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FACIES ARCHITECTURE AND DEPOSITIONAL ENVIRONMENTS STUDY OF THE "B2" RESERVOIR SAND (3764-3794) m, WELL-51, BOGA FIELD, NIGER DELTA, NIGERIA.

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ABSTRACT

The "B2" reservoir sandbody, in Boga Field, Niger Delta, was investigated for the facies architecture and depositional sequence. Textural analysis, sedimentary structure and bioturbation intensity were used to study the core data for the identification of various lithofacies types and these were integrated with the gamma ray log in the cored interval for the determination of facies association and depositional sequence. The study revealed nine (9) lithofacies types. Integration of the lithofacies with Well log data from base to top of reservoir sandbody helped to group the sandbody into facies associations that occur together and are considered to be genetically or environmentally related. Three facies associations were interpreted from the cored intervals: Fluvial channel-Point Bar, Tide-dominated estuary and a Shoreface succession comprising two domains of Middle Shore face, and Lower Shoreface, capped by a Shelf Mudstone subfacies. The channel facies association shows a fining upward sequence, capped by an overbank deposit of mudstone lithofacies, the tide-dominated estuary shows a fining upward sequence. It consists from base: medium to coarse grained sandstone (mcS) facies, and capped by a fine to silt grained tidal flats sediment (M), while the Middle and Lower Shoreface subfacies consist of coarsening upward sequence of sandstone succession of medium to coarse and fine to medium sand facies associations respectively. The facies associations of the sandbody in the study interval were interpreted as a deposit of fluvio-marine prograding shoreface overlaid by a fluvial Point bar deposits. This observation implies a fluvial dominated process as observed in the cored interval of "B2" reservoir sandbody, Boga Field.

Key words: Fluvial, Estuary, Shoreface, Fluvio-Marine, Tide-dominated.

INTRODUCTION

Siliciclastic shallow-marine deposits form reservoir in many of the world's major hydrocarbon provinces. These rocks hold the vast majority of the remaining hydrocarbon reservoir which is quite challenging because of genetic hierarchy of different scale and sets of heterogeneities (Numair, *et al*, 2017). Numerous studies by different groups have investigated the facies characteristic and have therefore defined various types of depositional environments. These studies were based on core data and wireline log interpretation and also to construct a depositional model bases on facies architecture.

The "B2" Reservoir Sandbody, Well 51 "Boga Field" is located within the Niger Delta basin. It lies between longitudes 5.05°E and 7.35°E and latitudes 4.15°N and 6.01°N (Figure 1) on the onshore part of the Niger Delta. The Tertiary 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 South America and Africa in the Late Jurassic (Whiteman, 1982).

The Niger Delta basin is a matured sedimentary basin with several works been undertaken and documented on the geology of the Tertiary Niger Delta basin. Short and Stauble (1967) was one of the pioneer workers on the geology of the Niger Delta: they provided the initial information on the sediments and subsurface distribution of the stratigraphic units in the Niger delta. Several other workers have done work in the Niger Delta, amongst them is Whitaker (1985); he identified the following depositional environments in the Niger Delta as mangrove swamp, channel deposits, shoreface and marine. This study is designed to take a look at the stratigraphy, and lithological characterization, in order to determine the various lithofacies types, in order to interprets the depositional environments and facies relationships responsible for the deposition of the reservoir sandbody in the cored depth "B2" (3764-3794)m, in Well-51, Boga Field, based on sedimentological studies using core and log data, and to create a conceptual depositional model for the Boga reservoir sandbody.

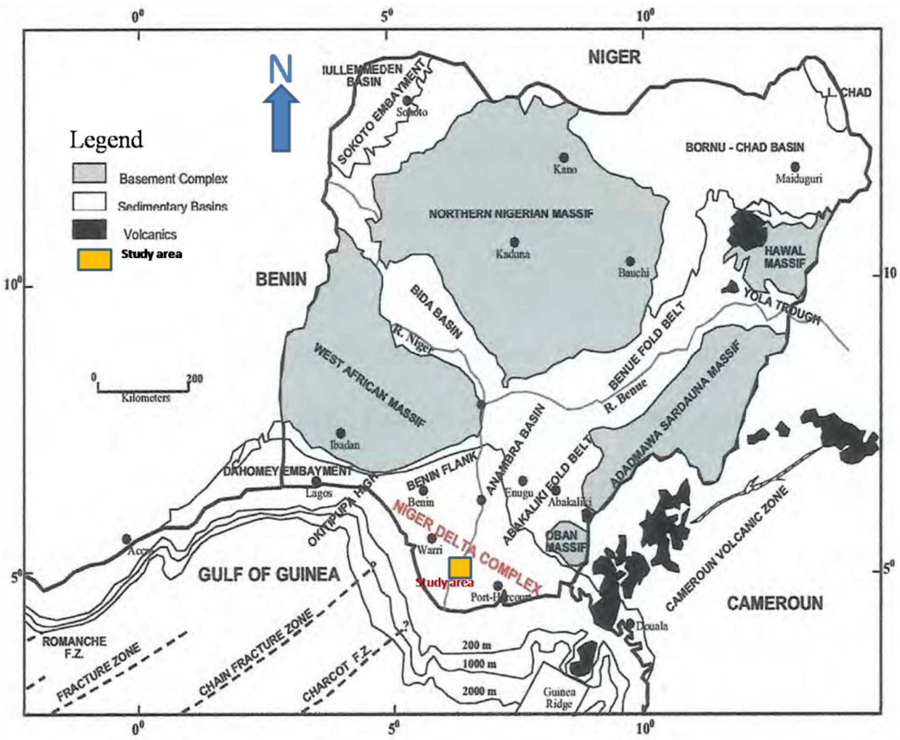

Figure 1: Map of Nigeria, showing Niger Delta Basin and the location of Study Area (Modified after Whiteman, 1982).

Stratigraphic and Geologic Setting

The origin and formation of the Niger Delta have been related to the separation of Africa and South America and the subsequent opening of the South Atlantic in Aptian - Albian times (Etu-Efeotor, 1997). According to Short and Stauble, (1967), the coastal sedimentary basin of Nigeria has been the scene of three depositional cycles. The first began with a marine incursion in

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the middle Cretaceous and was terminated by a mild folding phase in the Santonian time. The second included the growth of a proto-Niger Delta during the late Createaceous and ended in a major Paleocene marine transgression. The third cycle, from Eocene to Recent, marked the continuous growth of the main Niger Delta. Studies in the Niger Delta revealed three vertical lithostratigraphic subdivisions or Formations: the Benin Formation, which is an upper delta top lithofacies; the Agbada Formation, which contains the hydrocarbon reservoirs, and the lower Akata Formation, which is the over pressured shales and the source of hydrocarbon generation. Table 1shows the type section as described by Short and Stauble (1967).

Table 1: Stratigraphy of the Niger Delta and the Surface Equivalent (modified after Short and Stauble, 1967).

SUBSURFACE			SURFACE OUTCROPS		
YOUNGEST KNOWN AGE	FORMATION	OLDEST KNOWN AGE	YOUNGEST KNOWN AGE	FORMATION	OLDEST KNOWN AGE
RECENT	BENIN	OLIGOCENE	PLIO/ PLEISTOCENE	BENIN	MIOCENE
RECENT	AGBADA	EOCENE	MIOCENE	OGWASHI-ASABA	OLIGOCENE
			EOCENE	AMEKI	EOCENE
RECENT	AKATA	EOCENE	L. EOCENE	IMO SHALE	PALEOCENE
			PALEOCENE	NSUKKA	MAESTRICHTIAN
			MAESTRICHTIAN	AJALI	MAESTRICHTIAN
			CAMPANIAN	MAMU	CAMPANIAN
			CAMP/MAESTR	NKPORO SHALE	SANTONIAN
			CONIACIAN/ SANTONIAN	AWGU SHALE	TURONIAN
			TURANIAN	EZE AKU SHALE	TURONIAN
			ALBIAN	ASU RIVER GROUP	ALBIAN

The sediments of the Niger Delta can be divided into three diachronous units of Paleocene to Recent age that form a major regressive cycle, all of which are present in both onshore and offshore depobelts (Figure 2).The uppermost unit, the Benin Formation, comprises continental / fluviatile and backswamp deposits up to 2500m thick. These are underlain by the Agbada Formation of paralic, brackish to marine, coastal and fluvio - marine deposits, organized into coarsening upwards 'offlap' cycles. The underlying Akata Formation comprises up to 6500m of marine pro-delta clays. Shales of the Akata Formation are overpressured and have deformed in response to delta progradation. Shales of the Akata Formation constitute a world-class source rock.

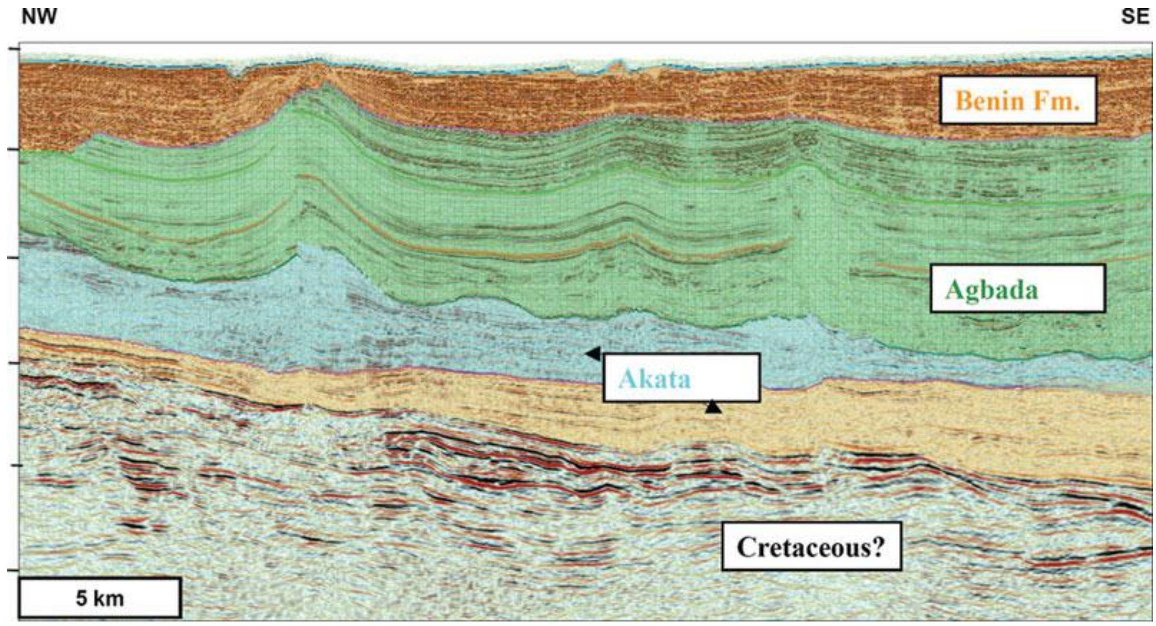

Figure 2: Schematic diagram showing the various Formations in the Niger Delta, (Ajakaiye and Bally, 2002).

MATERIALS AND METHODS OF STUDY

Materials

The data set used includes, base map showing the structural element and location of wells, suite of wireline log, and set of core photographs.

Methods

Several methods were adopted for this study.

Core Description

The core photographs provided by Total (E&P) was studied and described from bottom upwards.

The procedure for the description is as follows:

a. The detail of the core photos was done on the core sedimentological description chart,

b. Texture, litho unit boundaries, nature of contacts, composition, digenetic features, biogenic and physical sedimentary structures were described and recorded,

c. Their lateral and vertical changes in lithology was noted and studied,

d. Study of sedimentary structures such as crossbedding, lamination e.t.c. The degree of bioturbation was also indicated.

e. Based on the descriptions, lithology and grain size, dominant sedimentary structures, the lithofacies types were determined and interpreted using the lithofacies classification scheme (Table 2), and

f. Interpretation of various lithofacies within the core was intergrated with the wireline log pattern to arrive at lithofacies association and distinct reservoir genetic units

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Table 2: Tabulated Lithofacies Scheme (After S.P.D.C., Nigeria)

DOMINANT GRAIN SIZE	DOMINANT SEDIMENTARY STRUCTURE	SECONDARY SEDIMENTARY STRUCTURE
S (sandstone) **c** - coarse **m** - medium **f** - fine >90% sand **s** (sandstone dominant) **H** (heterolithic) >50% sand / >50% mud **m** (mudstone dominant) >90% mud **M** (mudstone) **C** (coal)	**M** (massive) **X** (cross-bedded) **P** (planar, parallel bedded) **H** (hummocky - swaley cross-bedded) **W** (wave rippled) **C** (current rippled) **B** (bioturbated) **R** (rooted) **F** (fossiliferous) **O** (organic-carbonaceous)	**c** (cement-general) **s** (siderite) **/d** (soft sediment deformed - slumped, slide, micro-faulted)

Wireline Log Shapes

Figure 3 shows facies indication from Gamma Ray, for idealized examples of both log shapes and sedimentological facies (Schlumberger, 1989). The sedimentological implication of this relationship leads to a direct correlation between facies and log shape. A funnel shape with the values decreasing regularly upwards shows a decrease in clay content. The decrease in clay content is correlated with an increase in sand content and grain size, and is interpreted to be a shoreface or delta front. A bell shaped log with gamma ray value increasing upwards to a lower value indicates increasing clay content (Figure 3) and is interpreted to be a fluvial point bar or a tidal channel deposit.

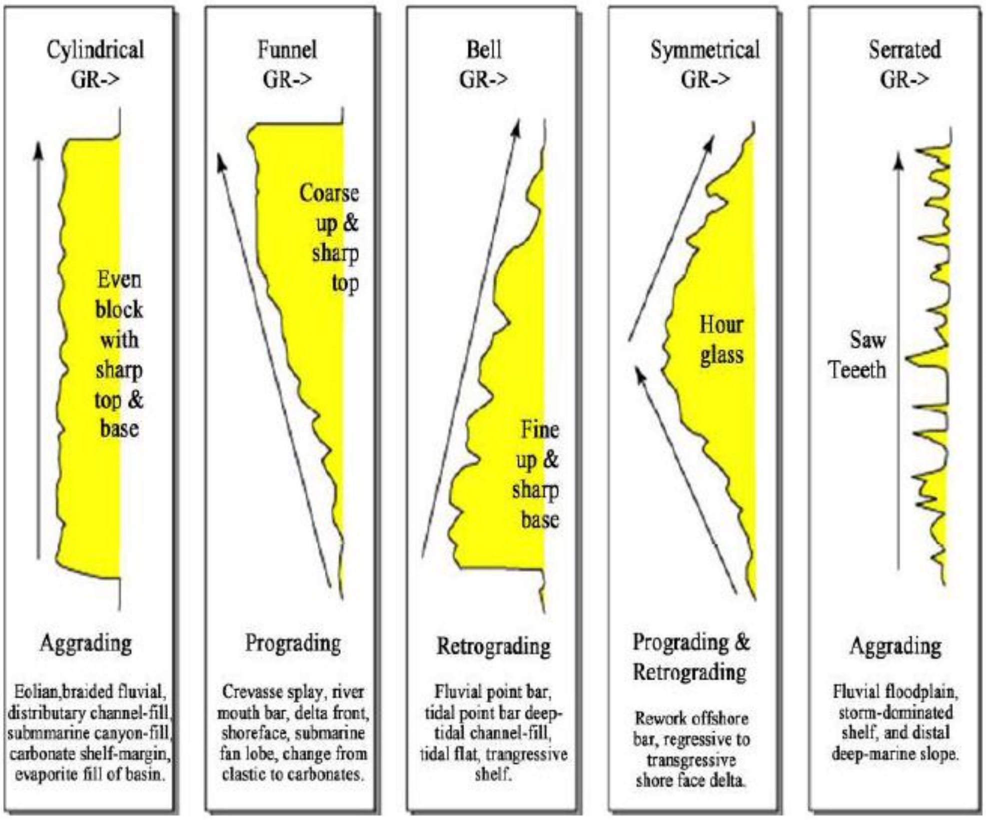

Figure 3: Facies indication from Gamma Ray, the idealized examples of both Log shapes and sedimentological facies (Schlumberger, 1989).

RESULT AND DISCUSSION

Lithofacies Types and Depositional Environments

The "B2" Reservoir Sand (3764-3794) m, well-51, Boga Field was studied in detail to identify the various lithofacies. For each lithofacies identified, facies description and interpretation for the facies followed immediately. The "B2"Sandbody had been subdivided into nine (9) lithofacies types on the basis of lithology, bed geometry and sedimentary structures (Table 3). Some facies appear more than once in the succession (Table. 3), and others appear only once. Therefore, lithofacies types are presented here from the top to the bottom of Reservoir "B2" as seen in the depositional sequence (Figure 4).

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Table 3: Lithofacies Identified in the Cored Reservoir Interval.

Depth (m)	Facies	Description
3764-3765	(M)	Mudstone: with abundant sideretized nodules in places
3765-3768	(BfS)	Sandstone: very fine sand to siltstone, strongly bioturbated, abundant siderite nodules with carbonaceous materials in places, Burrows are similar to *Paleophycus* @3768.5m
3768-3771	(BfmS)	Sandstone: Fine to medium grained, with granules in places, poorly sorted; bioturbation is rare except for few vertical burrows of *Ophiomorpha*
3771-3775	(PS)	Sandstone: very coarse to pebbly grained, poorly sorted, crudely bedded at base, no visible sedimentary structure, clast ranging between 3-5cm, defined scoured base, and bioturbation is rare.
3775-3778.3	(MCS)	Sandstone: granule to coarse grained, moderate sorting, carbonaceous materials in places, no visible sedimentary structure, bioturbation are rare.
3778.3-3779	(M)	Siltstone: apparently micaceous, slightly bioturbated
3779-3782	(MCS)	Sandstone: coarse to medium grained, planar cross bedded with mud drape in places, bioturbation is rare, but burrows of *Paleophycus* in places
3782-3787	(BMCS)	Sandstone: medium to coarse grained, planar bedding in place, mud drapes in places, slightly bioturbated, burrows of large *Ophiomorpha* and *Skolithos* in places.
3787-3789	(XfmS)	Sandstone: fine to medium grained, parallel bedded sandstone and mudstone heterolthic, planar cross bedding, slightly bioturbated with horizontal burrow of probable *Planolite or paleophycus.*
3789-3790	(BSH)	Sandstone: fine to medium grained sandy heteroliths, wavy planar bedding, with little amount of clay less than 5%, slightly bioturbated, burrow of probable *Planolite*.
3790-3792	(BSH)	Siltstone: very fine sand to siltstone heteroliths, planar bedding, with clay contents greater than the overlying facies, strongly bioturbated, locally wavy lamination.
3792-3794	(BfmSH)	Sandstone: very fine to medium heteroliths, planar bedding, well sorted, locally remain of primary laminations of Herringbone stratification

Facies A: Mudstone facies (M)

Mudstone lithofacies (M) encountered in the study section occurred twice in the study interval. It consists of laminated dark-greenish-gray to greenish-black mudstone (Plate 1a). The massive laminated black/dark grey shale with parallel silt laminae of >2 mm thick also occurred in the cored intervals (Plate 1b). This facies is characterized by thin elongate, digenetic siderite nodules.

The thinly laminated mudstone (Plate 1a) appears significantly different from the other laminated lithofacies on the cored interval. However, these two differences suggest that several processes may have operated in the depositional environment. Physical sedimentary structures present in this facies include wavy ripple-laminated siltstone and planar lamination. Bioturbation in this facies is slight to rare, with burrowing parallel to laminae.

Interpretation: The sediment of the mudstone facies (Plate1a-b) was deposited under quiet and low energy conditions, allowing for shale lamination. The facies with silty laminae are indicative of the intrusion of a more energetic event. Walker and Plint (1992) and Reineck and Singh

(1980) described mudstones as offshore or shelf deposits. The mudstone unit can be interpreted to have been deposited in an overbank of a channel or in a shelf environment.

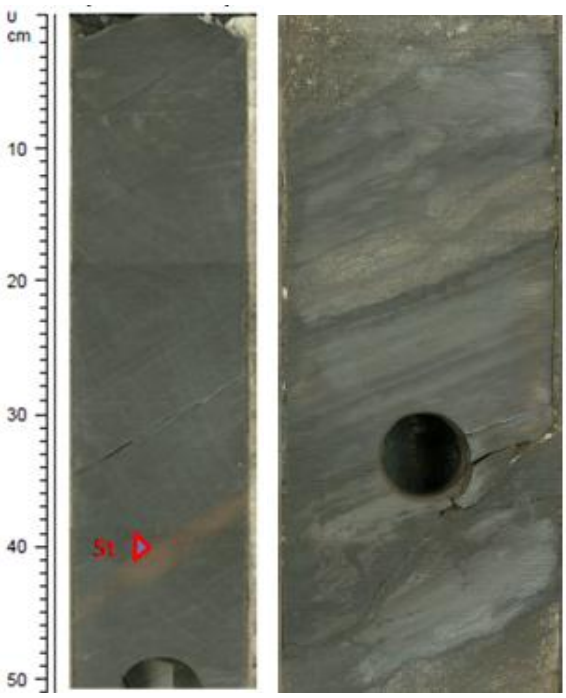

Plate 1a&b: Mudstone (M) Facies,
a- (Mudstone with si: siderite nodules 3764-3764.5); b- (3778.35-3778.65)

Facies B: Bioturbated Fine Sandstone Facies (BfS)

The lithofacies (BfS) encountered in the cored section consists of fine-grained sandstone, with little or no clay content, and moderately sorted. Bioturbation intensity ranges from slightly to moderately bioturbated (Plate 2). The grain-size indicates a reworking of sediment where the primary sedimentary structures have been obliterated with siderite nodules in place. The common burrows in the facies include that of probable sub-horizontal *Planolites* and burrows of *Paleophycus*.

Interpretation: Intensively bioturbation correspond to a zone where oxygen content is high, nutrient is abundant and low energy condition, below wave base. Dominance of large burrows of *Planolites and Paleophycus* with rare fossil shells, may characterize the influence of tidal or stressed estuarine environment. Predominance of fine sediment indicates low energy environment which together with burrows is characteristic of lagoonal, bay and offshore environments.

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Plate 2: Bioturbated Fine Grained Sandstone (BfS) Facies (3766-3766.5)

Facies C: Bioturbated Fine to Medium Grained Sandstone Facies (BfmS)

The lithofacies (BfmS)encountered in the cored section consists of fine to medium-grained sandstone, with little or no clay content, moderately sorted, with granules in places. This facies directly underline the BfS above. Bioturbation intensity ranges from slightly to moderately bioturbated (Plate 3). The grain-size indicates a reworking of sediment where the primary sedimentary structures have been obliterated. The common burrows include that of sub-horizontal *Planolites* and burrows of *Ophiomorpha nodosa*.

Interpretation: Intensively bioturbation correspond to a zone where oxygen content is high, nutrient is abundant and low energy condition, below wave base. Dominance of large burrows of *Ophiomorpha nodosa*, and *Planolites* with rare fossil shells, may characterize the influence of tidal or stressed estuarine environment (Pemberton, et al, 1992). Predominance of fine sediment indicates low energy environment which together with burrows is characteristic of lagoonal, bay and offshore environments (Miall,

1996).

Plate 3: Bioturbated Fine to Medium **Sandstone (BfmS) Facies (3769-3769.4)**

Facies D: Pebbly Sandstone Facies (PS)

The lithofacies PS occurs as a thick bed of very coarse to pebbly sandstone with sharply defined scoured base (Plate 4). The sandstone is poorly sorted with no visible sedimentary structure. The clast size ranges from pebbles to granules. The grain size generally reduces upward. Bioturbation is rare. This lithofacies occurs in the cored interval of (3771-3775) in study interval. The facies underlies the bioturbated fine to medium Sandstone facies.

Interpretation: The very coarse to pebbly grained nature of this lithofacies indicates a channel or a lag deposit, generated by repetitive strong ephemeral current as in storms and major flood (Moslow and Heron, 1978). Lack of predefined internal bedding structure indicates rapid sedimentation. Lack of Ichnofaunal is indicative of a restricted and stressed environment and thus interpreted to be of tidal channel deposit (Pemberton, et al, 1992).

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Plate 4: Pebbly Sandstone (PS) Facies (3773.55 - 3774)

Facies E: Medium to Coarse Grained Sandstone Facies (MCS)

This lithofacies (MCS) consists of medium to coarse grained sandstone (Plate 5). The facies is poorly sorted and consists of bimodal grain size sorting. The granules are rounded to sub angular in shape, with size ranging in size from 0.1-0,2cm and are predominantly of extra-formational lithology (typically quartz). Mud flasers are found in few places. Bioturbation intensity is rare to absent in this facies, but burrows of probable *Paleophycus* in place (Plate 5b). Physical sedimentary structures in this lithofacies are not pronounced except for the massive bedded nature of the facies. The lithofacies (MCS) in the cored interval occurred twice at (3777.4-3778) and (3781.6-3782).

a(3777.4 - 3778) b (3781.6 - 3782).

Plate 5: Medium to Coarse Grained Sandstone (MCS) Facies

Facies F: Bioturbated Medium to Coarse Grained Sandstone Facies (BmcS):

The facies BmcS consists of medium to very coarse-grained sandstone, poorly sorted, with bioturbation ranging from slight to moderate (Plate 6a-b). The sandstones contain grain-size of various clasts, with sizes ranging from medium to coarse. The sedimentary structure show planar cross bedding in places and has been obliterated by the action of bioturbation in places. The common traces include that of *Ophiomorpha nodosa* and *Irregularies* burrows (Plate 6 a-b). The *Ophiomorpha* burrows may be up to 3-4cm in diameter and up to 12 cm long.

Interpretation: The medium to coarse nature of this lithofacies suggests a channel deposit generated by strong ephemeral current as in storm and major flood (Dalrymple *et al.,* 1992). Lack of predefined internal bedding structure indicates rapid sedimentation (Allen, 1983). Intensively bioturbation correspond to a zone where nutrient is abundant. This lithofacies is suggestive of a tidal area where periodic high current velocities occur. The vertical burrow is typical of transitional marine environments where filter feeders are dominant.

a (3784.5-3785) **b (3786-3786.55)**

Plate 6: Bioturbated Medium to Coarse Grained Sandstone Facies

Facies G: Cross Bedded Fine to Medium-grained Sandstone Facies (CfmS)

The CfmS consists of moderate to well sorted, fine to medium grained sandstones (Plate7). This lithofacies occur in the cored interval (3787-3787.5).It consists of planar cross bedding; very clean sand with little clay content. Cross-beds typically contain single and/or paired mudstone drapes along forsets of topsets. The level of bioturbation in this facies ranges from low to rare. Burrow includes probable *Paleopyhcus* or *Planolites*.

Interpretation: Grain-size, sorting and trough cross-bedding are typical of proximal deposits under unidirectional

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current. They are formed under strong upper flow regime condition such as in channels and wave dominated environment (Walker, 1984). Presence of clay drapes, mud chips and the bimodal sorting is indicative of tidal current modulation. The lithofacies are interpreted to be a deposit of tide-dominated estuarine channels, tidal dominated delta, or a shoreface of moderate energy environment. The presence of alternating laminae of mud and sand indicate periods of low and high energy deposition.

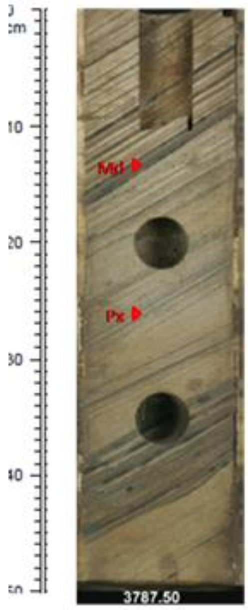

Plate 7: Cross Bedded Fine to Medium-grained Sandstone (CfmS) Facies (Planar (Px) cross bedded with relatively thicker mud drapes (Md) on forsets beds)

Facies H: Bioturbated Sandy Heterolith Facies (BSHF)

The BSH facies consists of fine-grained silty sand and muddy sandstone. This lithofacies occurs in two places. Sorting in this facies is moderate, with the heterolithic mixture of fine sand, silt and clay. Bioturbation ranges from moderate to intense and the bioturbation structures predominate over physical structures and it obliterate the bedding structure in places (Plate 8). The burrows in this facies is probable (*Skolithos* and *Planolites)* both horizontal and vertical; all of which cut or disrupts the original bedding or lamination. Some of the original clay lamination or ripple lamination are preserved. Physical structures on the lithofacies include, parallel to wavy bedding.

Interpretation: The lithofacies records the alternation of bedload and suspension depositional processes. The bedload sedimentation are deposited during migration of wave ripples under low flow regime oscillatory wave current while the clay and silt deposits are as a result of suspension fallout, periodically interrupted by sand deposition. The intense burrow activities are indicative of deposition in a low energy environment of shallow marine.

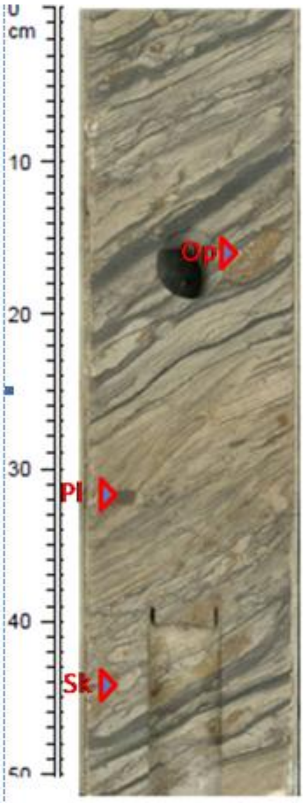

Plate 8: Bioturbated Sandstone Heterolith (BSH) Facies (BSH with Pl: *Planolite,* Sk: *Skolithos* burrow)

Facies I: Bioturbated Fine to Medium Grained Sandstone Facies (BfmS)

The facies BfmS consists of fine to medium-grained sandstone, with little or no clay content, moderately sorted, with bioturbation ranging from moderately to intensively bioturbated (Plate 9). The grain-size indicates a reworking of sediment where the primary sedimentary structures have been intensively obliterated. The common burrows include that of sub-horizontal *Planolites* and burrows of *Paleophycus.*

Interpretation: Intensive bioturbation correspond to a zone where oxygen content is high, nutrient is abundant and low energy condition, below wave base *Planolites and Paleophycus* burrows and with rare fossil shells, may characterize the influence of tidal or stressed estuarine environment. The intense bioturbation is an indication of Lower Shoreface environments (Walker and Plint, 1992)..

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Plate 9: Bioturbated Fine to Medium grained Sandstone (BfmS) Facies (3793-3793.5)

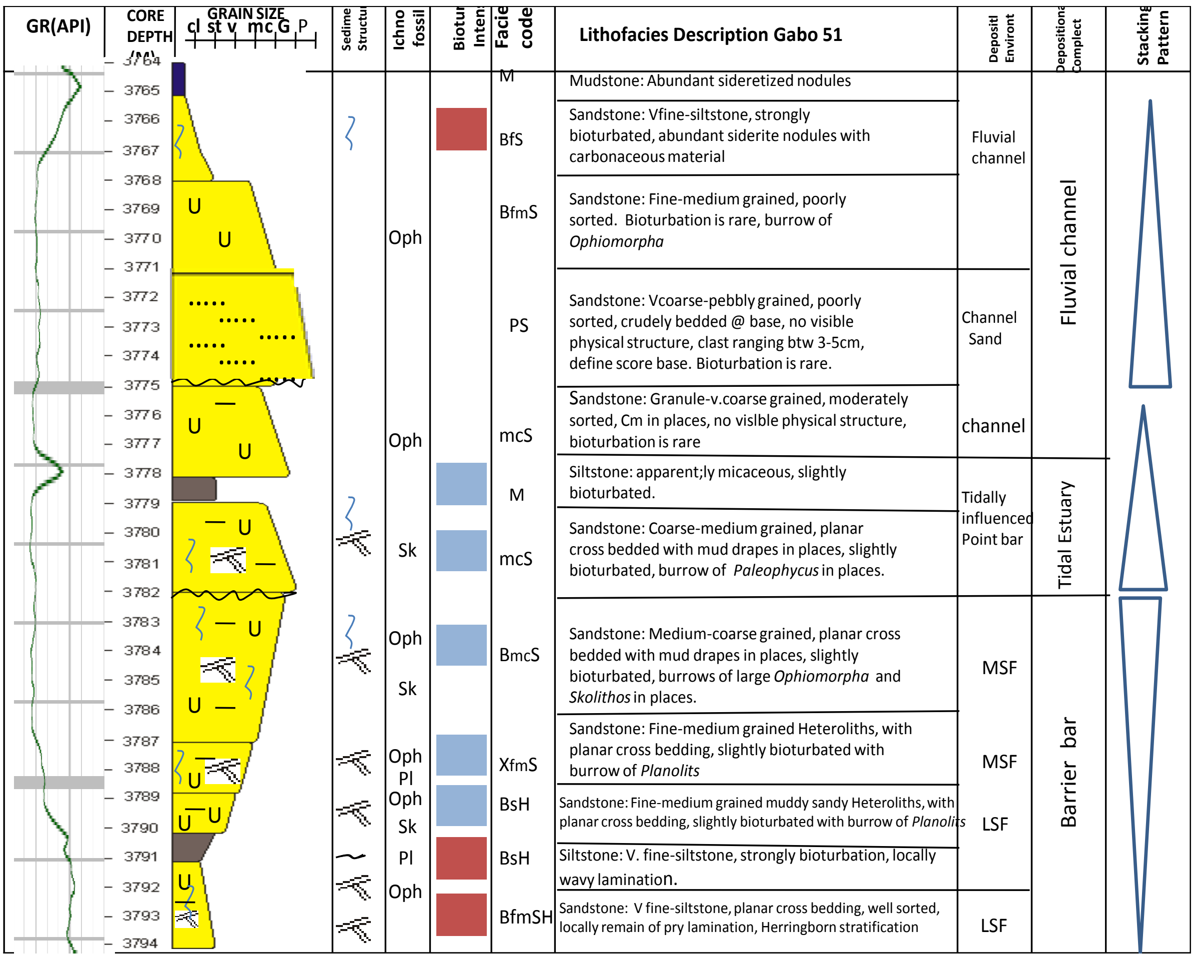

Figure 4: Depositional Sequence for Reservoir "B2" (3764 - 3794)m

Facies Association and Interpretation

The nine (9) lithofacies types identified and described above (Plate 1-9) were grouped according to Readings (1979) into facies associations: which have genetic and environmental significance and were identified as separate units in cores and on wireline logs (Figure 4). These facies associations form the primary basis of inferring the depositional setting under which the sediments were deposited and preserved. Three (3) facies associations were identified in the cored interval.

Facies Association 1(Fluvial Channel)

The fluvial channel facies association in the study interval shows a fining upward sequence. It consists from base pebbly sandstone (PS), slightly bioturbated fine to medium sandstone (BfmS), bioturbated fine grained sandstone (BfS) that fine upward and capped by overbank Mudstone (M) (Figure 10). The association is made up of over 70% coarse to pebbly sand of the total lithology. The poor sorting nature of the grain size indicates a fluvial dominated character in which sand deposit is by high energy fluvial current (Allen and Collinson, 1974). The mudstone sequence that capped the sequence as observed in the cored section (3764-3765) are the overbanks deposit which reflect waning current velocities as the channel is gradually filled. Despite the dominance of fluvial processes in these interval resulting ro the restricted of marine fossil assemblage, marginal marine ichnofacies of *Ophiomorpha* were found in few places. Figure 10, is the representative vertical facies model for the fluvial channel in the study well. The facies association has a finning upward gamma ray log signature with a sharp base.

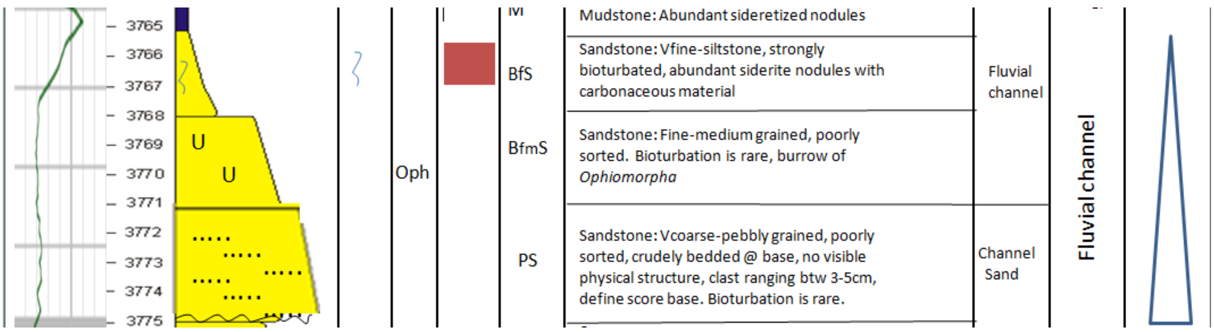

Figure 10: Fluvial Channel Facies Association 1 and Log Signature

Facies Association 2 (Tide Dominated Estuary)

An estuary is a partly enclosed body of water with one or more rivers or streams flowing into it and with a free connection to the open sea (Dalrymple, et al., 1992 and Wells, J. T. 1995). The physical and biological processes in nearly all estuaries are influenced by tides.

The tide dominated estuary facies association in the study interval (Figure 11) shows a fining upward sequence. It consists from base medium to coarse (McS) and capped by a fine to silt grained tidal flats sediment (M). The tidal flat sediments are

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common along prograding coasts, characterized by mean tidal ranges >=4 m (Numair, *et al*, 2017). They usually comprise of fine-grained marine sediments that have been transported towards the coast by strong currents associated with the larger tides.

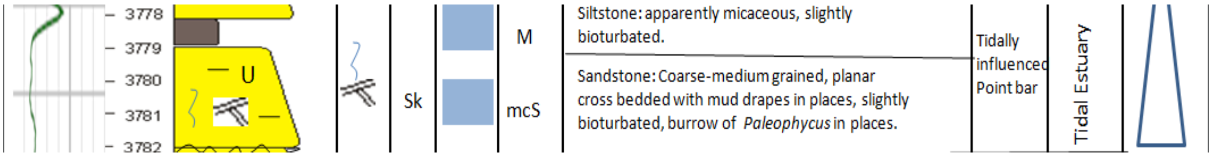

Figure 11: Tide Dominated Estuary Facies Association 2 and Log Signature

Facies Association 3 (Barrier bars)

The lithofacies association 3 consists from base to top, of Mudstone lithofacies (M), Bioturbated sandy Heterolith (BsH), Cross bedded fine to medium grained Sandstone facies (XfmS) and Bioturbated medium to coarse grained Sandstone facies (BmcS).They are interpreted as that of marine mudstone, lower shoreface, and middle shoreface respectively. The upper shoreface subfacies is not represented in the cored interval of study: this may be as a result of the fluvial erosion as seen in the depositional Log (figure 4). The stacking pattern displays a vertical coarsening upward sequence (CUS) and a gradual transition from one lithofacies to another in a prograding shoreface. Figure12 shows the vertical facies model for the barrier bar profile in the study area. This facies association in the studied interval of "B2" occur at (3782-3792)m depth.

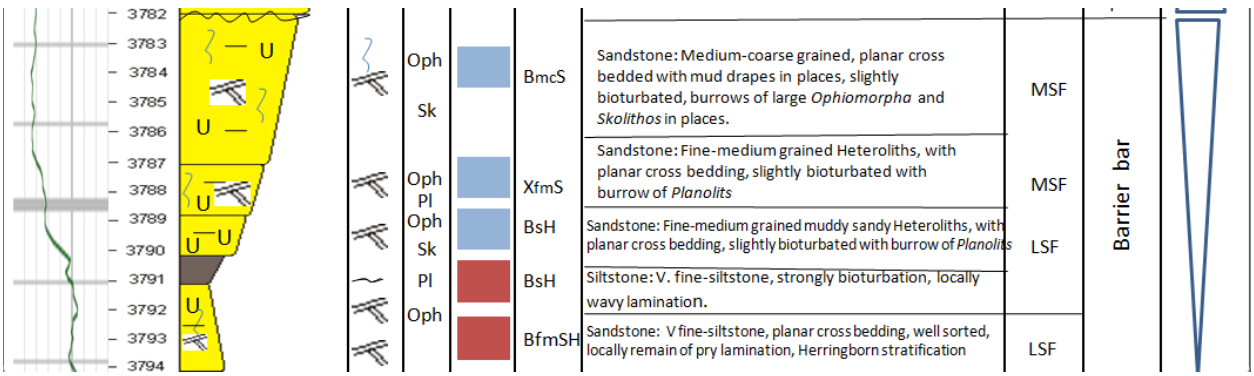

Figure 12: Barrier Bar Lithofacies association 3 and Log Signatures for Reservoir "B2"

Shelf Mudstone Subfacies

This subfacies association is made up of laminated dark-greenish-gray to greenish-black mudstone, very fine to siltstone, strongly bioturbation, locally wavy lamination and is marked by high GR and low resistivity log response. The mudstone deposits are suspension fall-out deposits which represent low-energy environment such as an open marine shelf below storm wave base.

Lower Shoreface Subfacies

This subfacies unit consists of fine grained to medium grained, bioturbated sandstone heteroliths interspersed with thin layers of siltstone and mud, with an upward increase in sand: shale ratio. The sedimentary structures in this facies include flaser bedding, very thin laminations. The facies is characterized by slight to moderate bioturbation and burrowing of *Ophiomorpha nodosa* and *Planolites*. The association is characterized by gradual coarsening-upward in grain size and is reflected by a funnel-shape of GR log curve repeated serration, indicating alternations of sand and shale as well as upward coarsening and thickening sequence of lower shoreface.

Middle Shoreface Subfacies

This subfacies unit overlie the lower shoreface described above. It is characterized by sand of cross bedded fine to medium grained sandstone (XfmS) and bioturbated medium to coarse grained sandstone (BmcS), coarser than the lower shoreface deposit described above. Bioturbation in this subfacies is low to moderate and less pronounced than that of lower shoreface. Due to strong wave interaction, the sands are well sorted with low shale interlamination than the underlying subfacies. Physical sedimentary structure include planar cross stratification and mud drapes, though, planar cross stratification may be locally developed.

Depositional Model for the "B2" Reservoir Sandbody

The facies association of the study intervals of "B2" reservoir sandbody can be interpreted as a deposit of fluvio - marine sediments. The succession of shoreface deposit, capped by a fluvial channel deposits (figure 4). This observation was implied from the lithofacies association as seen from the cored interval in the study well (figure 4). Indeed, this facies model is characterized by abundant fluvial processes, as well as tide dominated muddy laminations of the tidal flats sediments that are product of prograding coasts, characterized by mean tidal ranges >=4 m (Numair, *et al,* 2017).

The shoreface succession in the study section is well developed; it encompasses two main domains: the middle shoreface; the lower shoreface. The upper shoreface usually located landward is not well developed, probably due to the tide influence; Walker and Plint (1992), defined shoreface deposits as the interval between the mean sea-level and the mean fair-weather wave base. The shoreface model established for study well is similar to the shoreface model erected for "A1" reservoir sandbody, Well-5, Boga Field, Niger Delta (Okengwu and Amajor, 2014)

Ichnofacies serve as water depth indicators and are valuable aid to the interpretation of sedimentary environments (Pemberton et al., 1992). Hence, from the study of ichnofacies in the cored section of "B2" reservoir sandbody, distinct trace fossil assemblages such as *Ophiomorpha* and *Planolites* ichnofossils were observed, in the "B2" reservoir sandbody. The vertical movement of the *Ophiomorpha* trace fossils may have been as a result of the changing water level of the foreshore environment. Low or lack of bioturbation activity seen in the mudstone at the bottom of the Shoreface deposit may be attributed to the unfavorable conditions for organisms to thrive; such condition includes absence of light, food and oxygen in the environment of deposition.

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The depositional environment of the sand bodies in the study well can be interpreted as a deposit of fluvio - marine depositional environments.

Conclusion

The "B2" reservoir sandbody revealed nine (9) lithofacies types. Integration of the lithofacies with wireline log data helped to group the sandbody into three (3) facies associations that occur together and are considered to be genetically or environmentally related. The facies associations were interpreted as: Fluvial channel-Point Bar, Tide-dominated estuary and a Shoreface succession comprising two domains of Middle Shore face, and Lower Shoreface, capped by a Shelf Mudstone subfacies. The channel facies association shows a fining upward sequence, capped by an overbank deposit of mudstone lithofacies, the tide-dominated estuary shows a fining upward sequence. It consists from base: medium to coarse grained sandstone (McS) facies, and capped by a fine to silt grained tidal flats sediment (M), while the Middle and Lower Shoreface subfacies consist of coarsening upward sequence of sandstone succession of medium to coarse and fine to medium sand facies associations respectively. The facies associations of the sandbody in the study interval were interpreted as a deposit of fluvio - marine prograding shoreface overlaid by a fluvial Point bar deposits.

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