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SEDIMENTOLOGY AND RESERVOIR HETEROGENEITY OF THE "G1" RESERVOIR SANDBODY, BOGA FIELD, NIGER DELTA, NIGERIA

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ABSTRACT
Integration of sedimentologic, ichnologic, and stratigraphic studies of cores from "G1" reservoir, Boga Field, part of the Greater Ughelli depobelt, Niger Delta were undertaken to identify the depositional environment and reservoir heterogeneity. Two wells (Boga 51 and 52) were correlated to establish the lateral continuity of the "G1" reservoir sandbody across the field. Standard core description method was used to identify lithofacies and infer the depositional environment based on grain size and sedimentary structure. The result of the study reveals nine (9) lithofacies, grouped into two facies-assemblages (fluvial and barrier bar), were recognized from the Boga Field. The fluvial facies-assemblage, encompassing a variety of depositional environments includes, fluvial channel sand, tidal channel deposits, and upper-overbank. The shoreface facies assemblage includes upper-shoreface, middle-shoreface, lower-shoreface, and shelfal deposits. The Boga Fields' depositional system displays a wave-dominated depositional models, with local evidence of tidal action. The fluvial sandstones (facies Cbcms), encountered at the base of "G1" Boga 51, are the highest quality reservoirs. In the barrier bar system, the middle- to upper-shoreface sandstones (facies Mcs and Cbmcs) include reservoirs of high to moderate quality. Lower-shoreface sandstones (facies Bfms and Bmh) will contain relatively poor reservoirs because of their finer grain size and the intense and disruptive bioturbation. The study reveals that sedimentology and depositional environment of facies play a significant control on the reservoir quality. It also revealed a heterogeneous and compartmentalized reservoir, displaying a complex pattern in distribution and connectivity of reservoir sandstones at different heterogeneous scales.

INTRODUCTION
The "G1" Reservoir Sandbody of the Boga Field, Niger Delta is located within the Greater Ughelli Depobelt in the onshore part of the Niger Delta region. It lies between longitude 5.05°E and 7.35°E and latitude 4.15°N and 6.01°N (Figures 1) on the onshore part of the Niger Delta. The Reservoir Sand is between 3688m-3718m depth (30m thick) in Boga 51 and between 3322-3340m depth (18m thick) in Boga 52 Fields respectively. The cored section of the reservoir is thicker at Boga 51 than at Boga 52.

The Niger delta is a matured basin; several works have been undertaken on the Tertiary Niger delta sedimentary basin. Short and Stauble (1967) provided the initial information on the sediments and subsurface distribution of the stratigraphic units in the Niger delta. In that work, they studied the outline of the Niger delta and suggested that the major source rocks were shale of the Agbada Formation. Whitaker in (1985) identified the following environments in the Niger delta, mangrove swamp, channel deposits, shoreface and marine.

Adedokun, 1981 and Amajor and Agbaire, 1989, in their study evaluated the influence of depositional processes on, sedimentation, stratigraphy, reservoir facies distribution and architecture in the onshore basin of the Niger delta.

In recent years, the petroleum industry has increasingly used reservoir heterogeneity analysis of cores as an aid in reservoir characterization. MacEachern and Pemberton, in 1994, used ichnology data as instrumental in the recognition of estuarine deposits and their distinction from open-marine facies. The reconstruction of depositional environments in clastic sequences provides the optimum framework for describing and predicting reservoir development and reservoir distribution on both regional (exploration) and local (production) scales (Johnson and Stewart, 1985).

This study is designed to take a critical look at the stratigraphy, lithological characterization, in order to determine the various facies, depositional environments and the reservoir heterogeneity along lateral and vertical framework in the reservoir depth for the "G1" reservoir sand in Well-51 and Well-52, Boga field based on sedimentological studies using core and well log data. Sedimentology, ichnology and stratigraphy study are useful tools in defining depositional environmental and reservoir heterogeneity of sandstone reservoirs.

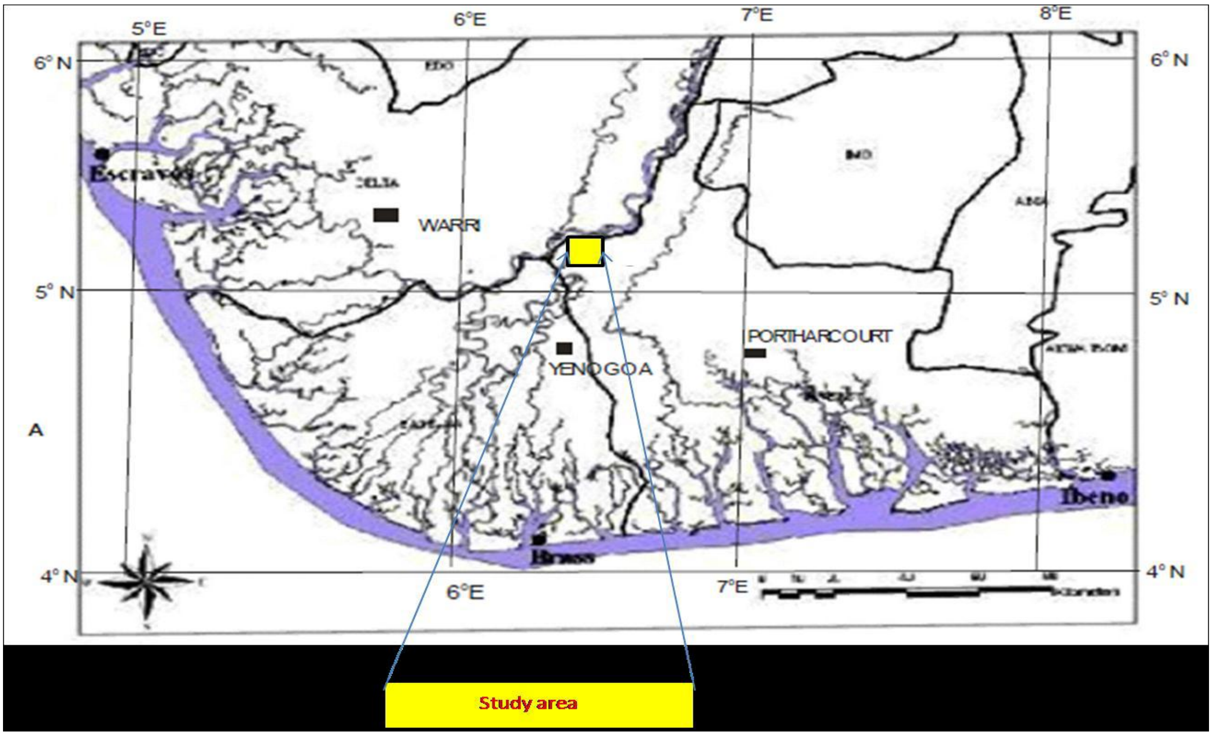

Figure 1--Map of Niger Delta basin, showing location of study area

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Stratigraphic and Geologic Setting

Studies by several authors in the Niger Delta revealed three vertical lithostratigraphic subdivisions: the Benin Formation, which is an upper delta top lithofacies; the Agbada Formation, which contains the hydrocarbon reservoirs and the lower part, the Akata Formation, which is the over pressured shale and the source of hydrocarbon generation. The type section as described by Short and Stauble (1967) is summarized in (Table 1) below.

Table 1: Regional stratigraphy of the Niger delta area (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/TUR	AWGU SHALE	TURONIAN
			SANTONIAN	EZE AKU SHALE	TURONIAN
			ALBIAN	ASU RIVER GROUP	ALBIAN

Benin Formation

The Benin Formation which is the upper deltaic-top like lithofacies has been described as "coastal plain sands" (Short and Stauble, 1967), the thickness of the Benin Formation ranges from 0-6000ft and is the source of the water supply. The formation outcrops in Benin, Onitsha and Owerri provinces and elsewhere in the delta area (Reyment, 1965). It consists mainly of massive, highly porous, fresh water sandstone with minor shale. The Benin Formation extends from the west across the Niger Delta area and southwards beyond the present coastline. The sands and sandstone are coarse to fine and the sediment consist of alluvial and upper coastal plain sands that are up to 2000 m thick (Avbovbo, 1978)

Agbada Formation

Deposition of the overlying Agbada Formation, the major petroleum-bearing unit, began in the Eocene and continues into the Recent (Short and Stauble, 1967),. The formation consists of paralic siliciclastics of over 3700 meters thick and represents the actual deltaic portion of the sequence. The clastics accumulated in delta-front, delta-topset, and fluvio-deltaic environments (Avbovbo, 1978). In the lower Agbada Formation, shale and sandstone beds were deposited in equal proportions, however, the upper portion is mostly sand with only minor shale interbeds.

Akata Formation

The Akata Formation is located at the base of the Niger delta sequence and consists of prodelta, hemipelagic, and pelagic shales deposited in marine environments. It is composed of thick shale sequences (potential source rock), turbidite sand (potential reservoirs in deep water), and minor amounts of clay and silt. Beginning in the Paleocene and through the Recent, the Akata Formation formed during lowstands when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency (Stacher, 1995). The Niger Delta basin consists of a series of depocenters or belts (Stacher, 1995). Major structure building growth fault determine the location of each depobelt. The entire sedimentary wedge was laid down sequentially in five major depobelt (Figure 2), each 30-60km wide, with the oldest lying further inland and the youngest located off shore (Reijers 1996).

Objectives of study

1. Describe and characterize using the core and well log response, the various lithofacies and facies association and determine their depositional environment.
2. Identify other sedimentological characteristics, such as ichnological aspects to characterize the various environments.
3. Utilize 2 and 3 above to establish reservoir heterogeneity for the vertical and lateral variations of lithofacies in the study area.

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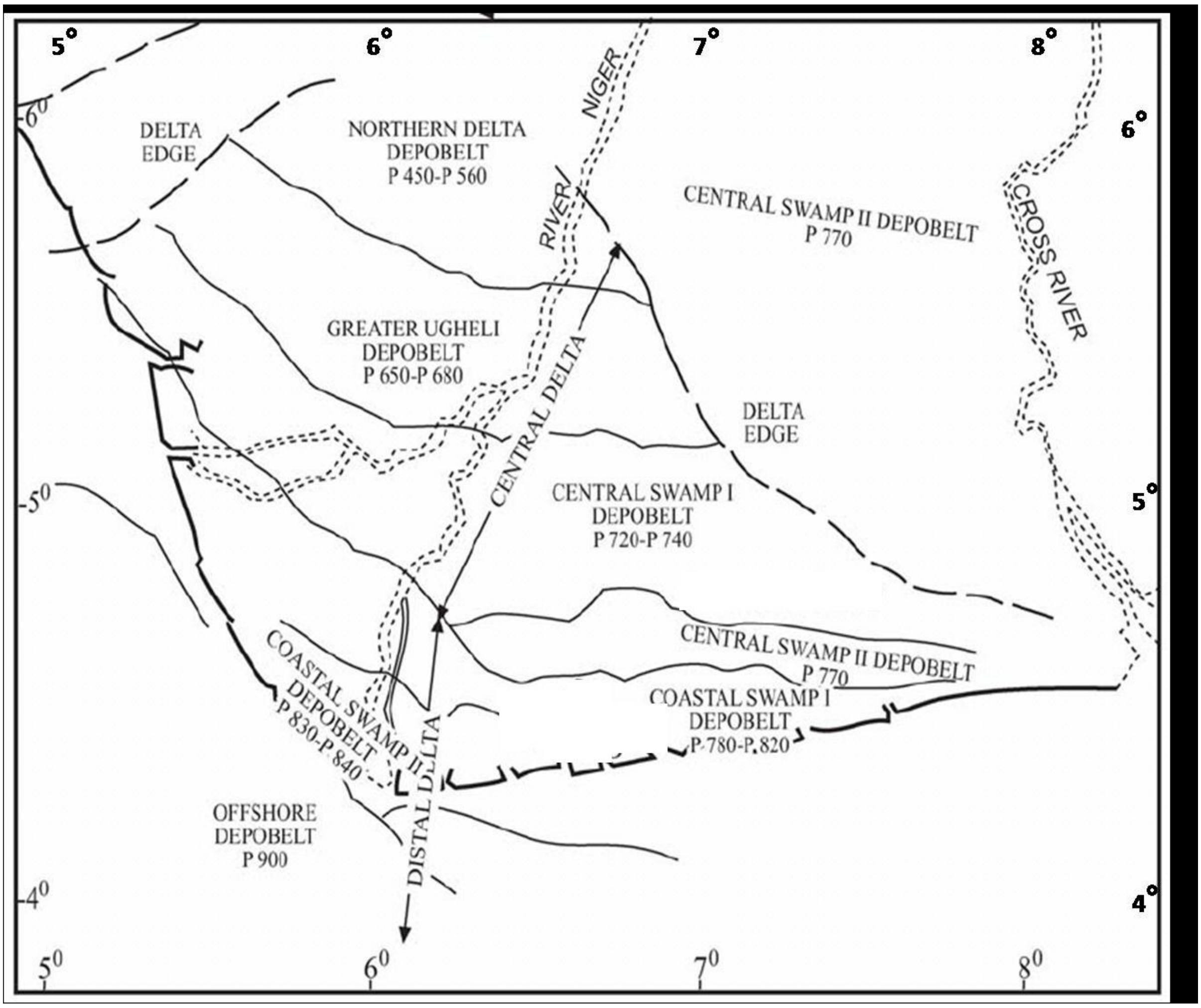

Figure 2: Map of Niger Delta showing the different depobelt (modified after Knox and Omotsola, 1989)

RESULTS

Facies Descriptions

Nine (9) lithofacies, grouped into two facies-assemblages (fluvial and barrier bar deposits), were identified in "G1" Reservoir of Boga 51 and Boga 52 Fields (Table 2). Each lithofacies were identified based on lithology characteristics, sedimentary structures and textural properties. The facies were grouped into associations for environmental interpretation.

The "G1" sandbody can be traced between the two closely located well of Boga 51 and 52 (Figure 3). The depositional sequence for the "G1" reservoir sandbody for both Boga 51 and Boga 52 are presented as Figure 4 and Figure 5 respectively.

The sedimentology and ichnologic content of each of these facies is discussed below, along with its implications in terms of depositional conditions and sedimentary environments. Facies descriptions include core data information. Information on the degree of bioturbation is based on the scheme by Taylor and Goldring (1993). Terminology for facie codes is based on the code that is consistent with Miall (1978) scheme of letter code.

Table 2. Facies scheme for the G1 Reservoir Sandbody for Boga 51 Field.

Facies Codes	Facies	Depositional Process	Sedimentary environment
Bcms	Bioturbated coarse to medium grained sandstone	Deposits of rapid sedimentation	Lag deposits / Channel
Ps	Pebbly sandstone	Tractive currents	Fluvial channels
Cbmcs	Cross bedded medium to coarse grained sandstone	Deposition by subaqueous dunes	Channel deposits
Cbfms	Cross bedded fine to medium grained sandstone	Deposits of channels and wave dominated environment	Estuarine channels
Mcs	Medium to coarse grained sandstone	Deposits of subaqueous dunes	Channels
Bsh	Bioturbated sandy heteroliths	Deposits as a result of suspension fallout	Shallow marine
Bmh	Bioturbated muddy heteroliths	Interplay of high energy event and fair-weather sedimentation.	Lower shoreface environment.
M	Mudstone	Deposit of low energy conditions	Shelf /overbank environment
Bfms	Bioturbated fine to medium grained sandstone	stressed estuarine environment	Lower shoreface

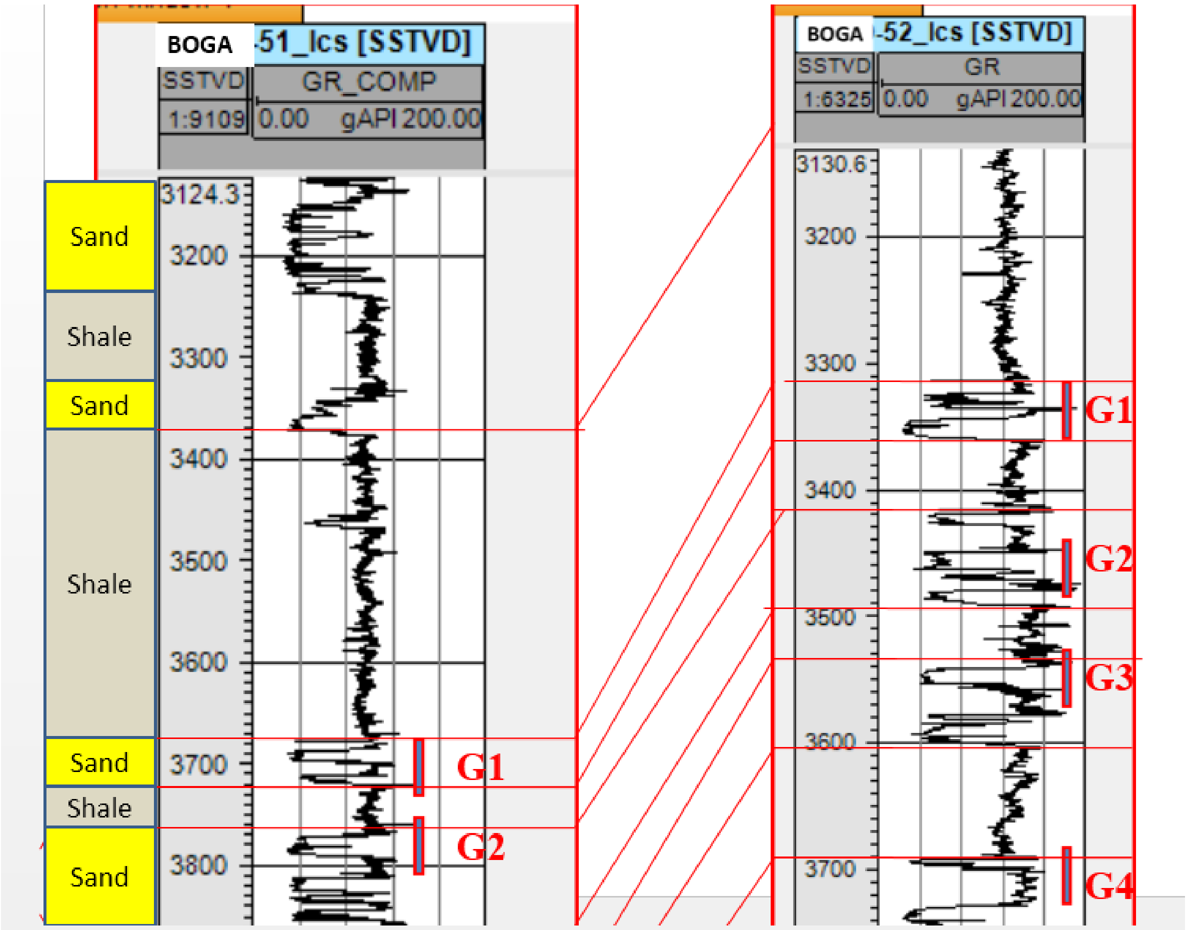

FIGURE 3: 'G1" Reservoir Sandbody, Boga Field, Niger Delta

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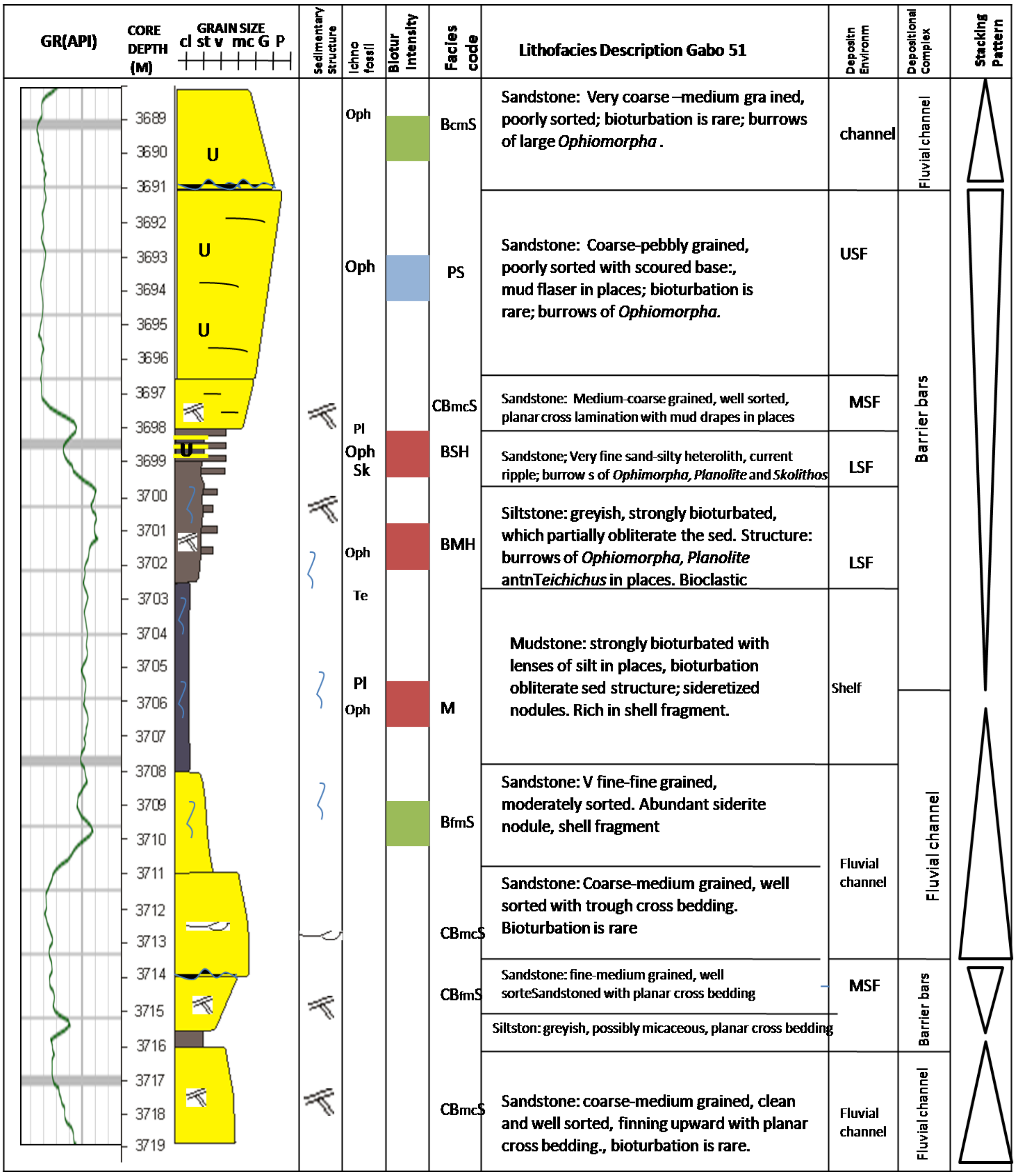

FIGURE 4: Depositional model for the "G1" Reservoir, Boga 51

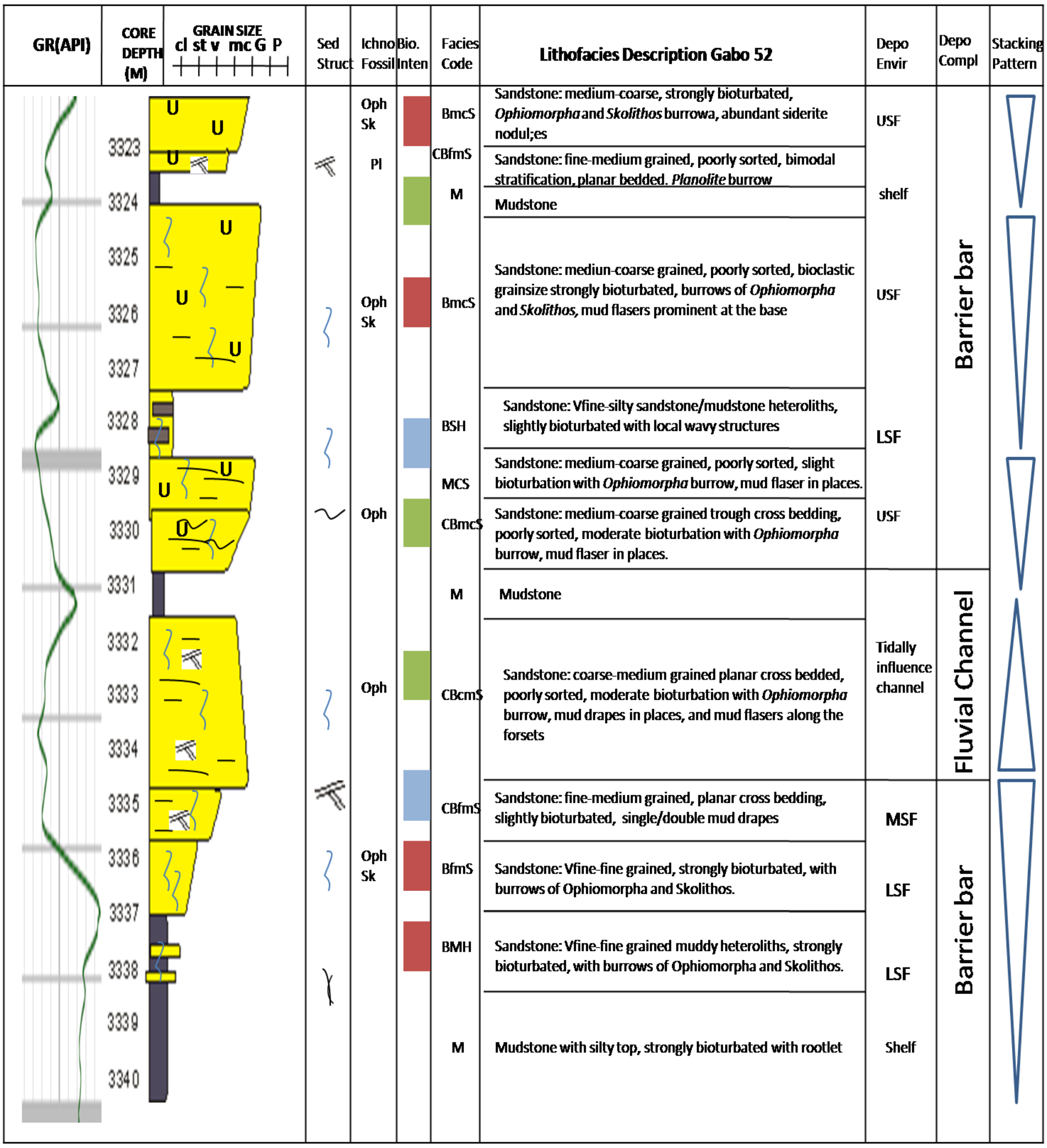

FIGURE 5: Depositional model for the "G1" Reservoir, Boga 52

Lithofacies and Facies Assemblage

Facies Bcms: Bioturbated Coarse to Medium Grained Sandstone

Description. The facies BmcS consists of medium to very coarse-grained sandstone, poorly sorted, with bioturbation ranging from moderate to intense (Figures 6 & 7). The sandstones contain grain-size of various clast, with sizes ranging from coarse to granule to pebbles. The sedimentary structure has been intensively obliterated by the action of bioturbation and the bioturbation structures have predominate over the bedding structure (Figures 6 & 7).

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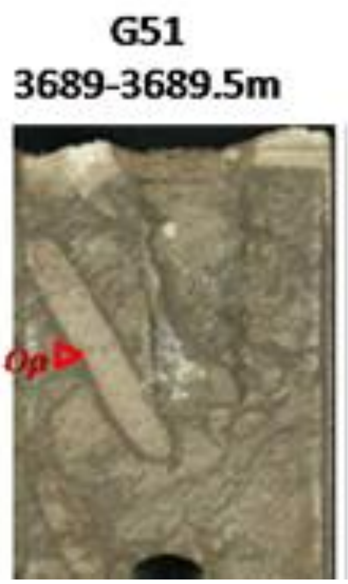

Figure 6

Figure 7

I*chnology*. The common trace includes *Ophimorpha nodosa*,and *Ophiomorpha Irregularia*, and *Skolithos* burrows (Figures 6 & 7).The Ophiomopha burrows may be up to 3-4cm in diameter and up to 12 cm long. This lithofacies occur in the cored interval of Boga 51&52.

Facies Ps: Pebbly Sandstone

Description. The lithofacies PS occurs as a thick bed of very coarse to pebbly sandstone with sharply defined scoured base (Figure 8). The sandstone is poorly sorted with no visible sedimentary. This lithofacies occurs only in the cored interval of Boga 51 study well but is missing in the Boga 52 cored interval.

Figure: 8

Ichnology. Bioturbation is generally rare.

Facies Cbmcs: Cross Bedded Medium to Coarse Grained Sandstone

Description. The cross bedded medium to coarse grained sandstone with cross bedding (Figure 9 & 10). Grayish brown in colour, and is moderately sorted. Grainsize is medium to coarse, shape range from angular to sub angular. It is bounded at the base by sharp erosive basal contact and overlying sharply on the Cross bedded fine to medium grained sandstone facies (Cbfms) in both Boga 51 and Boga 52 cored section.

G51
3713.5 – 3714m

Figure 9

G52
3333 – 3334.5m

Figure 10

Ichnology. Bioturbation is slight to rare

Facies Mcs: Medium to Coarse Grained Sandstone

Description. This lithofacies MCS consists of medium to coarse grained sandstone (Figures 11 & 12). The facies is poorly sorted and is characterizes by bimodal grain size sorting appearing as alternation of coarser and finer grain strata (Figures 11 & 12). The granules are rounded to sub angular in shape, with size ranging from 0.1-2cm and are predominantly of extra-formational lithology (typically quartz). Physical sedimentary structures in this lithofacies are not pronounced, except for the massive bedded nature of the facies. This lithofacies occur in the cored interval of the two study wells.

G51
3690-3690.5m

Figure 11

G52
3806-3806.5m

Figure 12

Ichnology. Bioturbation intensity is rare to absent in this facies.

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Facies Bsh: Bioturbated Sandy Heteroliths

The Bsh facies consists of fine-grained silty sand and muddy sandstone. This lithofacies occurs in the two cored study wells (Figures 13 & 14). 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 (Figures 13 & 14)). Some of the original clay laminations or ripple laminations are preserved. Physical structures on the lithofacies include parallel to wavy beddings.

Figure 13

Figure 14

Ichnology: The burrows of (*Skolithos* and *Planolites*) are both horizontal and vertical, all of which cut or disrupts the original bedding or lamination (Figure 13 & 14).

Facies Bmh: Bioturbated Muddy Heteroliths

Description. The lithofacies Bmh consists of light gray, moderate to intensively bioturbated mudstone, siltstone and relics of very fine sand (Figures 15 & 16). This lithofacies occurs in the two cored intervals (Boga 51 and 52) study wells. Physical sedimentary structures have not been properly preserved as a result of the bioturbation, and the only evidence of primary fabric is the presence of relics of wavy lamination. The interbedded very fine grained sandstone and siltstone are heavily bioturbated (Figure 14) while the mud intervals are slightly bioturbated. The bioturbated muddy heterolith overlies the mudstone facies in the two Boga fields.

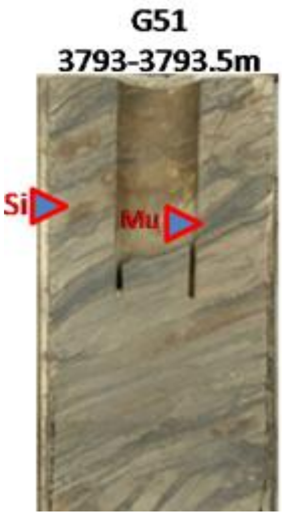

Figure 15

Figure 16

Ichnology. Bioturbation in this facies is dominated by *Ophiomorpha* and *Paleophycus* burrows, and is more intense in Boga 52 than Boga 51; this leads to partial obliteration of the sedimentary structures in Boga 51(Figure 15) and complete obliteration of the sedimentary structures in Boga 52 (Figure 16).

Facies M: Mudstone

Description. Mudstone lithofacies (M) encountered in the cored area consists of laminated dark-greenish-gray to greenish-black mudstone and it occurs in various stratigraphic intervals of all the study intervals (Figures 17 & 18). The massive laminated black/dark grey shale with parallel silt lamina of >2 mm thick (Figure 17) is common in the Boga 51 cored intervals. This facies is characterized by thin elongate, digenetic siderite nodules (Figure 17), and nodular concretions of digenetic siderite (Figure 18). Some are massive and strongly fissile (Figure 18). 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, planar lamination and oblique planar lamination.

Figure 17

Figure 18

Ichnology: Bioturbation in this facies is slight to rare, with burrowing parallel to laminae.

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Facies Bfms: Bioturbated Fine to Medium Grained Sandstone

Description: 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 (Figures 19 & 20). The grain-size indicates a reworking of sediment where the primary sedimentary structures have been intensively obliterated. This lithofacies occur prominently in the cored interval of Boga 52 but was not properly observed in the cored interval of Boga 51.

Figure 19

Figure 20

Ichnology: The common burrows include that of sub-horizontal *Planolites* and burrows of *Ophimorpha nodosa and Irregularies* (Figure 19).The Ophiomopha burrows may be up to 3-4cm in diameter and up to 10cm long.

Facies Cbfms: Cross Bedded Fine to Medium Grained Sandstone

Description The Cbfms Facies consists of moderate to well sorted, fine to medium grained sandstones (Figure 21 & 22). This lithofacies occur in the two cored interval of Boga 51 and Boga 52. It consists of planar cross bedded (Figure 21 of Boga51)); very clean sand with little clay content. The unit consists of locally trough cross-bedding (Figure 22 of Boga52)), Cross-beds typically contain single and/or paired mudstone drapes along forsets of topsets (Figure 21). The level of bioturbation in this facies ranges from low to moderate bioturbation.

Figure 21

Figure 22

Ichnology. Biogenic structure includes *Skolithos* and *Ophiomorpha* burrows.

DISCUSSION

Lithofacies Interpretation

The coarse to pebbly nature of lithofacies Bmcs (Figures 6 & 7) suggests a lag deposit generated by strong ephemeral current as in storm and major flood (Dalrymple, 1992). Lack of predefined internal bedding structure indicates rapid sedimentation (Allen, 1983). Intensity of bioturbation corresponds to a zone where nutrient is abundant. This lithofacies is suggestive of a lag deposits.

The very coarse to pebbly grained nature of this lithofacies Ps (Figures 8) 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.

The fining upward trend in lithofacies Cbmcs (Figure 9 & 10) is typical of unidirectional flow and is interpreted as sediments deposited within a channel. The cross beds structure depicts deposition by subaqueous dunes under strong, upper flow regime currents. During periods of strong lower flow regime, currents migration of subaqueous dunes deposited the cross beds. The very coarse grained character of the sediments suggests a fluvial origin. Absence of bioturbation and clean nature of sand suggest a deposition in a high energy environment and thus interpreted to be of tidal channel deposit.

The massive bedded sands in lithofacies Mcs (Figures 11 & 12) are the deposits of subaqueous dunes that were formed under strong upper flow regime. The coarse grained characters of the sediment are indicative of fluvial sourcing. The bimodal sorting (Figures 11 & 12) indicates cyclic, short term fluctuations in current strength and is interpreted to reflect tidal current modulation of the fluvial currents which supplied the coarse sediment (Walker and Plint, 1992 and Miall, 1996). This

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lithofacies is interpreted as a fluvial channel deposits.

The lithofacies Bsh (Figures 13 & 14) records the alternation of bedload and suspension depositional processes. The bedload sedimentations 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. The localized trace fossil assemblages are indicative of a stressed environment as a result of wave current action.

The analysis of lithofacies Bmh (Figures 15 & 16) reveals the interplay of high energy event and fair-weather sedimentation. The high energy depositional phase is recorded by the wavy rippled, finer grained sandstone; the fair-weather depositional phase is characterized by the presence of interbedded, very fine grained silty sandstones, siltstones and mud, which may record the latest stage of sediment fallout after the high energy sedimentation. The heterolithic nature of this facies indicates sedimentation in a setting characterized by alternating suspension fallout and bed-load, while its trace suite indicates deposition in a predominantly low energy setting below wave base. Thus this deposit is interpreted to have been deposited in the lower shoreface environment.

The sediment of the mudstone facies M (Figures 17 & 18) 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. Preservation of thin laminations, absence of bioturbation, and dark colours are suggestive of anoxic and reducing bottom-water conditions. Walker and Plint (1992) and Reineck and Singh (1980) described mudstones as offshore or shelf deposits. The mudstone unit with silty laminas is interpreted to have been deposited in an overbank of a channel while the black/dark laminated mudstone is interpreted to have been deposited in a shelf environment.

The bioturbation intensity in lithofacies Bfms (Figures 19 & 20) corresponds to a zone where oxygen content is high, nutrient is abundant and low energy condition, below wave base with dominance of large burrows of Ophiomorpha nodosa, Ophiomorpha Irregularies and Planolites with rare fossil shells, may characterize the influence of tidal or stressed estuarine environment. The intense bioturbation is an indication of lower shoreface. The sorting of the sandstone is probably by tidal currents or by wave action.

Recognition of Fluvial Channel Deposits

Fluvial channel systems were not well recognized in the G1 reservoir sandbody of the study area. Sedimentologic and ichnologic signatures indicate the presence of a channel deposit at the depth of 3331 - 3334.8m after the first open marine deposit, while the open-marine shoreface parasequences are dominant in Boga Well. Integration of ichnologic data with sedimentologic, stratigraphic, and paleogeographic information was crucial in the recognition of valley-fill sandstones in the Boga Well and in their distinction from open-marine shoreface deposits. The discovery of a low-diversity trace-fossil assemblage that records the activity of a marine fauna was essential in the recognition of a channel valley facies. This trace-fossil assemblage contrasts with the more diverse and abundant ichnocoenoses of the open-marine shoreface facies.

The recognition of the channel system is similar to the wave-dominated estuary characterized by Dalrymple, 1992). Tidal influence, however, is suggested by the presence of reactivation surfaces, mud drapes, and cross-lamination in the cross bedded medium to fine sandstones (facies Cbfm) and tidal-flat heterolithic deposits (facies Bsh).

Recognition of Valley fill and Open-marine / Shoreface Deposits

The base of the channel valley was recognized in the Boga well at the bottom of facies Cbfm interval (6333.4.8m). The channel valley was subsequently filled during sea-level transgression.

The Open-marine deposits is overlain by the fluvial channel facies deposit of sandstones with clay drapes (facies Cbfms), which are interpreted as having been deposited in the middle shoreface. The clay drapes indicate tidal influence. The ichnofauna consists of dwelling traces of suspension-feeders, such as *Skolithos* isp., and *Palaeophycus* isp., representing a typical example of the *Skolithos* ichnofacies. Ichnologic evidence supports marine influence during deposition. Sandstone packages deposited within the channels are replaced upwards by parallel-laminated Mudstone (facies M), interpreted as an overbank deposit. The mudstone facies is further overlain by the open marine deposits, including the upper and lower shoreface models. Sedimentologic, ichnologic, and stratigraphic information indicates deposition of cross bedded fine to medium sandstone and then overlain by the facies of medium to coarse grained sandstone and is interpreted to be the upper shoreface deposit. The shoreface model established for study well is similar to the shoreface model erected for "B3" reservoir sandbody, Well-05, Biwa Field, Niger Delta (Okengwu and Adiela, 2015).

The trace-fossil association in this facies includes *Palaeophycus* isp., *Planolites* isp., and *Skolithos* isp. The assemblage represents a mix between the *Skolithos* and *Cruziana* ichnofacies. Although ichno diversity is still low, the overall nature of the ichnofauna and the presence of certain ichnotaxa indicate less stressful conditions.

Implications for Evaluation of Reservoir Heterogeneity

Reservoir quality is largely influenced by external geometry and distribution of depositional facies (Buatois *et al.,* 1999). The integrated sedimentologic, ichnologic, and stratigraphic study shows that the "G1" reservoir sandstone have various types of heterogeneity because of the compartmentization between the depositional environments of fluvial to open – marine sandstone deposits. In these depositional systems, heterogeneity is created at different scales by facies and facies-assemblage distributions and by spatial partitioning within sandstone bodies.

Galloway and Hobday (1996) recognized five levels of heterogeneity in reservoir: gigascopic, megascopic, macroscopic, mesoscopic, and microscopic. Gigascopic heterogeneity is shown at the scale of depositional systems, while megascopic heterogeneity deals with the geometry of permeable and impermeable units. A clear example of controls on reservoir

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characteristics at the scale of gigascopic (depositional systems) is seen in the Boga Field, where distribution of fluvio-channel and tidal point bars, and open marine (shoreface) deposits create compartmnetization. The vertical and lateral changes in the depositional environment help to create a gigascopic heterogeneity.

Macroscopic heterogeneity is expressed at the facies scale. Sedimentologic and ichnologic analyses in this study indicate a high variability in sedimentary facies (recognition of nine (9) types of facies), these facies variations governs fluid behavior, porosity and permeability heterogeneities, both laterally and vertically. The proposed facies scheme (Table 1) for the "G1" reservoir sandbody, Boga Fields provides a way to analyze heterogeneity at the macroscopic scale. For example, the distinction between fluvial channels (facies) and tidally influence channel (facies) sands in 'G1" is based on the presence of bioturbation and mud drapes (as well as other tidal structures) in the channel sands. Although both channel fills contain good-quality reservoir sands, permeability is higher in the fluvial facies MCS because mud-baffles restrict the flow in the tidally influence cross bedded facies (Cbfms). Shoreface sandstone packages are laterally continuous in Boga Field. However, facies subdivision of these sandstone bodies in upper-, middle-, and lower-shoreface facies provides evidence of reservoir heterogeneity. Finer-grained sediments and mud drapes in the lower shoreface commonly create permeability barriers within reservoir shoreface sandstones.

Mesoscopic heterogeneity occurs at the scale of lithofacies and stratification, while microscopic heterogeneity is expressed at the scale of individual grains and pores. In the Boga Fields, mesoscopic and microscopic heterogeneities are reflected by the styles of bedding and lamination, presence of mud drapes, biogenic disruption of primary fabric, and diagenetic overprint (Buatois *et al.*, 1999)**.** Although the current assumption is that bioturbation reduces porosity and permeability, this is not necessarily the case. According to Muñoz, 1994; and Gingras *et al.*, 1997, deposit-feeders that backfill their burrows may damage pore connectivity in certain situations, but open structures produced by suspension-feeders and passive carnivores do not reduce porosity and permeability and may even act as conduits for fluid migration.

Integration of sedimentologic, ichnologic, and stratigraphic data will allow recognition of different reservoir zones within the "G1" sandbody. Fluvial sandstones (facies Cbcms), encountered at the base of "G1" Boga 51, are the highest quality reservoirs. These sandstones are mainly unbioturbated, well sorted and clean and have very high values of porosity and permeability (Whiteman, 1982)

In this study, however, permeability variations is most likely related to the presence of mud drapes, which act as local barriers for fluid migration. The overbank mudstone (facies M) does not include reservoirs because of their finer grain size, but they may have acted as effective seals for reservoirs in fluvial sands. Associated heterolithic deposits (facies Bsh and Bmh) are also poor reservoirs because of their very fine grained sandstones, intense bioturbation, and abundant clay drapes.

In the barrier bar system, the middle- to upper-shoreface sandstones (facies Mcs and Cbmcs) include reservoirs of high to moderate quality. Lower-shoreface sandstones (facies Bfms and Bmh) will contain relatively poor reservoirs because of their finer grain size and the intense and disruptive bioturbation, particularly in the distal lower shoreface. Finally, offshore and shelfal mudstone deposits (facies M) are very fine grained and locally bioturbated; therefore, they do not include reservoirs.

In summary, the study area revealed a picture of a heterogeneous and compartmentalized reservoir, displaying a complex pattern in distribution and connectivity of reservoir sandstones properties, both vertical and lateral changes at different heterogeneous scales.

By integrating data from sedimentologic, and stratigraphic studies of two cores from the "G1" Sandstone, we were able to distinguish between fluvial channel sand from barrier bar deposits and thus provide a more precise picture of reservoir sandstones in the Boga Field, Niger Delta.

The fluvial assemblage includes facies that have been deposited in fluvial channels, tidally influenced channels, and overbank mudstone facies M. The barrier bar assemblage includes upper shoreface, middle shoreface, and lower shoreface sandstones and capped by, offshore, and shelf fine-grained mudstone facies M. The "G1" deposits shows a laterally extensive deposits between the two widely spaced locations of Boga- 51 and Boga - 52.

The Boga Fields' depositional system displays a wave-dominated depositional models, with local evidence of tidal action.

Recognition of upper shoreface and fluvial channels deposits have implications for high hydrocarbon exploration and production. The study revealed that sedimentology and depositional environment of facies plays a significant control on the reservoir quality. It also revealed a heterogeneous and compartmentalized reservoir, displaying a complex pattern in distribution and connectivity of reservoir sandstones at different heterogeneous scales.

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