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Research Article

BIOTURBATION: IT'S EFFECT ON RESERVOIR QUALITY

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ABSTRACT

Bioturbation the reworking activity by organisms in and around sediment surfaces is a natural day to day and important process in the marine environment. This process brings about disruption and alteration to primary sedimentary lithologies though commonly overlooked in the areas of reservoir quality assessment. In other to assess the effect of these reworking activities on reservoir quality (porosity and permeability), two core samples of approximately 32ft, recovered from the Miocene interval of the parallic Agbada Formation, located in the South-eastern offshore Niger Delta were subjected to conventional core/thin section analysis. The resulting datasets containing digital core images. petrophysical plug data and thin section reports were employed in this study/research work. The samples showed dominance of bioturbated lithofacies with the spread of the [ruziana and Skolithos ichnofacie associations. It was revealed also that the cleaner sandstone fades have the best reservoir quality while the more bioturbated intervals of the entire cored sections had porosity and permeability values slightly higher than their rarely-lowly bioturbated counterparts. The identified l ithofacies and ichnofacies showed the distribution of trace fossils within the cored succession which when integrated with the porosity and permeability data, aided in the reconstruction of the depositional environments. Hence it is implied that bioturbation influenced porosity and permeability positively thereby improving the reservoir quality of the well.

INTRODUCTION

Core samples unlike outcrop samples are expensive but give data that are continuous and unweathered which the petroleum industries consider the best and most reliable source of data for determining paleogeography and paleoenvironment of deposits. Cores represent continuous, vertical succession of the subsurface lithologies that reveals detailed primary. secondary and biogenic structures, their intensities and distributions within cored intervals which when integrated, helps in the reconstruction of depositional environments as well as characterizing of reservoir qualities.

LOCATION OF STUDY AREA:

The study area is located in the Southeastern part of the offshore Niger Delta sedimentary basin of Nigeria between latitudes 4° and 4°30'N and longitudes 8° and B°30'E. It is bounded in the east by Cameroon, in the south by Gulf of Guinea and on the north by the Calabar flank.

SCOPE OF WORK:

The scope of this research work would include

- Review of existing literatures based on the research topic. general geology, ichnofacies groups and depositional environments of the Niger-Delta.
- Sourcing of required datasets and materials.
- Study, interpretation and preparation of a final thesis report

AIMS AND OBJECTIVES

The objectives of this research work are:

- Integrating the lithofacie description studies, ichnofacies and paleo environmental model of the study area to have a better understanding of the depositional environments.
- To Figure out the impact bioturbation has left on the porosity and permeability.

REVIEW OF THE ICHNOFACIES ANALYSIS OF NIGER DELTA SEDIMENTS:

Ichnofossils, otherwise known as trace fossil, are biologically-produced sedimentary structures. They record the activities of organisms or plant on or within the sediment. The sediment ichnofabric (Taylor a Goldring. 1993) results from all aspects of texture and internal structure of the sediment produced by biuturbation at all scales. This includes discrete trace fossils and mottled to homogenized sediment. Trace fossils analysis is particularly important in the sedimentological analysis of the Niger Delta succession because the sediments are largely unfossiliferous and biastratigraphical data is rarely vailahle during core description.

The degree and diversity of bioturbation is controlled by a number of factors including the rate of sedimentation, degree of oxygenation and salinity levels. Only a few mobile animals can cope with high rate af sedimentation. These include Macaronichnus and Anconichnus, which are produced by animals capable of colonizing mobile sand waves and ripples (Goldring. 1995) and are found in high - energy near shore sediments.

The review of the studied lenozoic sediments from the Niger Delta succession as conducted by various researching geologic groups have it that the sediments from the zone, have variations of both vertical (within well) and lateral (between well) types of bioturbation. The preserved sediments, range from virtually unhurrowed sandstone to thoroughly bioturbated muddy sandstone within the cored Niger Delta successions, one particular trace fossil dominates over all others and that is liphiomorpha nodosa, which was observed across the full range of near shore to distal offshore shelf zones. This burrow occurs in a variety of forms which include very large-scale forms at the maximum end of the documented size range for this trace. This pellet-lined burrow is today found over a range of near shore environment including lagoon and estuary floors, wherever the substrate consists mainly of sand-grade sediment (pollard et al. lA3).

In the Niger Delta sediment, the type of ichnofabric in which Uphiomorpha occurs can be used to help discriminate between shore face, estuarine and offshore sedimentary environ. The following section summarizes the main ichnofabric observed in the depositional sub environment of the shallow marine delta. Few trace fossils are observed within the distributary channel (fluvial-doniinated delta fop) setting and few recognizable traces were observed within the deep marine canyon fill sediment due mainly to strong soft sediment deformation

The greatest diversity and abundance of trace fossils was seen within the shallow marine setting of the lower shore face to distal offshore shelf within the shore face to upper offshore deposit. The observed variability in binturbation was believed to be due to the distance from the active distributary channels which enhance water turbidity and rate of deposition. High depositional rates coupled with increased water turbidity at a river- dominated site on the delta front may produce completely or near unburrowed sediment. The lower delta plain comprises high to moderate energy sand-filled distributary channels and floodplain. interdistributary bay and swamp areas which are dominated by muddy fades. It is shallow water to emergent setting, with variable very low to high energy depositional conditions.

NIGER DELTA ICHNOFACIES ATLAS

MAIN DEPOSITIONAL ENVIRONMENT	ICHNOFACIES TYPES	OBSERVED TRACE FOSSILS
Delta Plain	Softground Scoyenia & Psilonichnus	The Scoyenia ichnofacies characterized marginal-marine settings and is typically represented by very rare simple tube-like burrows.
Tidal Channel & Back barrier Tidal Flat	Softground Psilonichnus & Skolithos/Cruziana	The Psilionichnus ichnofacies characterizes marginal-marine settings which show extreme variation in energy levels. It is typically represented mainly by low density vertical J and U burrows.
Trangressive Estuarine-Lagoon	Skolithos/Glossifungites	The Skolithos ichnofacies is indicative of relative high levels of wave and current energy, typically developed in slightly muddy to clean, well-sorted, loose or shifting sands. It is characterized by mainly vertical or U-shaped burrows, few horizontal structures, low diversity (although can be abundance of individual forms), mostly dwelling burrows of suspension feeders. The Glossifungites ichnofacies occurs within firmground substrates and characterized by vertical, branching or U-shaped burrows.
Foreshore Beach or Barrier Top	Softground Skolithos	
Upper Shore face	Softground Skolithos	
Lower to Middle Shore face	Softground Cruziana	The Cruziana ichnofacies is most typical of sub tidal, poorly sorted and unconsolidated substrates with moderate to low energy conditions. It is characterized by a mixed association of vertical, inclined and horizontal burrows; generally high diversity and abundance; mostly feeding and grazing structures of deposit feeders.
Offshore Marine Shelf	Softground Cruziana	

Table 1: Summary of Niger delta Ichnufacies Broups (afIr Core lab research groups)

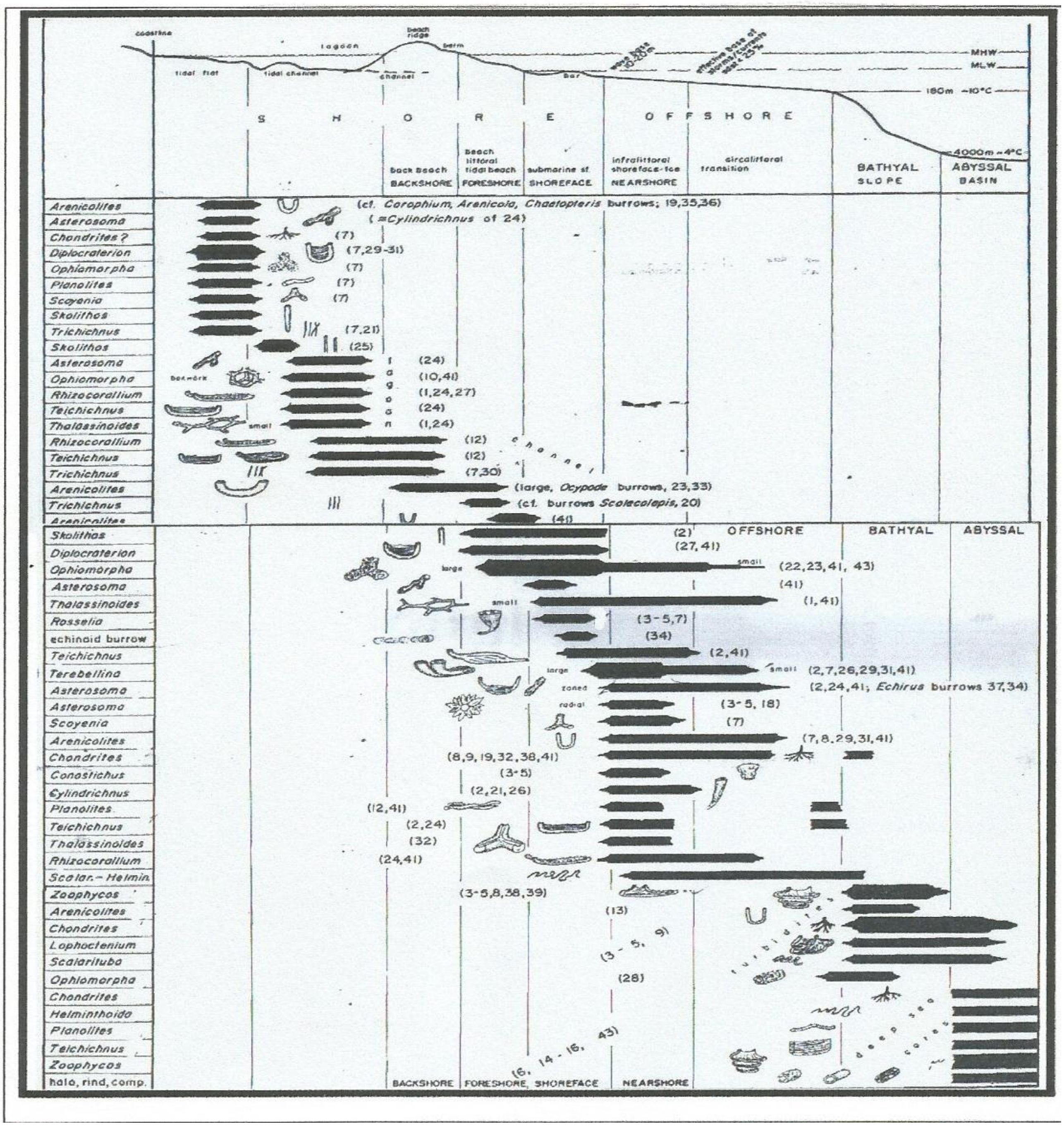


Figure 1: International range chart showing the distribution of trace fossils that are common in cores Within different depositional environments which indicates that certain trace fossils could be found in more than one environment

MATERIALS & METHODS OF STUDY

MATERIALS USED IN THE STUDY WORK:

The materials and datasets employed in this study /research work includes as listed below while the analysis were done in core lab.

- ❖ Petrophysical data of the proposed study well
- ❖ Location map of the study area.
- ❖ The study well's core samples (for visual study)
- ❖ The core images of the study well. (fur illustration in report presentation)
- ❖ The photnmicrograph/ thin section reports of the specific zones of interest.

METHOD OF STUDY:

This study actually started when the cores arrived at the core laboratory and involved four basic stages and other sub stages which includes as follows;

- ❖ An initial core handing procedure on arrival at the laboratory
- ❖ Gore preparation
- ❖ Core analysis
- ❖ Retrieved data study. interpretation and final report presentation.

CUTTING AND DRILLING OF CURE SAMPLE PLUGS:

The core has been frozen so as to keep them consolidated, were slabbed into two sections(for the sake of increasing its surface area) with thicknesses of 1/3 and 2/3 of the original diameter of the whole core after the optimum slabbing plane was determined through CT-scanning with the aid of an electric powered saw. Plugs were then drilled from the 2/3 diameter section using liquid nitrogen as a coolant locations, at intervals of say one foot.

CLEANING OF THE CORE SAMPLE PLUGS:

The frozen sample plugs were mounted in a core holder so as to keep them in place and a confining stress of 30-511 bars applied. Then the samples were allowed to thaw, after which they were cleaned by cold solvent flushing with chlorothene and toluene alternately.

CORE DRYING:

Here the already cleaned core plugs were dried in a vacuum oven (to remove any residual fluid) at

85°C to avoid over heating and fracturing.

CORE ANALYSIS:

The prepared core samples were at this point subjected to both conventional core analyses (Helium Porosity and Air permeahility) as well thin section analysis.

CORE POROSITY:

Porosity is the percentage storage capacity of a rock. It could both be calculated by summing pore volume and grain volume or by deducting grain volume from bulk volume, and can be mathematically represented as the ratio of pore volume/bulk volume in percentage.

BRAIN VOLUME:

Here the clean dried plug samples were each individually placed in a matrix cup of helium gas expansion porosimeter. Helium gas at a known pressure of lflflpsi from a reference chamber of known volume was then allowed to expand into the matrix cup and into any available pore space. After which the volume of expanded gas was recorded and used to calculate porosity employing the Doyles law principle.

Drain volume (Vg) Vr + Vc — (PVPz)/ Vr

Where

Vr = volume of reference cell in cc's

Vc= Vnlume of sample chamber in cc's

P_1= Initial Pressure in psi

P_2 = Equilibrium pressure in psi

PORE VOLUME:

After grain volume had been measured, the samples were then individually placed in a hydrostatic care holder. Helium was then injected into the samples pore space and when helium was stabilized, the volume of the injected helium gas was then recorded.

Pore volume (Vp) = (Pi/P2) VrVr-Vi

Where:

Pi, P2 a Vr are the same as indicated above

Vi=volume of line connecting the care holder

SEDIMENTARY STRUCTURES:

The structures were visually studied during the core description stage using the core samples in the core laboratory and later further reviewed with the aid of a hand magnifying lens as well as using the digitalized computers zooming facility, this time using the core images since the core samples could not be moved about to avoid distortion and damages in case of future reference. The bulk of the structures observed and studied were the biogenic structures like Skolithos, Rhyzocoralliuni, Planolite, Chondrites. bivalve escape traces etc. And some primary lamination, wavy and cross beddings,

RESULT OBSERVATIONS AND INTERPRETATIONS:

It is observed that the Cores have a separating gap dividing them into cores one and two as indicated in the petrophysical plug data

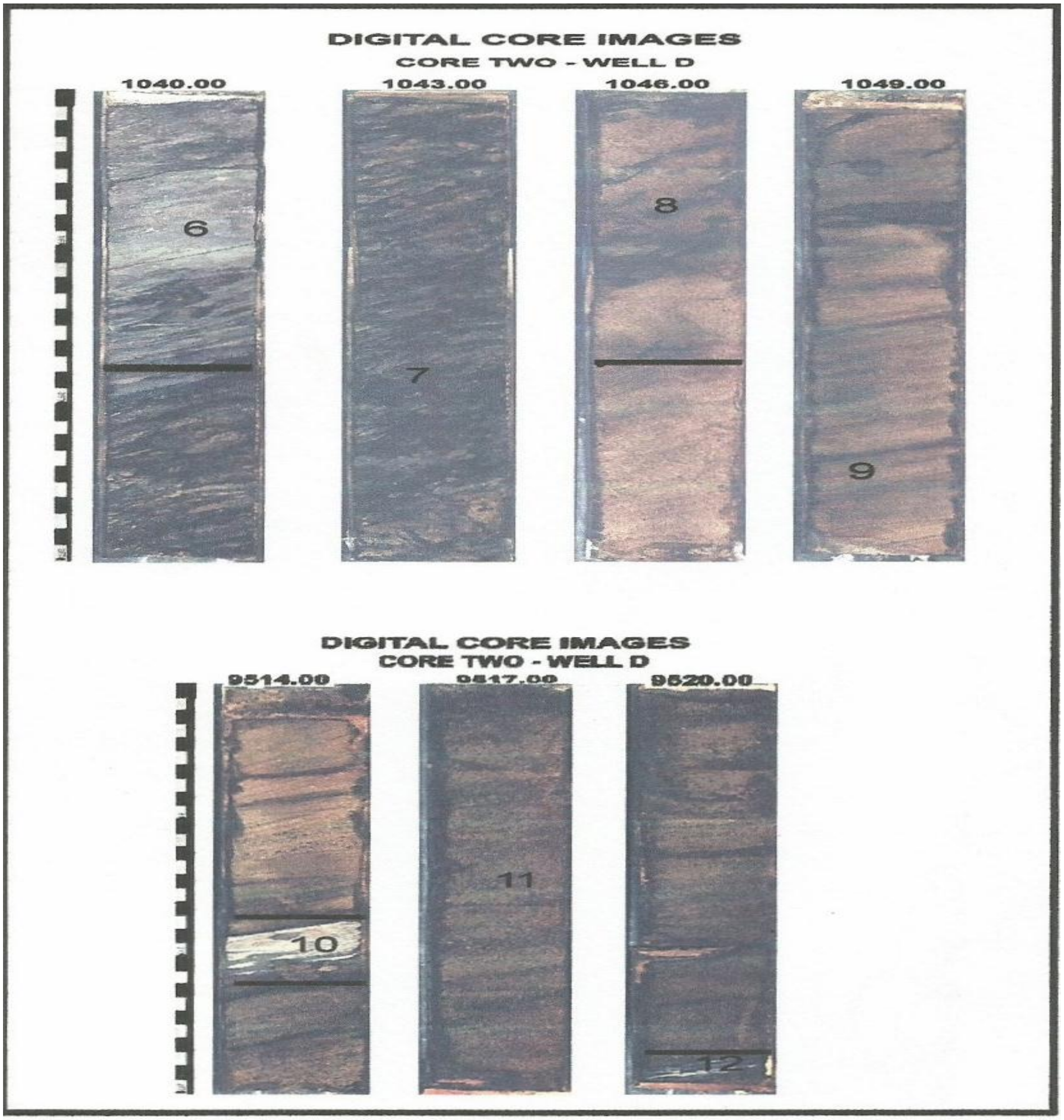


Plate 1 Core two digital image

Plate 1: shows a well defined fining upwards sequence of core two with transition from the -lower coarser, crass bedded sandstones of the estuarine channel through the -middle fore shore-lower shore face deposits to — an upper almost churned muddy sands of the transitions-well bioturbated silty shelf muds

CORES LITHOFACIES CHARACTERISTICS AND INTERPRETATIONS:

The lithofacie classification shows that the cored succession has dominance of bioturbated lithofacies (with bioturbated sandstone, bioturbated muddy sandstones and bioturbated sandy mudstone) over unbioturbated ones. Also observed were dominance of sand rich facies over locally significant mud rich lacies with a decrease in bioturbation as the sequence progrades from its lower muddy facie through cleaner sandy facies in core one while bioturbation increases from the lower cleaner and cross bedded sandstone facies to its upper muddy facies.

MUDDY SANDSTDNE:

These are of mid to light grey in color, mainly of very fine to fine grains with remnant traces of wavy bedding. They show better consolidation than the cleaner sandstone facies. They are poorly sorted due to disruptions by bioturbation. The degree of bioturbation varies from highly to almost completely churned in appearance (From depths 9502-U508 feet). Trace fossils include significant Chondrites and local Asterosoma.

SAND/ SILTY MUDSTONE:

These are grey in color with subordinate sand. They appear moderately to well sorted. The thin muddy sandstone separating the lower cross bedded, coarser sandstones of cores two from the finer cross bedded sandstone seem to have been replaced by carbonate and stands as a local permeability barrier between the cross bedded sands above and below core two. These facie appear to be moderately to strongly bioturbated with diverse trace fossils which is dominated by Chondrites (traces made by worms), local Planolites and Teichichnus.

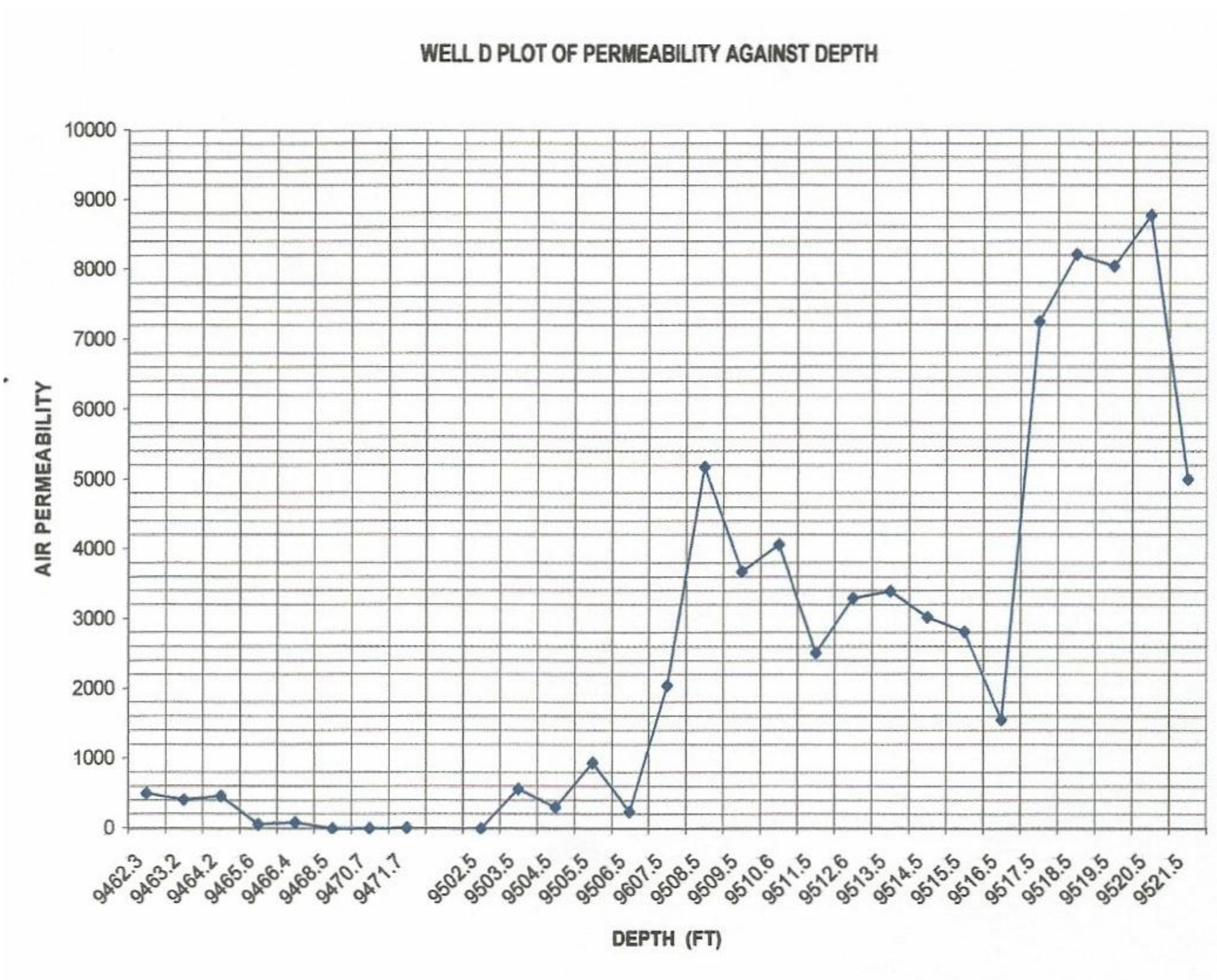
LITHOFACIES INTERPRETATION:

The vertical succession observed in the lithofacies characteristic shows an increase in grain size trend with transition from sandy mudstone at the base to cleaner sandstone facies at the upper part and a general decrease in the degree of bioturhation upwards which suggests a coarsening upwards sequence for core one which is interpretated as a prograding shoreline complex.

Meanwhile core two lithofacies characteristics show a general decreasing upwards grain size trend depicting a fining upwards succession with an increase in the degree of bioturbation from the lower cleaner, coarser, cross bedded facies of the estuarine complex to an upper finer grained. strongly bioturbated facies of the beach - transitional environment that is separated by a thin lagoonal shale suggesting an abandoned channel which may have been replaced by calcite?

PERMEABILITY AND VARIATION PATTERN:

Permeability data of well 0 shows values that range from locally poor to excellent ranging from as low as 2.D-BlBflmD with an average value of 2591.5mB (table 3.11) From the graphical plot most values fall in the range of 415-8780mB.



The highest value correspond to the coarser cross bedded sandstone facies of core two, followed by the finer sandstone fades which occurs within core one sandstone of the variety of the shore face deposits. The remaining values fall below 4l5mD and is revealed to correspond to the muddy facies though there are also significant values that fall between 2.D-BBmD and they correspond to the finer grained sandy mudstones facies that is almost churned in appearance.

THIN SECTION ANALYSIS REPORT:

Thin sections analyses were carried out on plugs I from core one and plug 23 from core two. There both revealed dominance of quartz and feldspar as their framework minerals with detrital clays as their matrix except for plug I which has got some of its detrital clays replaced by siderite clay (plate 3.11). Below are the photomicrographs and analysis report for the respective plugs.

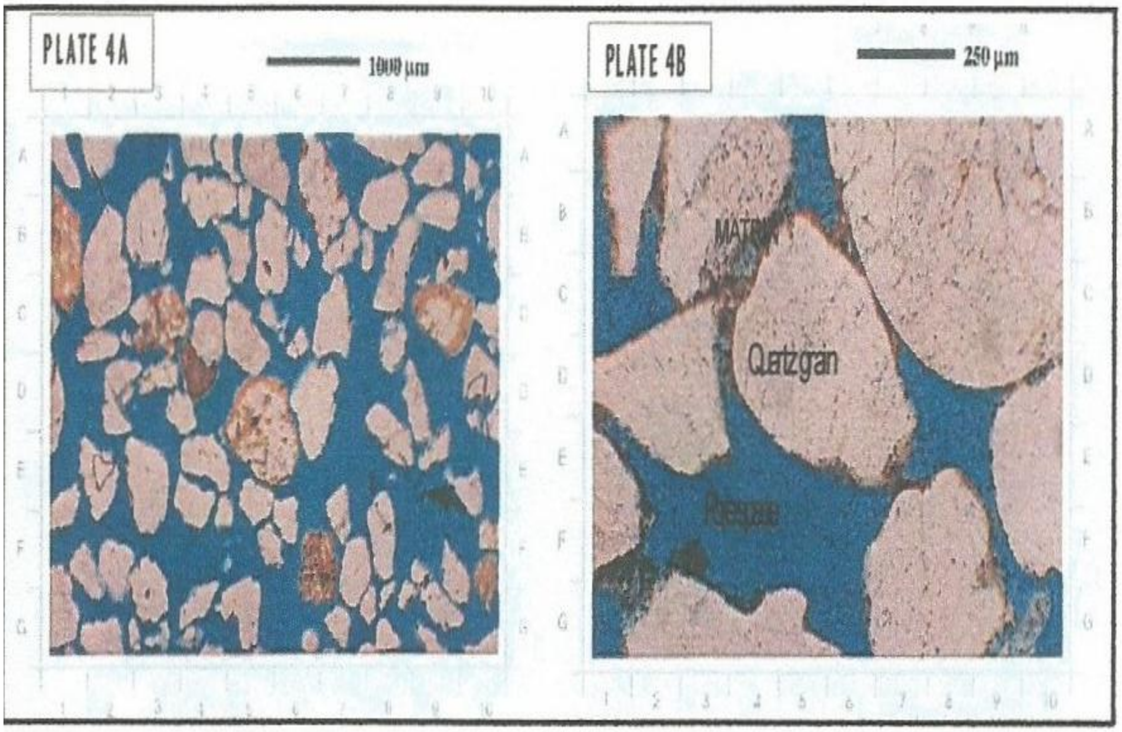


Plate 2: Thin section photomicrographs of Plug 28

Plate 2: is the photomicrograph of thin section taken from plug 28 of depth 6520.50 ft. It has 95% of quartz and 5% feldspar as framework minerals with traces of detrital clays attaches to isolated quartz grains. The grains are loosely packed with rare paint grain contact. Porosity is excellent due to the unconsolidated nature of the sediments with limited detrital clays while permeability is also excellent due to the larger grain sizes, larger pore throats and low capillary pressure.

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