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Research Article

PALEOENVIROMENTAL STUDIES OF AKA WELLS, NIGER DELTA, NIGERIA

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ABSTRACT

In this study, biostratigraphic data from two boreholes and 3D seismic data with suites of well logs from six (5) boreholes were used to evaluate the depositional environments of Aka- Field, Offshore-Niger Delta. The depositional environment interpretations of the s sedimentary succession in the Aka Field were analysed using integration of microfaunal, microfloral, paleobathymetric, lithologic and wireline (GR and Resistivity) log data. The results indicate that the stratigraphic development in the Aka Field, took place in delta plain to prodelta environments within non-marine to middle neritic paleo-water depths.

INTRODUCTION

There are seven sedimentary basins in Nigeria of which the Niger Delta basin is key, having a thickness of about 12 km in the depocenter (Short and Stauble, 1967) and an area extent of approximately 75,000 km2 essentially in southern Nigeria and the Gulf of Guinea , offshore Nigeria. It is rated the 12th largest crude oil producer in the world, resident in the elastic wedge sedimentary basin of known accumulation of recoverable hydrocarbon. Crude oil production from the prolific Niger Delta has reached reserves exceeding 34 bbls of oil and 93 tcf of gas

(Tuttle et al, 1999). The Niger Delta have been severally re-evaluated stratigraphically with the aim of adding to the reserve base of the nation. These re-evaluations are documented in volumes of published literature.

This study will employ the use of Paleoenviromental analysis approach in the determining the environment of deposition of the study area in Niger Delta.

Study Area:

The area studied is located in offshore Niger Delta, off the Nigerian coast, at a distance of 120km southwest of the Niger Delta (See fig. 1)

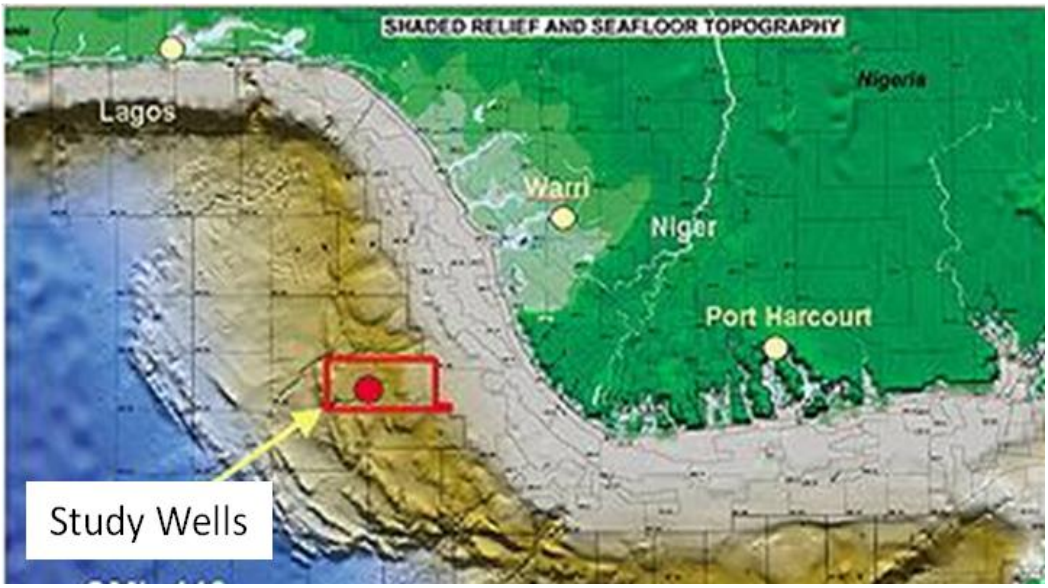

Figure 1: Niger delta map (showing location of study wells)

GEOLOGY OF NIGER DELTA:

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 (28000 ft) of section at the approximate depocenter in the central part of the delta (See figure 2).

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).

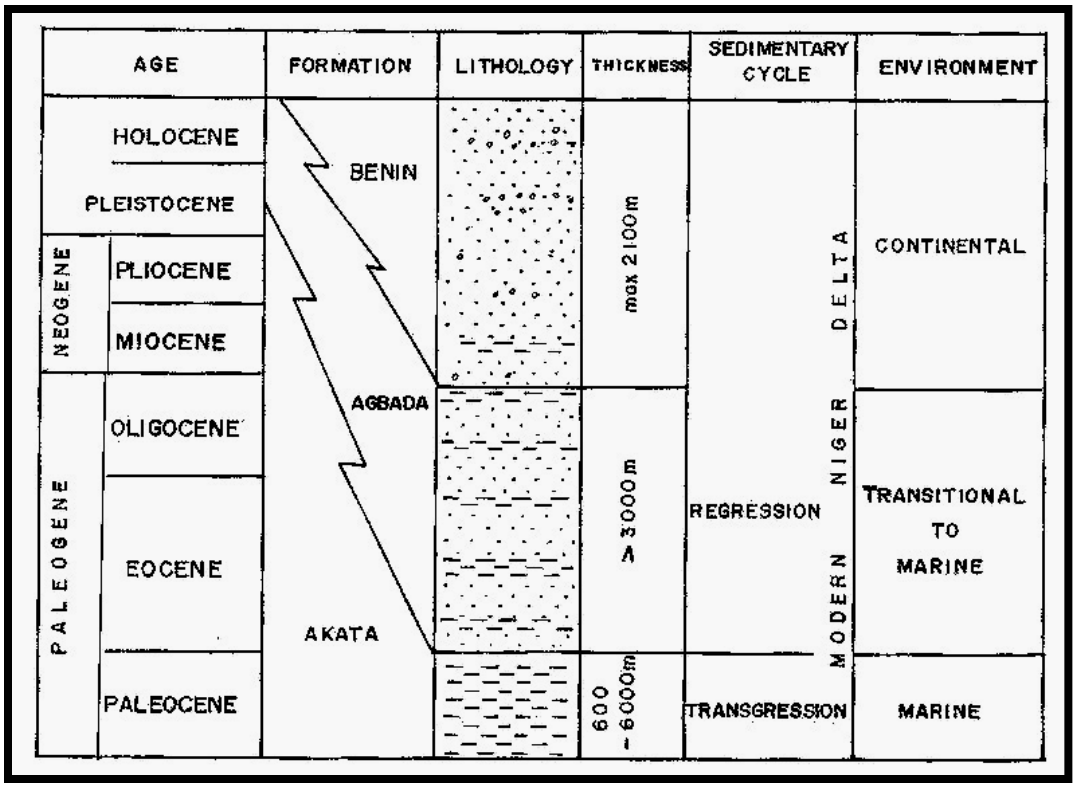

Figure 2: Stratigraphic section of the Niger Delta adopted from Doust, 1990

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.

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.

HYDROCARBON SOURCE Much discussion has been made about the source rock for petroleum in the Niger Delta. Possibilities include variable contributions from the marine shale interbedded with paralic sandstone in the Agbada Formation and the marine Akata shale. Based on organic matter content and type, Evamy et al., (1978) proposed that both the marine shale (Akata Formation) and the shale interbedded with paralic sandstone (Lower Agbada Formation) were the source rocks for the Niger Delta oils.

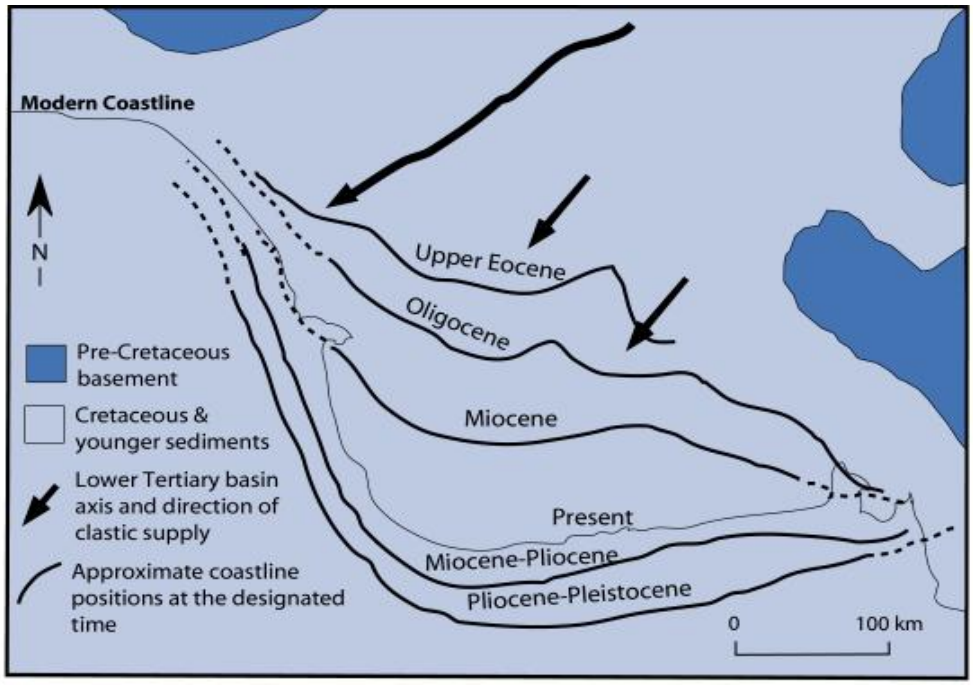

Figure 3: Progradation of the Niger Delta coastline since 35Ma.

AIM OF THE STUDY

The aim of this research is to interpret the environment of deposition of " Aka wells "in Aka field, offshore Niger Delta.

MATERIALS AND METHODS

Data Set:

The data used for this study include; wireline logs, biostratigraphic data and Chronostratigraphic charts. The wireline logs of the two wells comprise of gamma ray and resistivity logs. Biostratigraphic data includes biofacies data and foraminifera zone (F-Zone). The biofacies data provides information on total foraminifera abundance and diversity, total foraminifera planktonic abundance and diversity and also paleobathymetry.

The Cenozoic, Cretaceous, Jurassic and Triassic sequence Chronostratigraphic charts have information on the chronostratigraphy, relative age of systems, relative age of series, relative age of stages, sequence boundaries and maximum flooding surfaces.

This project was undertaken using data 3D Seismic, Suite of logs for 5 wells; Gamma Ray (GR) logs, Resistivity logs likewise Biostratigraphic data. Schiumberger Petrel 2014 was used for analyzing the 3D seismic and well log data sets used in this research.

A project was created in Petrel for this study and available data were loaded and quality checked before interpretation began, which include faults mapping so as to determine the trapping mechanism in play in the with biostratigraphic interpretation chart in pdf format were available, these were correlated with the GR and resistivity log data of six (5) wells namely: Aka- 1, Aka- 2, Aka- 3, Aka- 4, Aka- 5, received and were imported into the Petrel 2014 software in that format, facies, systems tracts and environments of deposition were delineated for the (5) wells and results were recorded accordingly.

Biostratigraphic Data

Biofacies data were depth matched with corresponding wireline logs in order to calibrate them. Environmental and paleobathymetric interpretation that was given were achieved from diversity and abundance (population) of benthonic and planktonic foraminifera,Biozone records given were the Foraminifera and Nanofossil Zones referred as the P and N zones.

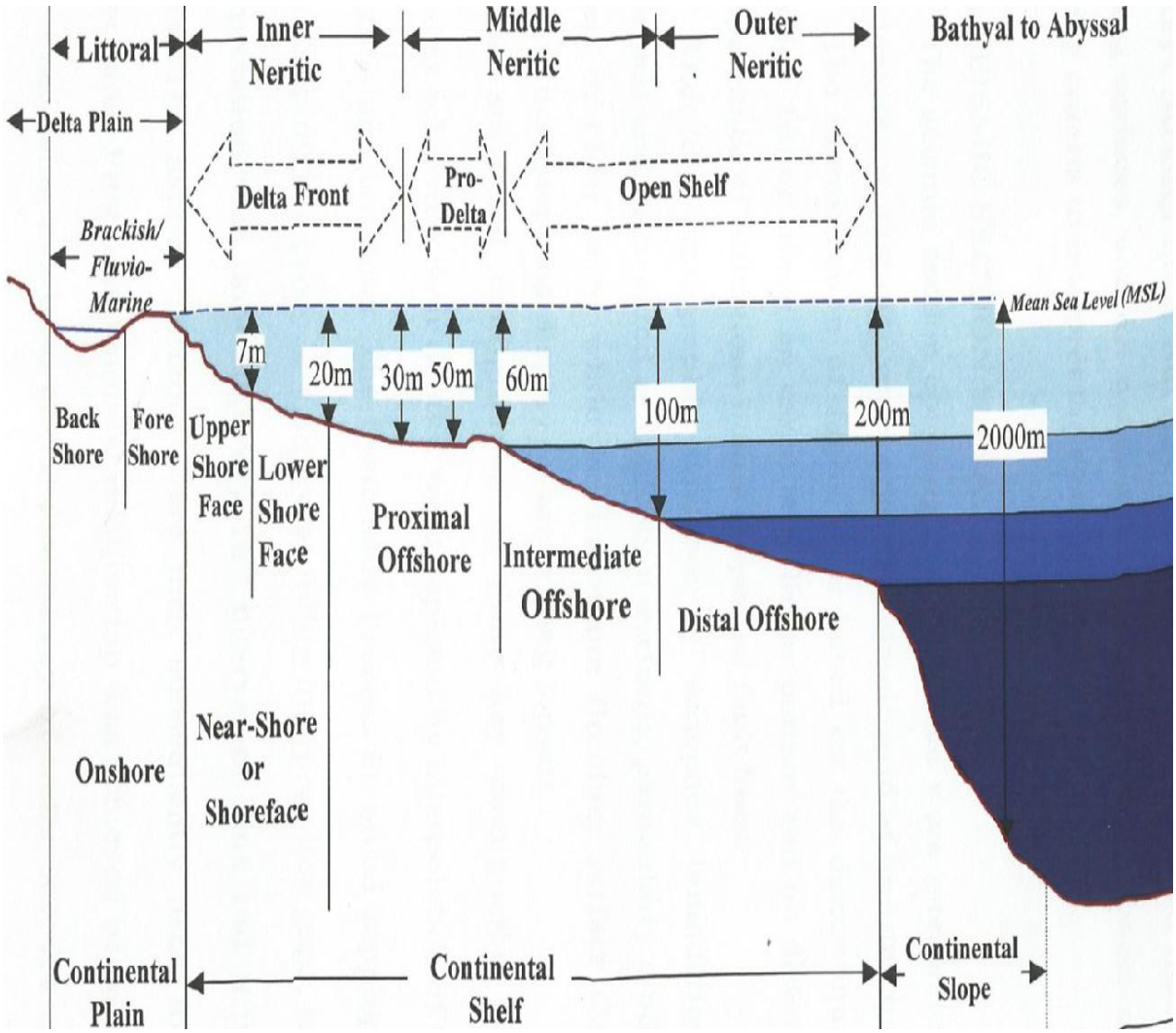

Figure 4: Depositional Enviroments and Bathymetric ranges used in Paleoenviromental interpretation

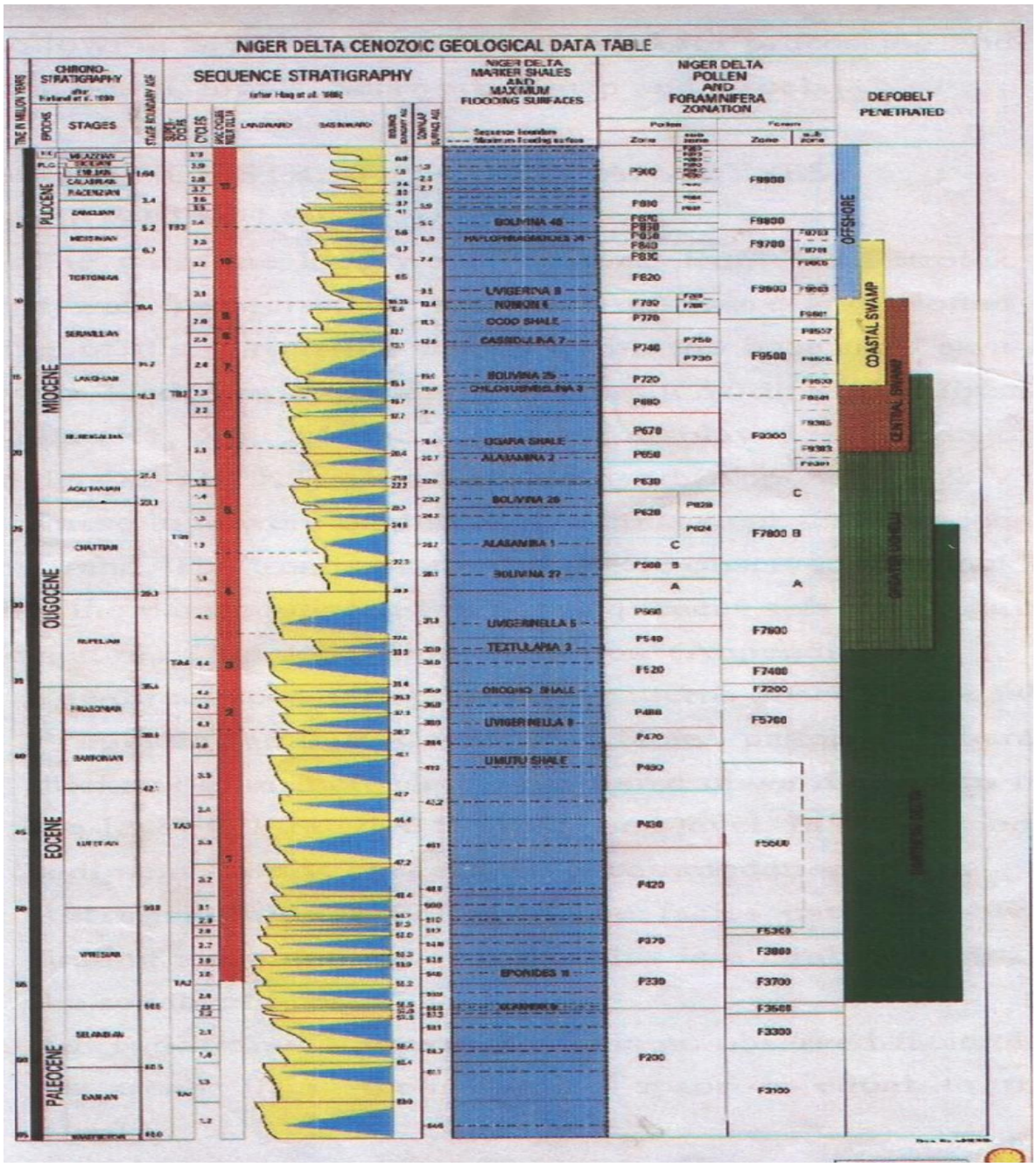

Figure 5: Niger Delta Cenozoic Chronostratigraphic Chart

RESULTS AND INTERPRETATION

PALEOENVIRONMENTS:

Paleoenvironmental interpretation of Aka 1 well and Aka-5wells (intervals 6360ft — 12,900ft and 50l0ft — 13,290ft respectively) was carried out through the integration of foraminiferal, palynological, lithologic and wireline (GR/Resistivity) log data. Foraminiferal data was most useful in the determination of paleo-water depth (paleobathymetry) by using population and diversity estimate of recovered foraminifera, likewise the observed environmentally significant benthic taxa.

Palynological data conversely was useful in the delineation of various palyno-ecological communities observed in the analyzed interval of the well. These communities include Savanna (Charred grarnineae cuticle and Monoporites annulatus); Fresh water swamp/Forest elements (*Concentricytes circulus, Pediastrum sp., Botryococcus sp., Psilastephanocolporites laevigatus and Pachydermites diederixi), Mangrove swamp (Zonocostites ramonae and Psilatricolporites crassus*); and marine indicators (Organic Walled Microplanktons - OWM).

The results indicate that sediments observed in the analyzed interval of Aka-1 well accumulated in non-marine to middle shelf paleo-water depths within Foreshore to lower shorface paleoenvironmental setting, while for the Aka-5 well deposition were in non- marine to middle shelf paleo-water depths within Foreshore to Upper shoreface paleoenvironmental settings.

The depositional environments and bathymetric ranges are used in these interpretations..

Interval: 7350ft — 8650f **Well**: Aka- 1

Paleobathymetry: Non-marine — shallow inner neritic

Paleoenvironment: Foreshore — upper shoreface

The upper interval (7350ff — 8650ft) and the lower interval (8260ft — 8780ff) are predominantly barren of foraminifera while the mid-section (interval 7600ff — 71 80ff) showed sparse occurrences of some benthic taxa such as *Saccammina complanata, Nodosaria sp, Quinqueloculina seminulum* and *Bulimina sp*, representing shallow inner marine deposition within a non-marine setting.

The palynological suite within this section is characterized by sporadic occurrence of marine indicators, moderately high frequency of mangrove elements, fresh water swamp/forest and savanna milieu and extremely low occurrence of montane elements.

The predominantly progradational/blocky sands and shales with minor silts are prevalent.

The medium — coarse grained sands described here probably suggest deposition within channel complexes in a delta plain depositional settings exposed to minor marine influence. Some coal materials occur here.

Interval: 8760ft — 9740ft **Well**: Aka- 2

Paleobathymetry: Inner — middle neritic

Paleoenvironment; Upper shoreface

This interval is characterized by fluctuation in paleobathymetry from inner — middle neritic realm. The upper section (8760ft — 9740ft) of this section showed a regular and sometimes abundant occurrence of some benthic taxa such as *Alveolophragmium crassum, Cyclammina sp, Lenticulina inornata and Quinqueloculina microcostata* which probably indicate deposition in an inner-middle neritic depositional settings. However, a drop in paleobathymetry to a predominantly inner shelf depositional setting is depicted by the low recovery of faunal taxa between 9380ft — 9750ft.

The moderately low occurrences of marine indicators and montane elements, moderately high observed savanna milieu and the high occurrences of mangrove, fresh water swamp / forest elements constitute the palynological community in this zone (interval).

The predominantly blocky sand with shale intercalation encountered in this zone depict channels/bar deposits of a delta front depositional setting.

Interval: 6020ft — 8750ft Well Aka- 3

Paleobathymetry: Non — marine - shallow inner shelf

Paleoenvironment: Foreshore — upper shore face

This interval is completely barren of foraminifera; while the palyno-assemblage consists of moderately high prevalence of Freshwater / Forest elements, moderately low — moderately high prevalence of Savanna elements, very low — low prevalence of Montane elements, moderately high — very high prevalence of Mangrove elements; coupled with sporadic — moderately low prevalence of marine elements. This suggests minor marine influence in an essentially non- marine setting.

Lithologically, the interval is composed of medium — coarse grained sands associated with silts and shale intercalations. These lithofacies are depicted by blocky log motifs typical of channels accumulated in a delta plain — proximal delta front setting.

Interval: 8050ft — 8700ft Well Aka- 4

Paleobathymetry: Non — marine

Paleoenvironment: Upper shoreface

The non-marine classification is as a result of non-recoverable micro fauna within this section. However, the palynological assemblage suggests that accumulation of sediments within this section is essentially in an upper shoreface setting. The assemblage consists of the low amount of Montane elements, moderately high percentage occurrences of Savanna and Mangrove elements, the absence of Fresh water I Forest elements; coupled with moderately low percentage occurrence of marine indicator elements.

Interval: 8810ft — 9570ff Well: Aka- 5

Paleobatbymetry: ?Non-marine — inner shelf

Paleoenvironment: Upper shoreface

The upper section (8810ff — 9570ff) is completely devoid of microfauna; suggesting a non- marine accumulation. Conversely, the lower section is characterized by the occurrences of *Alveolophragmium crassum, Epistominella vitrea, Florilus ex. gr. costiferum, Lenticulina inomata and Quinqueloculina vulgaris.* This benthic assemblage has an overall low planktic diversity within the interval.

Palynologically, the floral assemblage in this section is analogous to the preceding interval, and also suggests a predominantly upper shoreface deposition. Based on these evidences (faunal and floral), the accumulation of sediments in this section probably occur in an inner- shelf setting with some non-marine influence.

The lithofacies (predominantly shale with sand — silt intercalations) are depicted by aggradational log signatures; suggesting their deposition as interdistributary bay deposits in a delta plain — delta front setting.

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