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Research Article

PALEOENVIRONMENTAL STUDIES OF "*OLO*" RESERVOIR SANDSONE, NIGER DELTA, NIGERIA

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ABSTRACT

The *Olo* Reservoirs sands penetrated by well drilled in Niger Delta Basin, were investigated for its depositional environmentsl characteristics. Lithofacies analysis is grouped into facies association comprising tidal channels, Upper shoreface, and Lower shoreface. A mixture of marine reworked sands and subordinate fluvial sands, marked by erosion base characterizes the tidal channel.

The Upper shoreface facies consist of coarsening upward sequence, sandstone succession of fine to very fine sand facies associations and these were caliberated with selected logs to allow the field correlation. The result available from integration of wireline log and core data reveal that the environment of deposition of "Olo" reservoir sands lies within the marginal marine environments.

INTRODUCTION

This research work focuses attention on the Reservoir Characterization of a hydrocarbon bearing sand in 'Olo' field of the Niger Delta. The environment of deposition is examined and the type produced as a model of the sub-surface reservoir. To achieve this, an integrated analysis of cores from wells, as well as biostratigraphic data and wireline logs of the *Olo* sands were used for the study. The *Olo* sand of study comprises one major depositional sequence. Core analysis revealed the existence of lithofacies. These lithofacies are grouped into facies association in a vertical sequence with a genetic significance using primary structures and shape of wireline logs.

LOCATION OF STUDY:

The oil field in Niger delta used for this study is personally named *Olo* Well for the purpose of confidentiality. *Olo* Well is situated in the eastern part of Northern depobelt.

Figure 1: Location Map of the Study Area

AIM OF THE STUDY

The aim of the study is to provide a Paleoenviromental studies of the *Olo* reservoir sand with the effort of ascertaining the environment of deposition of the area

GEOLOGY OF THE NIGER DELTA BASIN:

The established Tertiary sequence in the Niger Delta consists, in ascending order, of the Akata, Agbada, and Benin Formation. The strata composed an estimated 8,535 m of section at the approximate depocenter in the central part of the delta.

Akata Formation:

The Akata Formation which is the basal unit of the Cenozoic delta complex is composed mainly of marine shales deposited as the high energy delta advanced into deep water (Schlumberger, 1985). It is characterized by a uniform shale development and the shale in general is dark grey, while in some places it is silty or sandy and contains especially in the upper part of the formation, some thin sandstone lenses (Short & Stauble, 1967).

The Akata Formation probably underlies the whole Niger Delta south of the Imo Shale outcrop of the Paleocene age from Eocene to Recent (Short & Stauble, 1967). The Akata Formation has been penetrated in most of the onshore fields between 12,000 and 18,000 ft (~3,700 – 5,500 m) and in many of the offshore fields between 5,000 and 10,000 ft (~1,530 – 3050 m); however, the maximum thickness of the Akata Formation is believed to average 20,000 ft (~7,000 m).

For all practical prospecting purposes, the top of the Akata Formation is the economic basement for oil; however, there may be potential for gas dissolved in oil field waters under high pressure in the deeper formation (Schlumberger, 1985).

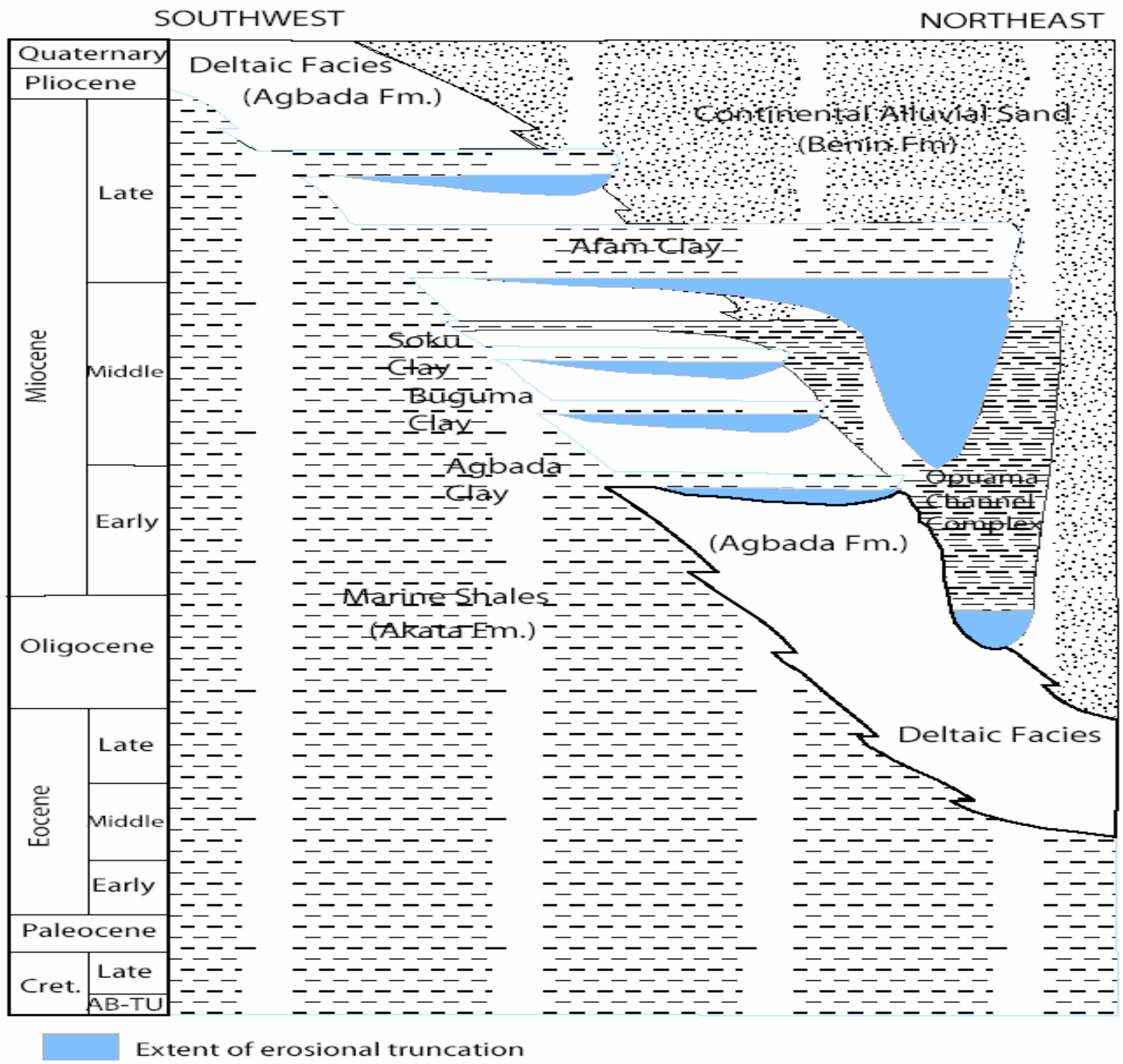

Figure 2: Stratigraphic column showing the three formations of the Niger Delta (Doust and Omatsola, 1990).

Agbada Formation:

The Agbada Formation is a paralic succession of alternating sandstones and shales, whose sandstone reservoirs account for the oil and gas production in the Niger Delta (Nwachukwu and Odjegba, 2001).

The formation consists of an alternating sequence of sandstones and shales of delta-front, distributary-channel, and deltaic-plain origin. The sandstones are medium to fine-grained, fairly clean and locally calcareous, glauconitic, and shelly. The shales are medium to dark grey, fairly consolidated, and silty with local glauconite.

The sand beds constitute the main hydrocarbon reservoirs while the shale beds present form the cap rock. These shale beds constitute important seals to traps and the shales interbedded with the sandstones at the lower portions of the Agbada Formation are the most effective delta source rocks (Schlumberger, 1985). Petroleum occurs throughout the Agbada Formation of the Niger Delta.

Maximum thickness of the formation is 3,940m (12,000ft) at the central part of the delta, and thins northward and toward the northwestern and eastern flanks of the delta. The formation is poorly developed or absent north of the Benin city-Onitsha-Calabar axis. The age of the Agbada Formation varies from Eocene to Pliocene/Pleistocene.

Benin Formation:

The Benin Formation consists of predominantly massive highly porous, freshwater-bearing sandstones, with local thin shale interbeds, which are considered to be of braided-stream origin. Mineralogically, the sandstones consist dominantly of quartz and potash feldspar and minor amounts of plagioclase. The sandstones constitute 70 to 100% of the formation. Where present, the shale interbeds usually contain some plant remains and dispersed lignite.

Benin Formation attains a maximum thickness of 1,970m (6,000ft) in the Warri-Degema area, which coincides with the maximum thickness (i.e. depocenter) of the Agbada Formation. The first marine foraminifera within shales define the base of the Benin Formation, as the formation is non-marine in origin (Short and Stauble, 1967). Composition, structure, and grain size of the sequence indicate deposition of the formation in a continental, probably upper deltaic environment. The age of the formation varies from Oligocene (or earlier) to Recent.

STRUCTURES OF THE NIGER DELTA BASIN:

The delta sequence is deformed by syn-sedimentary faulting and folding. Evamy et al. (1978) described the main structural features of the Niger Delta as growth faults and roll over anticlines associated with these faults on their downthrown (i.e. seaward) side.

Growth faults:

Growth faults are faults that offset an active surface of deposition. It is characterized by thicker deposits in the downthrown block relative to the upthrown block. The growth fault planes exhibit a marked flattening with depth as a result of compaction. Thus a curved, concave-upward fault plane is developed, which continues at a low angle.

The ratio of the thickness of a given stratigraphic unit in the downthrown block to that of the corresponding unit in the up-thrown block is termed the ‘growth index which in Nigeria can be as high as 2.5m.

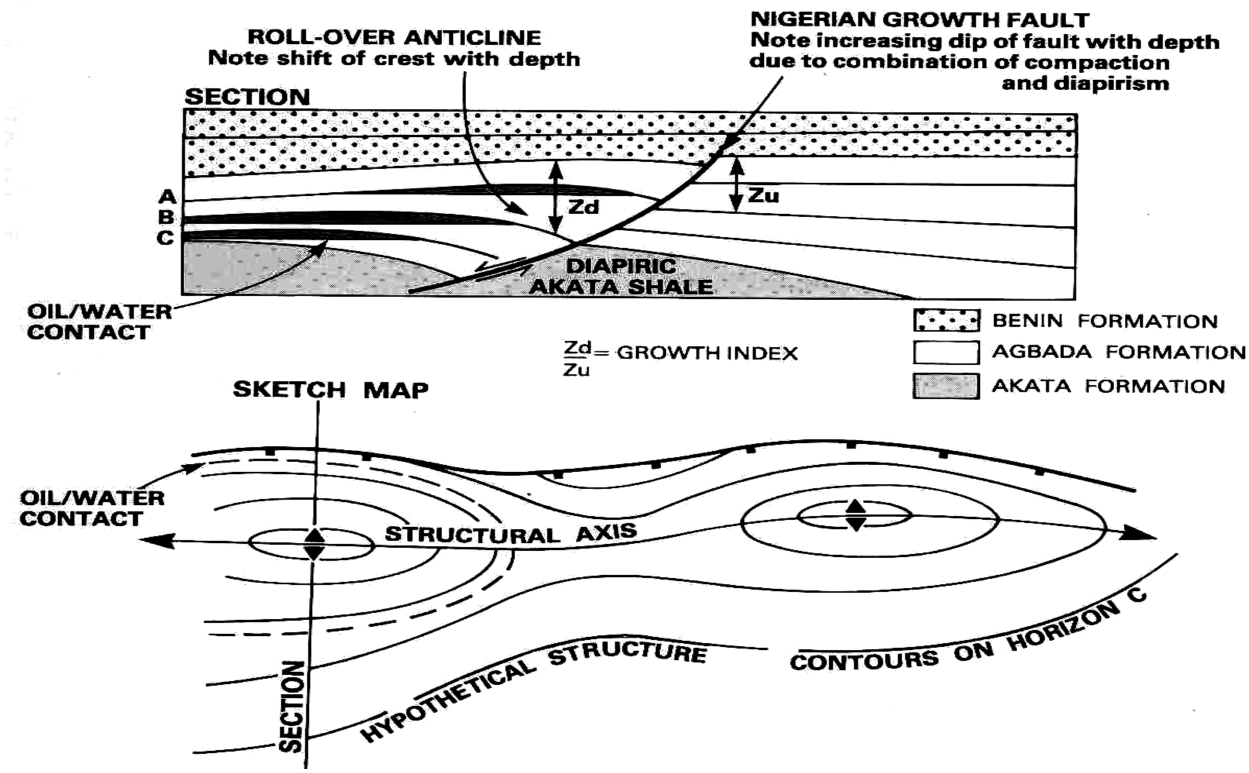

Figure 3: Schematic section showing a map of simple growth Fault and rollover anticline (After Schlumberger, 1985).

ROLLOVER STRUCTURES

They are anticlinal structures formed along the faults as a result of the enhancement of sedimentation along the growth fault that causes a rotational movement which tilts the beds towards the fault. Rollover structures can be classified into two main groups:

i. Simple rollover structures
ii. Complex rollover structures

Simple Rollover Structures:

Simple rollover features with anticlinal dips typically form the crests of macro structures . They are commonly cut by one or more crestal faults and show a moderate shift with depth of the structural culmination away from the structure-building fault.

Complex rollover structures:

These include collapsed-crest features, which have an overall dome shape, with strongly opposing dips at depth. Two swarms of faults dipping towards the crest typically 'collapse' the structural crest to compensate for overburden extension, one hading seaward and the other hading landward.

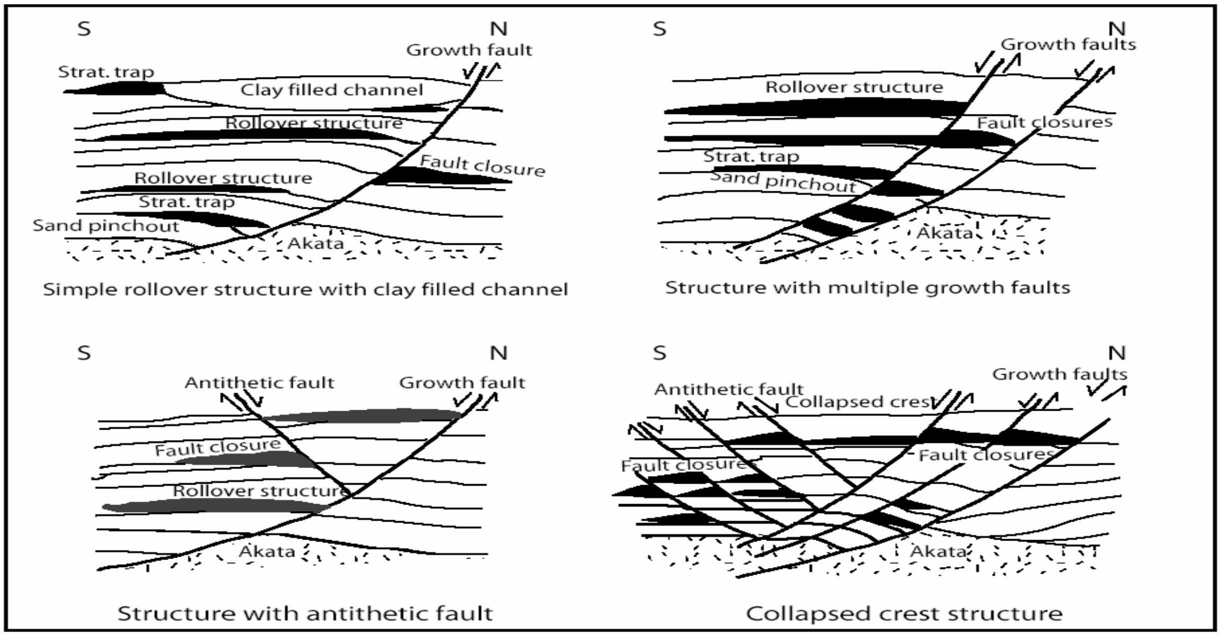

Figure 4: Principal types of oil-field structures in the Niger Delta with schematic indications of common trapping configurations. (Doust and Omatsola, 1990).

METHODOLOGY AND DATA SOURCE

Different methods of study have been adopted in this research for the evaluation of the *Olo* reservoir sands.

Data Available:

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

Procedures:

Core photographs were studied and described from bottom upwards.

The procedure for the description is as follows:

Close observation of the core photos noting the general characteristics and geological succession., Boundaries of each core section were noted. Study of sedimentary structures were carried out noting features like crossbedding parallel laminaion e.t.c. The degree of bioturbation was indicated, Based on the descriptions ,lithology and grain size ,dominant sedimentary structures, the lithofacies types were determined and interpreted using the lithofacies classification scheme. Core/log Calibration was carried out by using core information to characterized the well the well logs. .

RESULT AND INTERPRETATION

FACIES ANALYSIS:

The depositional environments have been inferred for the *Olo* 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 organics.(grain size, sorting, sedimentary structure) which are impacted by a particular set of energy.

Observation from the cores 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.

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

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 fining upwards sequence: resulting from low energy offshore sediments. Bioturbation is intense Plate 1.

Sedimentary Structures: Medium to fine grained sand stones highly bioturbated with heterolithic crossitratification.

Plate 1: Lithofacies Bioturbated sandy Heterolith

Depositional Environments: This section on the Gamma ray logs shows serrated bell shape which is diagnostic of offshore transgressive sands associated with the lower shoreface

CROSS BEDDED BIOTURBATED SANDSTONE: Characterize predominantly grey fine to medium- grained sands with erosional base and shale intercalation.

Sedimentary Structures: Consist of trough cross-Bed that displays a general finning upwards textural trend. The strong bioturbation tend to obliterate the sedimentary structures Plate 2.

Plate 2: Lithofacies Cross Bedded Bioturbated Sandstone

Depositional Enviroment: This section on the Gamma ray log shows serrated bell shape indicating a heavily bioturbated Tidal channel capping laminated tidal channel.

PLANAR/PARALLEL LAMINATED SANDSTONE Characterized by coarse grained light brown sandstone,

Sedimentary Structures: consist of multi directional trough cross bed-sets but also include low angle bidirectional cross bed and sub horizontal plane beds i.e hetrolithics planar cross stratification. Sporadic to weakly bioturbated base overlain by parallel to planar, laminated sands. Bioturbation very low.

Plate 3: planar/parallel Laminated Sandstone

Depositional Enviroment: This section on the Gamma ray log shows serrated funnel shape,indicating laminated uppershoreface.

DISCUSSION OF RESULT

Core Results: Core results of well indicate that the lithofacies are commonly sandstone/shale alternations or sequences. See (Plate 1-3), some of the parameters used in identifying the lithofacies are as follows:

Grain Sizes: Visually, the grain size distribution falls within the range of very fine to coarse grain hence, bedding surfaces are recognized mostly by abrupt vertical changes in sizes and sometimes gradational changes occur. One of the intervals where abrupt vertical changes occur is seen in well at a depth of 12256ft. Generally, there is mostly a decrease in grains sizes with an increase in depth from the lower half of the reservoir sand as seen in the well at a depth of (12312-12442) ft.

Sorting: This is the tendency of mineral grains in a particular rock to approach uniformity in size. However, it ranges from well sorting to poor sorting in the field of study. For example, there is well -sorted very fine grain materials between (12438- 12443) ft. Conversely, poorly sorted grains are seen at the upper part of the same well at a depth interval of (12299-12305) ft. The well -sorted zone in the wells contains shales, while the poor sorted parts constitute a mixture of different sizes of grain materials.

Colour: There are varieties of grey colours seen while examining the cores. Colour ranges from light grey to dark grey. For example, at the distal end of the two cored wells, the colour is found to be dark grey shale which is an indication of the presence of organic matter.

By going through the process of core description/interpretation. Detailed core analysis shows that the lithofacies are sandstone of fine to medium-grained texture and different sedimentary structures like cross and planar bedding, heterolithic stratification and so on as well as trace fossils like ophiormorpha burrows.

Environment of deposition was interpreted by the use of cores and inferred by comparing the shapes of the gamma ray logs signature with standard log motif of Schlumberger (1985) to determine whether it is a bell, funnel or block shape. It was deduced that the study area is within the marginal marine depositional environment and comprise of tidal channel sands ,distributary mouth bars, barrier island (lower, middle and upper shorefaces) and near offshore(the shelf).The lithofacies are stacked in an upward coarsening succession and fining upward succession and interpreted to represent progradational shoreface deposits.

The general depositional environment of the *Olo* reservoir lies within the marginal marine enviroment. Depositional system and their component facies form the primary building block of good reservoir quality. The reservoir quality of the cored section is highly variable.

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