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Lithofacies and Sedimentological Study of Tiko-Field, Coastal Swamp Depobelt, Niger Delta.

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ABSTRACT
The Lithofacies and Sedimentologicalstudy of the Tiko-Field, Coastal Swamp, Niger Delta was undertaken to determine the various lithofacies and the sedimentological aspect of the field from cores, well logs and biostratigraphy data. The log motif analysis, calibrated by lithologic descriptions based on core data for a depth interval of 8934.40 to 9022ft in well X-70, were used to define the Lithofacies and Facies Associations. Based on sedimentological analysis which considered colour, texture, sorting, sedimentary structure and ichnofossils, four (4) Lithofacies were recognized from the core photos and they include; Cross-Bedded Fine-Medium Grained Sandstone Facies, Cross-Bedded Coarse-GravelySandstone Facies, Wave-Rippled Sandy Heterolithic Facies, and Parallel Laminated Mudstone Facies. The lithofacies were grouped into three (3) Facies Associations namely; Tidal Channel Sandstones, Coastal Plain Heterolithics and Fluvial Channel Sandstones. The presence of ichnofossils of Ophiomorpha and Skolithos traces found on the cored photographs suggests a Coastal Deltaic environment of deposition. The age for the cored section of the X-70 Well was inferred using diagnostic biomarkers such as Eponides berthelotianus, Cyclicargolithus floridanus and Helicospharea ampliaperta. This suggests that these environments were deposited during the Middle to Early Miocene time.

Key words: *Facies, Heterolithic, Channel, Coastal, Environment, Miocene, Ichnofossils.*

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I. INTRODUCTION

Every depositional environment have specific elements which are the physical, chemical and biological conditions under which sediments accumulate and these environment play important part in discovering the resources of economic interest found in the rocks. These elements that characterize the depositional environment are often preserved as facies which by definition is a mass of sedimentary rock that has unique noticeable features such as lithology, texture, structures, geometry, fossil content, and paleocurrent directions which are shown in either outcrops, exposures, cores and some in wire line logsWalker and James, 1992). Depending on how these defining features of a sedimentary facies present itself during description, we can accurately ascertain the transporting medium as the time of deposition of the sediments, the flow direction and also predict whether the sand bodies are of good reservoir quality (Tyler et al., 1991), the recovery efficiency of oil on average base may be possibly related to the environment of deposition and mechanisms of recovery.Momta and Odigi (2015) opined that cores are the only samples that show uninterrupted formation properties, making them unavoidable parameters for studies regarding identifying lithofacies, depositional environment and lastly characterizing the reservoirs of interest. From the well logs, it is feasible for a series of log facies to be generated and used to infer the lithofacies and depositional environments in the uncored wells through correlation which can then be compared to those described from core and biostratigraphy to see if what was interpreted from the logs has a matching trend with those from cores and biostratigraphy.

This study aims at identifying the various lithofacies and their depositional environment in Tiko-Field, Niger Delta.

The study field, lies within the Coastal Swamp depocenter, onshore region of the Niger Delta basin (Figure 1).

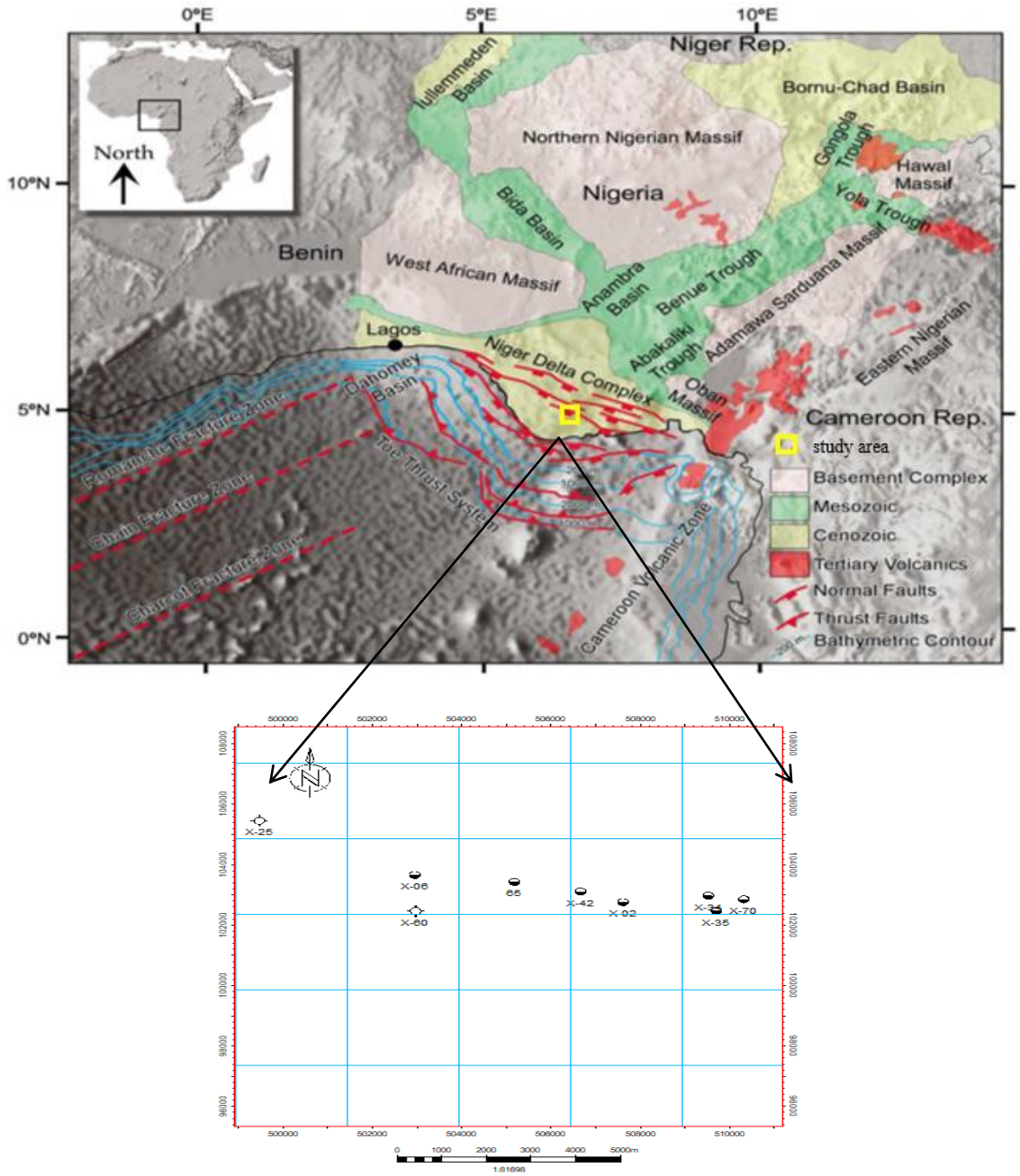

Figure 1: Location of the study area, onshore Niger Delta region (Corredor et al., 2005)

II. REGIONAL GEOLOGY

The Niger Delta sedimentary basin has an average thickness of 12000m and it lies within the Gulf of Guinea (Reijers et al. 1997). Three Formations according to Short and Stauble (1967) make up the Niger Delta; from the oldest to the youngest, they are; Akata Formation, Agbada Formation and Benin Formation (Figure 2).According to the following authors (Doust and Omatsola,1990; Stacher,1995 and Tuttle et al.,2006) the formations are found within growth fault surrounded by sedimentary units often known as depobelts that thrive in a southward direction that are six in numbers. (Figure 3).

Gressly in 1838 was the first to use the word facies and defined it as the sum of all the lithological and palaeontological aspects of a stratigraphic unit. Based on this definition, the word facies can be looked at in terms of either lithology, structural and organic contents. If the defining attributes of the word are based on organic content only, we can term it as biofacies. On the other hand, where such defining attributes are based on just lithological characteristics, we term it lithofacies. Rocks are often divided into different facies types when carrying out studies concerning depositional environments. Osayande and Okengwu, (2017) in their study of lithofacies analysis and depositional environments of Waz field, Niger Delta, identified nine Lithofacies.

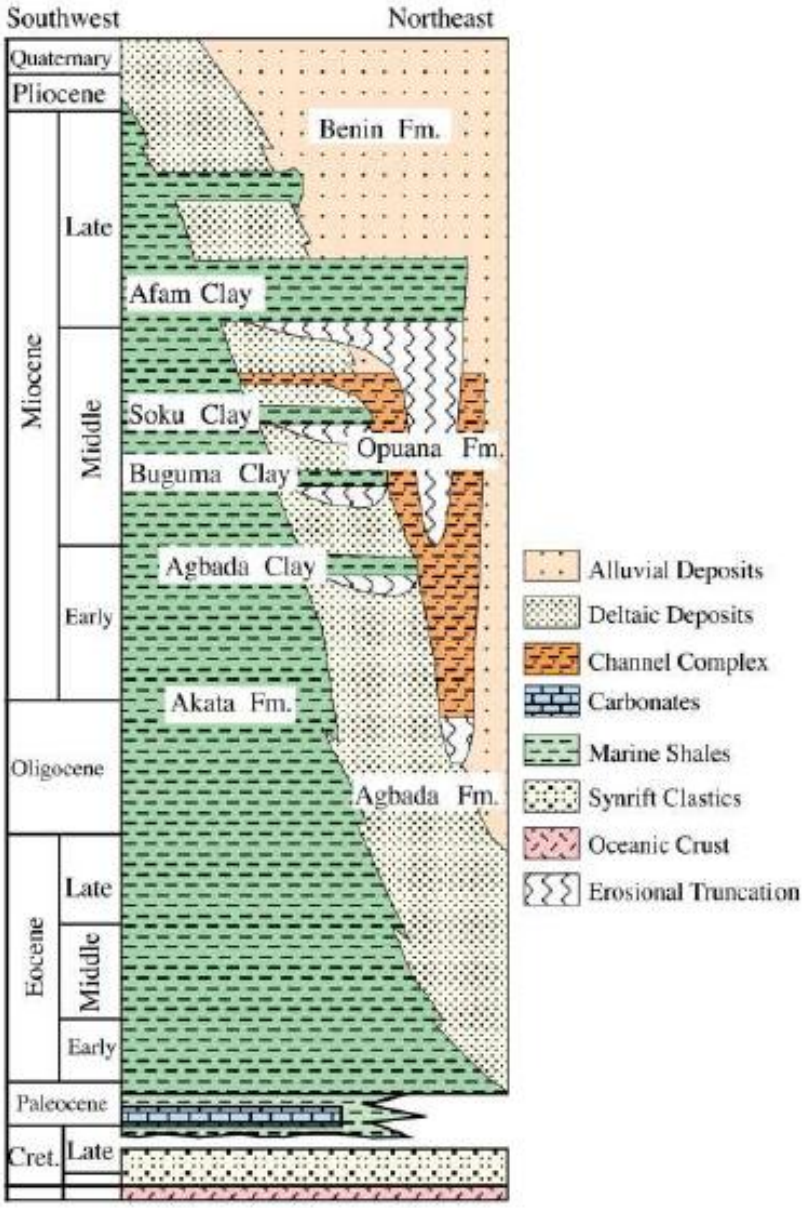

Figure 2: Stratigraphic units of the Niger Delta basin(Doust and Omatsola, 1990)

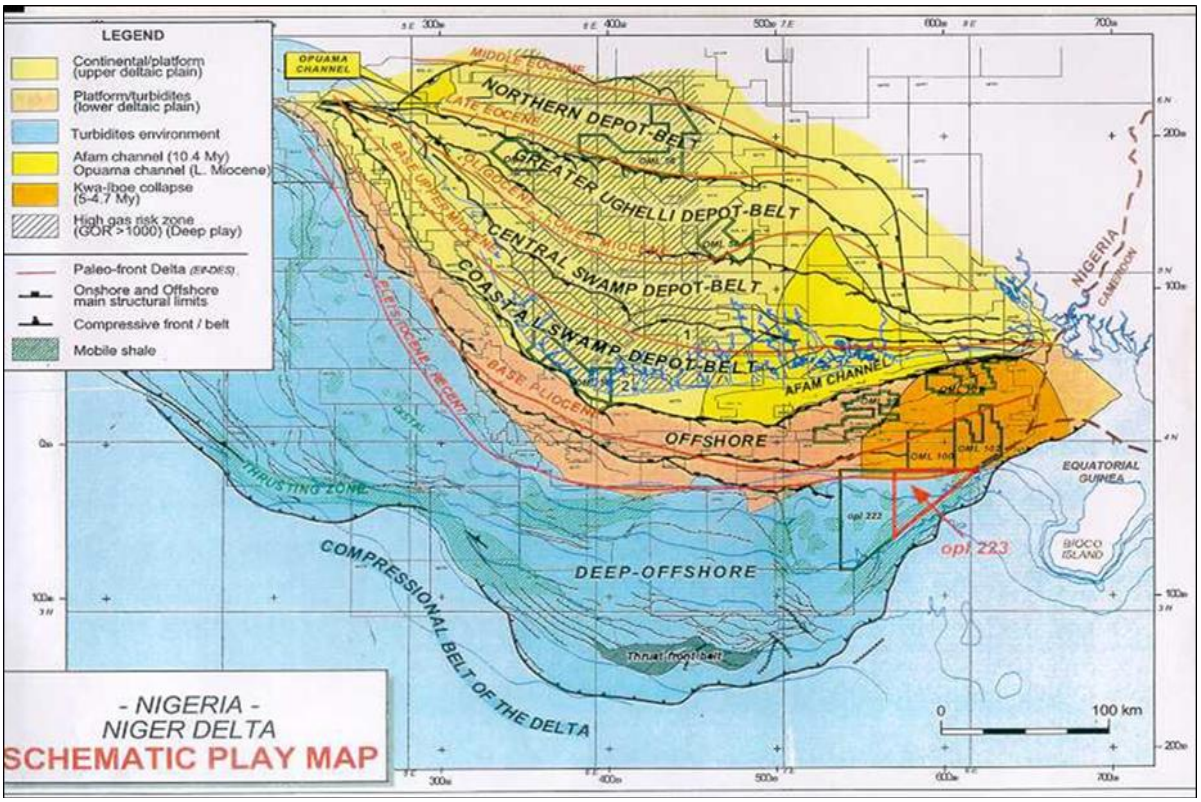

Figure 3: The Niger Delta Depobelts (Steele et al., 2009)

Most of these different facies in the course of interpreting their environment of deposition are usually grouped into an association following their genetic resemblance. According to Walker and James (1992), the facies associations serve as building blocks of various depositional systems and are also termed as architectural elements. The facies association provides additional evidence which makes environmental interpretation, particularly in the elimination of alternative interpretations, easier than treating each facies in isolation.

III. RESULT AND DISCUSSION

Lithofacies Types

Results of sedimentological description, lithofacies identified and interpretation from the core data are presented in Figures 4-7 respectively. Based on grain size, sorting and sedimentary structures interpretation, four Lithofacies were recognized from X-70 well cores acquired from a depth ranging from 8930 to 9022ft and includes. (Figure 8.1 – 8.4 is the results of sedimentological analysis (litholog) and facies description for the total cored depth).

Cross-Bedded Fine-Medium Grained Sandstone Facies (XFMS)

This lithofacies constitutes 35% (9.0ft) of the cored interval. The lithofacies is brown to grey in colour and consists of moderately well sorted, fine to medium-grained sandstones with unidirectional, internal cross-stratifications and rarely preserved reverse cross-stratifications. Coal / organic-rich laminae were abundant. Also, coarse-grained sands / granules occur occasionally as sparsely disseminated grains. The dominant physical structures preserved are horizontal to low angled inclined cross-stratifications and bed-sets bounded by sharp erosional surfaces. Bioturbation levels range from barren to low, but where it occurs, it is commonly by *Skolithos* burrows (Figure 4).

Interpretation: The good to moderate sorting, the concretions, the predominantly uni-directional cross-stratification and sharp bases indicate marine-sourced sands sorted by tidal / wave processes in a low to intermediate flow regime. The abundance of coal laminae / fragments within this facies indicates its closeness to the swamp. This facies is interpreted to be deposited in tidal channels with marine influence.

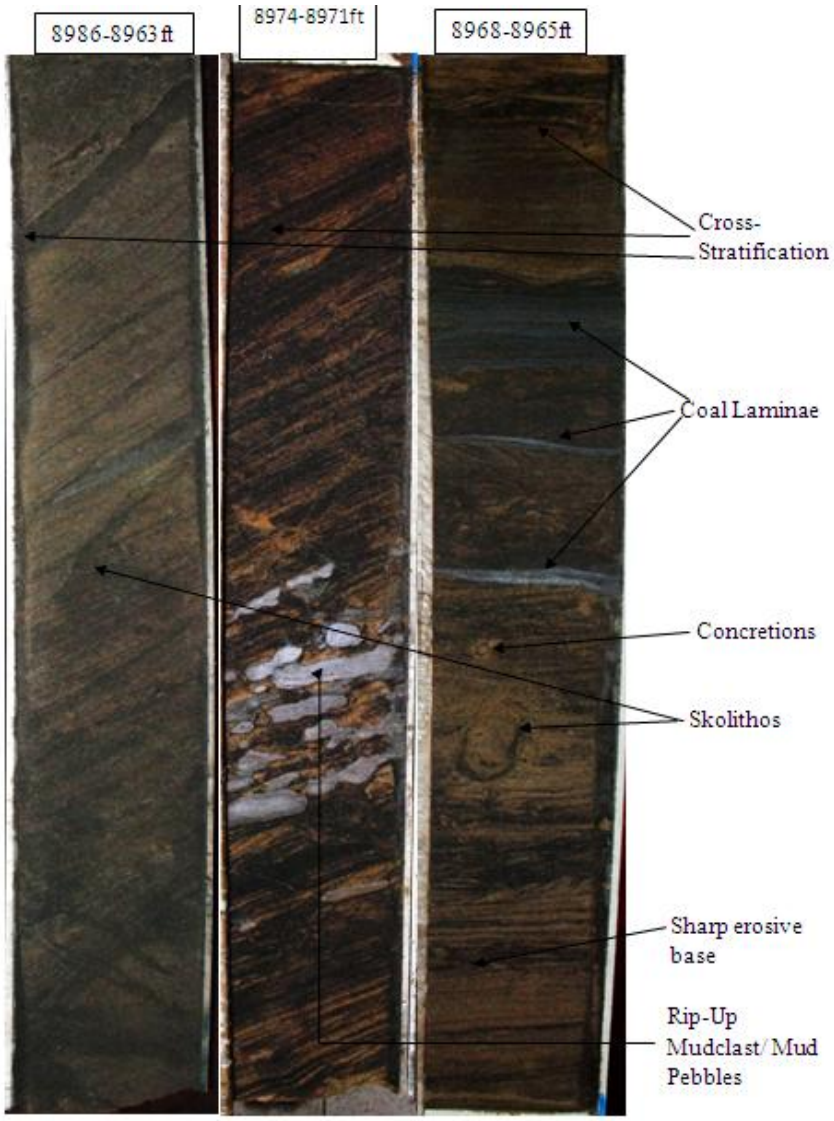

Figure 4:Cross Bedded Fine-Medium Grained Sandstone Facies

Cross-Bedded Coarse-Gravely Sandstone Facies

This lithofacies constitutes 19% (5ft) of the cored interval. It is found at a depth of 8992-8989 ft, 8975-8974ft, 8946.30-8945.40ft. It is composed of interbedded granular sandstones and fine-grained laminae. It alternates with 0.5-2 feet thick beds of coarse sandstones, which are poorly sorted, dominantly very coarse-grained, sub-angular to angular sandstones. This lithofacies is characterized by pebbles and granules (about 15%) which commonly aligned on the foresets but may also be dispersed throughout the lithofacies. This facies exhibits massive to low-angled cross stratifications. Bioturbation is mostly absent to rare. Each bed set depicts sharp basal contacts (Figure 5).

Interpretation: The coarse-grained, poor sorting, cross-bedding, and sharp erosive bases reflect a high energy flow regime (rapid emplacement) characteristic of a fluvial depositional system. The bimodal sorting is indicative of tidal current modulation and the restricted ichnofacies is suggestive of a stressed coastal environment. This lithofacies is interpreted to be deposited in a fluvial-dominated channel environment.

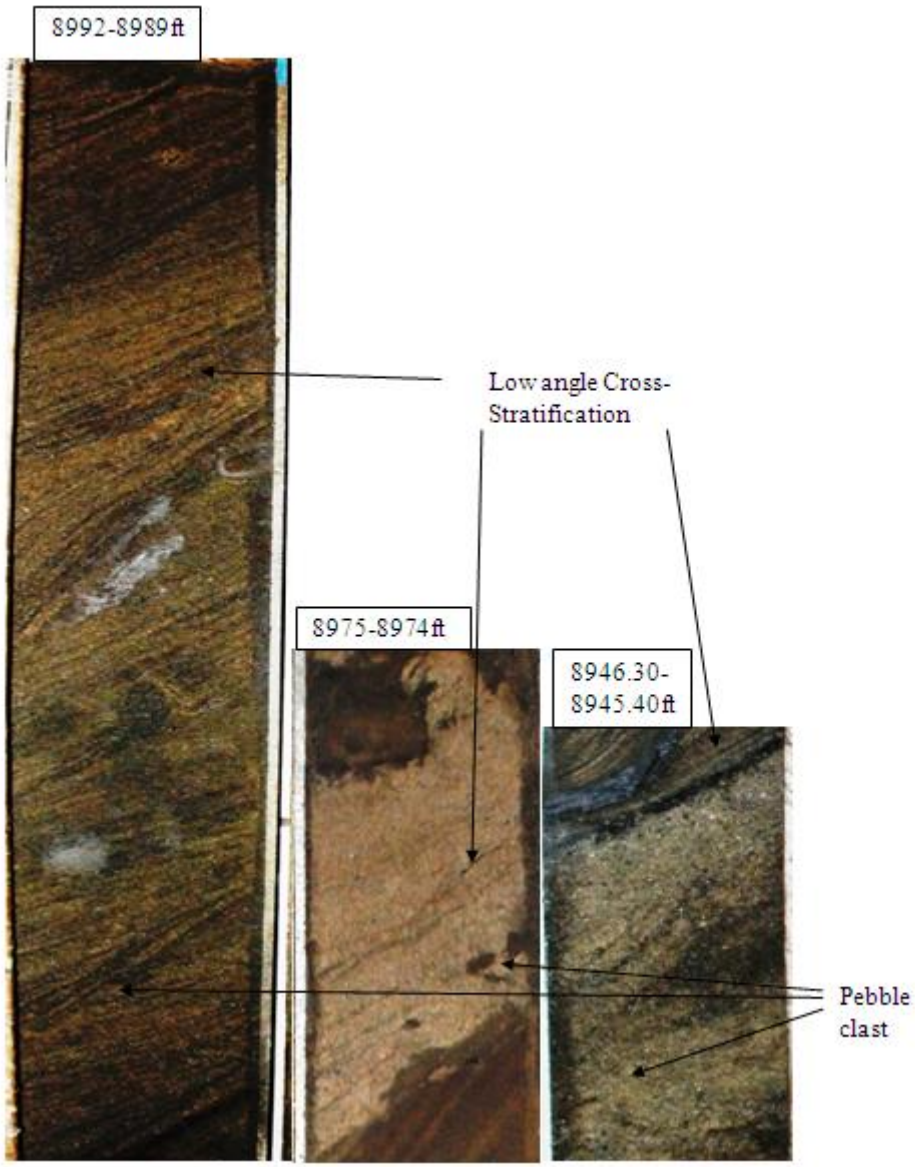

Figure 5: Cross-Bedded Coarse-Gravely Sandstones Facies,

Wave-Rippled Sandy Heterolithic Facies

This lithofacies constitutes 42% (11 ft) of the cored interval. The lithofacies consists of a heterolithic mix of sand, silt and claystones and is characterized by rippled to flaser-laminated fine-grained sandstones interbedded with wavy shale laminations. Bioturbation were identified with discrete spotty appearance. Ophiomorpha was the only identified ichnofossil (Figure 6).**Interpretation:**The sandy intervals are marked by the presence of current ripples and exhibit very good sorting. The rare to low bioturbation and heterolithic fabric of this facies indicates deposition in a low and stressed energy, shallow marine setting, characterized by alternating bed-load and suspension fallout.

Figure 6: Wavy Rippled Sandy Heterolithic Facies.

Parallel Laminated Mudstone Facies

This lithofacies constitutes 4% (1.0ft) of the cored interval with dark to light grey colours predominating. The facies consist of mudstone, silty, dark grey with discontinuous parallel to sub-parallel laminations. Bioturbation is absent. Clay percent is estimated to be greater than 85%. The core is mostly damaged with preservative and hence, difficult to interpret (Figure 7).

Figure 7:Parallel Laminated Mudstone Facies.

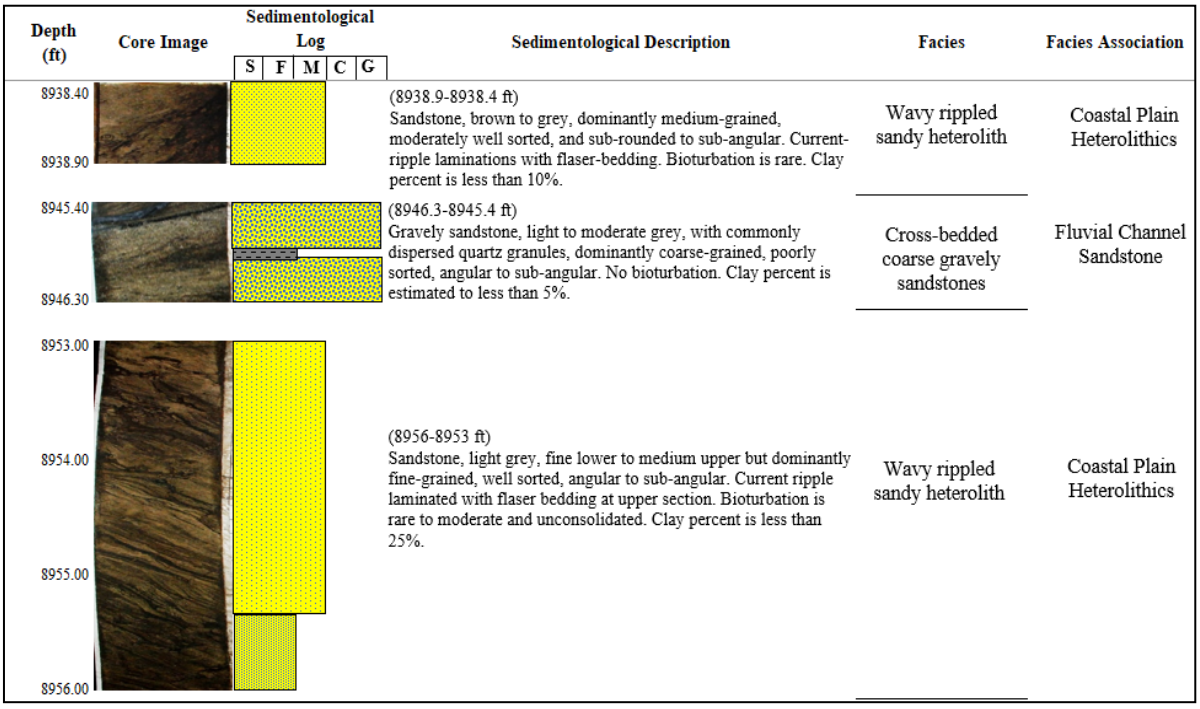

Figure 8.1: Results of sedimentological analysis and facies description from a depth range of 8956 to 8938.40ft

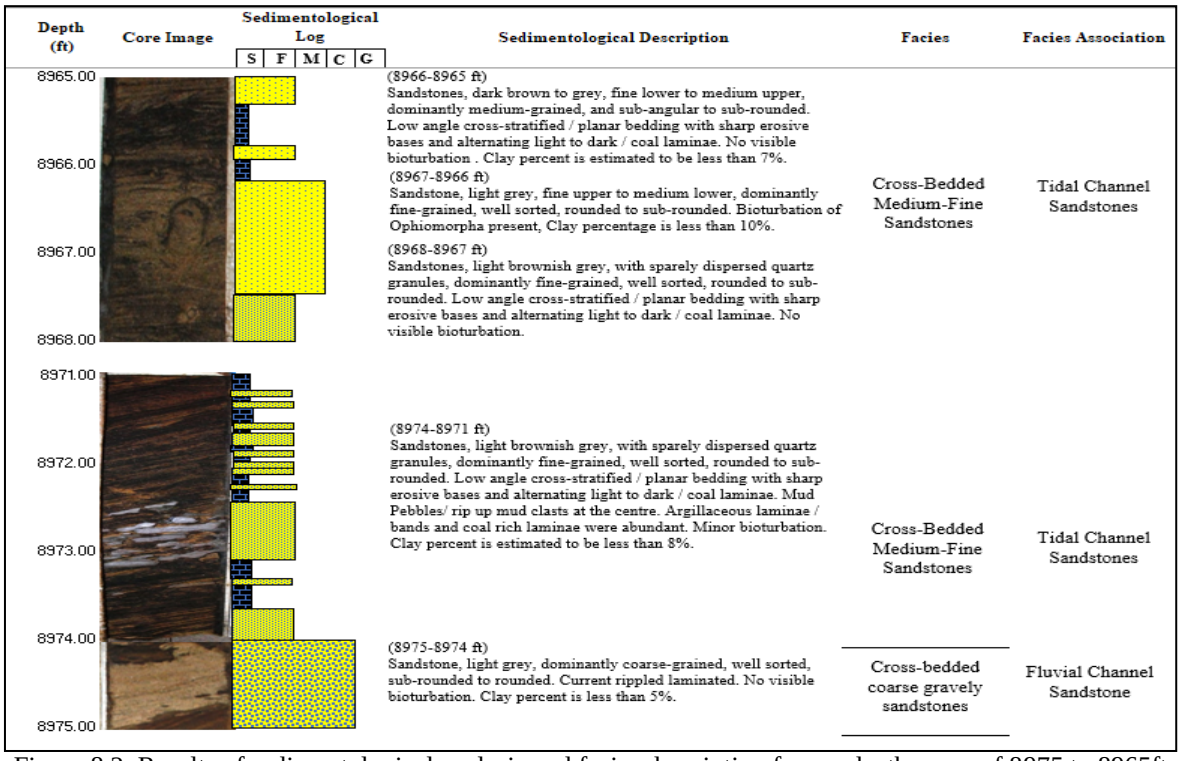

Figure 8.2: Results of sedimentological analysis and facies description from a depth range of 8975 to 8965ft

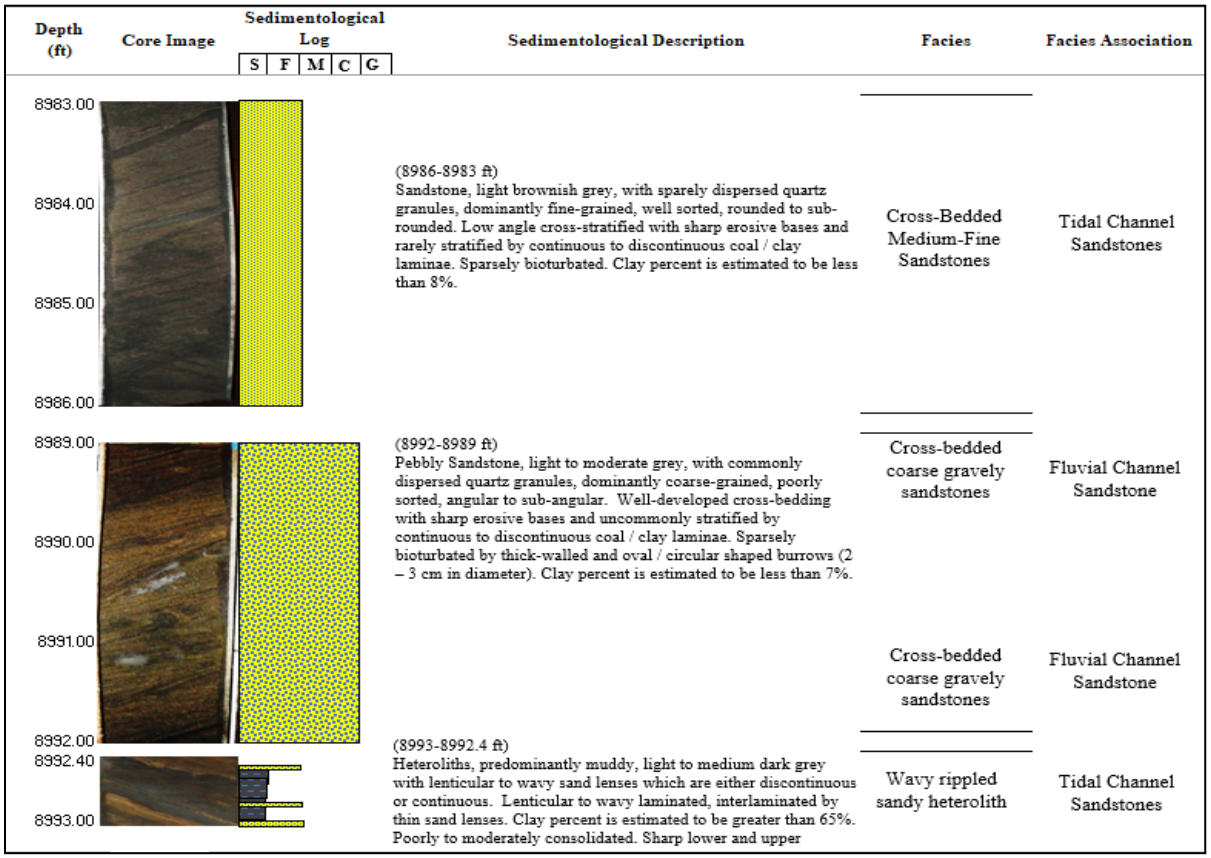

Figure 8.3: Results of sedimentological analysis and facies description from a depth range of 8993 to 8983ft

Figure 8.4: Results of Sedimentological Analysis (Litholog) and Facies description from a depth range of 9022.25 - 9010ft

Facies Association

The lithofacies identified were grouped into three facies association.Facies associations are thus the essential building blocks of facies analysis and, facies associations have been constructed for most environments.(Reading, 1996).

The facies associations recognized in this study are; i) Tidal Channel Sandstones, ii) Coastal Plain Heterolithics, and iii) Fluvial Channel Sandstones.

Tidal Channel Sandstones

This unit is characterized by medium-scale cross-stratified strata developed in well to very well sorted medium to fine-grained sandstones. The facies belonging to this group is the Cross-bedded Medium-Fine Sandstone facies. Cross-stratification is predominantly unidirectional with tidal influence rarely indicated by opposing sets of cross-strata, clay and coal laminae were commonly observed. Internally, they are characterized by the occurrence of restricted marine burrow assemblages dominated by Ophiomorpha and Skolithos ichnofossils. Bioturbation levels range from rare to moderate.

Coastal Plain Heterolithics

These units comprise of sandy / muddy heteroliths and interbedded mudstones and sandstones. Facies within this category includes; Wavy rippled sandy heterolith Facies and Parallel-laminated mudstone. The sandstones are very well to poorly sorted and fine to medium-grained. Cross-lamination occurs locally. In some units, the uppermost part comprises very well sorted, planar bedded sands. Bioturbation levels range from barren to rare with small Ophiomorpha and Skolithos traces.

Fluvial Channel Sandstones

The internal structure of these sand bodies is characterized by unidirectional, medium scale cross-stratification developed in poorly sorted, granular to coarse-grained sandstones of the Cross-bedded coarse gravely sandstones lithofacies. The coarse grain size and poor sorting of the sands reflect a fluvial dominated character. Bioturbation levels range from barren to low. Tidal influence is indicated by the rhythmic alternation of granular and coarse-grained fore-set strata, and more rarely by the occurrence of clay drapes.

IV. CONCLUSION

Lithofacies and depositional environment studies are crucial for proper evaluation of any given reservoir prospect. Information obtained from lithofacies analysis helps in providing better understanding of the distribution of source and reservoir rocks, the quality of the reservoir rocks, the sealing capacity and the geometry of the pore throats. Environment of deposition studies helps reveal the quality of the source and reservoir rocks. This study utilized well logs, core photographs and biostratigraphy information derived from the cored intervals for identifying lithofacies and interpreting the environment of deposition for the cored interval. Eight wells were utilized for this study and included; X-02, X-06, X-25, X-42, X-34, X35, X-60 and X70. Only well X-70 was cored from a depth of 8938.40ft to 9022.25ft.

Sedimentological analysis revealed four facies from the cored interval in X-70 well. The identified facies include; Cross-bedded Medium-Fine Grained Sandstone Facies, Cross-Bedded Coarse Gravely Sandstone Facies, Wave-Rippled Sandy Heterolith Facies, and Parallel Laminated Mudstone Facies.

The four lithofacies identified were grouped into three facies association and include; Tidal Channel Sandstones, Coastal Plain Heterolithics and Fluvial Channel Sandstones. These facies and facies associations showed a general progradational stacking parasequences pattern on the gamma ray log.

The presence of ichnofossils of *Ophiomorpha* and *Skolithos* traces found on the cored photographs confirms a Coastal Deltaic environment of deposition.The age for the cored section of the X-70 Well was inferred using diagnostic biomarkers such as *Eponides berthelotianus,Cyclicargolithus floridanus* and *Helicospharea ampliaperta*. This suggests that these environments were deposited during the Middle to Early Miocene time.

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