World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Calcareous nannofossils biostratigraphy of well Uche 1, Offshore Lagos, Eastern Dahomey Basin, South Western Nigeria

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World Journal of Advanced Research and Reviews, 2024, 21(03), 1961–1971

Publication history: Received on 02 February 2024; revised on 16 March 2024; accepted on 19 March 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.21.3.0849

Abstract

Well Uche 1 drilled in the offshore of Dahomey Basin was biostratigraphically analyzed, based on its calcareous nannofossils content. Thirty analyzed samples were collected from the Well at an interval range of 20m at a depth of 1284m- 1860m. The microscopic examination of the processed samples was carried out (using simple smear method) and this was found useful in the identification of the different biostratigraphic zones present. Moreover, it is equally found useful in age determination. In all, fifteen (15) calcareous nannofossil species (*Braarudosphaera bigelowii*, *Calcidiscus leptoporus*, *Coccolithus nitescens, Coccolithus pelagicus, Coronocyclus nitescens, Discoaster deflandrei, Discoaster druggii, Discoaster* sp (6rays), *Helicosphaera cateri,Pontosphaera multipora, Reticulofenestra haqii* (3-5 microns), *Reticulofenestra pseudoumbilicus* (5-7 microns), *Reticulofenestra pseudoumbilicus* (>7 μ), *Sphenolithus moriformis, Triquetrorhabdulus carinatus*) were identified and used for biozonation and identification of significant time surfaces. The distribution of the calcareous nanofossil species in the well enabled the establishment of zones belonging to the Early Miocene; NN2 zone. The most abundant calcareous nannofossils identified are *Triquetrorhabdulus carinatus, Cyclicargolithus abisectus* and *Discoaster druggi*. Two biozones of calcareous nannofossils were identified from the well as well as three significant surfaces.

Keywords: Calcareous nannofossils; Biozones; Dahomey Basin; Early Miocene

1. Introduction

The term 'calcareous nannofossil' is usually defined as including all calcareous fossils smaller than 30 microns (μm). It is based on the term nannoplankton which was defined by Lohmann [1] as including the plankton which pass through the finest plankton nets, that is, <63μm. As if might be expected, a diverse range of organisms can occur as calcareous nannofossils, including ascidian spicules, calcisphere (calcareous dinoflagellates) and juvenile foraminifera. The overwhelming predominant group, however, are the remains and probable remains of calcareous nannoplankton. Calcareous nannofossils are generally disc-like in form and clearly analogous to the calcite plates, coccoliths, produced living haptophyte algae, more specifically the coccolith-bearing sub-group known as coccolithophores. However, there are also significant numbers of variously-shaped nannofossils, nannoliths, whose biological affinities are less certain due to the lack of obvious living analogues [2]. Despite this, it is generally assumed that nannoliths had algal origins as they show closely-comparable distributions to coccoliths and many display only slight morphological modifications to the basic coccolith plan. Due to their great abundance, photosynthesis and calcification, haptophyte algae are significant components of the earth's biogeochemical cycles [3]. The evolution of nannoplankton resulted in a major shift in the locus of global calcification from the continental shelf towards deep oceans, with the accompanying effects on deep-ocean CO_2 budgets, calcite compensation depths and geological carbonate turnover rates. Nonetheless, the prime geological interest in the group has been their application to biostratigraphy.

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Nannofossils are exceptionally good for biostratigraphy since they are abundant, planktonic, rapidly evolving and largely cosmopolitan [4]. Also, their small size means they can be studied from minute rock chips which is of particular value in hydrocarbon exploration and development, and scientific drilling [5]. Their biostratigraphic potential was first realized in the 1950s and was initially applied in Cenozoic studies [6] leading to the standard zonation of Martini [7].

The huge volume of data on the stratigraphic distribution of nannofossils is synthesized in a number of relatively stable biostratigraphic zonation schemes covering the range of nannofossils notably [7]; [8]; [9]; [10]. These are primarily based on evolutionary first and last occurrence of species, supplemented by some abundance based events.

This research work is aimed at bringing additional contributions to the knowledge of nannofossil assemblages by the determination of the age of the well under study.

1.1. Geology of the studied area

The study area falls within the Nigerian sector of the Dahomey Basin. Benin (Dahomey) Basin forms one of a series of West African Atlantic Margin basins that were initiated during the period of rifting in the late Jurassic to early Cretaceous. [11]; [12]; [13]. The Basin is an extensive marginal sedimentary basin located in the continental margin of the Gulf of Guinea, southwestern part of Nigeria and extends from Nigeria through Benin republic to Ghana. (Fig.1).

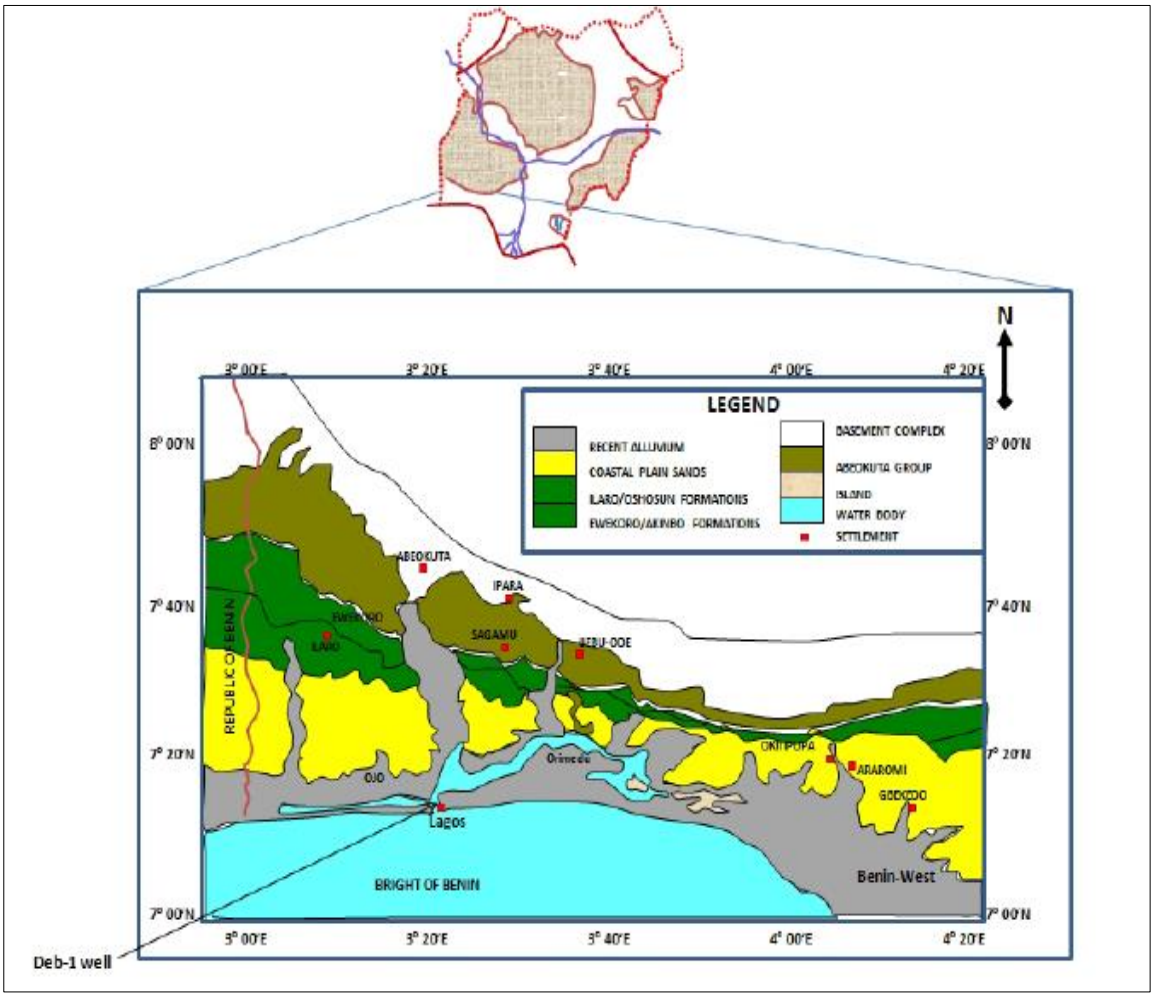

Figure 1 Geological Map of the Dahomey Basin with an inset map of Nigeria showing the location of Dahomey Basin (modified after [24]).

The basin is a marginal pull – apart basin [14] or a marginal sag basin [15], it is believed to have developed in the Mesozoic due to the separation of African plate from South American plate [16]; [13]. It is separated from Niger Delta in the Eastern section by a subsurface basement high referred to as the Okitipupa Ridge. Its offshore extent is poorly defined. Sediment deposition follows an east-west trend. In the Republic of Benin, the geology is fairly well known [17]; [18]. In the onshore, Cretaceous strata are about 200m thick [19]. A non-fossiliferous basal sequence rests on the

Precambrian basement. This is succeeded by coal cycles, clays and marls which contain fossiliferous horizons. Offshore, a 1000m thick sequence consisting of sandstones followed by black fossiliferous shales towards the top has been reported. This was dated by [17] as being pre-Albian to Maastrichtian. The Cretaceous is divisible into two geographic zones, north and south. The sequence in the northern zone consists of basal sand that progressively grades into clay beds with intercalations of lignite and shales.

The uppermost beds of the Maastrichtian are almost entirely argillaceous. The southern zone has a more complicated stratigraphy with limestone and marl beds constituting the major facies.

The stratigraphy of the basin was studied by [17] but was reviewed by [20] on the basis of new subsurface data. The stratigraphy of the Dahomey basin is made up of sediments ranging in age from Cretaceous to Tertiary. It is a coastal sedimentary basin filled with over 2500m of Cretaceous and younger sediments uncomfortably overlying the block faulted Basement Complex rocks.

The oldest sediments in the basin belong to the Abeokuta Group [20] which in turn consists of Ise Formation, Afowo Formation and Araromi Formation. The Abeokuta Group is Cretaceous in age. The Araromi Formation which is the youngest unit of the Abeokuta Group is overlain by the Imo Group which consists of the Ewekoro and Akinbo Formations. The Ewekoro Formation is the oldest of the tertiary sediments.

Overlying the Ewekoro Formation is the Akinbo Formation which is overlain conformably by the Oshoshun Formation and succeeded by the Ilaro Formation. The youngest formation in the basin is the coastal plain sands.

2. Materials and method

The Calcareous nannofossil biostratigraphy of Well Uche 1 was carried out using thirty ditch cutting samples. The samples were prepared and analyzed at 20 meters depth intervals. The simple smear method was routinely applied to process all the samples. Ditch cutting samples were acquired from the well at a depth of 1284m-1880m using a sampling interval of 20m, in which a small portion of the sediment (2g) was scraped and transferred onto a glass microscope slide. A drop of distilled water was then added to make a thick sediment suspension. Using a flat tooth pick, the suspension was smeared thinly across the surface of the glass slide and it was placed on a hotplate to dry rapidly. Each slide was labeled and the cover-slip affixed onto it using two blobs of Norland Optical Adhesive, which was then cured over ultraviolet light for 5-10 minutes. The slide was then inspected under the microscope.

The prepared slides were viewed under a polarized light microscope. For this, a binocular microscope was used with at a magnification of about 1250x with immersion oil. Then standard counts of 12 traverses were carried out followed by an extensive search of the slide for rare marker fossils. This method was standardized for each slide in the well.

The logged data was transferred into the strataBugs software, a cutting edge tool used in order to plot different types of biostratigraphic distribution chats. The chart was plotted and generated with the checklist of the different nannofossil species with their abundance and diversity peaks present. The interpretation helps to subdivide the study section into zones, dating different surfaces, and this was made possible by the presence of different index fossils.

3. Results and biostratigraphic interpretation

Biostratigraphic interpretation of the studied well sections was attempted based on recognized index nannofossil present. The following abbreviations were used in the zonal descriptions: LDO, last downhole occurrence; FDO, first downhole occurrence. Because the studied samples are all ditch cuttings samples, the nannofossil zones are described from top to base.

3.1. Calcareous nannofossil biostratigraphy of Well Uche 1

30 ditch cutting samples were analyzed at 20 meters interval for nannofossils. . A total of 15 species of nannofossils were recorded. The chronostratigraphic scheme adopted follows the usage of the worldwide zonation schemes of [7], [9] and [21]. Considerable effort was made to identify and define zonal tops with the First Down-hole Occurrence (FDO's), Last Down-hole Occurrence (LDO's) of diagnostic marker species, abundance, and species diversity peak as these form the most reliable events. The chart generated using the StrataBugs software is shown in figure 2.

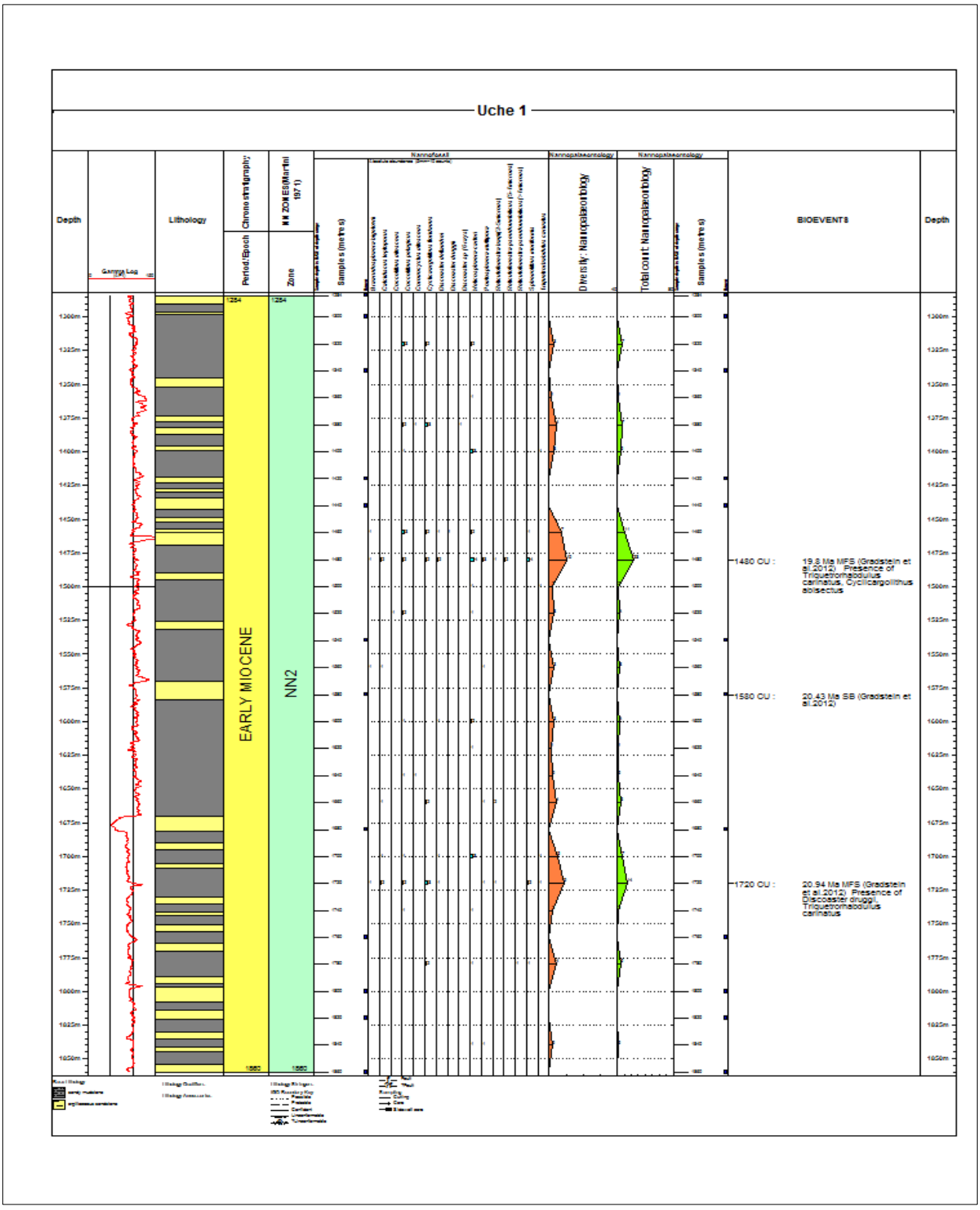

Figure 2 The depth, biozones, abundance and diversity of nannofossils in Well Uche 1 Calcareous Nannofossil Biozonation

Three (3) nannofossils "surfaces" and two (2) "zones" are recognized in the Well Uche 1 based on the critical evaluation of the key bioevents, particularly the First Downhole Occurrence (FDO) of chronostratigraphically important nannofossil markers. The zones are characterized briefly and correlated with the standard nannofossil zones (See Table 1) of various authors as detailed below [21]:

Table 1 Depth, bioevents and age of Well Uche 1

DEPTH (METERS)	FIRST DOWNHOLE OCCURENCE OF CALCAREOUS NANNOFOSSILS AND OTHER USEFUL EVENTS	AGE (Ma) Gradstein et al. 2012	NN ZONES MARTINI (1971)	INFERRED RELATIVE AGES
1284	First sample analysed			
1480	Maximum Flooding Surface, Presence of Triquetrorhabdulus carinatus and Cyclicargolithus abisectus	19.80		
1580	SB	20.43	NN 2	EARLY MIOCENE
1720	Maximum Flooding Surface, Presence of Discoaster druggi, Triquetrorhabdulus carinatus	20.94		
1860	TD			

The highest nannofossil peaks were dated using important marker species such as

- *carinatus,*
- *Cyclicargolithus abisectus*
- *Discoaster druggi*

The stratigraphic distribution of the recorded species along with the significant datum, suggested Maximum Flooding Surfaces, nannofossil zones and age interpretations are presented in distribution chart and biostratigraphy summary figure. The highlights of the results are summarized as follows:

3.1.1. Triquetrorhabdulus carinatus / Cyclicargolithus abisectus Zone.

Stratigraphic Interval: 1284m -1480m

Equivalent Neogene Nannofossil Zone: NN2.

Age: Early Miocene (19.80Ma and younger)

Diagnosis: This is the first zone encountered in the studied section of the well. The zonal top is tentatively placed at 1284m, the depth of the first sample analyzed, while the base is placed at the 19.80Ma MFS of [21] recognized at 1480. The zone is correlated with the NN2 Neogene nannofossil Zone of [7]. The age is Early Miocene.

3.1.2. Discoaster druggi / Triquetrorhabdulus carinatus Zone.

Stratigraphic Interval: 1580m – 1720m

Equivalent Neogene Nannofossil Zone: NN2

Age: Middle Miocene (20.94Ma MFS and Older)

Diagnosis: The top of this zone is placed at the 20.43Ma SB; [21] while the zonal base is placed at 20.94 Ma MFS, the depth of the last sample of the studied section. The zonal markers, *Discoaster druggi / Triquetrorhabdulus carinatus* whose LDO mark the top of the zone were recorded at 1720m. The zone is correlated with the NN2 Neogene nannofossil Zone of Martini (1971). The age is Early Miocene.

Age

The lithostratigraphic sequence of the studied section of Well Uche 1 is dominantly Deep Marine Shales of Early Miocene age. The Deep offshore marine sequence is considered to be the stratigraphic equivalent of Oshohun Formation of the deep offshore Dahomey/ Western Nigeria Basin which can be correlated to the Oshosun Formation (Onshore) [11] (See Table 2). During the Tertiary period, five stratigraphic units consisting mainly of marine sandstones and shales with insignificant carbonate rocks were deposited in alternating regressions and transgressions phases.

Table 2 Stratigraphic chart of the western Nigeria Basin and offshore Benin basin [11]

<table>
<tr><td colspan="2" rowspan="3">AGE</td><td colspan="4">FORMATIONS</td></tr>
<tr><td colspan="3">WESTERN NIGERIA BASIN</td><td rowspan="2">OFFSHORE BENIN BASIN</td></tr>
<tr><td colspan="2">Onshore
Omatsola &Adegoke (1981)</td><td>Offshore</td></tr>
<tr><td>QUART.</td><td>PLEISTOCENE-RECENT</td><td colspan="2">BENIN Fm.</td><td rowspan="2">BENIN Fm.</td><td rowspan="2">BENIN/IJEBU Fm.</td></tr>
<tr><td rowspan="5">TERTIARY</td><td rowspan="3">EOCENE-PLIOCENE</td><td colspan="2">ILARO Fm.</td></tr>
<tr><td colspan="2" rowspan="3">OSHOSUN Fm.</td><td></td><td>AFOWO Fm.</td></tr>
<tr><td>ILARO Fm.</td><td></td></tr>
<tr><td>OSHOSUN Fm.</td><td>OSHOSUN Fm.</td></tr>
<tr><td rowspan="2">PALEOCENE</td><td colspan="2" rowspan="2">AKINBO Fm.</td><td></td><td></td></tr>
<tr><td>AKINBO Fm.</td><td rowspan="2">IMO Fm.</td></tr>
<tr><td rowspan="4">CRETACEOUS</td><td colspan="2">EWEKORO Fm.</td><td>EWEKORO Fm.</td></tr>
<tr><td>CAMPANIAN-MAASTRICHTIAN</td><td rowspan="3">ABEOKUTA GROUP</td><td>ARAROMI Fm.</td><td rowspan="2">NKPORO Fm.</td><td>ARAROMI Fm.</td></tr>
<tr><td>TURONIAN-CONIACIAN</td><td rowspan="2">AFOWO Fm.</td><td></td><td>AWGU Fm.</td></tr>
<tr><td rowspan="2">NEOCOMIAN-CENOMAIAN</td><td>AWGU Fm.</td><td rowspan="2">ABEOKUTA Fm.</td></tr>
<tr><td rowspan="2">ISE Fm.</td><td>AFOWO Fm.
(ABEOKUTA Fm.)</td><td></td></tr>
<tr><td></td><td>ALBIAN SST.</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td>ISE Fm.</td><td>ISE Fm.</td></tr>
</table>

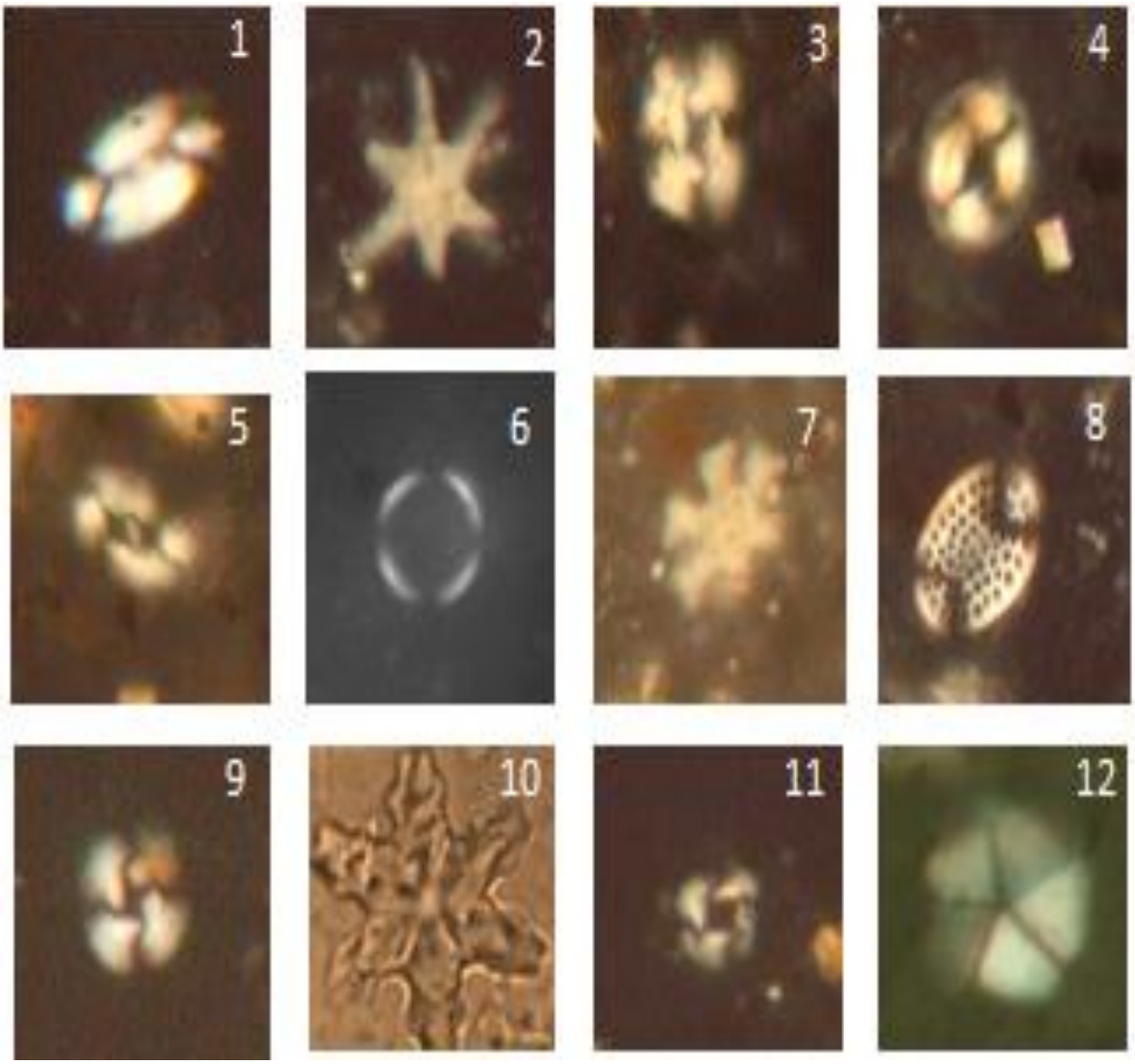

Figure 3 Nannofossil photomicrographic images for Well Uche 1

1. Helicosphera cateri **2**. Discoaster brouweri **3**. Cyclicargolithus abisectus **4.** Coccolithus pelagicus **5**. Helicosphera intermedia **6.** Coronocyclus nitescens **7**. Discoaster deflanderi **8 .** Pontosphera multipora; **9**. Cyclicargolithus floridanus **10.** Discoaster druggi **11**.Reticulofenestra haqii 3-5µ **12**. Braarudosphaera bigelowii

4. Conclusion

Ditch cuttings samples from Well Uche 1 were studied based on the calcareous nannofossils present to determine the biostratigraphy and age. A total of fifteen (15) calcareous nannofossils were identified in the well. The calcareous nannofossil assemblages of the well are moderately rich and diversified. The lower section of the well, representing 1460m-1480m is highly fossiliferous than the middle section while the upper section is richer in calcareous nannofossil at the interval 1720m-1720m, but the middle section has a sparse assemblage of calcareous nannofossil .

The highest nannofossils abundance is shown by Early Miocene index species, such as *Triquetrorhabdulus carinatus, Cyclicargolithus abisectus* and *Discoaster druggi*. The biozones recognized in the wells corresponded to NN2 zone of [11] zonation scheme. The highest peak is dated 19.8 Ma MFS [21] condensed section. The 20.94Ma MFS [21] is dated at 1720 meters with the presence of *Discoaster druggi* which further confirms this zone. The studied interval is not older than 20.94Ma MFS within the NN2 zone.

However, in relation to past works such as that of [22], [24] where he considered the age of the Oshosun Formation to be Early to Middle Eocene on the basis of foraminifera and ostracods. A more recent work [23] suggested the age of the

exposed section of the Oshosun Formation in the Shagamu quarry to be of Late Paleocene to Early Eocene due to the occurrence of diagnostic cysts.

However from this present research work based on calcareous nannofossil assemblages, the age of the Oshosun Formation is Early Miocene.

Compliance with ethical standards

Acknowledgement

We acknowledge the contribution of the postgraduate students at the Geosciences Department, University of Lagos. Professor Akinmosin A. of the same department is appreciated for his careful supervision and other contributions.

Disclosure of conflict of interest

There was no conflict of interest.

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APPENDIX

Table A-01 Calcareous nannofossil Data Sheet for Well Uche 1

Species	Depth	1284	1300	1320	1340	1360	1380	1400	1420	1460	1480	1500	1520	1540	1560	1580	1600	1620	1640	1660	1680	1700	1720	1740	1760	1780	1800	1820	1840	1860
Coccolithus pelagius				3			2	1		3	2		2				1		1			1	1	1					
Cyclicargolithus flunridanus				2			3			2	2									2			3			2				
Helicosphera cateri				1		1		3		2	4	1	1				1	1				3		1		1			1	
Discoaster sp (6 rays)							1																							
Coronocyclus nitescens							1						1						1											
Triquetrihabdulus carinatus								1				1										1	1							
Discoaster druggii										1																				
Braaudosphaera bigelowii										1	1				1								1							

Sphenolithus moriformis										1	4												2			1			
Caladiscus leptoporus											2				1					1		1	2						
Discoaster defladrei										1	2						1					1	1						
Pontosphaera multipora											3				1					1			1					1	
Reticulofenstra pseudo (5-7µ)											2																		
Reticulofenestra haqii (3-5µ)											1									2			1						
Reticulofenestra pseudo (>7µ)																										1			