IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 8, Issue 3 Ser. I (May – June 2020), PP 08-17
www.iosrjournals.org

Calcareous Nannofossil Biostratigraphy of Well X-1, OML, 108, Ukpokiti Field, Offshore Niger Delta Nigeria.

Asadu A.N[1]. and Onifade, E.O[1]
[1]*Department of Earth Sciences, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria*

Abstract
***Background**:The relevance of nannofossils is becoming increasingly important not only because of the advantage of its size, the limited stratigraphic range of many of its species with resolution to some thousands of years, but also its cheap and speedy processing technique that yields rapid result where real time age determination is required especially at this time of paradigm shift of exploration to the deep offshore areas in Niger delta. Generally, published literature on calcareous nannofossil is scarce in Niger Delta, this is due to the obvious fact that calcareous nannofossil studies are undertaken by the oil and gas industry who deems the information as proprietary, hence this study is undertaken to analyze well X-1, for calcareous nannofossil distribution and use it to establish the biozonation framework and calibrate with standard zonation schemes of [1] for the purpose of age characterization and paleoenvironmental synthesis.*
***Materials and Methods**:Calcareous Nannofossil biostratigraphic studies was carried out on 50 ditch cutting samples obtained between interval 8040 ft. and 11010 ft. of Well X-1, located in the Ukpokiti field, OML 108, offshore Niger Delta Nigeria. Slide preparation followed the standard calcareous nannofossil sample processing techniques using the pipette spray method.*
***Results**: Analysis yielded fairly moderate distribution of species whose stratigraphic ranges have been well established in the Niger Delta. Species recorded include Discoaster kugleri, Discoaster hamatus, Catinaster coalithus, Helicosphaera sp, Sphenolithusabies, Discoaster cf. deflandrei, Calcidiscusmacintyrei, Helicosphaera minuta, Pontosphaeramultipora, Amaurolithussp, Discoaster brouweri, Reticulofenestra pseudoumbilicus, Reticulofenestra haqii and Coccolithuspelagicus. Four calcareous nannofossil zones (Discoaster kugleri Concurrent range zone, Catinaster coalithus top zone, Discoaster hamatus top zone and Reticulofenestra pseudoumbilicus Concurrent range zone,) were recognized and calibrated with [1] classic zonation scheme NN7, NN8, NN9, and NN10, respectively. Paleoenvironmental deduction was made from the combined association of some ecologically related species of both shallow water and open ocean recovered from the interval studied.*
***Conclusion**: the rock succession studied is datedMiddle to Late Miocene in age and was deposited in an environment rangingfromshallow to deep water settings.*
***Key Word**: Nannofossil; Age,Environment;Biozonation;Miocene, Offshore, Niger Delta*

Date of Submission: 17-04-2020 Date of Acceptance: 02-05-2020

I. Introduction

Calcareous nannofossils are the smallest of all skeletal fossils routinely preserved in marine sediments. They are the main component of chalk. The rapid evolution of this group and their global distributions make them ideal biostratigraphic indicators. Calcareous nannofossils include the coccoliths and coccospheres of haptophyte algae and the associated nannoliths (Discoasters, Nannoconids, Schizosphaerellids, Pithonellidsetc[2]). A coccolith is a single disc-like plate which is secreted by the algal organism and held in combination with several other, sometimes varying shaped plates by an organic coating to form the coccosphere. On death the individual coccoliths invariably become separated and it is these that are most commonly preserved and are abundant in the sedimentary record from late Triassic to Recent[3]. Coccoliths due to their minute sizes, rapid turnover rate, ability to carry out photosynthesis, calcification by biomineralization and abundance plays the role of primary producers[4]. They are predominantly abundant in sea floor sediments and preserve the composition of the overlying photic-zone communities. Apart from the advantage of its size, the limited stratigraphic range of many of its species with resolution to some thousands of years, its cheap and speedy processing technique that yields rapid result where real time age determination is needed has recently made the study increasingly popular.

The aim of this research was to analyze the ditch cutting rock samples obtained between interval 8040 ft. and 11010 ft. of Well X-1, for calcareous nannofossil distribution and use it to establish the biozonation framework and calibrate with standard zonation schemes of [1] for the purpose of age characterization and infer the environment of deposition of the rock succession from the abundance and diversity peaks of the nannofossil species.

Well X -1 is located in the Ukpokiti field, OML 108, offshore Niger Delta Nigeria (figure 1). Slide preparation followed the standard calcareous nannofossil sample processing techniques. The pipette spray method was used for even spatial distribution on the slides.

Previous calcareous nannofossil studies:

Generally, most published literature on biostratigraphy of the Niger Delta, have focused on foraminifera and palynology due to the secrecy of oil companies in Nigeria who considers nannofossil information as proprietary, however a few calcareous nannofossil biostratigraphic studies of Niger Delta has been documented.[5] studied four deep water wells in Offshore Niger Delta and documented the calcareous nannofossil distribution as well as biozonation of the area. They recovered forty-two calcareous nannofossil species using the first and last datum appearances of the index fossils and also on their relative abundances and used it divide the wells into five zones and two sub-zones. Among the zones are *Catinaster coalitus* (zone NN8), *Discoaster hamatus* (zone NN9), *Discoaster loeblichi* etc. They used these zones to delineate the age from middle Miocene to early Pliocene.[6] studied nannofossils encountered from two deep offshore wells and subdivided it into eight zones and correlated the zones between the wells.[7] studied field XY-1 in the Offshore Western Niger Delta area and carried out calcareous nannofossil biozonation, age dating as well as correlation of the five wells of the field. They recognized four zones: *Calcidiscuspremacintyrei* (zone NN6-NN7) and*Catinaster coalitus* (zone NN8). [8], studied the Calcareous Nannofossil Biostratigraphy of Well 'K-2', Deep Offshore Niger Delta and recognized two major nannofossil zones: *Gephyrocapsacarribeanica* and *Gephyrocapsaparallela* corresponding with NN 19 and NN 18 and dated Pleistocene and Pliocene ages respectively.

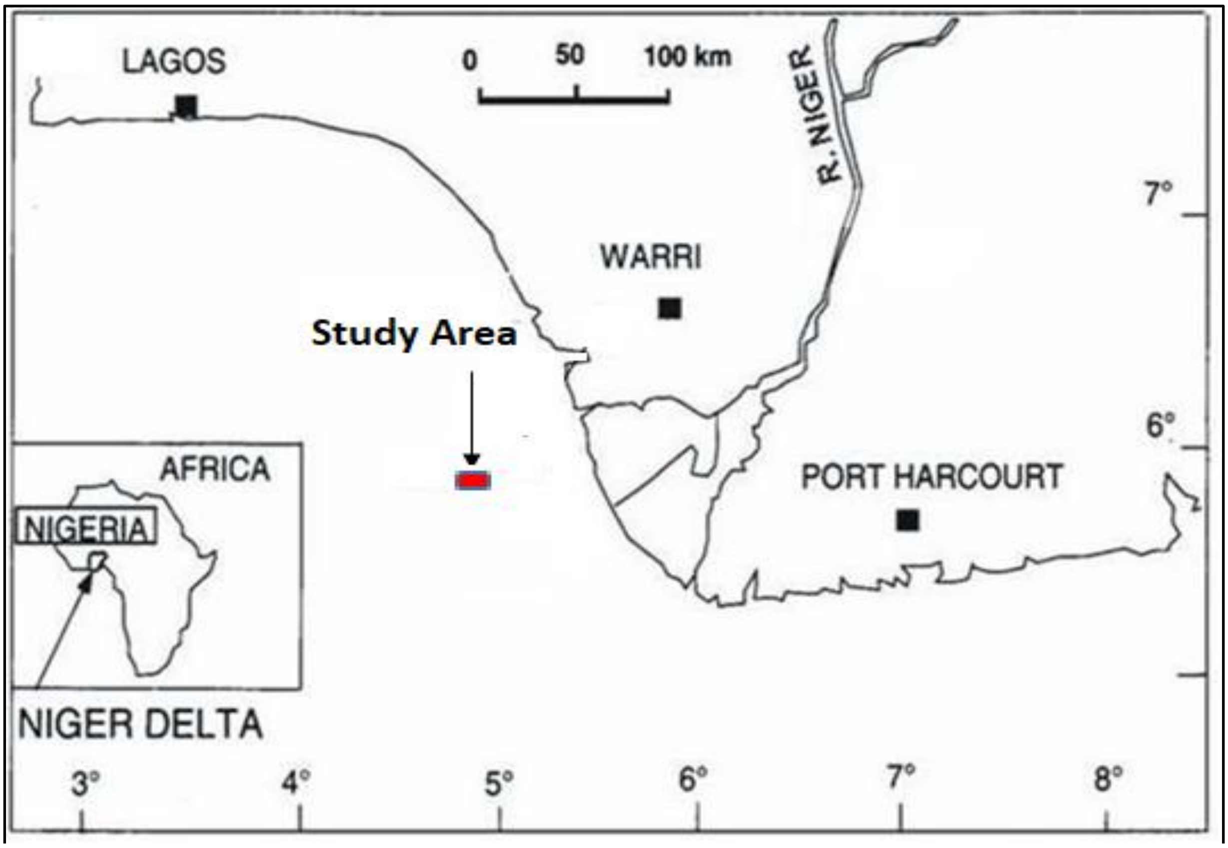


Fig 1: Map of Nigeria showing the Location of the study Area.

[9] carried out a nannofossil biostratigraphic review XH-1 well from the deep-water offshore Niger Delta. In their report, 41 species of nannoplankton were identified and used to establish nannozones among which are; NN11 (CN10) and NN10 (CN9/CN8) zones of Late Miocene age. Three condensed sections associated with 5.8 Ma. 7.0 Ma. And 9.0 Ma. were also delineated.[10], studied the Offshore Depobelt, Niger Delta to establish a nannofossil biozonation, age, and correlation across the studied interval. Calcareous nannofossils zones were established based on first and last occurrences of readily identifiable marker species

and their relative abundances. The data set obtained, demonstrated that the zonation of the study wells ranges from NN15 through to NN5 zones dated Early Pliocene through to Middle Miocene in age.

Many other pioneering standard detailed calcareous nannofossil zonation schemes which are widely used to correlate rocks worldwide exist. [1,11]erected biozonation models for the entire Cenozoic. [1]recognised 25 Paleogene and 21 Neogene zones (NP/NN zones), codified Bukry's 19 Paleogene and 15 Neogene zones (CP/CN zones) and also codified 20 Paleogene and 24 Neogene subzones. He aimed to establish a general framework for relative dating of open ocean sediments rather than producing the highest possible resolution. These two zonal systems are still widely used today. [12]based his study on the distribution and fluctuation pattern of calcareous nannofossils to delineate environmental changes that took place during the Oligocene in the Eastern Carpathians. He was able to recognize the cool and warm regimes associated with the nannoplankton distribution patterns**.**

Niger Delta Geology:

The Niger Delta province is located in the Gulf of Guinea, from where it extends through the entire Niger Delta Province [13]. It is situated between latitudes 4° N and 6°N as well as longitudes 3°E and 9°E. The onshore portion of the Niger delta is delineated by the geology of southern Nigeria and south-western Cameroon. The northern boundary is the Benin-flank which is an East-Northeast trending hinge line south of the West Africa basement massive. The North eastern boundary is defined by outcrops of the Cretaceous Abakiliki high and further south east by the Calabar flank which is a hinge line bounding the adjacent Precambrian (Figure 2). The offshore boundary of the Niger delta province is defined by the Cameroon volcanic line to the east and Dahomey Basin to the west. The province covers 300,000km^2.The Niger Delta started to evolve in early Tertiary times when clastic river input increased [13]. Three main lithostratigraphic units which reflect a complex mixture of marine, fluvio- marine, littoral and deltaic plain environment are recognized and delineated in the Niger Delta (the Akata, Agbada and Benin Formations).

The Akata Formation is the basal sequence and it is characterized by uniform shale development and the shale is generally dark grey, with some sandy or silty shale at the upper part with plant remains and mica flakes. This marine shale forms the base of the sequence in each depobelt and range from Paleocene to Holocene in age. They crop out offshore in diapirs along the continental slope, and onshore in the north-eastern part of the delta, where they are known as the Imo Shale. The shale is about 600 m thick [14] and is the major source of hydrocarbon generation in the Niger Delta.Overlying the basal marine unit is the paralic **Agbada Formation**, which is made up of alternating sandstone, siltstone and shale. The percentage of sand increases upward while that of shale increases downward. This indicates a cyclic sequence of fluvial and marine deposits. This Formation extends throughout the Niger Delta subsurface and is the most explored unit. The age of Agbada Formation decreases from north to south, that is Eocene to possibly Recent. The Formation is about 4500 m thick [14]and contains hydrocarbon prospective sequences in the Niger Delta.**Benin Formation** is the topmost and most shallow part of the deltaic clastic wedge. According to, the Formation can be easily recognized based on its high sand percentage (70% -100%). This Formation has little shale intercalations at some horizons. This continental deposit has a thickness of about 200m with age of Oligocene in the north and becomes progressively younger southward.

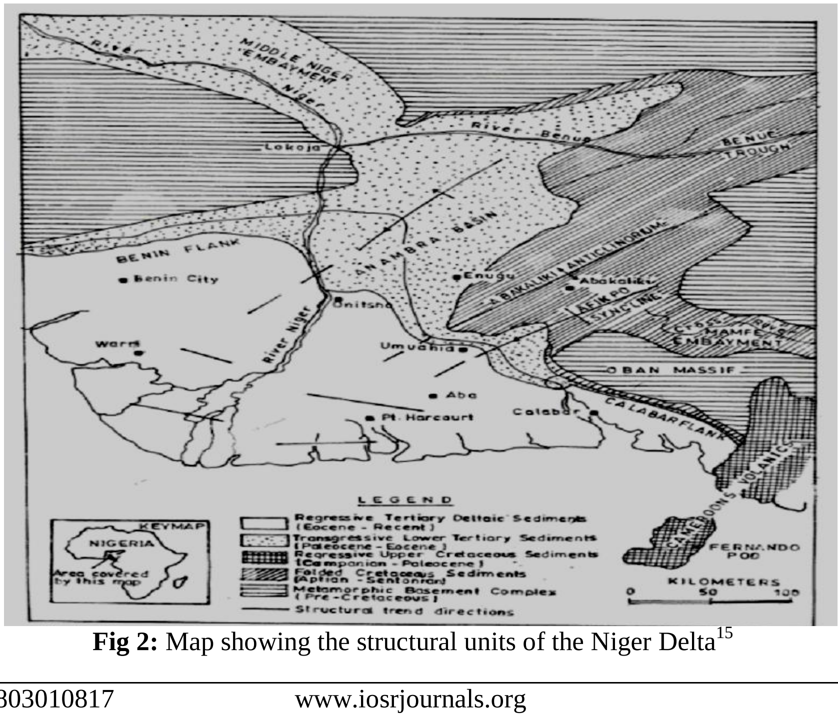


Fig 2: Map showing the structural units of the Niger Delta[15]

II. Material and Methods

A total of fifty (50) ditch cutting samples from Well X-1 were sampled from intervals 8,040ft and 11,011ft and subjected to standard calcareous Nano-fossil sample processing techniques using the pipette straw method. The most favorable lithologies for Nannofossil are shale, marl and chalk, but muddy sand and silt can often contain good assemblages.

Analytical procedure:

Step1: Cleaning and labelling of apparatus: All dishes (beakers, test tubes, stirring rod and pipette) for the experiments were thoroughly rinsed in 10% hydrochloric acid, washed and rinsed with distilled water to avoid contamination and samples serially arranged with well name and their corresponding depths.

Step 2: Grinding of samples: About 1-2g of samples was grounded to a fine powder using a mortar and pestle (oil stained samples are soaked in freshly boiled calgon solution before treatment).

Step 3: Soaking of samples: The finely grounded samples were soaked in 25ml of freshly boiled distilled water in a 100ml beaker overnight.

Step 4: Mounting on cover slips: The suspension was thoroughly mixed and allowed to settle for 10 seconds, pipetted from half way down the tube and gently spread on a 22mm square cover slip on a hot plate of not more than temperature of 40^0C. The ideal slide contains particles sizes range between 0 and 30µm with an even spatial distribution throughout the slide to allow for easy identification and location of nannofossils. For this research the pipette spray method was used.

Step 5: Mounting on microscope glass slide: Two drops of the Norland optical adhesives were placed on a glass microscope slide (one for each cover slip) and the cover slips were then inverted and placed on top of the Canada balsam (the centrifuged cover slip should be nearest the slide label). The slides were transferred to a hotplate (with the temperature at approximately 200^0 C). The cover slips were gently pressed down to achieve even spread of the Norland adhesive under cover slips to expel air bubbles and then left on the hotplate for one hour after which it was removed and cleaned.

Step 6: cleaning of slides: All excess Canada balsam was removed from the slides with acetone and by methanol.

Calcareous Nannofossil slides were observed under a MEIJI MX9300 polarizing light microscope (with gypsum plate which shows birefringence). Species were identified and detailed abundance counts of the assemblages present at each depth were made at x1000 magnification.

III. Result

The result of the Nannofossil analysis of the Well X-1 is presented in figure 3. Calcareous nannofossil assemblage over the interval studied is generally rich and diverse. Species recorded include *Discoaster kugleri, Discoaster hamatus, Catinaster coalithus, Helicosphaera sp, Sphenolithusabies, Discoaster cf. deflandrei, Calcidiscusmacintyrei, Helicosphaera minuta, Pontosphaeramultipora, Amaurolithussp, Discoaster brouweri, Reticulofenestra pseudoumbilicus, Reticulofenestra haqii*and*Coccolithuspelagicus* (figure 3).

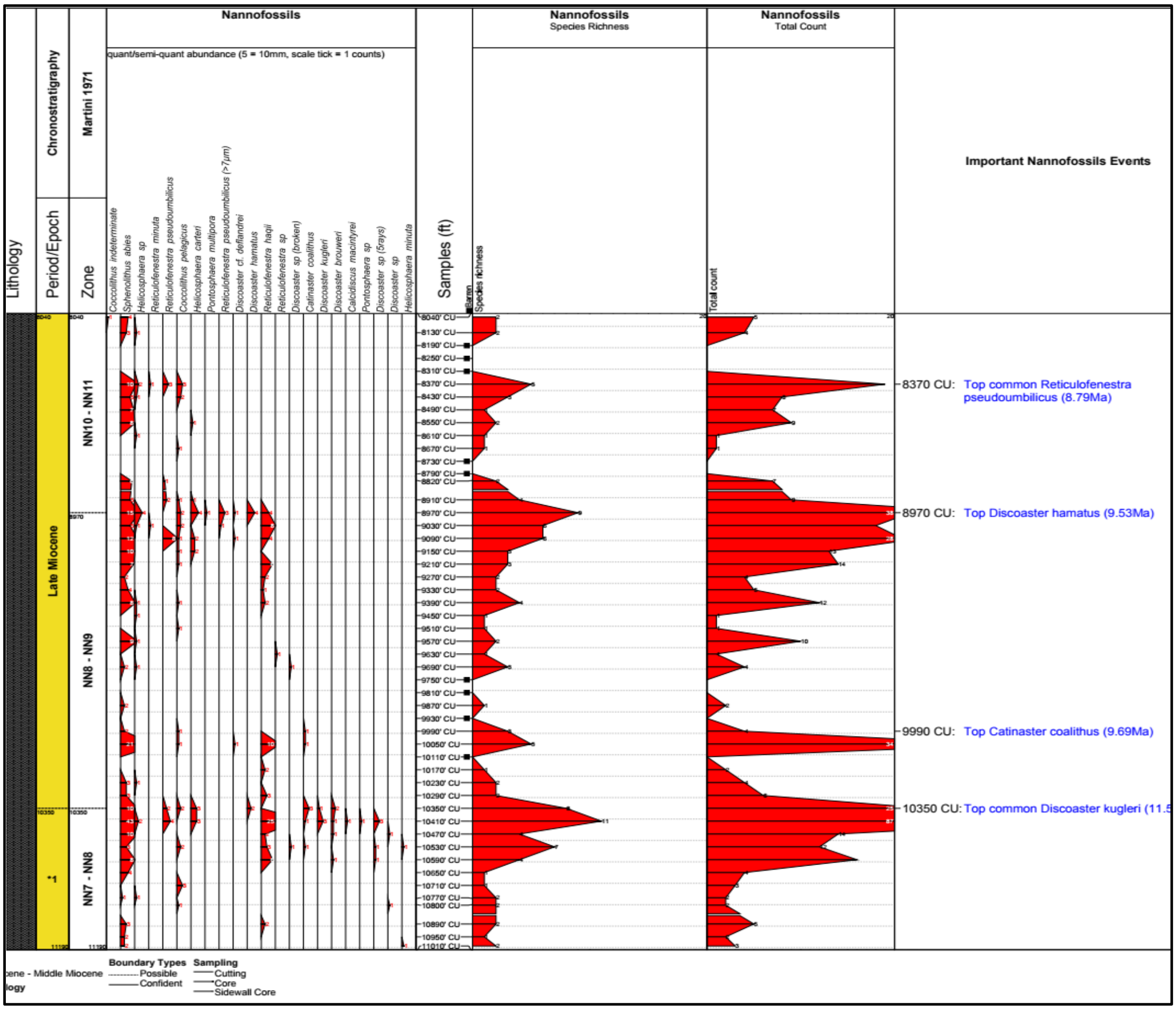


Figure 3: Calcareous Nannofossil distribution, abundance and diversity chart and nannofossil zones in well X-1

The calcareous nannofossil zonation of this samples was guided by the works of 1,11 while the estimation of the age was done using the Geomagnetic Polarity Time Scale (GPTS) of 16 (figure 4). Though the species distribution is fairly moderate in the well, species whose stratigraphic distributions have been well established in the Niger Delta were recovered and calibrated with 1 scheme for the purpose of zonation and age characterization in this study. The zones were recognized based on the important calcareous nannofossil bio-events such as the Base and Top chronostratigraphic significant signals denotingthe stratigraphic lowest and highest occurrences of taxa which corresponds to first Downhole Occurrence (FDO) and Last Downhole Occurrence (LDO) of calcareous nannofossil marker species respectively. Base common (Bc) and top common (Tc) occurrence were also used in cases where the absolutely lowest or highest occurrences were considered to provide a less reliable biostratigraphic information when compared to the base and top of the continuous occurrences of the taxon at higher abundances. The summary of the Biohorizons used to define the biozones and the estimated age is presented in table, 1. Calcareous Nannofossil presence, abundance and diversity peaks were also used to decipher the paleoenvironment of deposition (figure 3).

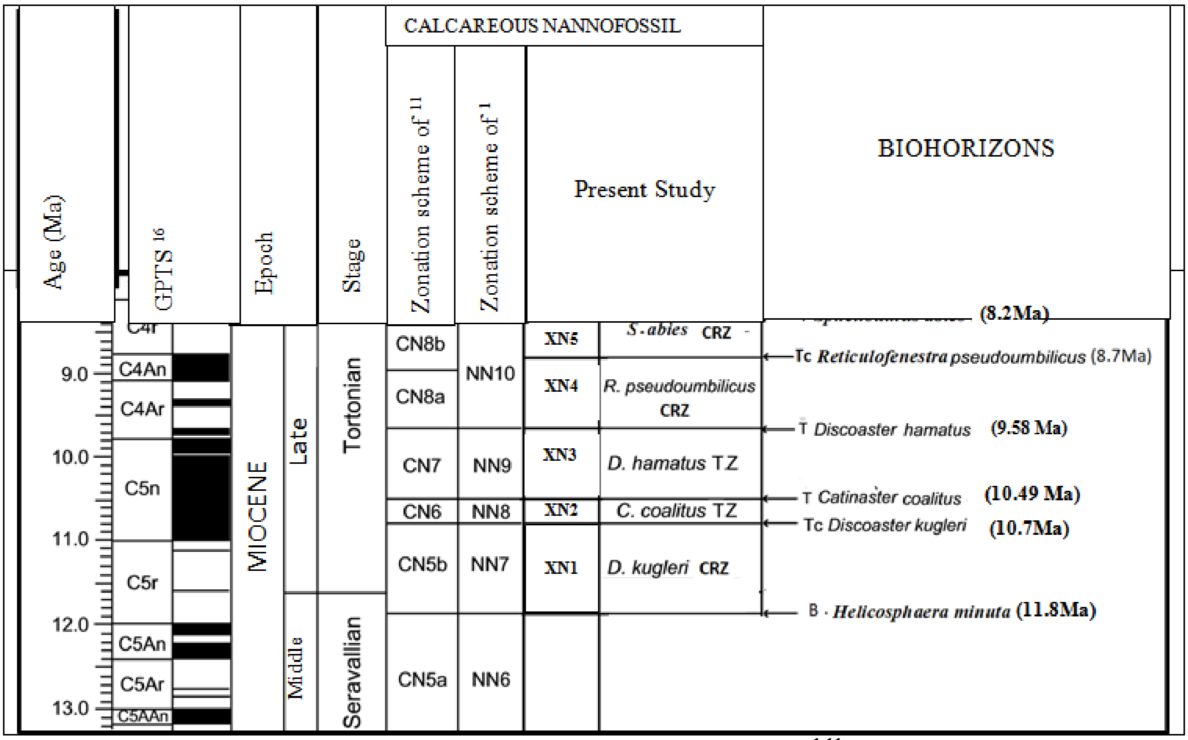


Figure 4: Biozones and Biohorizons in Comparism with biozonations of [1,11] and the Geomagnetic Polarity Time Scale (GPTS) of [16].

IV. Discussion

Calcareous Nannofossil Zonation (from the youngest to oldest**):**
Nannofossil Zone XN5 : *Sphenolithusabies*Concurrent range zone
Interval: 8040 – 8370 ft.
[1] Code: NN10
Age: Late Miocene
Definition of the biozone: this zone is defined at the top by the last downhole occurrences of *Sphenolithusabies* and *Helicosphaera* spat 8040 ft which is the top of the studied section while the baseis the same as the top of *Reticulofenestra pseudoumbilicus* zone XN4. This zone compares well withCN8b of[11] and NN10 of[1], therefore indicating a late Miocene (Tortonian) age estimated at 8.2 Ma.

Nannofossil Zone XN4 : *Reticulofenestra pseudoumbilicus* Concurrent range zone
Interval: 8370 – 8970 ft.
[1]Code: NN10
Age: Late Miocene
Definition of the biozone: The interval zone is characterized by the top common occurrence of *Reticulofenestra pseudoumbilicus* and top *Reticulofenestra minuta*, at 8370ft., other nannofossil species recorded at this horizon include *Helicosphaera sp, Sphenolithusabies* and the lower limit is marked by the stratigraphic top of *Discoaster hamatus* top zone at 8,970ft.
Remarks : This Interval recorded fairly good recovery of nannofossil species and Comparism with the standard zonation scheme of [1], NN10 indicates a Late Miocene age for the top of the interval estimated at 8.7Ma.

Table 1: summary of the Biohorizons Used for the Definition of the Biozones in well X -1.

Epoch	Marker Taxon for Base of Zone	Type of Event	Marker Taxon for Top of Zone	Type of Event	Biozones		[1]Codes (Adopted for this study)	Estimated Age of The Biohorizons	Depth (Ft) 8040
	Reticulofenestra pseudoumbilicus	Top	*Sphenolithusabies*	LDO	XN 5	*Sphenolithusabies*(CRZ)	NN10	8.6 Ma	8370
Late Miocene	*Discoaster hamatus*	Top	*Reticulofenestra pseudoumbilicus*	Top common	XN 4	*Reticulofenestra pseudoumbilicus* (CRZ)		9.58Ma Ma	8970
	Catinaster coalithus	Top	*Discoaster hamatus*	Top	XN 3	*Discoaster hamatus* (TZ)	NN9	10.49 Ma	9990
	Discoaster kugleri	Top common	*Catinaster coalithus*	Top	XN 2	*Catinaster coalithus* (TZ)	NN8	10.7Ma	10350
Middle - Late Miocene	*Discoaster hamatus*	Base	*Discoaster kugleri*	Top common	XN 1	*Discoaster kugleri*(CRZ)	NN7	11.6 Ma	11010

TRZ: Concurrent Range Zone, TZ: Top Zone

Nannofossil Zone XN3 *Discoaster hamatus* Top zone:
Interval: 8,970 – 9,990ft.
Age: Late Miocene
[1] Code: NN9.
Definition of the biozone: This interval zone is defined at the top by the top *Discoaster hamatus* at 8,970ft. and Top *Catinaster coalithus* at 9,990ft.
The *Discoaster hamatus* Top zone has moderately good recovery of nannofossil species. The observed increase in abundance and diversity of nannofossil species between 8,880ft and 9,120ft could possibly mean that this interval is a condensed section. Some important nannofossil taxa that recorded include: *Catinaster coalithus, Discoaster hamatus, Helicosphaera* sp, *Sphenolithusabies, Reticulofenestra haqii, Reticulofenestra minuta, Pontosphaeramultipora, Reticulofenestra pseudoumbilicus, and Coccolithuspelagicus.* This zone compares well with zone NN9 of [1], zonation scheme therefore indicates a late Miocene age estimated at 9.58 Ma at the top.

Nannofossil Zone XN2 : *Catinaster coalithus* Top zoneInterval: 9,990ft – 10,350.
Age: Late Miocene
[1] Code: NN8
Definition of the biozone: This interval zone is defined at the top by the top *Catinaster coalithus* at 9,990ft. and at the base by the top common occurrence of *Discoaster kugleri*at 10,350ft. A diversity peak is also recorded between 9,990ft and 1,110ft with *Discoaster hamatus* and *Sphenolithusabies* having the major contribution to the calcareous nannofossil population at this interval. Other species in association include *Reticulofenestra pseudoumbilicus* and *Reticulofenestra haqii.* This zone correlates well with [1] NN8 zone therefore dated Late Miocene, estimated at the top of the zone at 10.49Ma.

Nannofossil Zone XN1 : *Discoaster kugleri*Concurrent range zone
Interval: 10,380 – 11,010 ft.
Age: Middle - Late Miocene
[1] Code: NN7

Interval age was based on Top common *Discoaster kugleri* at 10,380ft estimated at 10.7Ma. Interval characterized by sparse to fairly good recovery of nannofossil species. The observed increase in abundance and diversity of nannofossil species between 10,380ft and 10,530ft shows that this interval could possibly be a condensed section. Some important nannofossil taxa that characterized this interval include*: Discoaster kugleri, Catinaster coalithus, Discoaster hamatus, Helicosphaera sp, Sphenolithusabies, Reticulofenestra haqii, Reticulofenestra minuta, Pontosphaeramultipora, Discoaster cf. deflandrei, Calcidiscusmacintyrei, Discoasterbrouweri, Reticulofenestra pseudoumbilicus, and Coccolithuspelagicus.* The lower limit of this zone is tentatively placed at terminal depth (TD) 11,010ft. Correlation of the *Discoaster kugleri*Concurrent range zone with [1], NN7, zone indicates an age not older than middle Miocene, and the age at the base is estimated at 11.6Ma.

Paleoenvironmental Synthesis:

Interval 8,040 – 11,010 ft: Shallow to Deep Marine setting:

Although Coccolithophorids do not give a clear indication of depth of deposition of the sediments in which they are found due to planktic mode of life (they however survive transport into greater depths by turbidity currents[17], some of them are known to be environmentally controlled. Paleoenvironmental deductions over the analyzed interval were based primarily on presence, abundance and diversity of some recovered calcareous nannofosil species. Warm water indicators species which preferentially occupy shallower water areas recovered in the studied section are *Helicosphaera carteri, Helicosphaera minuta, Helicosphaera* sp, and *Sphenolithusabies*. Diverse species of discoasters which occupy relatively deeper water are also recorded in the studied section. This include *Discoaster hamatus, Discoasterbrouweri,Discoaster cf. deflandrei* and *Discoaster kugleri*. The combined association of these forms allows the interpretation of depositional environment ranging from shallow marine to deep marine setting to be inferred for the interval studied.

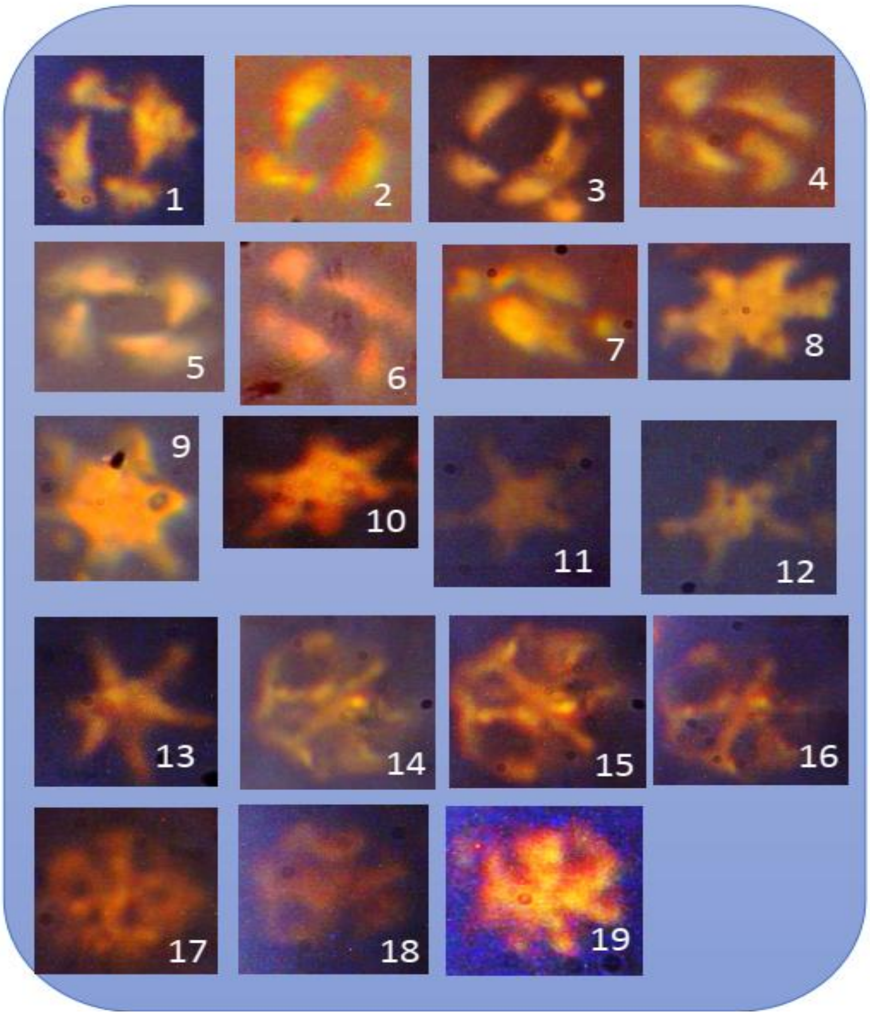
V. Conclusion

In conclusion, the studied interval (8040 – 11010 ft) of well X -1, range in age from Middle to Late Miocene as deduced from the Comparism between the biozones of[1], NN7 – NN10,zones. The presence, abundance diversity and the combination of ecological groups of both shallow and open ocean nannofossils species recovered was used in deciphering the paleoenvironment from shallow to deep marine setting.

Plate 1 (photomicrographs)

1. *Reticulofenestra pseudoumbilicus*
2. *Reticulofenestra pseudoumbilicus >7µm*
3. *Reticulofenestra pseudoumbilicus >7µm*
4. *Reticulofenestra haqii*
5. *Reticulofenestra haqii*
6. *Reticulofenestra haqii*
7. *Helicosphaera cateri*
8. *Discoaster kugleri*
9. *Discoaster kugleri*
10. *Discoaster Cfdeflandrei*
11. *Discoaster hamatus*
12. *Discoaster hamatus*
13. *Discoaster brouweri*
14. *Catinaster coalithus*
15. *Catinaster coalithus*
16. *Catinaster coalithus*
17. *Catinaster coalithus*
18. *Catinaster coalithus*
19. *Catinaster Sp*

Plate 1



References

[1]. Martini, E. (1971): Standard Tertiary and Quarternary calcareous nannoplankton zonation. In :*Farinacci (Editor), Proceedings II Planktonic Conference, Roma,* 1970, 2 : 739 – 785.

[2]. Tappan, H., 1980. The paleobiology of plant protist.W.H Freeman and company, San Francisco, USA, XXIV+1028P

[3]. Bowen, G. J., Beerling D.J., Koch, P.L., James C. Zachos, J.C., and Quattlebaum, T., 2004 A humid climate state during the Palaeocene/Eocene thermal maximum. Nature Vol 432,21–230

[4]. Winter, A. and Siesser, W.G. (1994). Coccolithophores. Cambridge, Cambridge University Press, 242p.8.

[5]. Ajayi, E., & Okosun, E. (2014). Calcareous Nannofossil Biostratigraphy of A, B, C, D Wells Offshore Niger Delta, Nigeria. *Earth Science Research Vol. 3, No 1*, 108-123.

[6]. Ojo, E.A., Fadiya, L.S., and Ehinola, O. A., 2009. Biozonation and correlation of BDX-1 and BDX-2 wells of deep offshore Niger Delta using calcareous nannofossils. Search and Discovery Article (AAPG), no. 50194, 8 pp. 2009.

[7]. Obaje, S.O., Okosun, E.A., 2013. Taxonomic notes on discoasters and catinasters from tomboy field, offshore western Niger delta, Nigeria. Int. J. Sci. Technol. 2 (11), 810-813.

[8]. Adetola S.O., 2014. Calcareous Nannofossil Biostratigraphic Analysis of Well 'K-2', Deep Offshore Niger Delta, Nigeria. Advances in Research 2(12): 696-711.

[9]. Boboye, O.A., Fowora, O., 2007. Biostratigraphic study of the calcareous nannofossil of well XH-1, deep offshore, Niger Delta, Nigeria. J. Min. Geol. 43 (2), 175e186.

[10]. Okewale A.O and Omoboriowo, A.O., 2017. Application of calcareous nannofossil to petroleum exploration: a case study of offshore Niger Delta. International journal of scientific engineering and science, volume 1, issue 6, p. 26 – 41.

[11]. Okada, H. and Bukry, D., 1980. "Supplementary Modification and Introduction of code numbers to Low Latitude Coccolith Biostratigraphic Zonation", *J, Marine Micropaleontology*, Vol.5, pp.321-325.

[12]. Melinte, M. (2005). Oligocene Paleoenvironmental Changes in the Romanian Carpathians, Revealed by Calcareous Nannofossils. *Studia Geologica Polonica, Vol 124*, 341-352.

[13]. Doust, H., and Omatsola, E. 1990. Divergent and Passive Margins Basins. *American Association of Petroleum Geologist Memoir*, pp.239-248.

[14]. Kulke, H., 1995**.** Nigeria, *in,* Kulke.H., ed., Regional Petroleum Geology of the World. Part II: Africa, America, Australia and Antarctica: Berlin, GebriiderBorntraeger, P. 143172.

[15]. Short, K. C., and Stauble, A.J., 1967. Outline of geology of Niger Delta: American Association of PetroleumGeologists Bulletin, v.

51, p. 761-779.
[16]. Lourens, L.J., Hilgen, F.J., Shackleton, N.J., Laskar, J., Wilson, D., 2004. The Neogene Period. In: Gradstein, F.M., Ogg, J.G., Smith, A.G. (Eds.), A Geological Time Scale 2004. Cambridge University Press, Cambridge, 409–440.
[17]. Bolli, H. M. and Saunders, S. B. (1988*): Oligocene to Holocene low latitude planktic foraminifera. In Bolli*, H. M.; Saunders, J. B. and Perch-nielsen, K (Eds.). *Plankton Stratigraphy*, Cambridge University Press: 155 - 262

Asadu A.N. "Calcareous Nannofossil Biostratigraphy of Well X-1, OML, 108, Ukpokiti Field, Offshore Niger Delta Nigeria."*IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG),* 8(3), (2020): pp 10-17.