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Calcareous Nannoplankton Analysis of Well BL-2, Deepwater Offshore, Niger Delta Basin

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Abstract

Sequence Stratigraphy and biostratigraphy are recent tools that are being developed and incorporated together for the understanding of stratigraphic distribution and prediction of source, reservoir and seal rocks. These tools were used to analyze well BL-2, within the depth intervals of 6000ft - 8880ft offshore, Niger Delta. Calcareous Nannoplankton assemblages encountered in the study were used in determining the biozone and age of the samples of the penetrated well. Intercalation of sand and shale lithologies obtained from the well logs suggests the well BL-2 penetrated the Agbada Formation. Three nannozones were determined - NN10, NN11 and NN12, two sequence boundaries and three maximum flooding surfaces with ages and 5.0Ma, 5.8Ma, 7.0Ma respectively were delineated and used to divide the stratigraphic succession into depositional sequences and their corresponding system tracts. Highstand and Transgressive system tracts were identified in each of the three depositional sequences. However the absence of lowstand system tract can be inferred to have resulted from erosion by succeeding transgressive system tracts. The alternation of highstand and transgressive system tracts is inferred to provide the desired combination of reservoir and source rock required for hydrocarbon generation. The unit's age is Late Miocene to Early Pliocene.

Keywords: *Calcareous Nannoplankton, Sequence stratigraphy, Biozones*

Introduction

Calcareous Nannofossil has been applied in the recognition and delineation of key stratigraphic surfaces like maximum flooding surface (MFS) and their associated condensed sections based on the globally recognized zones of some index nannofossils (Okosun *et al*, 2012, Fadiya, 2012). Therefore, nannoplankton investigations are recommended to complement current biostratigraphic zonal scheme of the Niger Delta Basin, and it is expected to be immensely useful for stratigraphic correlation as exploration activities progress further into the deep offshore. Rapid increasing demand for oil and gas, worldwide, has necessitated the exploration of more detailed methods apart from the structural approach being developed and as the emphasis therefore shifts from structural traps to stratigraphic prospects, more accurate techniques of stratigraphic analysis are needed. Such techniques include sequence stratigraphy and biostratigraphy.

Calcareous nannoplankton has emerged as vital and useful tools in biostratigraphy,and together with structural methods, it can help locate some of the world's largest known oil reservoirs and even remain the major frontier plays of the immediate future. This work is a study on the lithostratigraphy, Calcareous nannofossil, and determination of the age of strata penetrated by the well, and an attempt on the tentative sequence stratigraphic framework for the studied intervals.

Location of Study Well

The study well BL-2 is located in the offshore region of the Niger Delta Basin (Fig 1). Data was obtained from an oil producing company in Nigeria.

The Niger Delta Basin is located on the continental margin of the Gulf of Guinea in equatorial West Africa. The Delta formed at the site of a rift triple junction related to the opening of the Southern Atlantic which started in the Late Jurassic and continued into the Cretaceous. The Delta proper began developing in the Eocene, accumulating sediments. From that Eocene the Delta has prograded southwestward, forming depobelts that represent the most active portions of the Delta at each stage of its development (Doust and Omatsola, 1990). The Niger Delta Basin is further subdivided into three formations: Pro-delta shales of the Akata Formation (Palaeocene to Recent), deltaic and parallic facies of the Agbada Formation (Eocene to Recent) and fluviatile facies of the Benin Formation (Oligocene-Recent). In cross-section, it is a large arcuate sediment wedge and constructive wave-dominated delta.

The onshore portion of the Niger Delta Province is delineated by the geology of southern Nigeria and southwestern Cameroon. Stable mega-tectonic frames flank the boundaries of the Niger Delta Basin. These include Benin and Calabar flanks at the northwestern and eastern boundaries of the delta respectively. The

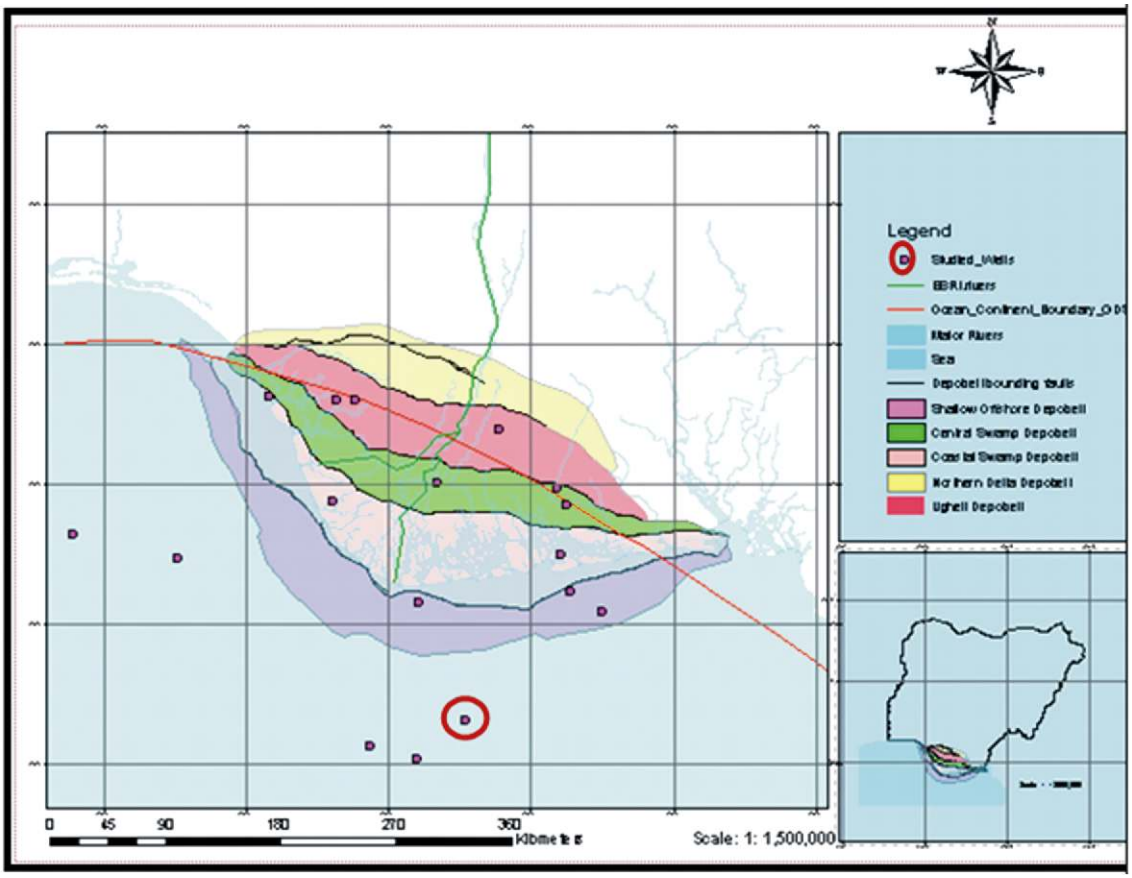


Fig. 1: Location Map of Kafin-Koro and its environs.

Anambra Basin and Abakaliki mark the northern boundary of the delta. The Gulf of Guinea borders the Niger Delta Basin in the south. It is the oil province of Nigeria and between latitudes 4° and 7°N and longitudes 3° and 9°E (Whiteman, 1982). The total sedimentary prism, an area of 140,000km (75,000 km2) has a stratigraphic thickness of about 12km and is composed of an overall regressive clastic sequence that reaches a maximum thickness of 9,000-12,000 metres (Evamy et al. 1978).

It ranks among the worlds' most prolific petroleum producing Tertiary deltas that together account for about 5% of the worlds' oil and gas reserves. It is one of the economically prominent sedimentary basins in West Africa and the largest in Africa (Reijers, 1997). Subsequent to its discovery as a petroleum-laden basin, the onshore areas of the Niger Delta were extensively explored for oil and gas. Currently, attention is being shifted to the offshore areas and the forecast have been hopeful. A lot of work has been concentrated on the Niger Delta Basin since its discovery as a petroliferous basin in the 1950s.The development of geophysical technologies has assisted greatly in deepwater drilling and other exploration techniques, which have proved useful in the search for oil and gas. The integration of these techniques with biostratigraphy, well log, reservoir sequence stratigraphy and so on, have contributed enormously to oil and gas exploration in the Niger Delta Basin.

Materials and Methods

Twenty-five ditch cuttings samples, Gamma ray and Resistivity well log data between the depths intervals of 6000 – 8880ft were obtained from an oil producing company for the study.

Lithofacies Description

A combination of the Gamma ray and resistivity log signatures of the Well BL-2 and the use of a stereo-binocular microscope were employed in the lithologic description of the samples. The lithologic types in the sample were observed and recorded. Gamma ray

logging is a method of measuring naturally occurring gamma radiation to characterize the rock or sediment in a borehole. The difference in radioactivity between shales and sandstones/carbonate rocks allows the gamma tool to distinguish between shales and non-shales. The Gamma ray log's scale ranges from 0-150 API units, if the signature reads more towards 0 (i.e towards the left) the lithology indicates a sandy lithology and when the signatures tend towards 150 (i.e towards the right) then it indicates a shaly lithology.

Nannoplankton Preparation/Analysis

Twenty five (25) ditch cutting samples from interval 6000 – 8880ft of well BL were processed and analysed at 120ft intervals for calcareous nannofossils. About 5grams of the sample was placed in a mortar and crushed with a pestle. The crushed material was then placed in a test tube and a few drops of distilled water were addedto the test tube to make a muddy suspension. This was further stirred with a glass rod then a few more drops of distilled water were added. The suspension was allowed to settle for between 3 – 4 minutes. A portion of the suspension was poured into another test tube and a few drops of distilled water were added to dilute it. A drop of the suspension was placed on a cover slip with the aid of a disposable pipette and dried on a hot plate. The dried cover slip was then mounted on a glass slide with Norland (optical adhesive) as the mounting medium. The slides were then left to dry up for some hours.

Detailed identification of forms (to species level where possible) was made of all taxa encountered in each slide. Eight (8) traverses were studied in each slide. The clear mount slide was inspected under the microscope for calcareous nannofossil at ×1000 magnification. The cascading counting method (Styzen1997) was employed in determining relative abundance and diversity of the assemblages. These details with all other relevant information were recorded on the analysis logging sheet for each sample.

Sequence Stratigraphy

A tentative sequence stratigraphic framework was attempted by identifying key stratigraphic surfaces in the study well, which included Maximum Flooding surfaces (MFS) and sequence boundaries (SB). Calcareous nannoplankton like those in other basins worldwide, have similar assemblages characteristic of some major condensed sections (Fadiya, 2010).

Hence, calcareous nannoplankton abundance/ diversity minima and maxima patterns were used for defining sequence boundary and condensed section respectively. The tentative sequence stratigraphic framework was correlated with the Global Sea Level Cycle Chart of Haq *et. al*., (1987) and guided by chronostratigraphically significant nannoplankton bioevents recorded over the studied section. Condenses sections were delineated from the Nannoplankton abundance and diversity patterns.

Results and Discussion

Lithofacies

Lithofacies identification from Gamma Ray and Resistivity log for the study interval was essentially a shale lithology with two thin sand layers at an approximate depth of about 6615ft-6640ft and 8820ft-8830ft. On the Resistivity log the signature is noticed to have sharply diverted to the right and as well on the Gamma ray log (Fig 2).

Biostratigraphy

The result of the analysis shows that the analysed section is characterized by common to fairly abundant and diverse nannoplanktons. The straigraphic intervals were subdivided into biozones based on the recovery of the Calcareous nannofossil content. The results are as below (Table 1):

Stratigraphic Interval	:	*6000 – 7080ft*
Age	:	*Early Pliocene - Late Miocene*
Nannofossils Zone	:	*NN12*
Top	:	Shallower than first analysed sample
Base	:	Top *Discoaster quinqueramus*

The zone is defined based on its stratigraphic position above the positively recognized zone NN11 below. The presence of *Ceratolithus sp* at depth 6120ft indicates that the well section is not older than Early Pliocene at this depth.Nannofossils recorded here include *Discoaster pentaradiatus, Sphenolithus abies, Ceratolithus spp, Reticulofenestra pseudoumbilicus, Discoaster variabilis* and *Reticulofenestra haqii*. Others are *Helicosphaera carteri, Pontoshaera multipora, Cocolithus pelagicus* and *Calcidiscus leptoporous*. The slight flora increase over interval 6120 – 6360ft to represent a condensed section associated with the 5.0Ma Maximum Flooding Surface based on the presence of

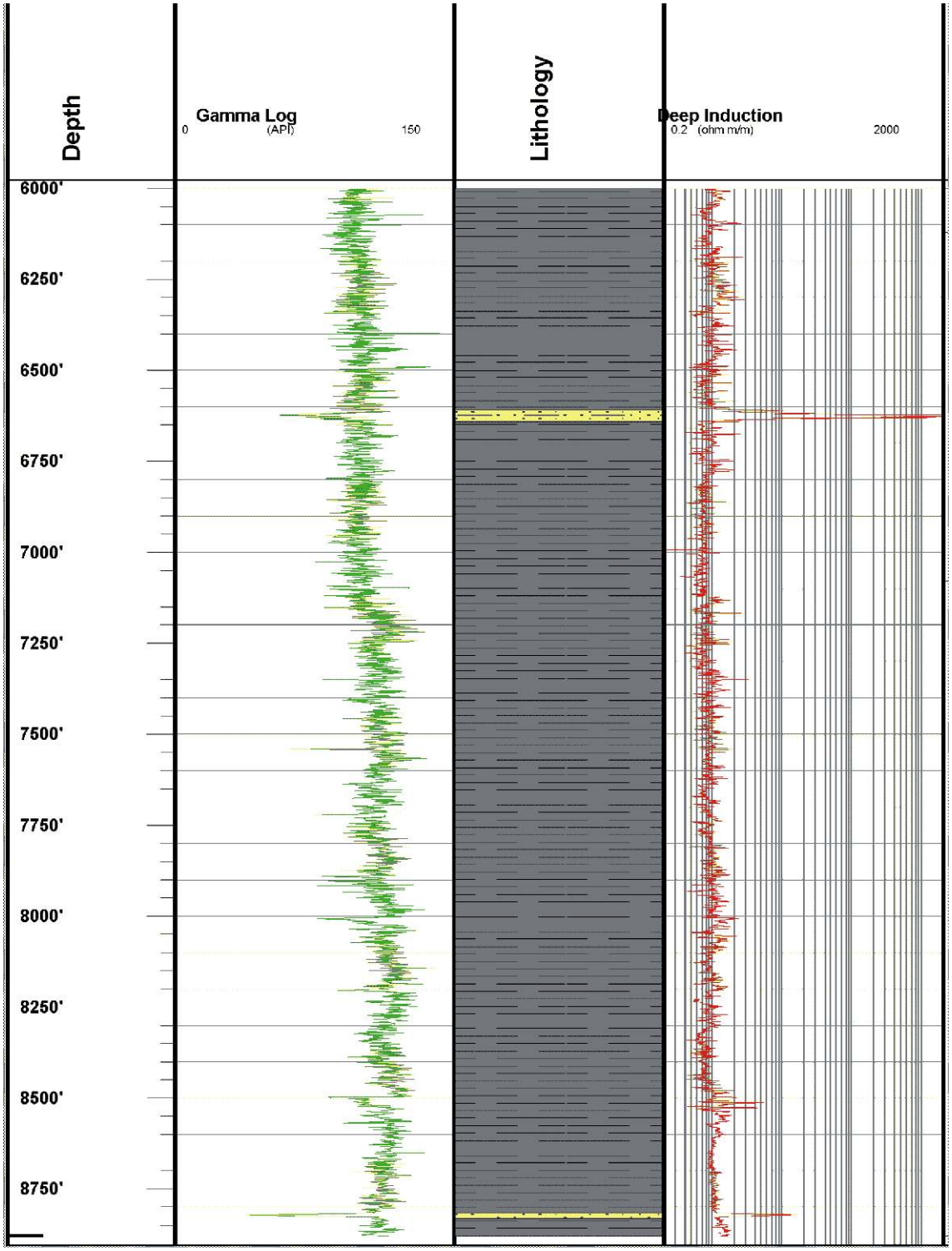


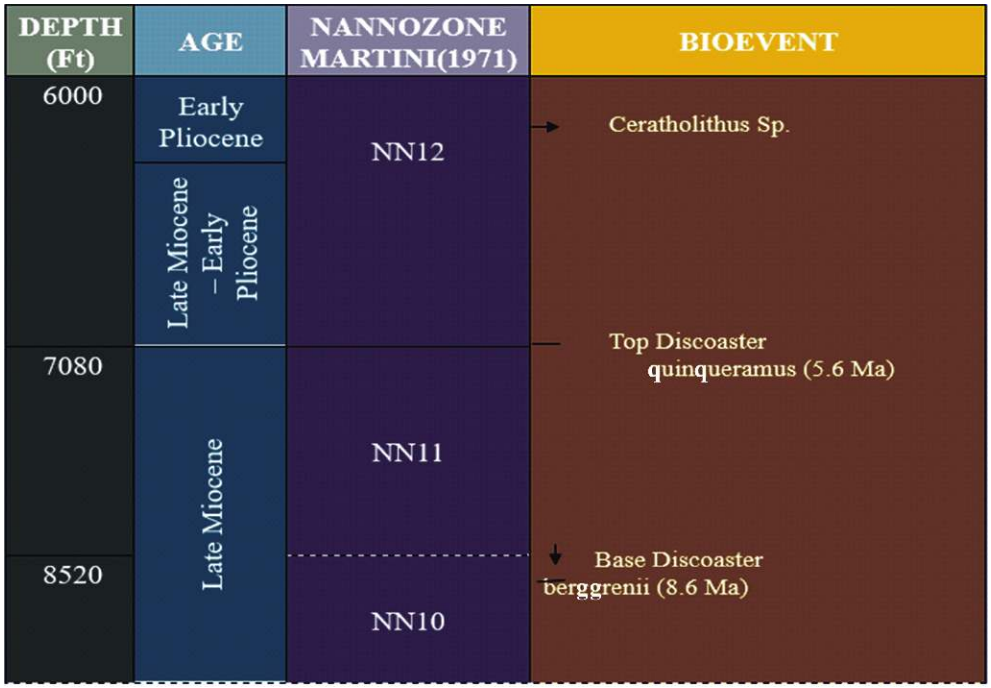
Fig. 2: Lithologic Section of Well-BL-2

Ceratolithus sp at depth 6120ft and the position of the condensed section above the 5.8 Ma MFS (Fig. 3).

Stratigraphic Interval : *7080 – 8520ft*

Age : *Late Miocene*
Nannofossils Zone : *NN11*
Top : Top *Discoaster quinqueramus*
Base : Base *Discoaster quinqueramus*

Table 1: Showing Biozonation of Calcareous Nannofossils



Interval characterized by abundant and diverse assemblage of typical Late Miocene NN11 nannofossil assemblage. Recorded nannofossils in high abundance include *Discoaster quinqueramus, Discoaster berggrenii, Sphenolithus abies, Sphenolithus moriformis, D. brouweri, D. pentaradiatus, D. variabilis, Reticulofenestra pseudoumbilicus,* and *R. haqii*. Others include *Helicosphaera carteri, Pontosphaera multipora* and *Calcidiscus leptoporous.* Condensed interval 6960 – 7560ft is believed to be associated with the 5.8Ma Maximum Flooding Surface with the top of *Discoaster quinqueramus* at depth 7080ft

Stratigraphic Interval	:	*8520 – 8880ft*
Age	:	*Late Miocene*
Nannofossils Zone	:	*NN10*
Top	:	Base *Discoaster quinqueramus*
Base	:	Deeper than last analysed sample

Interval characterized by rare and scattered occurrence of nannofossils including *Calcidiscus leptoporous, Helicosphaera carteri* and *Reticulofenestra spp*. The zone is defined based on its stratigraphic position below the positively recognized zone NN11. Above in absence of a definite marker.The analysed section is dated Late Miocene to Early Pliocene based on their calcareous nannofossil content.The well was sectioned using the globally recognized calcareous nannofossil zonation scheme of Martini (1971), these are the NN12, NN11, NN10 zones while ages in Ma were based on Berggren *et al* (1995). Condensed Sections were correlated to the Global Cycle Chart of Haq *et. al.,* (1987).

Sequence 2 (Table 2, 7790 – 6630ft)
7790 - 7080ft: Transgressive Systems Tract (TST)
Characteristics: Increasing - upward nannofossil abundance and diversity.
An age of 5.8 Ma (Haq *et al.*, 1987) has been assigned to the MFS based on the Top Occurrence of the nannofossil species, *Discoaster quinqueramus* (5.6 Ma) at 7080ft.
7080 - 6630ft: Highstand Systems Tract (HST)
Characteristics: Decreasing - upward nannofossil abundance and diversity; Coarsening - upward profile.

The Sequence Boundary (SB) has been dated 5.5 Ma based on its stratigraphic position between the positively identified 5.8 Ma and 5.0 Ma Maximum Flooding Surfaces and its correlation with the Global Sea Level Cycle Chart of Haq *et al.,* 1988.

Sequence 3 (6630 – 6000ft)
6630 - 6120ft: Transgressive Systems Tract (TST)
Characteristics: Fining-upward profile; Increasing - upward faunal and floral abundance and diversities and Termination in a condensed section at 6360 - 6120ft.

The MFS has been correlated with the 5.0 Ma MFS of

Haq *et al.,* (1987). This age has been assigned on the based on the presence of *Ceratolithus sp* at depth 6120ft and the Top Occurrence of the nannofossil species, *Discoaster quinqueramus* (5.6 Ma) at 7080ft. This is further confirmed by the occurrence of the condensed section within zone NN12.

6120 - 6000ft: Highstand Systems Tract (HST)
Characteristics: Coarsening - upward profile; Decreasing - upward nannofossil abundance and diversity; directly overlying a Maximum Flooding Surface.

Table 2: Sequence Stratigraphic framework of BL-2 Well

Sequence	Depth(Ft)	System Tracts	Important Key Bounding Surfaces
3	8880-8400	TST	MFS
	8400-7790	HST	SB
2	7790-7080	TST	MFS
	7080-6630	HST	SB
1	6630-6120	TST	MFS
	6120-6000	HST	

LEGEND
HST – Highstand system tract
TST – Transgressive system tract
SB – Sequence Boundary
MFS – Maximum Flooding Surface

Implication for Exploration and Development

The cyclic pattern of the alternating TST and HST in the studied well is indicative of a good environment for organic accumulation and generation. The shales of the transgressive system tract could form good source and cap rocks given the right conditions.

Summary and Conclusion

Calcareous nannoplankton analysis was carried out on sequences within the interval 6000-8880ft of well-BL-2 located in the deep offshore area of Niger Delta, Basin, Nigeria. A lithological analysis of the well shows that the bulk of the lithofacies are made up of shale and few sandyshale which are grey to brownish grey to brown in colour, with bulky and fine- grained texture. A major lithofacies sequence was delineated based on its characteristic features. It is notably the Agbada Formation (characterized by intercalation of shale and sandstone). The section yielded rich and diverse assemblages of well to moderately preserved calcareous nannofossils of about Seven hundred and eighty (780) of ten genera.

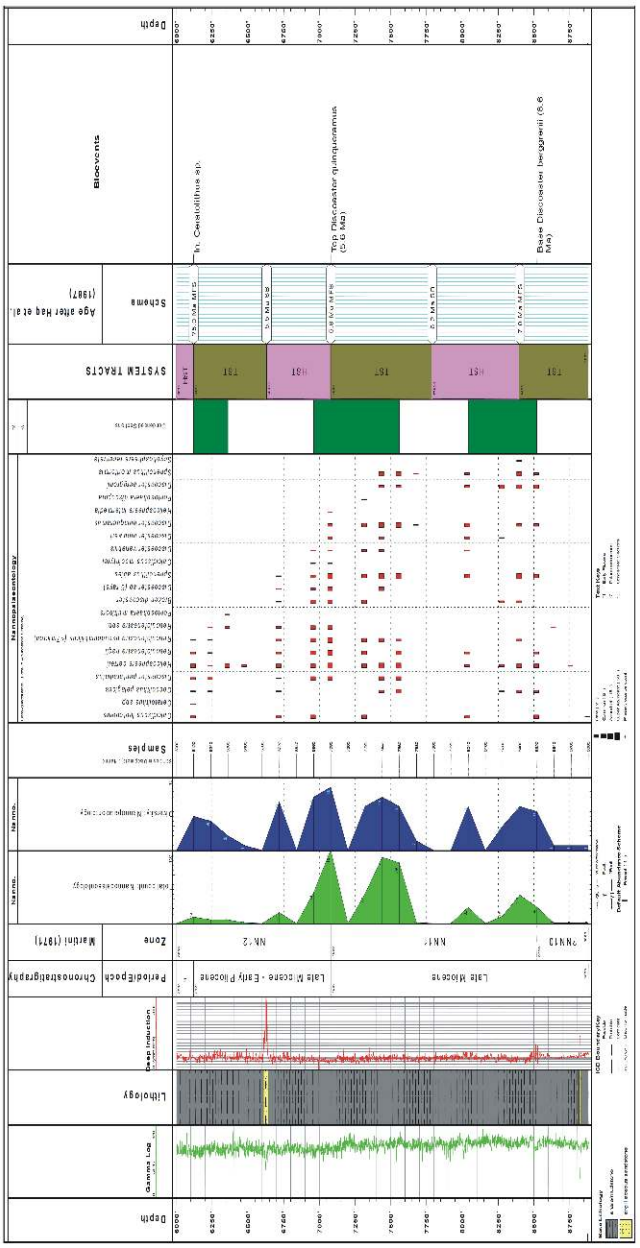


Fig. 3: Composite plot of Lithologic, Biostratigraphic and Sequence Stratigraphic Analysis for well BL-2, Niger Delta.

Three major nannofossil zones (NN12, NN11 and NN10) belonging to the Early Pliocene to Late Miocene age were identified following the standard zonation schemes of Martini (1971). The nannofossils abundance and diversity patterns calibrated with time-significant depositional and bio-events facilitated the recognition of three condensed sections related to the zones above. They are believed to be associated with the?5.0 Ma, 5.8 Ma, 8.6 Ma maximum flooding surfaces respectively. Two sequence boundaries were also identified dated 5.5Ma and 6.2Ma. Ages were identified for specific depth with the help of calcareous nannofossil markers at depth 7080 - 5.6Ma (Top Discoaster quinqueramus) and

depth 8520 - 8.6Ma (Base Discoaster Berggrennii).The stratigraphic unit is divided into three sequences (1, 2 and3) which all contain highstand and transgressive system tracts respectively. The alternation of highstand and transgressive system tracts is inferred to provide the desired combination of reservoir and source rock required for hydrocarbon generation.

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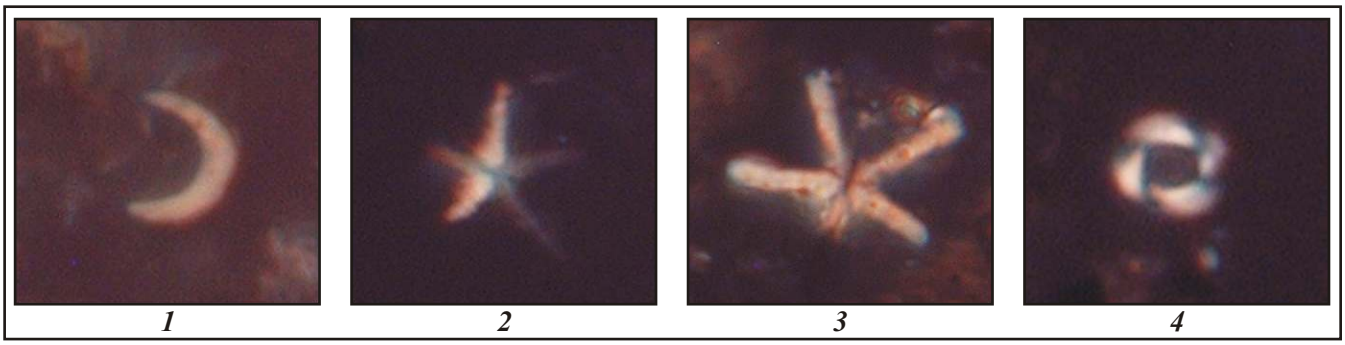
APPENDIX

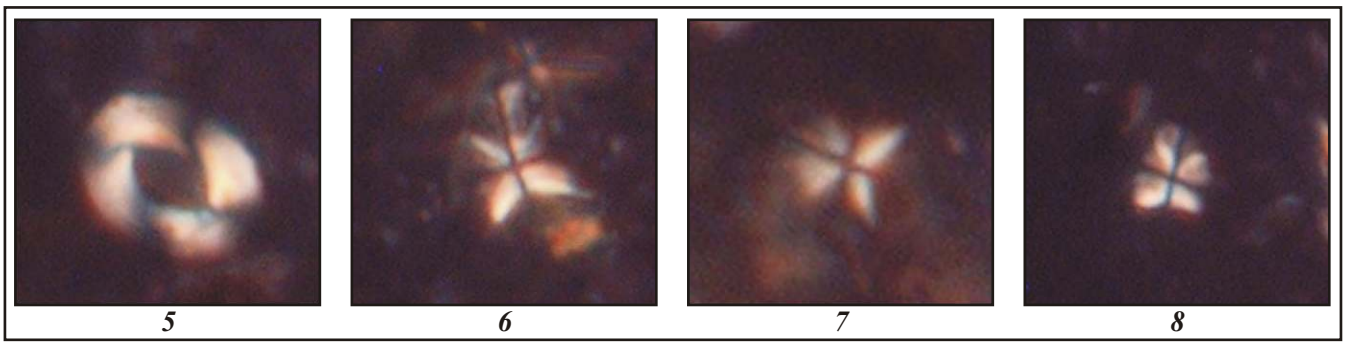
MONOGRAMS OF CALCAREOUS NANNOFOSSIL ASSEMBLAGES (X1000)

PLATE 1



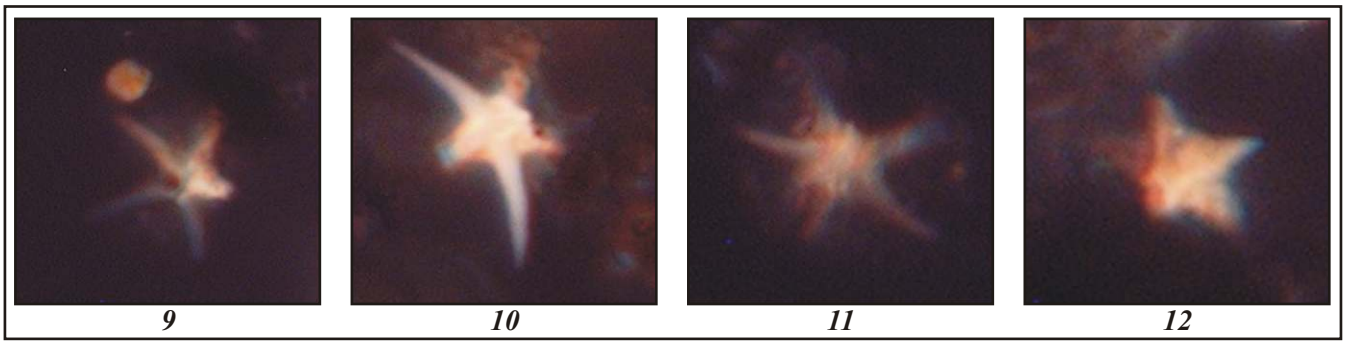
1. Ceratolithus sp. 2-3 Discoaster pentaradiatus 4. Reticulofenestra haqii

PLATE 2



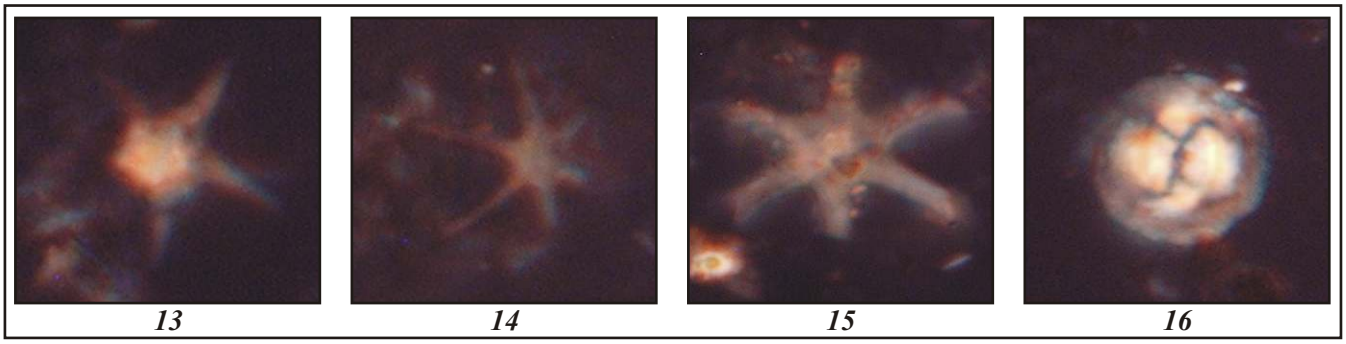
5. Reticulofenestra pseudoumbilicus 6-7. Sphenolithus abies 8. Sphenolithus moriformis

PLATE 3



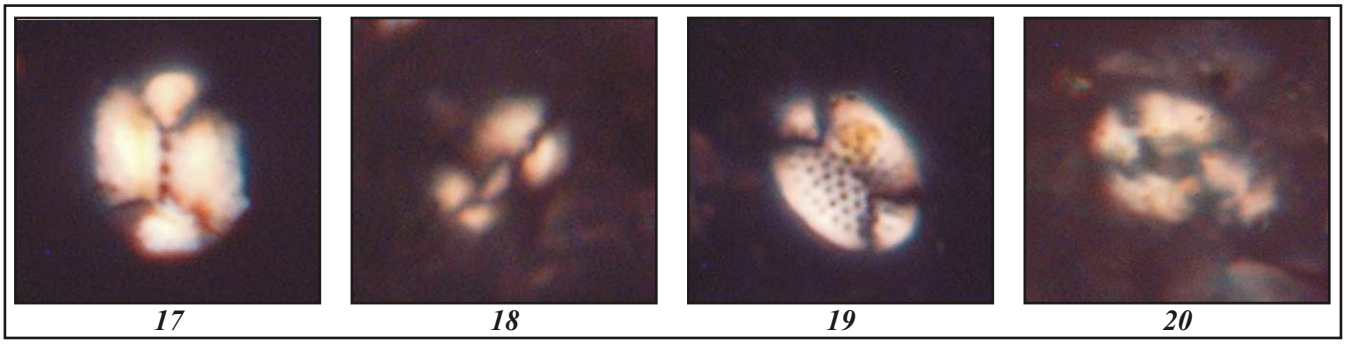
9-11. Discoaster quinqueramus 12. Discoaster berggrenii

PLATE 4



13. Discoaster berggrenii 14. Discoaster brouweri 15. Discoaster variabilis 16. Coccolithus Pelagicus

PLATE 5



17. Helicosphaera carteri 18. Helicosphaera intermedia 19. Pontosphaera multipora 20. Calcidiscus macintyrei