355.50 and no permeability is recorded.

Reservoir unit in Well 3 was found at depth 8412.50ft (Maker top) and the base found at 9032.00ft (Marker base). Net thickness of 618.00m and it has a permeability of 0.0276.

At Well 4, the same reservoir unit was discovered to exist at depth is found 6793.90ft (Maker top) and bounded at the base at depth 7826.40ft. The net thickness is estimated to be 1021.50m. The well has permeability of 0.1126 and transmit fluid slowly.

Reservoir unit in Well 5 was found at depth 8361ft (Maker top) and the base found at 8947ft (Marker base). Net thickness of 1653.50m and it has a permeability of 0.0290.

At Well 6, the same reservoir unit was discovered to exist at depth is found 8361.00f(Maker top) and bounded at the base at depth 6282.30ft. The net thickness is estimated to be 583.00m. The well has permeability of 0.5729 and can transmit fluid more than the other wells.

Table 4: Tabular Presentation of the Results and Interpretation of Reservoir unit Three.

Well Name/Properties	Well 1	Well 2	Well 3	Well 4	Wel1 5	Well 6
Formation Top(ft) TVD	8422.00	3927.50	8412.50	6793.90	8361.00	5699.30
Formation Bottom(ft)TVD	9030.50	4283.00	9032.00	7826.40	8947.00	6282.30
Gross Thickness(m)	608.50	1763.00	619.50	1032.50	586.00	583.00
Net Thickness(m)	386.00	355.50	618.00	1021.50	579.50	583.00
Net/Gross	0.920	-	0.998	0.989	0.989	1.000
Phi	0.216		0.230	0.286	0.232	0.369
(Φe)	0.2237		0.0764	0.2700	0.2046	0.2177
Water Saturation (Sw)	1.000		0.332	0.101	0.344	0.078
Vsh	0.234		0.113	0.056	0.118	0.041
Sh		1.000	0.668	0.899	0.656	0.922
Swirr	0.0689		0.0875	0.0704	0.0866	0.0543
BVW	0.2237		0.2536	0.0273	0.0704	0.0170
K	0.0127		0.0276	0.1126	0.0290	0.5729

3.3.4 **Hydrocarbon Reservoir Unit Four**

The sand unit is found in Well 1 at a near depth of 9096.50 ft (Marker Top) and its base is found at depth 9345.50ft. The Net thickness is 132.00m and the permeability is 0.0185 (relatively low).

At Well 2, this reservoir unit was discovered to exist at depth 4325.50ft (Maker top) and bounded at the base at depth 8498.50ft (Maker base). The Net thickness is 2336.25m and permeability is 0.1272.

Reservoir unit in Well 3 was found at depth 9119.50ft (Maker top) and the base found at 9360.50ft (Marker base). Net thickness of 240m and it has a permeability of 0.0308.

At Well 4, the same reservoir unit was discovered to exist at depth is found 7848.90ft (Maker top) and bounded at the base at depth 8226.40ft. The net thickness is estimated to be 377.50m. The well has permeability of 0.913 and transmit fluid slowly.

Reservoir unit in Well 5 was found at depth 9039.00ft (Maker top) and the base found at 9269.00ft (Marker base). Net thickness of 229.00m and it has a permeability of 0.0344.

At Well 6, the same reservoir unit was discovered to exist at depth is found 6313.30f(Maker top) and bounded at the base at depth 8355.80ft. The net thickness is estimated to be 2042.50m. The well has permeability of 0.2951 and can transmit fluid more than the other wells.

Table 5: Tabular Presentation of the Results and Interpretation of Reservoir unit Four.

Well Name/Properties	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Formation Top(ft) TVD	9096.50	4325.50	9119.50	7848.90	9039.00	6313.30
Formation Bottom(ft)TVD	9345.50	8498.50	9360.50	8226.40	9269.00	8355.80
Gross Thickness(m)	249.00	4173.00	241.00	377.50	230.00	2042.50
Net Thickness(m)	132.00	2336.25	240.00	377.50	229.00	2042.50
Net/Gross	0.920	0.560	0.996	1.000	0.996	1.000
Phi	0.2160	0.292	0.235	0.277	0.238	0.333
(Φe)	0.1523	0.2768	0.2052	0.2512	0.1085	0.3140
Water Saturation (Sw)	1.000	0.107	0.455	0.146	0.456	0.095
Vsh	0.295	0.052	0.127	0.093	0.159	0.057
Sh		0.893	0.545	0.854	0.544	0.905
Swirr	0.0930	0.0866	0.0857	0.0725	0.0846	0.0604
BVW	0.1523	0.0296	0.0934	0.0367	0.0495	0.0298
K	0.0185	0.1272	0.0308	0.0913	0.0344	0.2951

3.3.5 **Hydrocarbon Reservoir Unit Five**

The sand unit is found in Well 1 at a near depth of 6070.00ft (Marker Top) and its base is found at depth 7977.00ft. The Net thickness is 1754.25m and the permeability is 0.0291 (relatively low).

At Well 2, this reservoir unit was discovered to exist at depth 8562.00ft (Maker top) and bounded at the base at depth 129.50ft (Maker base). The Net thickness is 129.50m and permeability are 0.0269 (relatively low).

Reservoir unit in Well 3 was found at depth 9423.50ft (Maker top) and the base found at 9627.50ft (Marker base). Net thickness of 195.50m and it has a low permeability value of 0.0093.

At Well 4, the same reservoir unit was discovered to exist at depth is found 8301.40ft (Maker top) and bounded at the base at depth 8958.40ft. The net thickness is estimated to be 147.24m. The well has permeability of 0.0867 and transmit fluid slowly.

Reservoir unit in Well 5 was found at depth 9525.00ft (Maker top) and the base found at 10344.50ft (Marker base). Net thickness of 815m and it has a low permeability value of 0.0403. At Well 6, the same reservoir unit was discovered to exist at depth is found 8424.80ft (Maker top) and bounded at the base at depth 8554.80ft. The net thickness is estimated to be 130m. The well has permeability of 0.2029 and can transmit fluid more than the other wells.

Table 6: Tabular Presentation of the Results and Interpretation of Reservoir unit Five.

Well Name/Properties	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Formation Top(ft) TVD	6070.00	8562.00	9423.50	8301.40	9525.00	8424.80
FormationBottom(ft)TVD	7977.00	8691.50	9627.50	8958.40	10344.50	8554.80
Gross Thickness(m)	1907.00	129.50	204.00	657.00	819.50	130.00
Net Thickness(m)	1754.25	129.50	195.50	147.24	815.00	130.00
Net/Gross	0.920	1.000	0.958	0.224	0.995	1.000
Phi	0.232	0.229	0.194	0.275	0.244	0.314
(Φe)	0.1550	0.2145	0.1515	0.2401	0.2172	0.2807
Water Saturation (Sw)	1.000	0.267	0.511	0.203	0.293	0.189
Vsh	0.332	0.063	0.219	0.127	0.110	0.106
Sh		0.733	0.489	0.797	0.707	0.811
Swirr	0.0869	0.0877	0.1037	0.0731	0.0825	0.0640
BVW	0.1550	0.0572	0.0774	0.0487	0.0634	0.0531
K	0.0291	0.0269	0.0093	0.0867	0.0403	0.2029

3.3.6 **Hydrocarbon Reservoir Unit Six**

The sand unit is found in Well 1 at a depth of 9682.00ft (Marker Top) and its base is found at depth 9862.00ft. The Net thickness is 108.00m and the permeability is 0.0096 (relatively low).

At Well 2, this reservoir unit was discovered to exist at depth 8742.50ft (Maker top) and bounded at the base at depth 9146.00ft (Maker base). The Net thickness is 403.50m and permeability is 0.0629.

Reservoir unit in Well 3 was found at depth 9698.50ft (Maker top) and the base found at 10097.00ft (Marker base). Net thickness of 394.50m and it has a low permeability value of 0.0107.

At Well 4, the same reservoir unit was discovered to exist at depth is found 9024.40ft (Maker top) and bounded at the base at depth 9302.90ft. The net thickness is estimated to be 278.50m. The well has permeability of 0.0506 and transmit fluid slowly.

Reservoir unit in Well 5 was found at depth 10500.0ft (Maker top) and the base found at 10752.50ft (Marker base). Net thickness of 250.50m and it has a low permeability value of 0.0068.

At Well 6, the same reservoir unit was discovered to exist at depth is found 8606.80ft (Maker top) and bounded at the base at depth 9036.80ft. The net thickness is estimated to be 130m. The wellhas permeability of 0.1474 and can transmit fluid more.

Table 7: Tabular Presentation of the Results and Interpretation of Reservoir unit Six.

Well Name/Properties	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Formation Top(ft) TVD	9682.00	8742.50	9698.50	9024.40	10500.0	8606.80
Formation Bottom(ft)TVD	9862.00	9146.00	10097.00	9302.90	10752.50	9036.80
Gross Thickness(m)	180.00	403.50	398.50	278.50	252.50	430.00
Net Thickness(m)	108.00	403.50	394.50	276.00	250.50	430.00
Net/Gross	0.920	1.000	0.990	0.991	0.992	1.000
Phi	0.195	0.208	0.198	0.253	0.185	0.299
(Φe)	0.1351	0.1718	0.1681	0.1958	0.1591	0.2392
Water Saturation(Sw)	1.000	0.443	0.420	0.431	0.377	0.288
Vsh	0.307	0.174	0.151	0.226	0.140	0.200
Sh		0.557	0.580	0.590	0.623	0.712
Swirr	0.1032	0.0465	0.1015	0.0797	0.1089	0.0675
BVW	0.1351	0.0761	0.0706	0.0843	0.0600	0.0689
K	0.0096	0.0629	0.0107	0.0506	0.0068	0.1474

From the table and chart below it was delineated that Well 2 had the lowest porosity and the fluid in it may require pressure to be extracted if in economic quantity. It can also be inferred that the sandstone in Well 2 is more compacted than the other wells and this also means that there is a reduction in permeability in Well 2.

The Average porosity of all the wells used for this study is relatively high.

Table 8: Porosity at each sand depth

SN	Wells	Sand A		Sand B		Sand C		Sand D		SandE		Sand F		Average Porosity
		Top and Bottom depth (Ft)	Porosity	Top and Bottom depth (Ft)	Porosity	Top and Bottom depth (Ft)	Porosity	Top and Bottom depth (Ft)	Porosity	Top and Bottom depth (Ft)	Porosity	Top andBottom depth (Ft)	Porosity	
1	Well 1	6070.00-7977.00	0.292	7997.5083 56.00	0.250	8422.00 9030.50	0.216	9096.50 9345.50	0.216	9435.50 9610.50	0.232	9632.00 9852.00	0.195	0.2335
2	Well 2	1804.50-3567.50	一	3617.50 3880.00	一	3927.50 4283.00	-	4325.50 8498.50	0.292	8562.00 8691.50	0.229	8742.50 9146.00	0.208	0.1215
3	Well 3	6161.50-7533.00	0.297	7551.50 8338.00	0.273	8412.50 9032.00	0.230	9119.50 9360.50	0.235	9423.50 9627.50	0.194	9698.50 10097.00	0.198	0.2378
	Wall 4	5413.39-6128.40	-	6143.30 6781.90	0.316	6793.90 7826.40	0.286	7848.90 8226.40	0.277	8301.40 8958.40	0.275	9024.40 9302.90	0.253	0.2345
5	Well 5	6234.00-7889.50	0.306	7930.00 8217.50	0.296	8361.00 8947.00	0.232	9039.00 9269.00	0.238	9525.00 10344.50	0.244	10500.00 10752.50	0.185	0.2502
6	Well 6	4921.26-5085.80	0.392	5170.80 - 5682.30	0.379	5699.30 6282.30	0.369	6313.30 8355.80	0.333	8424.80 8554.80	0.314	8606.80 9036.80	0.299	0.3477

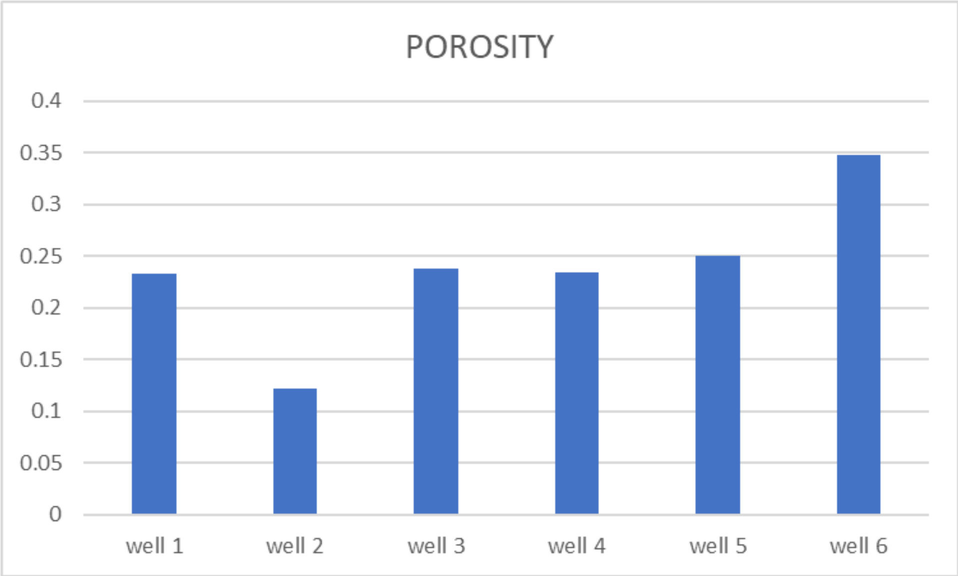


Figure 5:Porosity of each well

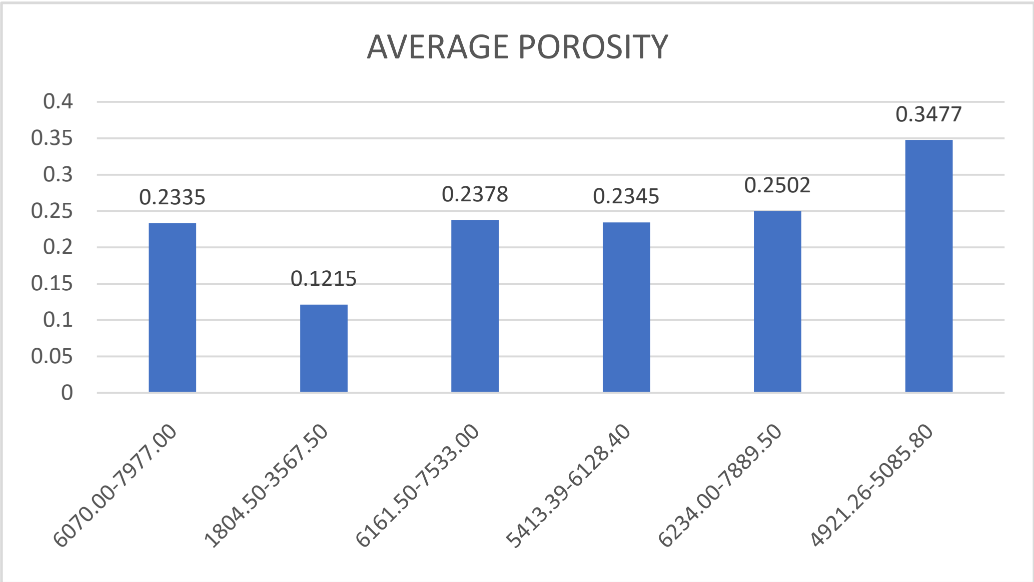


Figure 6: The average porosity of the wells

From figures 7 and 8, it can be deduced that the wells have fluid in this case oil in economical amounts at various depth.

WELL 1 WELL 2 WELL 3

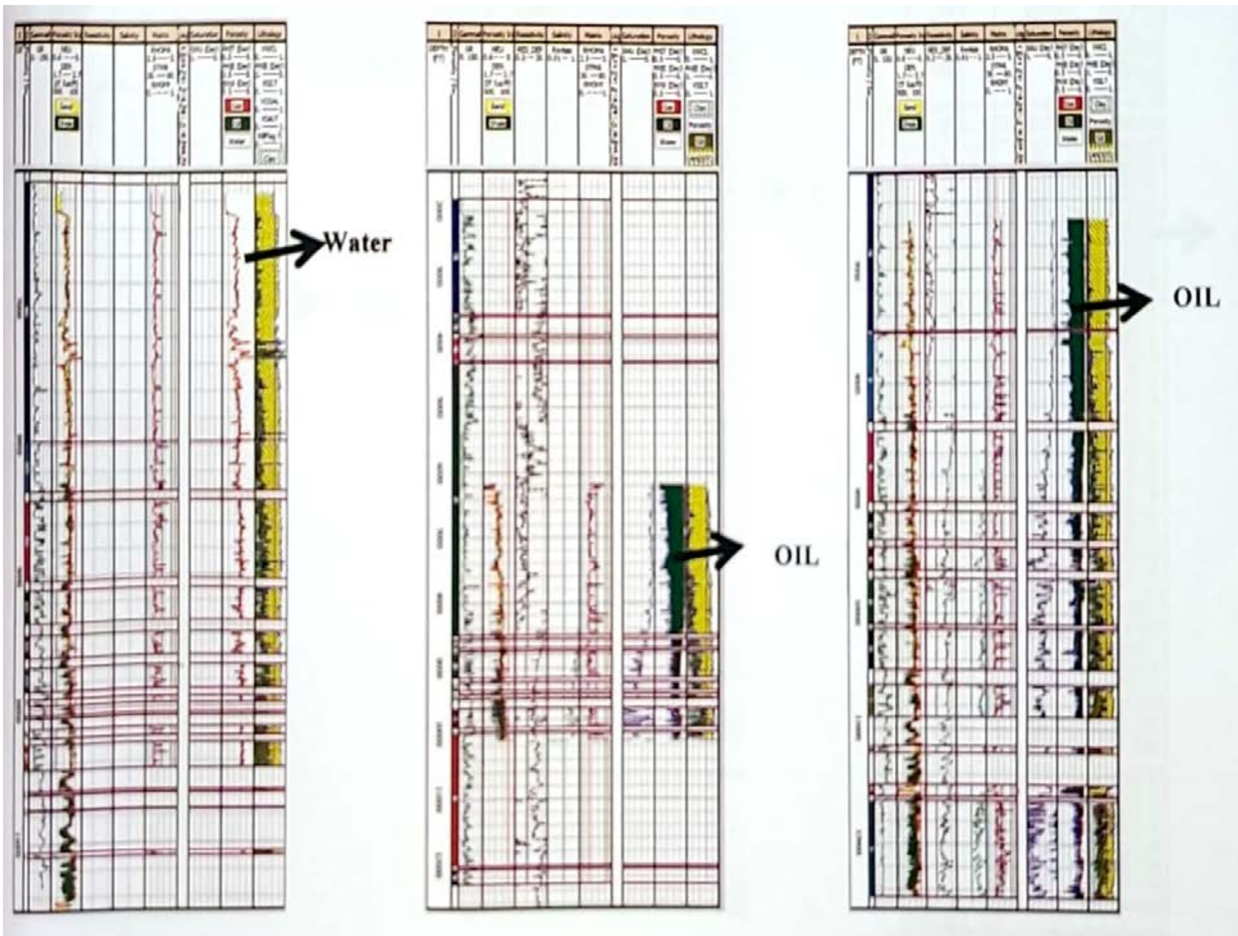


Figure 7: Porosity plot of Well 1, Well 2 and Well 3

WELL 4 WELL 5 WELL 6

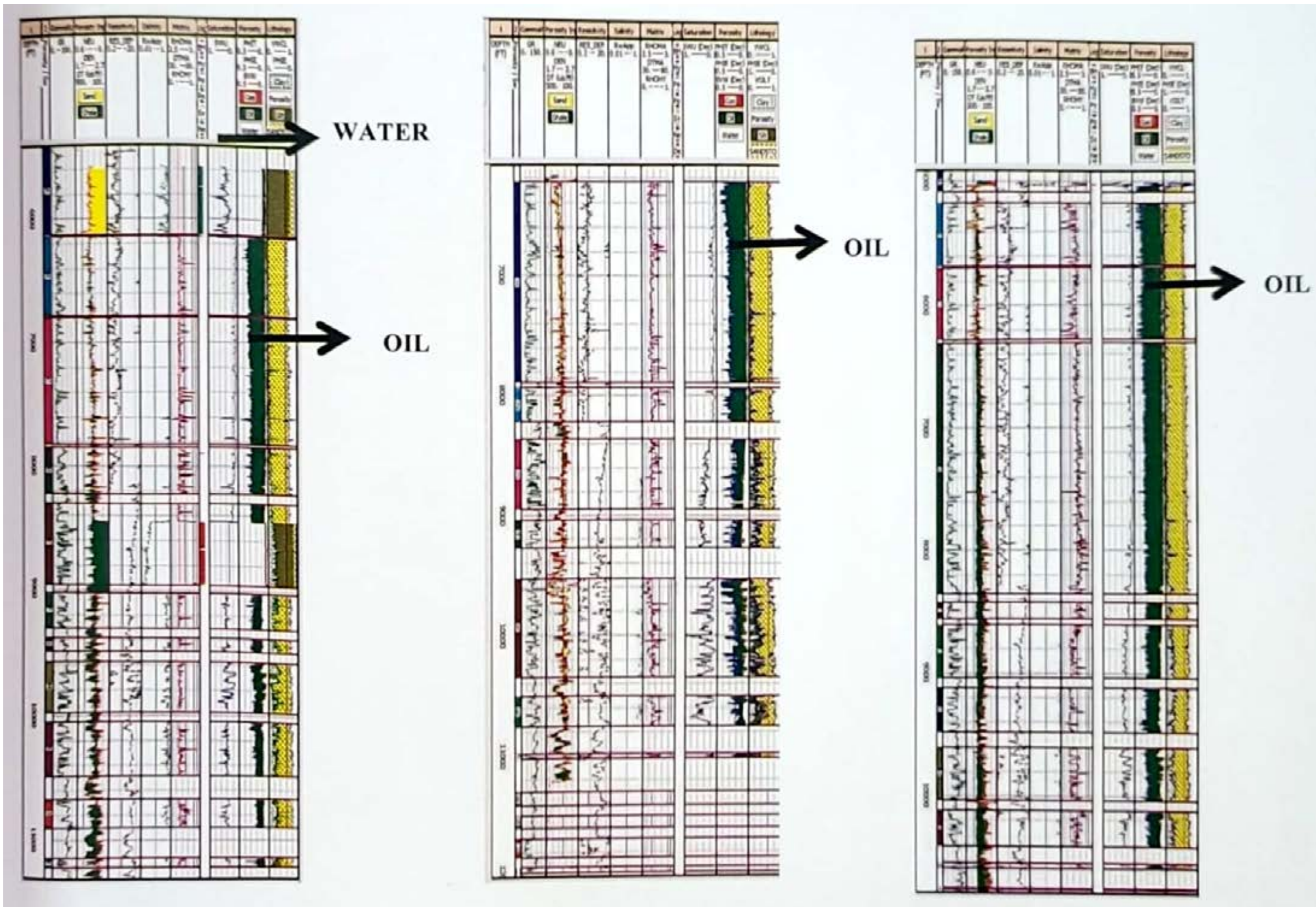


Figure 8: Porosity plot of Well 4, Well 5 and Well 6

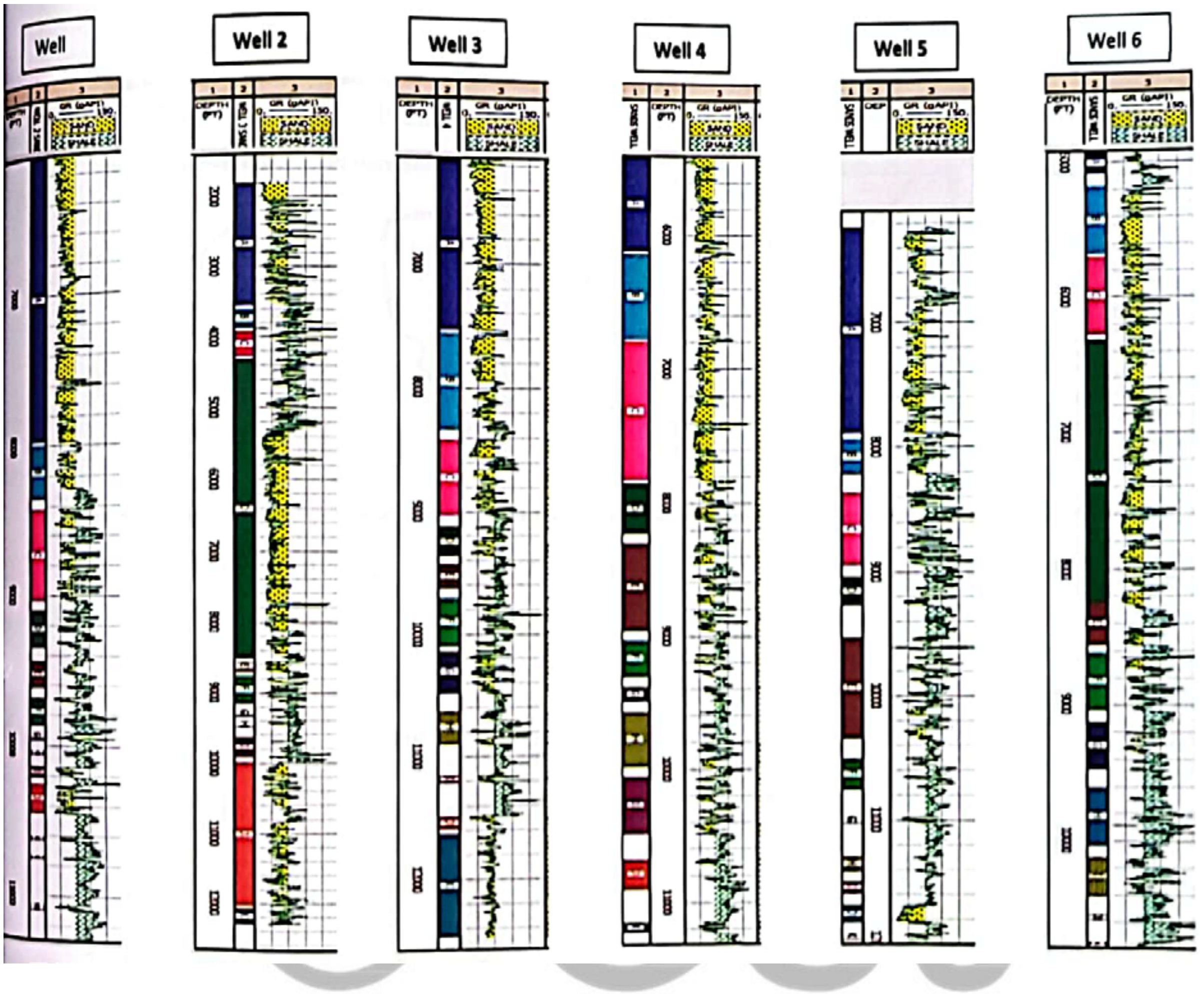


Figure 9: Depositional pattern of the wells

3.4 **FUNNEL SHAPES**

Based on geology funnel shape is a coarsening-up succession which can be divided into three categories namely; Regressive barrier bars, prograding marine shelf fans and prograding delta or crevasse splays.

The first two environments are commonly deposited with glauconite, shell debris, carbonaceous detritus and mica. The crevasse splay is a deposit of deltaic sediments formed after the flooding of the bank which leads to fan-shaped sand deposit on the delta plain. Generally, a funnel shape is a coarsening-up succession which may be a deltaic progradation or a shallow marine progradation (Figure 12). The analogies may even be extended to deep sea deposits. In these cases, the log shapes are those of overall successions rather than individual bodies.

Also, shapes on the gamma ray log can be interpreted as grain-size trends and, by sedimentological association as facies successions. A decrease in gamma ray values will indicate an increase in grain size: small grain sizes will correspond to higher gamma ray values. The sedimentological implication of this relationship leads to a direct correlation between facies and log shape not just for the bell shape and funnel shape as described above, but for a whole variety of shapes.

3.5 **CYLINDRICAL SHAPES**

It shows relatively consistent gamma ray readings, indicates no systematic change in grain size or thickness of interbeds and abrupt upper and lower contacts. It also shows even block with sharp top and base. It is indicative of aggrading condition. The Cylindrical-shaped GR log pattern is indicative of environments such as aeolian, braided fluvial, distributary channel-fill, submarine canyon-fill, carbonate shelf margin, evaporite fill of basin.

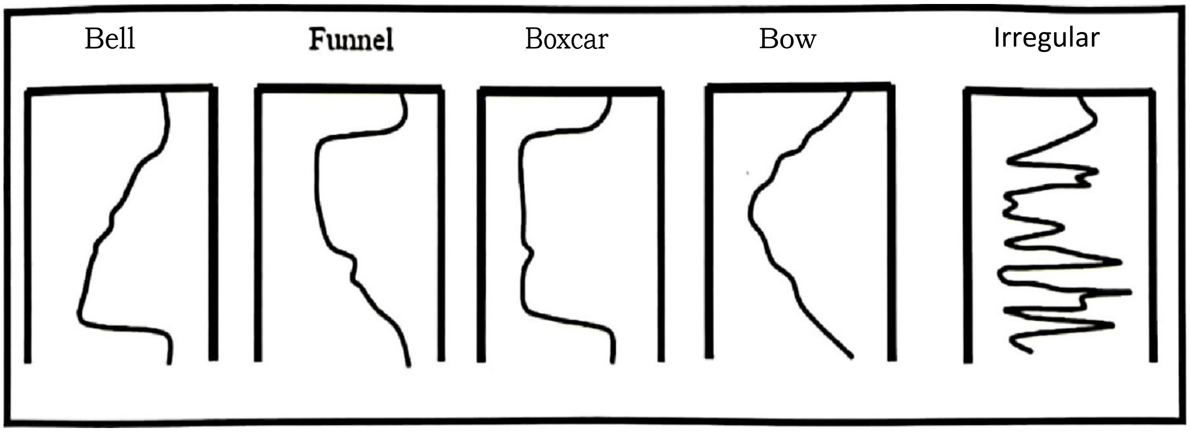


Figure10:Welllogresponsecharacterfordifferentenvironments,(BekaandOti 1995)

Figure11:Welllogresponsecharacterfor differentenvironments.(BekaandOti1995)

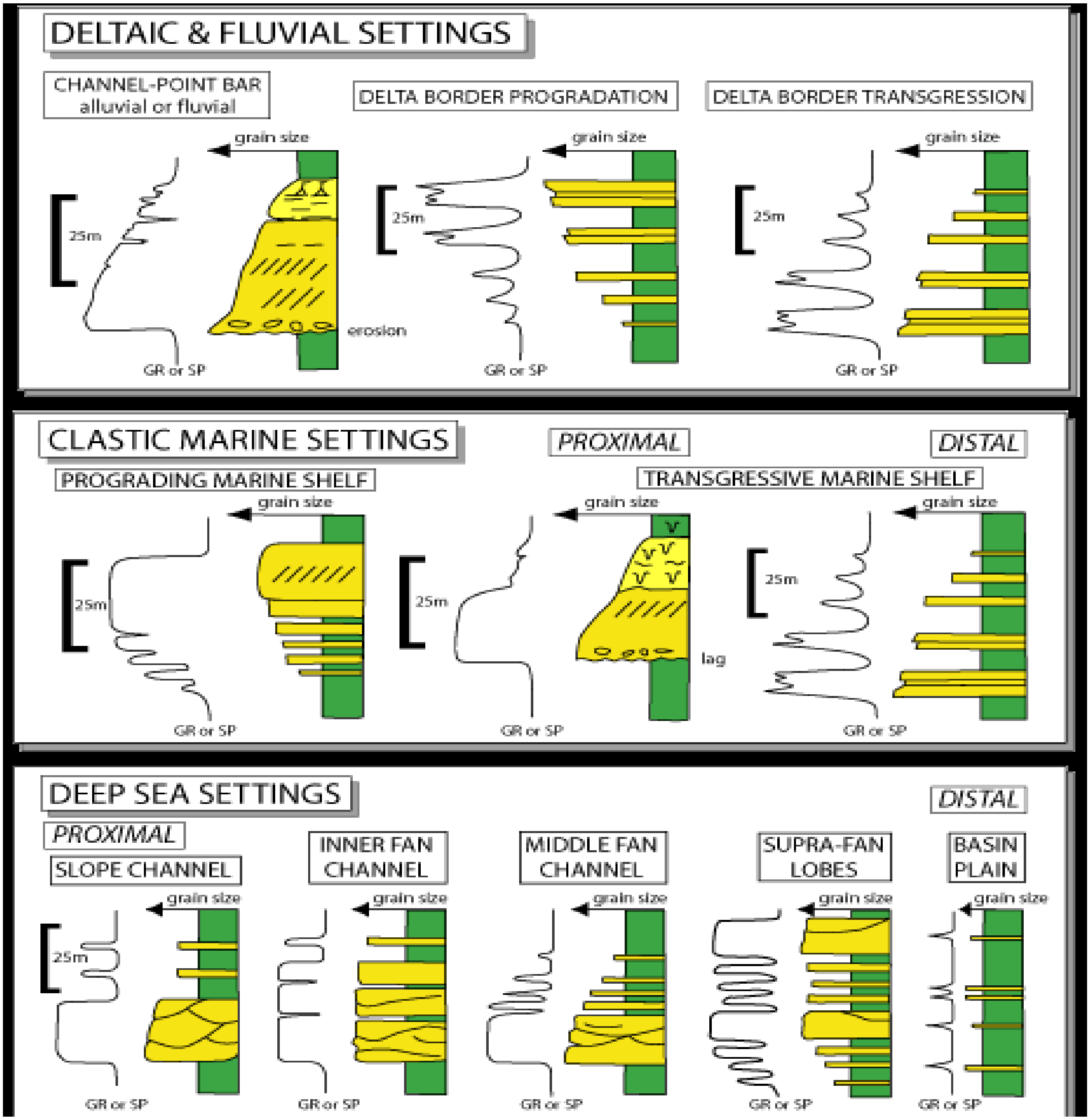


Figure12:Gammaraylog shapes anddepositionalsettings(Rider,1999)

4.CONCLUSION

Any rock may act as a reservoir as long as it fulfills the criteria of a reservoir. The major known reservoirs are sandstone and limestone. Sandstone serves as reservoir in the study.Four composite wire-line logs were integrated to characterize the reservoirs in Y field. The subsurface geology and prospect areas of "Y" field offshore Niger Delta have been studied composite well logs. Eleven hydrocarbon reservoir sand was identified based on log curve signatures of the Gamma ray log, Neutron log, Formation density log, and Resistivity logs but only six were used for this study. Lithologic panels derived from well log data show that the area of study is characterized by sand-shale inter-beds.The petrophysical parameters in some of the reservoirs show that they can aid economic hydrocarbon accumulation. From the petrophysical analysis result, the porosity values of the wells ranged from 19.5 % to 39.2 % and permeability values ranged from 9.6 md to 833.6 md with hydrocarbon saturation ranging from 0.00 % to 93.0 %. Deductions from the six reservoirs shows that they are mostly oi and water saturated. Reservoir 6 is the most prolific reservoir in the field. It is a potential reservoir because it shows good petrophysical values.The result of the qualitative interpretation of the gamma ray and resistivity logs shows that the reservoir contains hydrocarbon of appreciable thickness. The depositional environments obtained from the study are Funnel and Cylindrical shaped. Based on geology funnel shape is a coarsening-up succession which may be a deltaic progradation or shallow marine progradation. The Cylindrical shape shows relatively consistent gamma ray readings, indicates no systematic change in grain size or thickness of interbeds and abrupt upper and lower contacts. It also shows even block with sharp top and base. It is indicative of aggrading condition.The study has been able to highlight the importance of petrophysical evaluation in effectivereservoir characterization and hydrocarbon exploration. Further work such as reservoir modelling and sequence stratigraphy should be done to determine the location and the actual depth where hydrocarbon can be optimally tapped.Within the limits of the available data, it is recommended that further studies should include for interpretation of the depositional environments.As a result of the succinct work carried out on the reservoir sand units, I hereby recommend that seismic interpretations should be done for “Y” in order to clear out every uncertainty left before the commencement of drilling.

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