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Research Article

FACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT OF OBUA FIELD, NIGER DELTA, NIGERIA

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ABSTRACT

The facies analysis of OBUA field, Niger Delta Basin has been investigated to reconstruct the paleoenvironment ofreservoir sand bodies across the field. The research methodology involved delineation of lithologies, identification of reservoirs, correlation of sand units and identification of electrofacies from log signatures of gamma ray, spontaneous potential and resistivity logs, and also paleoenvironmental reconstruction based on integration of the analysis of log motif with side wall core sample data. The results showed that two lithologiesrecurrently recognized in OBUA field are sand and shale.Stratigraphic correlation of the studied wells led to a division of sand bodies into two units. They are sand A and D respectively. Sand A thin towards the eastern part of the field.Sand D is cleaner than that of A and is also thicker.Three log facies were recognised in the study area: funnel-shaped facies representing prograding delta andsubmarine fans; cylindrical-shaped facies representing delta distributary channel and grain flow fill (submarine channel); bell-shaped facies representing turbidite fill(submarine channel). These environments identified are potential reservoirs for hydrocarbon accumulation.

Keyword: Paleoenvironment, Lithologies, Electrofacies, Environments,Correlation.

INTRODUCTION

Facies analysis provides useful information in paleoenvironmental reconstruction. The criteria commonly used to identify facies on the logs are based upon characteristic shapes and changes in the log curves. A sharp shift in the curve is indicative of an abrupt bed boundary and highly contrasting depositional energies. Geophysical logs provide a complete vertical profile of the borehole and also yield to the trained interpreter curve shapes and features representative of depositional facies. Some of these features include fining upward sequences(which indicate decreasing depositional energy towards the top of the units), coarsening upward sequences (which indicate increasing energy of deposition up section) and uniform sequences (which is an indicative of more uniform massive bedding and consistent depositional energy within the bed).

Extensive descriptions of depositional facies and environments in Niger Delta Basin are presented in many publications. Some of these include,Odoh (1993), Nton and Adesina (2009), Onyekuru et al, (2012), Omoboriowo et al (2012) among others.

This study therefore utilizes these previous research as well as that of Chow et al (2005) who defined the paleoenvironment of the Hydrocarbon Producing zones in the Erchungchi Formation, Hsinyin, SW Taiwan using integration of well logs with well sample data.

Therefore, by combining data from well logs and side wall core sample, reasonable and practically rewardingpaleoenvironmental reconstruction is made.

GEOLOGIC SETTING AND STRATIGRAPHY

OBUA Fieldis locatedwithin southwest ofthe Central swamp Depobelt of Niger Delta Basin (Fig.1). The Niger Delta Basin is situated on the continental margin of the Gulf of Guinea in Equatorial West Africa between latitude 3^0N and 6^0N and longitude 5^0E and 8^0E (Reijers 1996). It is the most prolific and economic basin in Africa. The sediments of Niger Delta comprise of three stratigraphic formations namely, Benin, Agbada and Akata Formations.

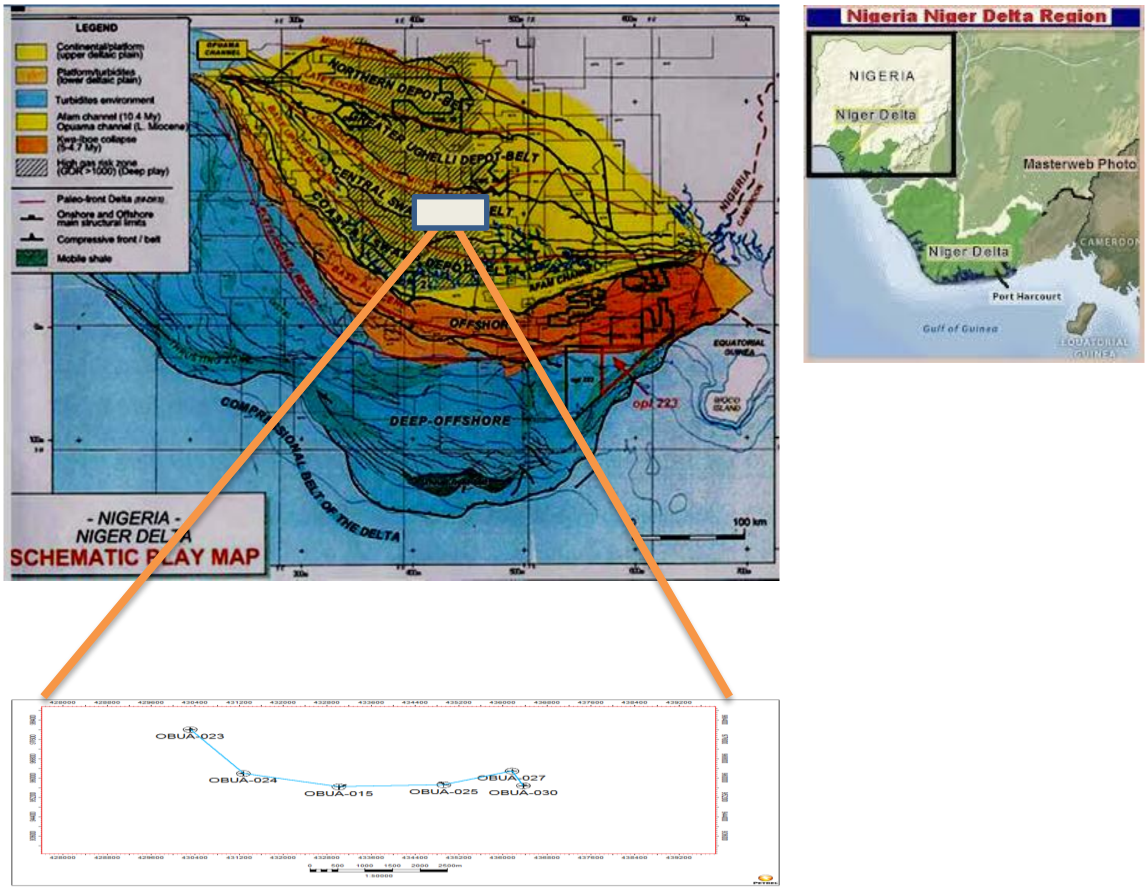

Figure 1: Location map of Niger Delta showing the study area and the inset of map of Nigeria

The Benin Formation which is the topmost section of the Niger Deltaconsists predominantly continental sands. Benin Formation is underlain by the paralicAgbada Formation which is the major petroleum bearing unit in Niger Delta. Most of the hydrocarbon accumulations in Niger Delta occur in this unit where they are trapped by rollover anticlines related to growth fault development (Morgan, 2003). The Agbada Formation consists of sand/shale sequence. The Akata Formation lies at the base of the Niger Delta sequence. It is predominantly marine prodelta shale. Also turbidite sands with minor amounts of clay and silt are common (Avbovbo 1978).

Depobelts otherwise known as sedimentation cycles are common in Niger Delta. These cycles progradesouthwestward over oceanic crust into Gulf of Guinea (Stacher, 1995),and are defined by synsedimentary faulting that occurred in response to variable rates of subsidence and sediment supply (Doust and Omatsola, 1990).Integrated geological studies have shown that five depobelts exist in Niger Delta Basin. They are Northern depobelt, Greater Ugheli, Central swamp, Coastal swamp, and Offshoredepobelt (Figure 1).

MATERIALS AND METHODS

The data used for this research were provided by Shell Petroleum Development Company with permission of the Department of Petroleum Resources (DPR), Port Harcourt. The data include; base map, welllogs (gamma ray, spontaneous pontential and resistivity) and side wall core samples description.

The research methodology involved delineation of lithologies, identification of reservoirs, correlation of sand units, identification of electrofacies andpaleoenvironmental reconstruction.The well log data were checked for quality to avoid interpretation pitfalls before being imported into the interactive Petrel workstation. The relevant wireline log signatures were employed to identify the lithologies and facies.

Lithology was determined using evidence from wireline log characteristics. Sand was recognised with low gamma ray readings and maximum leftward deflection of spontaneous potential log signature. Shale sequence on the other hand, showed high gamma ray reading and deflection of spontaneous potential to the right. Reservoirs were defined by high resistivity and low gamma ray readings. Sand correlations were based on pattern recognitions on both the gamma ray and SP curves. Depositional facies (elecrofacies) wereidentified based upon the characteristic shapes and changes on the gamma ray and spontaneous potential curves. Paleoenvironmental reconstruction was made by correlating the analysis of log motif with the composition of side wall core sample data according to Selly 1998; Murkute 2001; and Chow et al, 2005).

RESULTS AND DISCUSSION

Lithologic Analysis:

Results from well logs revealed sand and shale as the two keylithologies commonin OBUA field.The interval coloured yellow depicts sand while the interval coloured black represents shale.

Sand Analysis and Correlation:

Two sand units were correlated in this field. They are **sand A** and **sand D** (Fig.2).

Sand A:

The results of the sand analysis and correlation show that at OBUA-023, sand A is located between depths 10875 – 10940ft true vertical depth subsea (SSTVD). The thickness of the sand body is about 65ft (20m). In OBUA-024, sand A is at a depth range of 10940 – 11015ft (SSTVD). Sand thickness increases from OBUA-023 to OBUA-024 with the thickness measuring about 75ft (23m). In OBUA-015, the same sand is located between 10930 and 11000ft. The thickness is 70ft (21m). At OBUA-025, sand A occurred at 11055 – 11130 SSTVD with thickness measuring about 75ft (23m). Same sand is located in OBUA-027 between depths 11055 – 11125ft SSTVD. The thickness is 70ft (21m). At OBUA-30, sand A occurred between depths 10910 – 10970ft SSTVD with thickness of 60ft (18m). Sand A is thickest in OBUA-024 and 025. Sand thickness decreases from OBUA-025 to OBUA-030 with the thinnest being recorded at OBUA-030 (Table 1). Sand A becomes dirtier towards the eastern part of the field.

Sand D:

At OBUA-023, sand D ranges in depth between 11620 and 11805ft SSTVD. The thickness is about 185ft (56m). In OBUA-024, same sand is located between depths 11570 – 11740ft. The thickness of sand D as observed in this well is 170ft (51m). Sand D was observed to recur in OBUA-015 at a depth range of 11610 – 11785ft. The thickness is 175ft (53m). In OBUA-025, same sand occurred between depths 11695 – 11880ft with thickness measuring about 185ft (56m). At OBUA-027, sand D is located between depths 11690 - 11890ft. Sand thickness is recorded as 200ft (60m). Sand D is also recorded at OBUA-030 at a depth range of 11970– 12120ft SSTVD. The thickness is measured as 150ft (45m).

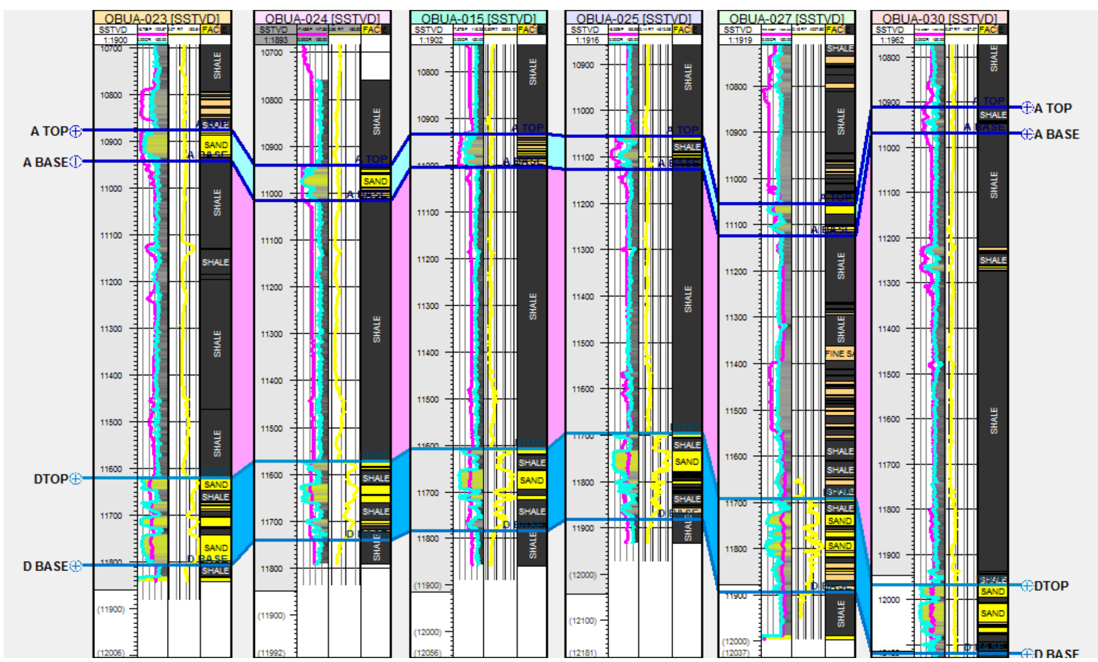

Figure 2: Welllogs correlation of the "OBUA" field, Central swamp Depobelt of Niger Delta Basin

Sand D is generally thicker than sand A, with the thickest sand body occurring at OBUA-027. The sand distribution within the reservoir regionsindicate that the reservoir sands are interspersedwith shaly sand units. Figure 2 shows sand correlation in OBUA Field.

	OBUA-023				OBUA-024				OBUA-015				OBUA-025				OBUA-027				OBUA-030			
	Top (ft)	Base (ft)	Th (ft)	Th (m)	Top (ft)	Base (ft)	Th (ft)	Th (m)	Top (ft)	Base (ft)	Th (ft)	Th (m)	Top (ft)	Base (ft)	Th (ft)	Th (m)	Top (ft)	Base (ft)	Th (ft)	Th (m)	Top (ft)	Base (ft)	Th (ft)	Th (m)
Sand A	10875	10940	65	20	10940	11015	75	23	10930	11000	70	21	11055	11130	75	23	11055	11125	70	21	10910	10970	60	**18**
Sand D	**1162 0**	**11805**	**185**	**56**	**11570**	**11740**	**170**	**51**	**11610**	**11785**	**175**	**53**	**11695**	**11880**	**185**	**56**	**11690**	**11890**	**200**	**60**	**11970**	**12120**	**150**	**45**

Table 1: Sand analysis of OBUA field

Where th = thickness, ft = feet, m= meter

Facies Analysis:

Three log facies were recognized in six studied wells. They include; funnel shape (coarsening or cleaning upwards sequence) which shows increasing energy of deposition and also decrease in clay contents, bell shape (finning or dirtying upwards sequence) representing decreasing depositional energy and also increase in clay content. Finally, cylindrical shape which is asuggestive of more uniform bedding and consistent depositional energy within the bed (Figure 3).

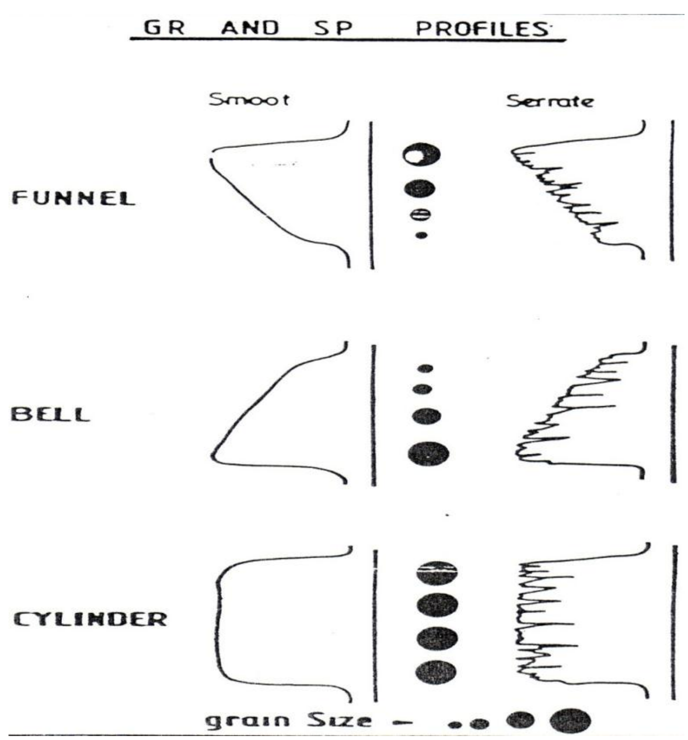

Figure 3: Gamma ray and SP log profiles showing the basic shapes of facies (After Shell, 1982).

Sand A:

The result of the correlation of sand bodies in the field shows that at OBUA-023, sand A is identified between depths 10,875 to 10940ft SSTVD. The gamma ray log identified in this section exhibits a funnel shaped character.

At OBUA-024, sand A occurred between depths 10,940 to 11,015ft SSTVD. Bell shaped log pattern on gamma ray logs was observed in this section of the field.

Also, a bell shaped log motif on gamma ray logs recurs at OBUA-015 between depths 10,930 to 11,000ft SSTVD.

At OBUA-025, sand A which was identified between depths 11,055 to 11130ft SSTVD shows the gamma ray log signature of bell motif.

The gamma ray log in OBUA-027 appears to show a funnel motif. This sand A was observed at depths 11,055 to 11,125ft SSTVD in this well.

Interpretation:

Sand A, as observed in OBUA field is generally dirty and it appears to thin out at OBUA-030. No side wall core samples were provided within this unit. Based on this, paleoenvironmental reconstruction is not made since accurate depositional interpretation is made by integrating both well log motifs with side wall core sample data.

Sand D (Description):

Analysis of the logs shows that the log motifs of sand D fall mostly into three categories. They are; funnel-shaped, bell-shaped and cylindrical-shaped motifs.

OBUA-023 (Funnel-shaped succession):

Description:

The gamma ray log of OBUA-023 shows a funnel shape which is about 185ft (56m) thick. Mica flakes and plant remains are common in this well.

Interpretation:

Glauconite, shell debris, carbonaceous detritus and mica are commonly recorded in well sample explanations in well reports. Their presence (but not their absence) helps in reconstructing environment of deposition. Carbonaceous detritus includes coal and plant fragments. The funnel-shaped successions with carbonaceous matter represent a coarsening-upward environment of rapid deposition (Chow et al 2005). Selly (1998) suggested three categories of environments for coarsening upward succession. The environments include; regressive barrier bars, prograding submarine fans, prograding delta or crevasse splays. Both regressive barrier bars and prograding submarine fans are usually deposited with glauconite and shell debris (Selly 1998; Nelson and James 2000; Marenssi et al 2002; Chow et al 2005). Since no glauconite is recorded in this succession, the paleoenvironment can be inferred to as prograding delta or crevasse splays. Prograding delta is distinguished from crevasse splays on the basis of the depositional scale. Prograding delta is relatively large. The thickness of the funnel-shaped succession encountered is about 185ft (56m). Based on this thickness, the paleoenvironment of this funnel-shaped succession can be inferred to as prograding delta.

OBUA-024 (Funnel-shaped succession):

Description:

Funnel-shaped succession recurs again in OBUA-024. The thickness of the funnel profiles is about 170ft (51m). This succession is associated with mica flakes and weathered glauconitic.

Interpretation:

Like earlier stated, funnel motif indicates the deposition of coarsening or cleaning upwards of sediments. According to the identification system of Selly (1998), the paleoenvironment of funnel-shaped successions with the presence of glauconite and mica flakes can be interpreted as prograding submarine fans.

OBUA-015 (cylindrical-shaped succession):

Description:

In OBUA-015 of the study area, the gamma ray and SP logs show a cylindrical motif. This cylindrical motif is formed due to the presence of shales at the boundaries. The thickness as observed in this succession is about 175ft (53m). Associated minerals include, mica flakes and pyrite inclusions in quartz.

Interpretation:

The cylindrical shaped motif shows the truncation or rapid termination of deposition at the upper and bottom boundaries. Three general categories of environments can form cylindrical shaped successions (Selly 1998). The environments include; tidal sand wave, grain flow fill and delta distributary channel. The first two environments, tidal sand wave and grain flow fill are commonly associated with glauconite and shell debris (Chafetz and Reid 2000; James and Bones 2000; Chow et al, 2005). Therefore, the paleoenvironment can be inferred to as delta distributary channel since no glauconite is recorded in this succession.

OBUA-025 (cylindrical-shaped succession):

Description:

Cylindrical-shaped succession recurs again in OBUA-025.

The thickness of this succession is about 185ft (56m). No side wall core sample report was provided for this succession.

Interpretation:

The unavailability of side wall core sample data in this well restricted accurate paleoenvironmental interpretation. Considering only the log motifs, the environment of deposition may be said to be that of tidal sand wave, grain flow fill or delta distributary channel.

OBUA-027 (Bell-shaped succession):

Description:

The gamma ray log of OBUA-027 appears to show a bell motif. Mica flakes, quartz inclusions, weathered glauconite and rare lignite are common in this unit. The thickness of this succession is about 200ft (60m).

Interpretation:

The bell shaped succession occurs in three environments (Selly 1998, Chafetz and Reid 2000, James and Bones 2000, Nelson and James 2000, Marenssi et al 2002, and Chow et al 2005). These environments include; tidal channels, turbidites fills and fluvial or deltaic channels. According to the above well log researchers, tidal channels and turbidite fills are associated with glauconite and shell debris. But the presence of mica suggests a paleoenvironment of Turbidite fill (submarine channel).

OBUA-030 (Cylindrical-shaped succession):

Description:

In the study area, a cylindrical motif appears again in the gamma ray log of OBUA-030. The thickness of this succession is about 150ft (45m). Weathered glauconite, plant remains, mica flakes, lignite and quartz are common.

Interpretation:

Similar to OBUA-015 and 025, cylindrical -shaped gamma ray log motif represents deposition of coarsening or cleaning upwards of sediments. The possible environments of deposition of a cylindrical motif as documented by Selly (1998) include; tidal sand wave, grain flow fill and delta distributary channel. According to Selly, a cylindrical motif associated with glauconite and mica is Grain flow fill (submarine channel).

SUMMARY AND CONCLUSIONS

The facies analysis and paleoenvironmentalreconstruction of OBUA field, Niger Delta Basin revealed sand and shale as the two key lithological units in the studied area. Two sand units (**sand A** and **D**)were correlated in this field. Sand D which is deeper than that of A has better sand development for hydrocarbon accumulation.

From well log analysis, three facies have been outlined in both sand bodies. They are funnel shaped, bell shaped and cylindrical shaped motifs. The faciesin reservoir D denotespaleoenvironment of Prograding delta, Prograding submarine fan, Delta distributary channel, Turbidite fill (submarine channel) and Grain flow fill (submarine channel). These environments identified are potential reservoirs for hydrocarbon accumulation. According to Sneider et al (1978), distributary channel deposits encompass the best reservoir quality within the deltaic system. Submarine fans can also be prolific hosts for hydrocarbon (Pettingill and Weimer 2002).

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