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Research Article

DEPOSITIONAL ENVIROMENT OF "XY" RESERVOIR SANDS, PAMMA, FIELD, NIGER DELTA, NIGERIA

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ABSTRACT

Geological analysis of core samples and qualitative interpretation of wireline log shapes aided the identification of depositional environments of various XY sand units in Pama oil field. These include distributary channels, mouth bar, point bar, tidal channel, tidal flat, middle shoreface and lower shoreface. The properties of typical sand units indicate that the environments of deposition formed very good reservoirs. The sedimentary core log of cored hydrocarbon bearing intervals showing a depositional interpretation and key sedimentary structures reflects heterogeneities associated with sedimentary processes; that can have impact on hydrocarbon recovery.

INTRODUCTION

A reservoir rock may be defined as a formation that has the capacity to store fluid and have the ability to release the fluid when tapped as a resource (Etu –Efeotor, 1997). Such fluid can be oil, gas or water. Therefore, the exploration for oil and gas in the Niger Delta is actually, the search for hydrocarbon bearing reservoir which is either carbonates or clastics (sandstone and conglomerate). Studies by geologists such as Short and Stauble (1967), Weber and Daukoru (1975), Doust and Omatsola (1990), Reijer (2011), etc reveal that the reservoir rocks in Niger Delta are mainly sandstone.

The exploration and development of a reservoir requires reasonable understanding of its occurrence and morphology. Sandstone occurs in different sedimentary environments, which is a part of the earth's surface that is physically, chemically and biologically distinct from adjacent terrains. (Selley, 1985). The variation in sedimentary environments may be attributed to differences in energy levels, flow velocity and climate, resulting in differences in morphologies and qualities of sandstone reservoir.

The environment of deposition of sediment is the sum of the physical, chemical and biological condition under which it was deposited. These conditions are recorded in the form of sedimentary facies, which is a mass of sedimentary rock that can be defined and distinguished from others by observed rock properties such as lithology, texture, sedimentary structures, geometry, fossils and paleocurrent pattern displayed in sequence on core samples and some in wireline logs. From observed succession of these rock properties in sandstone, a judgment can be made of the transporting medium, the condition of flow at the time of deposition, the nature of the depositional site and then qualitatively predict the quality of the reservoir sand body. According to Tyler et al. (1991), average recovery efficiency of oil could be tied closely to depositional environments and recovery mechanism.

Field Location: The oil field in Niger delta used for this study is personally named " XY Reservoir sand Pamma Field" for the purpose of confidentiality. The field is situated in the eastern part of Greater Ughelli depobelt. It is located within OML 62 and lies between the latitudes 50 ^{0}and 50^{0} 40' north of Equator and longitudes 60^{0} and 60^{0} 55' East of Greenwich Meridian.

Objectives Of Study: The objectives of this study are to use core and wireline logs to investigate the lithological, textural and structural characteristics of sand bodies in the cored intervals and correlate them with wireline log pattern, to establish their probable environments of deposition and also identify and interpret depositional characteristics of non-cored interval using wireline log shape.

METHODOLOGY

Different methods of study have been adopted in this research for the evaluation of the XY reservoir sands. The research materials used are;

(A) DATA AVAILABLE:

- Base map and contour map showing the structural element and location of well.
- Wireline logs (GR, FDC, CNL).
- Core photographs.

(B) PROCEDURES:

The core photographs provided were studied and described from bottom upwards.

The procedure for the description is as follows:

i Close observation of the core photos noting the general characteristics and geological succession.

ii. Boundaries of each core section were noted.

iii. Study of sedimentary structures were carried out noting features like crossbedding ,laminaion e.t.c. The degree of bioturbation was indicated.

iv. Based on the descriptions,lithology and grain size,dominant sedimentary structures, the lithofacies types were determined and interpreted using the lithofacies classification scheme.

v. Core/log Calibration was carried out by using core information to characterized the well the well logs .

RESULT ANALYSIS

(A) FACIES ANALYSIS:

The depositional environments have been inferred for the XY reservoir sand. Reconstruction of the depositional environment is the main aim of facies analysis. Lithofacies can be defined as a body of sediment/rock with specific lithologic and organic characteristics.(grain size, sorting, sedimentary structure) which are impacted by a particular set of energy. Lithofacies can be distinguished in cores but cannot always be distinguished from logs because the resolution of the logs (minimum 2ft) does not allow subtle difference between some lithofacies types. Observation from the cored well 1 was used in the analysis of the Lithofacies type. This classification is based on four descriptors or facies elements (Rider,1996). They are lithology, grain size, and dominant sedimentary structure.

(i) Lithology: This is the first and highest order descriptor. It is grouped into:

Sandstone (S), Heterolithic (H), Mudstone (M)

(ii) Grains Size: This is the second descriptor. Sandstone lithofacies are differentiated into coarse (C), medium (M) and fine grained. Heterolithic lithofacies are differentiated into sandstone (S) mudstone(m).

(iii) Dominant Sedimentary Structure: This is the third descriptor. It can be cross – bedded,wave rippled e.t.c.

(B) GEOLOGICAL CORE ANALYSIS:

Up to three reservoirs were identified in Pama well-1 which were correlated across the three wells and they are labelled Reservoir sand 1,2 and 3.

However only the Reservoir 1 are within the cored interval which lie the within 129346-13451ft. The stacking of the above listed lithofacies aided the reconstruction of the sub-enviroment of deposition of reservoir sand within the cored intervals. The interpretation of the stacked lithofacies are tied to the interpretation of the wireline logs shapes of the sand units(i.e matching of of the cores and logs.

Therefore, the details description of the core samples based on lithofacies (lithology, grain size, and colour),sedimentary structures` are presented below

Figure 1: Bioturbated sandy heterolith

(a) Lithofacies 1: Bioturbated sandy heterolith :

Dominantly medium-fine grained, poorly sorted grayish brown sandstone with vertical gradation to dark colour ripple laminated shaley sands on top showing a finning upwards sequence: resulting from low energy offshore sediments.Bioturbation is intense. (figure 1)

Sedimentary Structures range from medium to fine grained sand stones, highly bioturbated with heterolithic crosstratification. This section on the Gamma ray logs shows serrated bell shape which is diagnostic of offshore transgressive sands associated with the lower shoreface

Figure 2: Bioturbated Cross bedded sandstones

(b) Lithofacies 2: Bioturbated Cross bedded sandstones:

Dominantly medium-fine-grained, moderately sorted light-Brown sandstones with gradation to dark colour. With graduation to dark colour rippled laminated shaley sands on top. Bioturbation degree is very high. (figure 2)

Sedimentary Structures consist of weakly to moderately bioturbated with heterolithic cross stratification and shale ripple horizontal laminar overlain by medium-fine-grained sands with intense bioturbation which tent to obliterate the sedimentary structures. This section on the Gamma Ray log shows serrated bell Shaped signature typical of Tidal channel.

Figure 3: Bioturbated sandy heterolith

(c) Lithofacies 3; Bioturbated Sandy heterolith: The lithofacies consists of a heterolithic mixture of sand, silt and thin mudstone beds and laminae. It is well sorted with fine to very fine grain size ranges. The clay content moderate. Nodules of carbonate cement (probably of calcite composition) are present in the lithofacies. The sediment is highly bioturbated as such; there is complete destruction of primary sedimentary structures therein. The lithofacies is also parallel to wavy bedded and frequently distorted. Bioturbation is dominant with some patches of clay materials. The numerous burrow activities is an indication of deposition in a low energy shallow marine environment. The localized trace fossil assemblages indicate a stressed environment probably with a wave current action. (figure 3)

(C) FACIES ASSOCIATION:

Facies association reflects the combination of processes which occur in the depositional environment. From Walther's law, it is believed that if one facies is superimposed on another without a break, then the two facies would have been deposited adjacent to each other at any one time in their geologic history. Thus, facies associations have genetic significance and could be identified as separate units using wireline logs and cores. Three facies associations and their environments are identified in the field of study using wells 1,2 and 3. The integrated interpretations of the facies association are hereby presented according to their vertical arrangement in the XY sands and starting from the base of the reservoir to the top.

(i) Facies Association 1: The interval of this facies association on gamma ray log is between 124528 to 12491 ft and 12120 to 12070ft on wells 1and 2 respectively. It is identified in the *gamma* ray log as sand and is more extensive in well 1 than in well 2. The facies association is characterized by intensive wavy ripple structure and has a very fine- to -fine grain composition. Symmetrical and asymmetrical ripples exist locally. Examination of the core indicates that it has a gradational relationship with facies associations above and the bottom seal below respectively. Facies association 1 is strongly to very strongly bioturbated. Trace fossils of Ophiomorpha and Paleophycus are common. It shows a funnel shape in gamma ray and bell shape in neutron density profile. Thus, there is a decrease in clay value upward.

Fine deposition indicates a low energy current while the dominance of wave rippled structures shows deposition in a wavy environment. However, the inter-lamination of siltstones and shales highlights deposition below wave base. Serrated nature of the gamma ray log is an indication of silty heteroliths, though Bioturbation activity and diversity of fauna coupled with its gradational upward relationship with facies association 2 shows an influence of lower shoreface environment.

(ii) Facies Assocciatton 2: The facies association ranges in depth from 124528 to 12491 ft and 12120 to 12070f for 1 and 2 respectively. It is thicker in well 1 than in well 2. The major lithofacies that make up facies association 2 are hummocky stratified sandstone and planar laminated sandstone. There is a minor composition of wavy rippled sandstone. The grain size range in the facies association 2 is fine to medium, though it grades upwards to

coarse planar cross- bedded sandstone, probably reflecting the base of a channel deposit. However, it grades downward into finer hummocky stratified sandstone. Sorting is moderate to poor. Bioturbation activity ranges from moderately bioturbated to none. However, there is the occurrence of sub-vertical ichnofacies burrows of Ophiomorpha nodosa and Skolithos. Traces of Planolites are also present. The hummocky cross -stratified sandstone is characterized by concave upward swales. The gamma ray log at a depth of about 12380 ft shows a coarsening upward pattern and low gamma ray value. The vertical facies sequence from the base to the top of these two sand bodies shows wave rippled sandstone and planar laminated sandstone. However, it comprises mainly hummocky stratified sandstone and a minor facies of wave rippled sandstone.

From the aforementioned characteristics, coarsening upward pattern is an indication of upward increase in energy. Hummocky cross stratification as a result of combined flow which occurs when a current is generated by a storm at the same time a high amplitude wave reaches down below the surface. Hummocky crossstratification is a characteristic of the upper shoreface. High diversity of sub-vertical burrows of ichnofacies suggests high energy environment, that is above fair weather base or shallow marine. Sub-vertical burrows result from organisms that move up and down in the sediment with the changing water level of the shoreline. The facies association is therefore inferred to occur in a wave dominated upper shoreface environment.

(iii) Facies Asociation 3: This comprises facies association 3. The depth range of the facies association is 124718 to 12325 ft and 12015 to 12023 ft in wells 1 and 2 respectively. It is well developed and thicker in well 1 than in well 2. Facies association 3 is mainly made up of cross-bedded sandstone and wavy sandy heteroliths. Wave rippled sandstone could be a minor lithofacies in the association. The facies consist of medium to fine-grained sandstone and is poorly sorted, though there is little inter bedded mud drapes. It is characterized by fining upward sequence with an erosive base. Coarse grains are found at the erosive base. From the Gamma ray log, it is found to overlie the upper shoreface and has a bell shaped fining upward of grains and a positive separation of the neutron density logs. Bioturbation activity is rare. However, there is presence of sub-vertical and sub-horizontal burrows of Ophiomorpha and Planolites respectively.

The presence of coarse grains in the scoured or erosive base is an indication of a channel setting and the fining upward succession shows a decrease in energy of deposition upward and more likely an abandonment of channel lobe. The low diversity and presence of trace fossils of Ophiomorpha and Planolites is an indication of mixed energy environment. Therefore, facies association 3 is inferred to be a tidal deposit.

DISCUSSION OF RESULT

From the gamma ray log of the reservoir XY researcvoir sand of study; the reservoir could be divided into two sequences based on the mode of deposition. These are the upper and lower part, i.e. the transgressive and regressive sections. However, the core gamma ray signature shows that the upper part of the lower XY sand and the lower part of sand are not cored due to the muddy nature. Therefore, the reservoir model is considered along this line. The upper part which ranges in depth from 12344 to about l2l60ft, consists of the following facies associations, namely from the base; tidal deposit, amalgamated channel, tidal flat, tidal channel, and marine shale. Therefore, the model will be that of transgressive estuarine system. Some of the sedimentary structures associated with the estuarine deposits are reactivation surfaces as a result of the influence of flood and ebb currents (bipolar current) on the sedimentary deposits. Couplets of sand and shale in heterolithic sequence and sporadic trace fossil assemblages with an increase in faunal diversity upward. Furthermore, the lower regressive part of the reservoir sand of study ranges in depth from 12362 to 1272 ft. This lower part which forms a progradational sequence consists of the following facies associations starting from the base of the reservoir sand, offshore marine mud, lower shoreface and upper shoreface. The lower depositional sequence of XY sand are deposits of a prograding wave dominated shallow marine shoreface setting. This interpretation is supported by the abundance of hummocky cross stratification structures, abundance of diverse marine trace fossils, and the upward decrease in diversity and population of these trace fossils. However, the two channel sandstones in the D7.000 reservoir have different geological properties and should be identified with different geological models. The tidal channel has a transgressive property, that is, it exhibits a fining upward sequence. Also, it has a gradational and erosional upper and lower contact respectively. Furthermore, in gamma ray log, it has a bell shape structure, while in the amalgamated channel of the upper retogradational sequence, it has abrupt upper and lower erosional boundaries respectively, blocky gamma ray log signature and shows little or no separation in neutron-density logs. In summary, the depositional model of the reservoir sand of study consists of the upper transgressive estuarine deposits and the lower progradational shallow marine sequence which is being influenced by the presence of bipolar currents involving wave/fluvial processes. A decrease in accommodation space results in a progradation of the facies belt across the shelf thereby giving rise to shelf deposits. Regression is consequently followed by a transgressive phase which resulted in the deposition of the upper part of the reservoir sand or the estuarine deposits. Hence, succession of sediment depositions in the reservoir sand of study involves a transgressive estuarine deposit overlying a progradational shallow marine shoreface deposits.

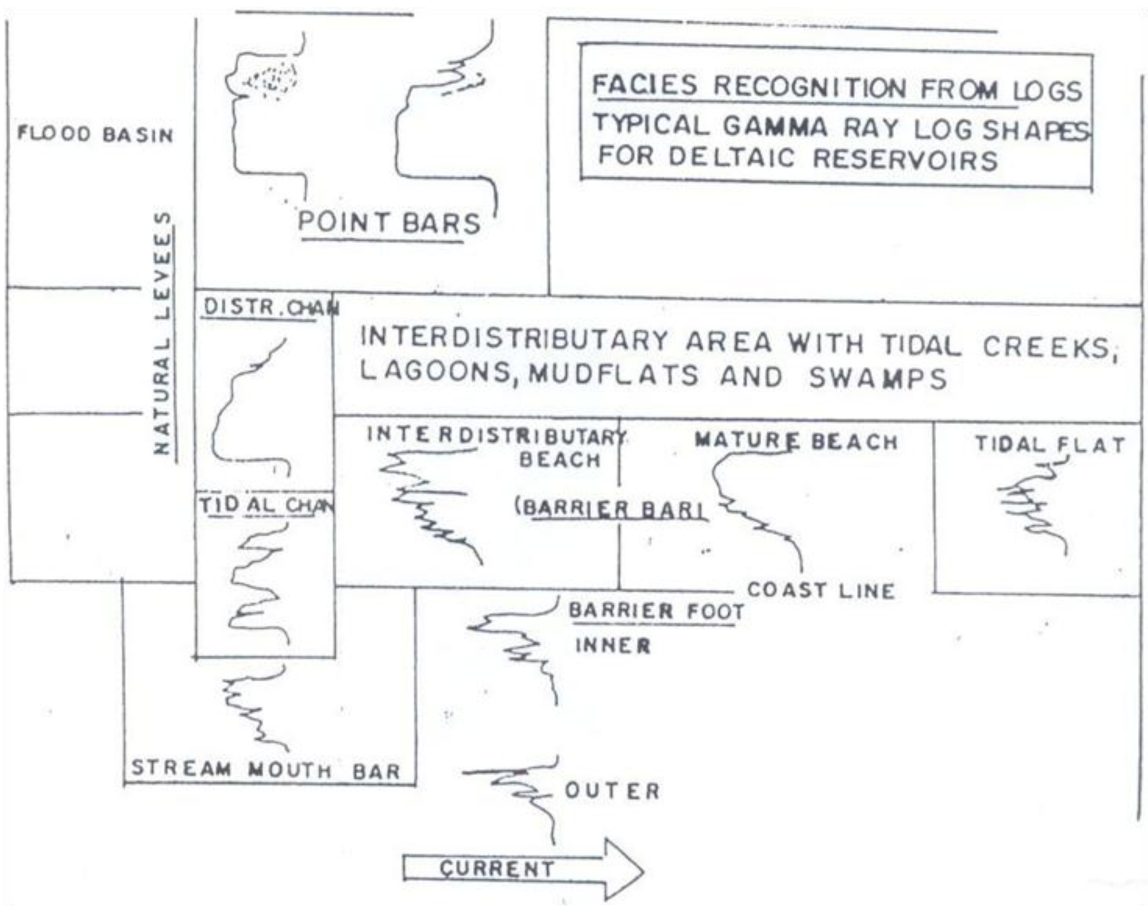

Figure 4: Electrofacies Classification For Deltaic Enviroments (Adapted From Bigelow,1987)

ENVIRONMENTS					
TRANSITIONAL	DELTAIC	UPPER DELTAIC PLAIN		MEANDER BELTS	CHANNELS
					NATURAL LEVEES
					POINT BARS
				FLOOD BASINS	STREAMS LAKES SWAMPS
		LOWER DELTAIC PLAIN		DISTRIBUTARY CHANNELS	CHANNELS
					NATURAL LEVEES
				INTER DISTRIBUTARY AREAS	MARSH LAKES TIDAL CHANNELS & TIDAL FLATS
		FRINGE	DELTA FRONT	INNER	RIVER-MOUTH BARS, BEACHES & BEACH RIDGES TIDAL FLATS
		DISTAL		OUTER	

Table 5: Classification of Depositional environments of Sand Bodies and their related Geomorphology features

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