IJSES

International Journal of Scientific Engineering and Science
Volume 4, Issue 5, pp. 1-7, 2020. ISSN (Online): 2456-7361

Nano-Bioevents and Condensed Section of Well – BXW Offshore, Niger Delta, Nigeria

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Abstract*— Ditch cutting samples from well - BXW in the offshore area of the Niger Delta were studied for their lithofacies and nannofossil content with the aim of establishing age and stratigraphic significance of the condensed section delineated from the well. Standard procedures were employed for lithologic description and nannofossils preparation techniques. The lithofacies penetrated thick shale units and some sandy shales. The rich and well preserved calcareous nannofossils recovered allowed the establishment of four zones of NN12, NN11, NN9 and ?NN8 belonging to early Pliocene - Late Miocene (Zanclean - Tortonian stage). The condensed sections identified were tied to 5.0Ma, 5.8Ma, 7.4Ma and 9.5Ma maximum flooding surfaces. Detailed analyses of condensed sections as important framework for assessing: age; acme /characteristic assemblages of nannofossils within the condensed section; paleo-depositonal environment; potential source rock; information on rate of sedimentation, and a glimpse of the oceanographic condition in the studied basin was presented.*

Keywords*— Bioevents; Condensed section; Nannoplankton; Niger Delta.*

I. Introduction

Bioevents are results of the fluctuations in abundance and diversity of assemblages from the spatial and temporal distributions of nannoplanktons or other microfossils. Sequence of bioevents provide information where deductions can be made in terms of reliable zonations, Paleoclimatic trends, Paleoecologic signals, paleoceanographic and paleodepositional (key stratigraphic surfaces) changes. Calcareous nannofossils stratigraphically significant bioevents have over time provided the industry and academia as tools for proper basin analysis.

Recently, Calcareous nannofossils aside its ability for biostratigraphic deductions for zonation and dating of sequence, has provided much more breaking grounds in researches. It is worth of note that, calcareous nannofossil on the palaeontologic platform is providing excellent basis for the subdivision of strata into biozones; monitoring changes in primary productivity in the ocean due to their sensitivity to surface water conditions; temperature; salinity; availability of nutrients; location and other biogeographical factors (Okada and Honjo, 1973; Bralower, 2002; Perscio and Villa, 2004 and Melinte, 2005).

Nannofossils have been applied in the recognition and delineation of key stratigraphic surfaces like Maximum flooding surfaces and their associated condensed sections based on the globally recognized zones of some index nannofossils (Alkali et al., 2014, Fadiya et al, 2014) and many other works in the Niger delta.

Condensed section can be defined as a representation of time by an abnormally but normally complete thin layer of fine grained sediments that accumulated slowly. They are normally marine consisting of pelagic and hemipelagic sediments and could even be referred to as “Marine hardgrounds” (Glenn, *et al*., 1993). They are mostly characterized by high abundant and diverse microfossil assemblages, organic matter and other minerals. Condensed sections represent a physical stratigraphic link between shallow and deepwater sections (Loutit *et al*., 1988).

Calcareous nannofossils have been studied and reported in several literatures (Boboye and Fowora, 2007; boboye and Adeleye, 2009; ojo et al., 2009;Umoh, *et al*., 2011; Fadiya and Salami, 2012; Fadiya, 2014; Obaje, et al., 2014; Adetola, 2014; Alkali et al., 2014; Boboye, *et al.*, 2017; Okewale and Omoboriowo, 2017; Ola, 2018; Umoh, *et al.*, 2019), but much more published researches are expected and necessary to unravel and present a clearer resolution of the subsurface stratigraphy of the highly resourceful Niger Delta basin, as exploration activities progress further into the deep offshore.

This paper documents the age determination and importance of condensed sections from the bioevents observed and some possible deductions from the condensed section delineated from the study interval.

II. Location And Geology Of The Study Area

The studied area well – BXW, is located on the deepwater offshore portion of the Tertiary Niger Delta (Fig. 1) belonging to OML 118 block. In turn the Niger Delta basin is situated on the continental- margin of the Gulf of Guinea and extends throughout the province as defined by (Klett et al 1997). The Niger Delta is a large, arcuate, classical delta of the destructive, wave dominated type (Allen, 1965). The Niger delta sedimentary basin wedge formed as a result of two depositional cycles. The Proto-Niger Delta from late Mesozoic to a major Paleocene marine transgression (Reijers *et al*., 1996) and from Eocene to recent continuous growth Niger Delta. At each stage of development, the most active portion of the Delta is the depobelts (Doust and Omatsola, 1990). The Niger Delta sedimentary wedge is among the world’s most prolific petroleum producing Tertiary deltas today.

The thick sedimentary wedge is considered to be divided into three subsurface units (Weber and Daukoru, 1975; Short and Stauble, 1967). The Akata Formation is the basal unit composed mainly of marine shales with few sand beds. Thickness ranges from 600 to about 7,000 meters (Doust and Omatsola, 1990). The overlying paralic sequence is the Agbada formation consisting of interbedded sands and shales with about 300 – 4,500metres thick sediments. The Benin

International Journal of Scientific Engineering and Science
Volume 4, Issue 5, pp. 1-7, 2020. ISSN (Online): 2456-7361

formation is the topmost unit composed of continental deposit of alluvial and coastal plain sands that are up to 2,000 meters thick. It extends from west across the whole of the Niger Delta area and Southward beyond the present coastline.

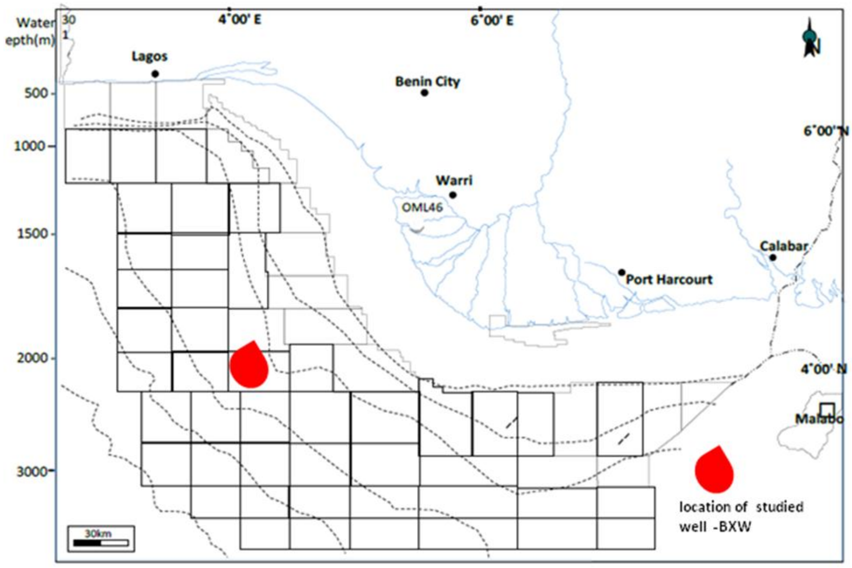


Fig. 1. Map of Niger Delta showing the location of Well –BXW

III. Materials And Methods

Twenty-five ditch cutting samples and well logs from deep offshore, western part of Niger Delta within the intervals of 6400 – 10340ft were obtained from an Oil producing company in Nigeria. The lithology of the study interval was determined from both petrographic and gamma ray interpretations. The samples were processed for their nannofossil content using standard procedures.

A few grams of the samples were initially crushed in a mortar with pestle and a few drop of distilled water added to make muddy suspension. This was allowed to settle for between 3-4 minutes. A portion of this suspension was poured into a test tube, a few drops of water was added to dilute it. A drop of this suspension was placed on a cover slip with the aid of disposable pipette and dried on a hot plate. The cover slip was mounted on a glass slide with Norland (optical adhesive) as the mounting medium and cover over ultra violet light. The clean mount slide was then inspected under the microscope for calcareous nannofossils at X1000 magnification (see Plate I few representative species).

VI. Results And Discussions

A. Lithologic Unit of Well - BXW

The lithologic interpretation from gamma ray log and depth by depth description with the aid of a petrographic microscope describes the entire studied interval (6440 – 13640ft) of the study well as a succession of shales/ mudstone with variably minor proportions of sand. The sandstones–mudstone ratio of the section is approximately 1: 9. The sandstones are few and generally occur in relatively thin units (Fig. 2).

B. Calcareous Nannofossil Biostratigraphy

The samples analyzed yielded about 1272 total abundance from 15 genera of preserved nannofossil species with minimum dissolution effect. The stratigraphic interval studied have been sub-divided into biostratigraphic zones based on their calcareous nannofossil recovered. The well was sectioned using the globally recognized calcareous nannofossil zonation scheme of Martini (1971) Okada & Bukry (1980. Four major zones were identified belonging to the early Pliocene and late Miocene, the NN12, NN11, NN9 and ?NN8 zones. The nannofossils assemblages recovery from this study demonstrate abundance and diversity enough to zone and date the intervals of the sediment penetrated in the study area (Table 1).

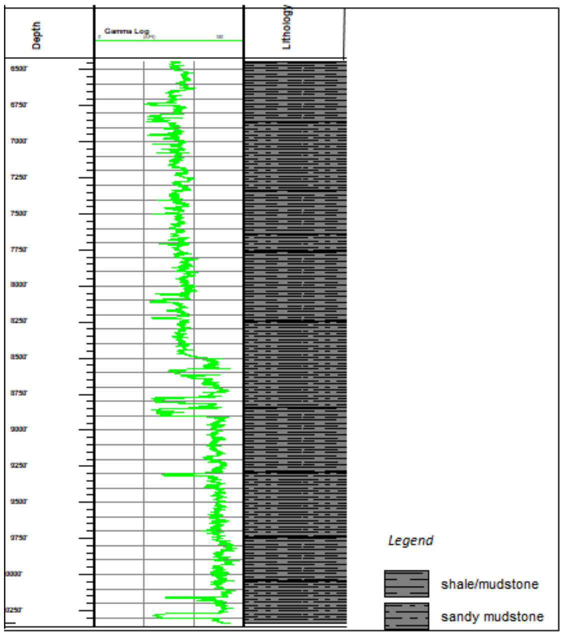
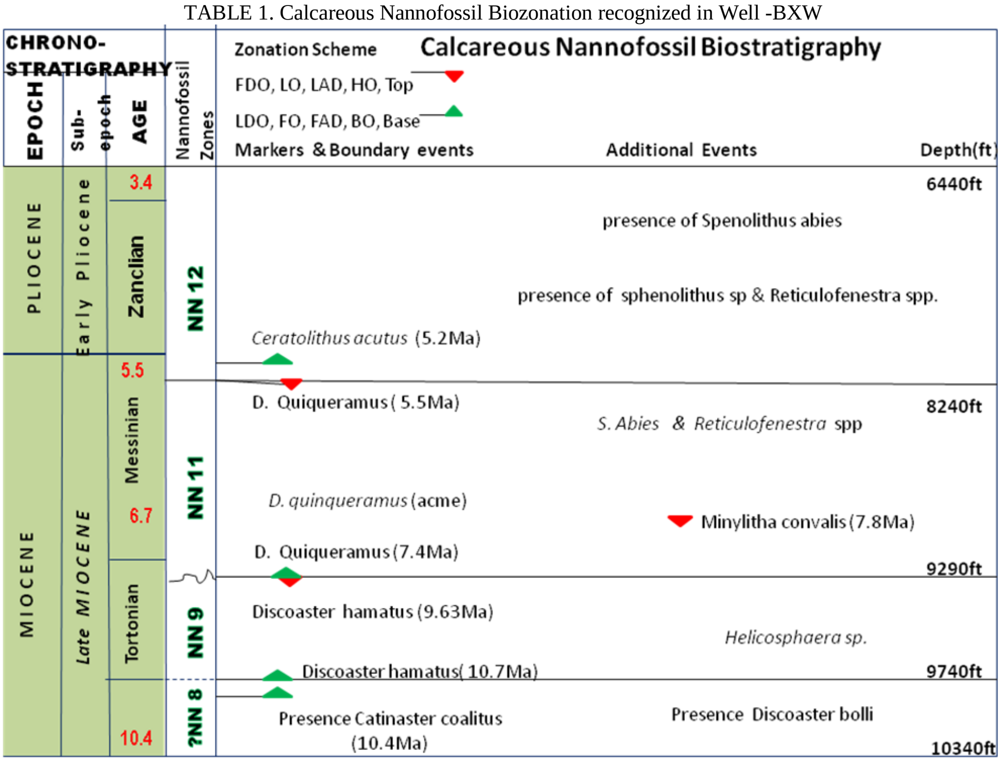


Fig. 2. Lithostratigraphy of well – BXW

International Journal of Scientific Engineering and Science
Volume 4, Issue 5, pp. 1-7, 2020. ISSN (Online): 2456-7361

Nannofossil zone: *Catinaster coalitus*- ?NN8
Stratigraphic interval: 9740 – 10340ft
Age: Late Miocene
Top:First Occurrence of *Discoaster hamatus*
Base: Shallower than last sample analysed
Description: The interval is characterized by paucity of nannofossils and the zone recognized by its stratigraphic positioning below the positively recognized zone NN9 above. The continuous presence of *Catinaster coalitus* and *Discoaster bollii* confirms that the interval is not older than zone NN8. Additional bioevents with rare and scattered occurrences within the zone include *Coccolithus pelagicus*, *Reticulofenestra pseudoumbilicus*, *Sphenolithus moriformis*, *Helicosphaera carteri* and *Calcidiscus leptoporous.*
Nannofossil zone: Discoaster hamatus zone - NN9
Stratigraphic interval: 9740 – 9290ft
Age: Late Miocene
Top: Last Occurrence of *Discoaster hamatus*
Base: First Occurrence of *Discoaster hamatus*
Description: The interval is characterized by fairly abundant and diverse nannofossil assemblages. The interval represents the entire stratigraphic occurrence of *Discoaster hamatus.* Characteristic nannofossils occurring with *Discoaster hamatus* within the zone include *Discoaster bollii*, *Reticulofenestra pseudoumbilicus* (> 7 microns), *Discoaster variabilis*, *Catinaster coalitus*, *Sphenolithus moriformis*, *S. abies* and *Coccolithus pelagicus*. The actual top of *Discoaster hamatus* is believed to have been eroded due to the presence of an unconformity as indicated by the absence of zone NN10 (Table: 1)
Nannofossil zone: Discoaster quinqueramus- NN11
Stratigraphic interval: 9290 – 8240ft
Age: Late Miocene
Top: Top *Discoaster quinqueramus*
Base: Base *Discoaster quinqueramus*
Description: Zone NN11 is characterized by fairly abundant and diverse nannofossil assemblage. Important nannofossils within this zone alongside the nominal taxon - *Discoaster quinqueramus/berggrenii*, include *Sphenolithus abies*, *S. moriformis Catinaster mexicanus*, *Discoaster variabilis*, *Discoaster brouweri* and *Minylitha convalis.* Other bioevents present within the interval include *Reticulofenestra pseudoumbilicus*, *R. minuta*, *Helicosphaera carteri*, *Calcidiscus leptoporous*, *C. macintyrei*, *Coccolithus pelagicus* and *Pontosphaera multipora.*
Nannofossil zone : NN12
Stratigraphic interval: 8240 - 6440ft
Age: Late Miocene – Early Pliocene
Top: Shallower than the first analyzed sample
Base: Top *Discoaster quinqueramus*
Description: This zone is characterized by typical NN12 nannofossil assemblage including *Helicosphaera sellii*, *Discoaster pentaradiatus*, *Sphenolithus abies*, *Ceratolithus acutus* and *Amaurolithus delicatus.* Additional bioevents present in common to high abundance within the interval include *Reticulofenestra pseudoumbilicus*, *R. minuta*, *Discoaster brouweri*, *Discoaster variabilis*, *Helicosphaera carteri*, *Calcidiscus leptoporous*, *C. macintyrei*, *Coccolithus pelagicus* and *Pontosphaera multipora.*
The Late Miocene/Early Pliocene boundary is tentatively placed at the base occurrence of *Ceratolithuis acutus* at depth 7460ft (Table 1).

TABLE 1. Calcareous Nannofossil Biozonation recognized in Well -BXW



Volume 4, Issue 5, pp. 1-7, 2020.
ISSN (Online): 2456-7361

C. Notes on Condensed Sections

Condensed section (CS) is defined as a thin marine stratigraphic unit that consists of hemipelagite and pelagite deposits (marine sediments) formed from very low rates of sedimentation (Loutit, *et al.,* 1988). They are recognized as the type of sediments that cover vast area at the time of maximum regional transgression of the shoreline. Some authors classify condensed sections as 'marine hardgrounds' (Bromley, 1974; Kennedy and Garrison, 1975; Baum, *et al,* 1984). Condensed sections are usually characterized by high abundant and diverse microfossil assemblages, organic matter, and concentration of some kind of elements or minerals etc.

Calcareous nannofossils diversity and abundance pattern in the studied interval allowed the recognition of some condensed section (Figure 3). The CS recognized, were correlated with the global cycle chart of Haq, *et al*., 1987; 1988). The occurrence of condensed sections in time and space has made them stratigraphically very important.

1. Condensed sections are considered as fundamental stratigraphic units which are usually seen in association with maximum flooding surfaces (MFS) and in turn are dated by the MFS. They are regarded as useful sequence stratigraphic markers too. Condensed sections in the studied intervals include (See Fig. 2):

5. 0 Ma Condensed Section (Haq *et al.,* 1987)
Age: Late Miocene (Messinian)
Interval 7160 – 7760ft is believed to be associated with the 5.0 Ma Maximum Flooding Surfaces with the base of *Ceratolithus acutus* (5.2 Ma) at depth 7460ft.
at depth 8240ft.
5.8Ma Condensed Section (Haq *et al.,* 1987)
Age: Late Miocene (Messinian)
Interval 8660 – 8840ft. Associated with 5.8 Ma maximum flooding surface, top occurrence of *Discoaster Discoaster quinqueramus*
7.4 Ma Condensed Section (Haq *et al.,* 1987)
Age: Late Miocene ((Tortonian)
Interval 8360 – 8240ft
7.4 Ma and 5.8 Ma Maximum Flooding surfaces respectively with the top of *Minylitha convalis* at depth 9140ft
9.5 Ma Condensed Section
Age: Late Miocene (Tortonian)
Interval 9140 – 9690ft is believed to be associated with the 9.4Ma Maximum Flooding Surface with the Top of *Discoaster hamatus* at depth 9740ft.

2. Condensed sections are characterized by the acme event of microfossil in the interval of the CS. This is termed "Characteristic Assemblage. All condensed section can be dated by the nannofossils datum contained within them (Fig 3).
3. Some of the characteristic assemblages housed within the condensed sections are good paleocologic indicators. The stratigraphic distribution of calcareous nannofossils shows that the diversity and abundance of the nannoplantkon becomes more significant in the upper part of the studied well.

Discoaster species are common as zonal markers and are of immense chronostratigraphic value in the Miocene. *Coccolithus pelgicus* are *indicators* of cooler water conditions while *Sphenolithus – Discoaster* and *Reticulofenestra* indicates warmer marine water conditions (Mcintyre et al., 1970; Rahmann and Roth, 1990). *Sphenolithus – Discoaster* assemblages seem to be dominant in the Miocene. *Discoaster- Sphenolithus* assemblage shows fluctuation patterns that were typically the opposite of *Coccolithus pelagicus* patterns in the study (Fig. 3), this may have interpreted cooling and warming episode between 7.4 and 9.4 Ma.

4. Condensed Sections reveal the different morphotype of the group of assemblages in the region delineated. Enrichment of well preserved nannofossils were noticed within the zone. The chronostratigraphic species types within condensed section are key and permitted age determination. (Wornardt, 1989), thus provided additional age information.
5. Condensed sections are commonly deposited during transgression periods. This can provide a framework for assessing the transgression / regression cycles and their significance in interpreting sea-level changes that affected the basin during the Miocene.
6. Condensed section is associated with paleobathymetry and maximum water depth during deposition of sequence. Thus, paleobathymetric estimates may be utilized to record transgressions and regressions produced by sea level changes.
7. A condensed section represents a physical stratigraphic link between shallower landward and deepwater sections (Fig. 3) they can be utilized in reconstructing paleo-depositional facies. The CS regions in the study intervals align with the lithofacies (Fig 2) described as shale/mudstone – open marine environments.
8. Condensed section can demarcate intervals of increased and decreased sedimentation and nature of influx of sediments in the basin.
9. The condensed sections at each of the ages in this study provide both physical and temporal control for stratigraphic correlation of each age. This will provide key to regional correlations in the Niger delta.
10. Condensed sections are of various thickness and depths. The point to be made here is that parts of the analyzed intervals represent transgressive units of variable lithofacies and thicknesses were deposited during a period of increasing water depth.
11. Condensed section by their lithologic characteristics may represent sites for accumulation of organic matter, which implies good petroleum potential as source rock materials for the Niger delta.

V. Conclusion

The studied intervals yielded rich and diverse assemblages of well-preserved calcareous nannofossils. Four nannofossil zones (NN12, NN11, NN9 and? NN 8) belonging to the Early Pliocene to Late Miocene age (Zanclean – Tortonian stage) were identified following the standard zonation schemes of Martini (1971) and Okada and Bukry (1980). The nannofossils abundance and diversity patterns calibrated with time-

International Journal of Scientific Engineering and Science
Volume 4, Issue 5, pp. 1-7, 2020. ISSN (Online): 2456-7361

significant depositional and bio-events facilitated the recognition of the following 5.0Ma, 5.8Ma, 7.4Ma and 9.5Ma condensed sections tied to Maximum Flooding surfaces of Haq et al., 1987 and 1988.

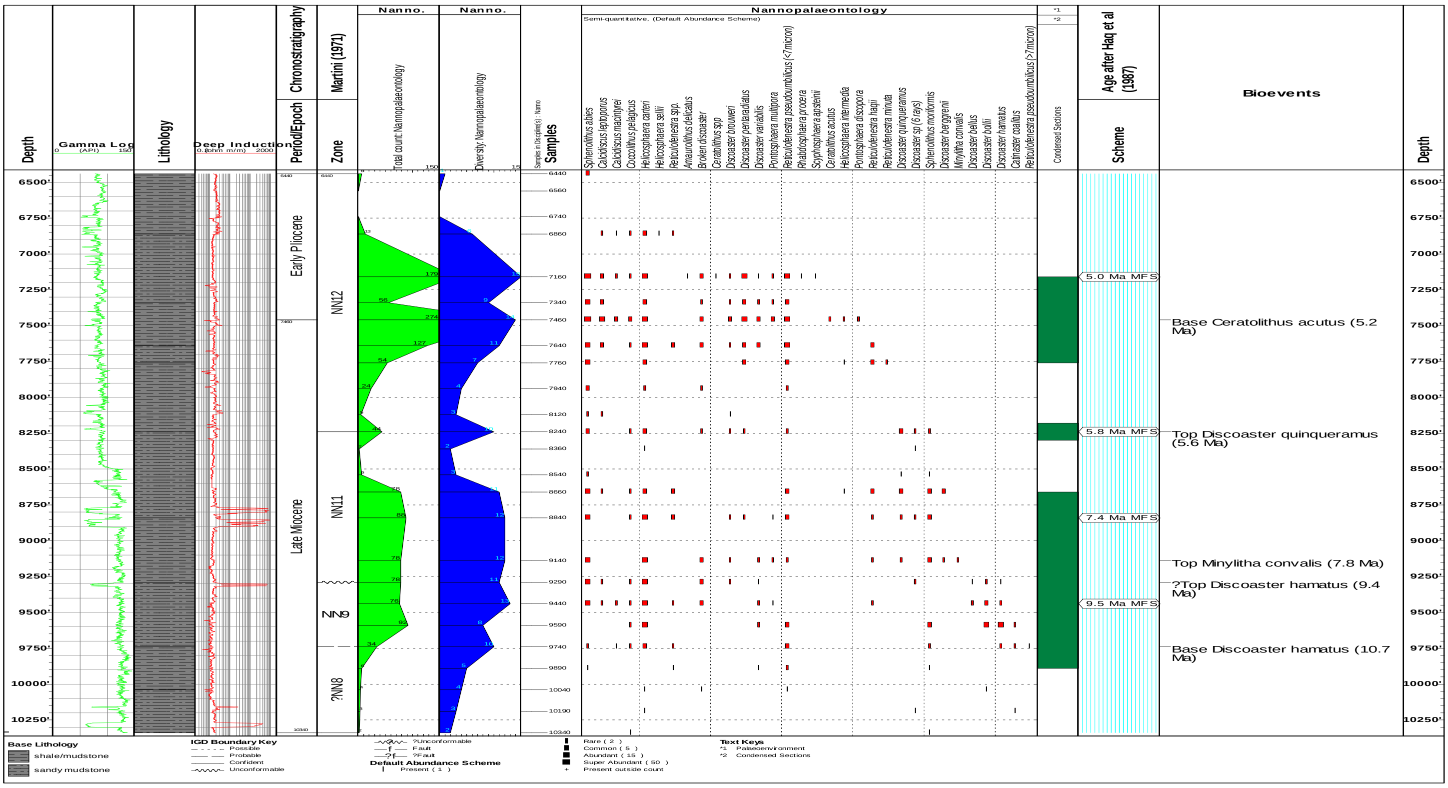


Fig. 3. Calcareous Nannofossil Distribution of Well - BXW

Continuous insight into the condensed section data provide the following information: condensed section in this study occurred as a result of major sea-level rise during the Late Miocene; different nannoplankton characteristic assemblages are associated with each condensed section; they serve as a framework for assessing transgression and regression cycles. Paleo-depositional environment can be reconstructed; Rate of sedimentation can be estimated and condensed sections are potential sites for petroleum source rocks in the Niger delta.

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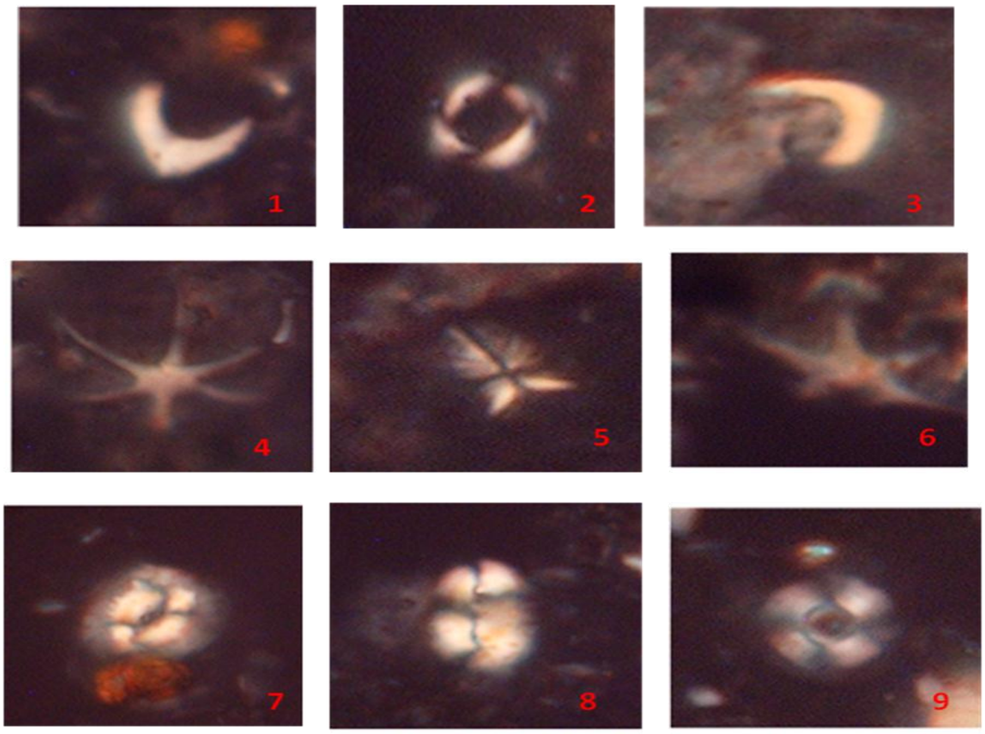
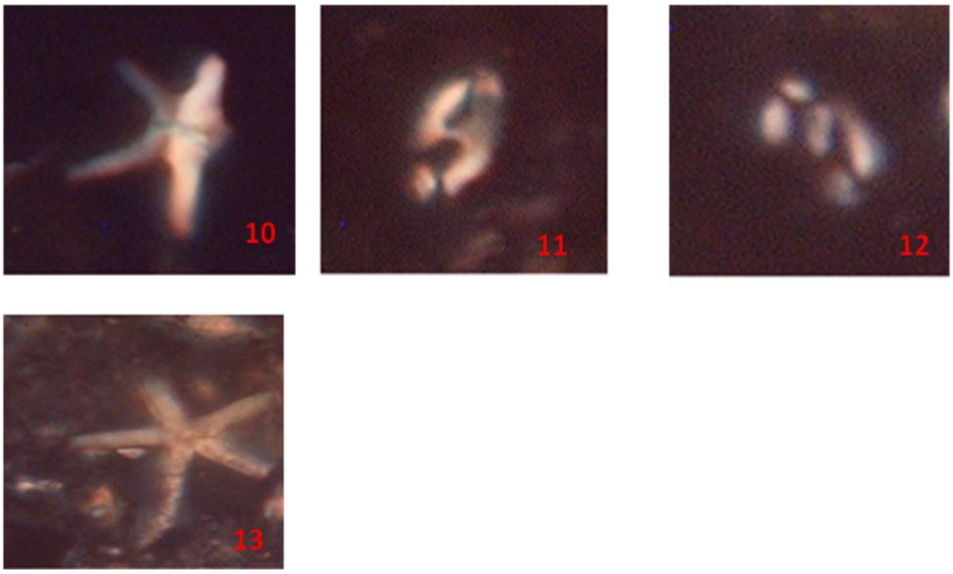
PLATE 1: PHOTOMICROGRAPH OF SOME NANNOFOSSIL SPECIES



International Journal of Scientific Engineering and Science
Volume 4, Issue 5, pp. 1-7, 2020.
ISSN (Online): 2456-7361



1. *Ceratolithus acutus;* 2 .*Reticulofenetra pseudoumbilicus;*
3. *Amaurolithus delicates;* 4. *Discoaster quinqueramus;*
5. *Sphenolithus abies;* 6. *Discoaster brouweri;*
7. *Calcidiscus macintyrei*; 8. *Helicosphaera carteri;*
9. *Coccolitus pelagicus;* 10. *Discaoster pentaradiatus;*
11. *Helicosphaere sellii;* 12. *Helicosphaera intermedia;*
13. *Discoaster hamatus.*