

Morphological Description of Calcareous Nannofossils Assemblage of a Middle-Miocene to Late-Miocene Section in the Niger-Delta, Nigeria

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Abstract

Forty four (44) different forms of nannofossils recovered from the middle-Miocene to late-Miocene sediments of a section ((8900 - 11,000) ft (2713 - 3353 m)) of a well in the prolific oil producing Niger delta, Nigeria were described and grouped into twelve, though not on phylogenetic relationship, for documentation purpose. The standard strewn-slide technique was used to recover the fossils. The aim is to present the distinguishing morphological features of each of the nannofossils group. Of the recovered forms Genus, *Discoaster*, was found prominent and divisible into six sub-groups: 6-rayed *discoaster* with bifurcations, 6-rayed *discoasters* without bifurcation, 5-rayed *discoasters*, 5-rayed *discoaster* with acute bifurcations, 5-rayed nannolith and the indeterminate forms. Genus *Sphenolithus* recovered is also divisible into two: species without prominent apical spines and species with prominent, monocrystalline apical spines. Other genera found and described are *Catinaster*, *Cyclicargolithus*, *Coccolithu*, *Minylitha*, *Syracosphaera*, *Helicosphaera*, *Pontosphaera*, *Calcidiscus* and *Reticulofenestra*. All the nannofossils fall within NN11, NN10, NN9, NN8 and NN5 zones belonging to the Middle-Late Miocene age.

Keywords

Nannofossils, Morphology, Niger Delta, *Discoaster*, *Sphenolithus*, Miocene

1. Introduction

Until recently, published biostratigraphic information on the prolific oil producing Niger delta were based mainly on palynomorphs and foraminiferal un-

like nannofossils [1] [2] [3] [4] [5]. Such publications include [5] [6] [7] [8] [9]. This could be attributed to the proprietary nature of the data of the oil companies that contract out routine nannofossil biostratigraphic works. The use of nannofossils for biostratigraphic studies has increased greatly because of their unique microscopic size and the age range of many of its species that make them serve as index fossils as well as the speedy processing techniques of samples that yield rapid and excellent results. Refinement of an existing chronostratigraphic scheme of various oil companies in Nigeria to levels of accurately tying local sequence to regional and global bio- and chronostratigraphic schemes is still ongoing. This requires the use of nannofossils' results in addition to the traditional use of foraminiferal and other palynomorphs.

This work aims at presenting the morphological features of some nannofossils group recovered from a section of a well in the Niger delta. The morphological groups constitute neither a classification nor an attempt to organize possibly phylogenetically related forms under the same heading. The goal is to point out the distinguishing features of forms within each group for documentation purpose. Although the samples are recovered from the Agbada Formation no emphasis is laid on their biostratigraphic and paleoclimatic significance. Of note is the use of the ratio of *D. brouweri* and *Coccolithus pelagicus*, which are common in this study, for paleoclimatic studies [10]. It is envisaged that the knowledge from this offshore study could provide a clue to the age of some nannofossil assemblages without major index markers found in some onshore well sequences in the Delta.

2. Regional Geological Setting

To date the Niger Delta is perhaps the most important sedimentary basin in Sub-Sahara Africa in terms of petroleum production. It covers an area of about 75,000 square kilometers on the continental margin of the Gulf of Guinea in equatorial West Africa between latitudes 3°N and 6°N and longitudes 5°E and 8°E (**Figure 1**). The evolution of the Niger Delta followed the separation of the South American from the Africa plate during Mesozoic break up of Gondwanaland [11].

Three major lithostratigraphic units make up the Cenozoic Niger Delta. They are: a sequence of over-compacted over pressured pro-delta marine shales, named Akata Formation; which is overlain by a paralic sequence of alternating sands and shales, named Agbada Formation; and finally covered by continental sands and gravels of Benin Formation (**Figure 2**). These units are strongly diachronous becoming younger in age from the north (Eocene) to the South (Recent) and were built up by the imbricated super position of numerous offlap cycles [12]. Progressive outbuilding of the delta into the sea is shown by a shift in the inferred positions of the coastline from Eocene to the present.

Presently the Cenozoic Niger Delta is a large, high-energy arcuate delta of the destructive, wave-dominated type divisible into offshore and onshore (**Figure 1**).

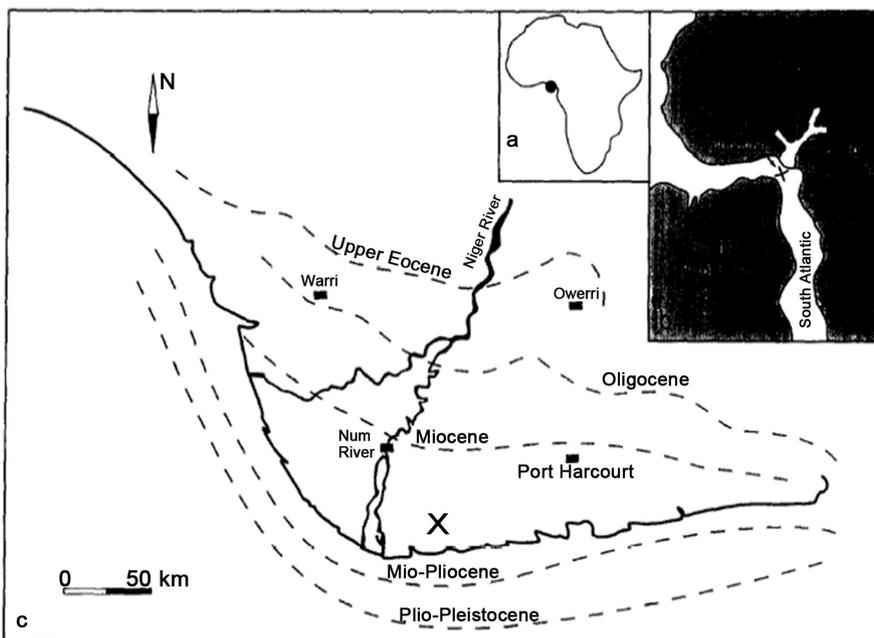


Figure 1. Location of the Niger delta oil province. The approximate location of well 1 is marked X.

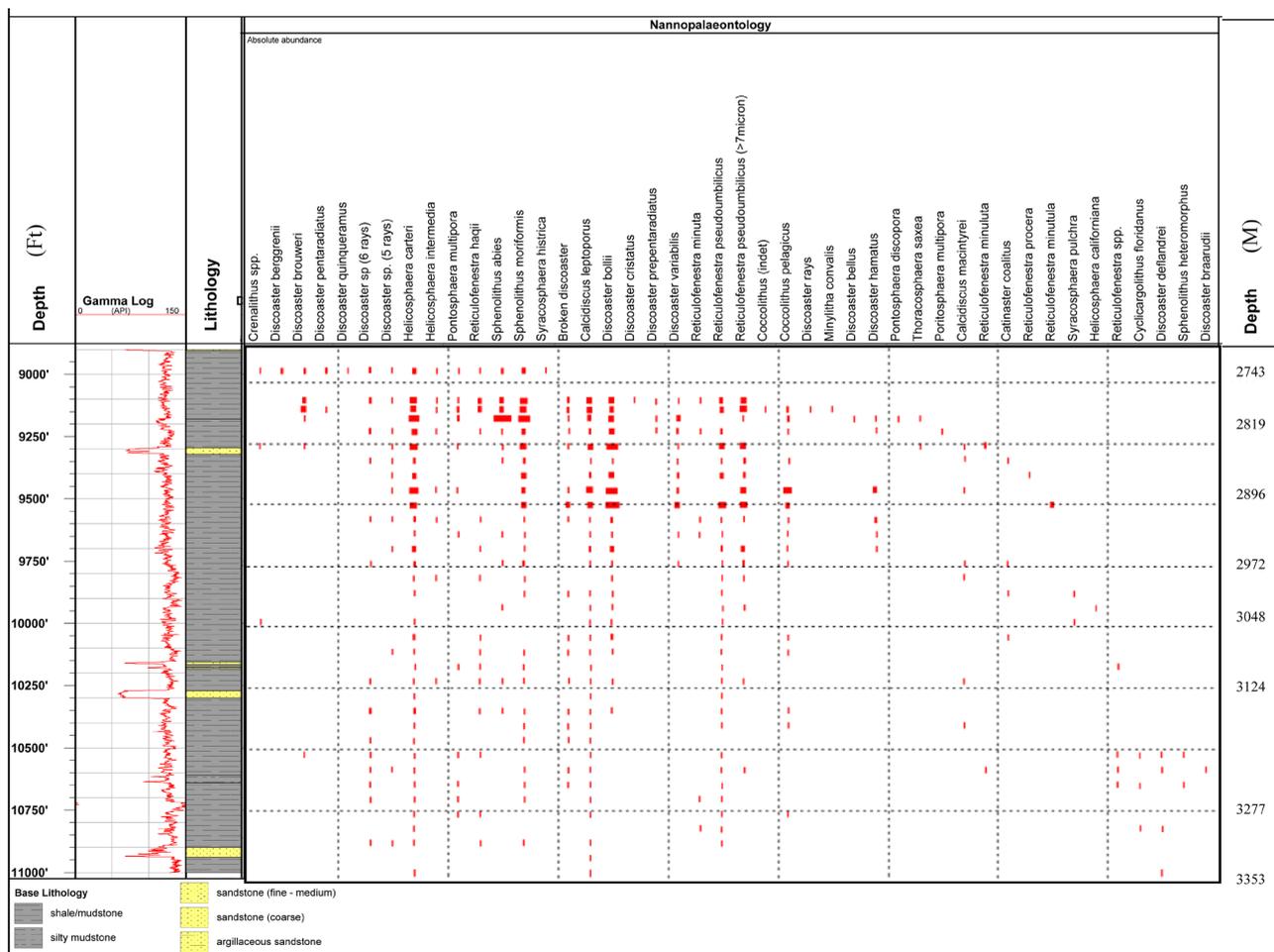


Figure 2. Distribution pattern of the described nannofossils of a Middle-Miocene to Late-Miocene Section in the Niger-Delta, Nigeria.

The changes in the stratigraphy of the Akata shale have been described from in-board to ultra-deepwater as a time-transgressive series of Lower Tertiary pro-delta and marine shales that prograded from onshore Nigeria to ultra-deep water areas. The outbuilding and general geology are contained in several publications including [13].

3. Materials and Methods of Study

The technique used to retrieve the forms described in this study follows the standard strewn-slide technique of [14]. Two to four (2 - 4) grams of fresh shale was carefully selected from each of the 35 composite ditch cutting samples recovered within a section (8900 - 11,000 feet) of an offshore Niger delta oil well. Oily samples from oil based drilling mud were gently washed with domestic detergent to remove drilling mud. Each of the samples was put on a clean white sheet of paper, which folded, and then gently crushed because of the fragile nature of nannofossils using pestle. The crushed materials were then dispersed in distilled water inside a glass vial and stirred with a stirring rod after which it was decanted in another glass tube. Using a disposable pipette, the resulting suspension was pipetted onto a 22 × 40 mm cover slip, then placed on a hot plate and gently dried at a temperature of approximately 50°C - 60°C. Thereafter, cover slip was then mounted on a labeled glass slide using two drops of Norland optical adhesive mounting medium and then cured under the ultra violet light for forty five minutes. The prepared slides were examined for their calcareous nannofossils' content under a high powered Olympus light microscope in cross-polarized and transmitted light. About three (3) traverses are studied in each slide. The numbers of different species found were recorded to get its known Abundance and Diversity. Detailed identification of the assemblages and description are basically based on previous works of [15] [16] [17] and other relevant texts mentioned in the discussion section. Photographs of the forms were taken using an OLYMPUS CX31PF binocular microscope with camera attachment.

4. Result

From the section studied, 44 different forms were recovered. Of all these forms, the following are the marker species identified: *Discoaster quinque-ramus*, *Discoaster bergrenii*, *Discoaster bollii*, *Discoaster hamatus*, *Discoaster prepentaradiatus*, *Reticulofenestra pseudumbilicus* (>7 microns), *Catinaster coalitus*, *Sphenolithus abies*, *Sphenolithus heteromorphus*, *Minylitha convalis*. Absolute abundance of all the forms recovered shows dominance of *Sphenolithus abies*, *Sphenolithus moriformis* and *Discoaster bollii* and their acme events (Figure 2). On the distribution chart (Figure 2) it is significant to note that the general abundance and diversity of the forms decrease with depth within the studied section. *Minylitha convalis* occurs only in one sample (Figure 2).

5. Discussion

5.1. Morphology

Generally the forms recovered from the studied well are herein grouped into twelve genera: *Discoaster*, *Catinaster*, *Helicosphaera* [18], *Pontosphae*, *Syracosphaera* [19], *Cyclicargolithus*, *Reticulofenestra*, *Coccolithus*, *Calcidiscus*, *Minylitha*, *Sphenolithus* and *Thoracosphaera*. Each of the group is further divided into sub-groups based on some minor morphological differences. These morphological differences are briefly discussed in this section, commonly in line with [20].

5.1.1. Genus: *Discoaster*

The genus found in this study could further be grouped into six thus:

1) 6-Rayed *Discoaster* with Bifurcations

This is the predominant group of Neogene *discoasters* [20]. However asymmetric 5-rayed specimens of all these species occasionally occur [20]. *Discoasters* found during analysis that fall in this group include:

a) *D. bolli* (Plate 1, photograph numbers: 11, 12 and 13)

Description: This species has relatively short arms bifurcating into terminations in different planes. Both sides of the large central area have a stellate stem, one small, one large, a structural element which distinguishes *D. bollii* from any other species of otherwise somewhat similar appearance. According to [21], it is similar to *Discoaster exilis* but with large distal boss, wide central-area, and usually smaller (<10 µm) [20].

b) *D. variabilis*

Description: This form was described by [20] as having a central area with proximal and distal ridges; the small size of the bifurcations indicates its failure to develop bifurcating arms. It usually has 6, sometimes 5 and rarely 4 or 3 arms and a stellate central knob with the tips of the star extending to the margin between the arms on one side and along the median line of the arms [22] on the other (concave) side. The arms terminate with a bifurcation forming an angle of about 90°, which is more or less filled with an additional web. The arms themselves are parallel-sided or slightly tapering and the inter-arm area is V-shaped. *D. variabilis* differs from *D. deflandrei* by the V-shaped inter-arm area, the longer arms and the web between the bifurcated ends of the arms.

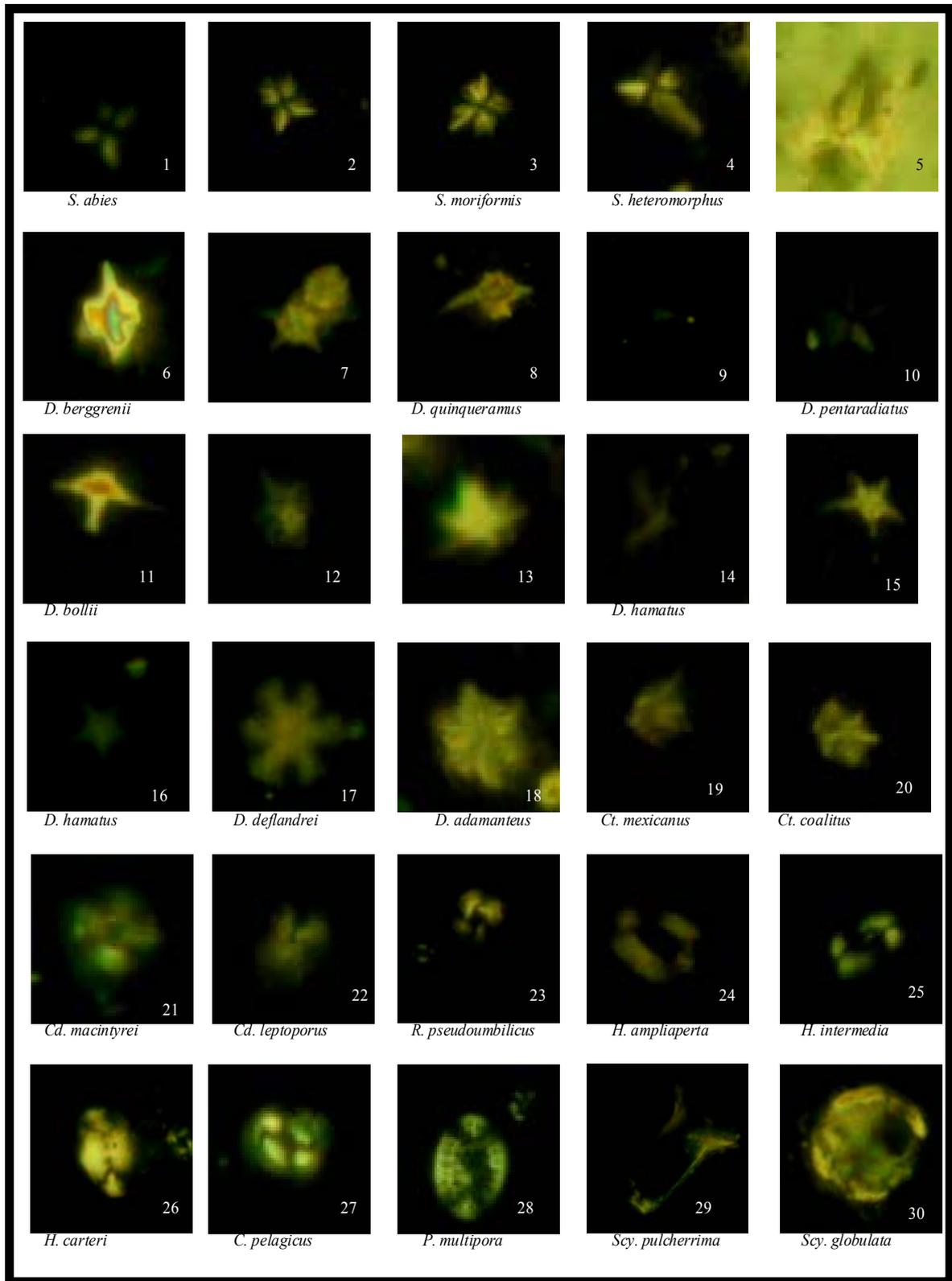
c) *D. deflandrei* (Plate 1, photograph number; 17)

Description: [20] describes the central-area as wide and rather featureless. It has short rays and wide bifurcations and that asymmetric 5 and 7-rayed forms do occur.

2) *D. brouweri* Group

These are 6-rayed *discoasters* without bifurcation, which are closely related to *D. brouweri* with fewer rays [20]. The following *discoasters* fall in this group:

a) *D. braarudii*. It is described by [23] as been similar to *D. brouweri* but their ray-tips (tips of arm) are simple without proximal extensions [20].



Sphenolithus (S.), Discoaster (D.), Catinaster (Ct.), Calcidiscus (Cd.), Reticulofenestra (R.), Helicosphaera (H.), Coccolithus (C.), Pontosphaera (P.), Scyphosphaera (Scy.).

Plate 1. Photomicrographs of Some of the Forms Recovered in well A1, Niger delta, Nigeria.

N.B. *Discoasters* with this general morphology also often occur through dissolution or poor development of other species e.g. *D. exilis*, *D. brouweri* [20].

b) *D. brouweri*

c) Description: This is a 6-rayed *discoaster* without bifurcation. This form has been to include forms with usually 6 long arms that bend down like umbrella ribs with or without a central knob on the concave side [20].

It differs from other 6-armed forms by the absence of any bifurcation or side-ward bending of the tips of the arms.

3) Symmetric 5-Rayed *Discoasters*

The followings were identified within this group:

a) *D. quinqueramus*

Description: According to [24], *D. quinqueramus* has 5 tapering, long non-bifurcating arms arranged symmetrically and a robust central area with a very prominent, 5-armed central knob. Early forms are difficult to distinguish from the older *D. berggrenii*, which features an even more prominent central knob and shorter arms. Other 5-armed species either have bifurcating arms and/or no prominent central knob or bending arms.

Range: NN11 [25] which is equivalent to CN9 [26].

b) *D. berggrenii* (Plate 1, photograph numbers: 6 and 7)

Description: This form is similar to *D. quinqueramus* but with a central area that is two times wider. It is a symmetric, 5 armed form with tapering arms and a very prominent knob consisting of the inwardly directed prolongations of the ridges on the arms on one side and of ridges extending from the inter-arm area over a depressed central area to form a central knob (CSEM in [17]) on the other side. The free length of the arms is about equal to the diameter of the central area [24].

4) a) *D. pentaradiatus* (Plate 1; photograph number: 10)

Description: In [20] [26] described it as a 5-rayed *discoaster* with acute bifurcations, strongly concavo-convex and birefringent (each ray is a separate crystal-unit, with c-axes inclined slightly from vertical toward radial), this was later amended by [24] as having 5 thin, tapering arms with a terminal bifurcation which characteristically is thin and delicate (and therefore, often broken off) and shows slight birefringence when viewed between crossed nicols [24]. It also shows only little of the umbrella-like bending of *D. brouweri*, from which it differs by also having 5 instead of 6 arms. *D. prepentaradiatus* is flatter than *D. pentaradiatus* and has shorter and more robust bifurcations [20].

b) *D. hamatus* (Plate 1, photograph numbers: 14, 15, and 16)

Description: It is a large, symmetric, 5 rayed form with a small knob in the centre. The arms are long, somewhat curved, and turn sharply clockwise and downward near the end, as viewed on the convex side. A much smaller knob is usual as a bifurcation, although it appears to be a continuation of the main part of the arm as it extends in the same direction. *D. hamatus* differs from *D. neo-*

hamatus and *D. calcaris* by having only 5 arms instead of 6. The other two species have tapering and terminally bent arms.

Range: NN9

5) *D. prepentaradiatus*

D. prepentaradiatus is described as a 5-rayed nannolith with broad bifurcations, it is planar and non-birefringent [20].

Range: NN9-NN10

6) Indeterminate Forms

Unidentifiable/Broken discoasters fall under this group. They are usually common, and for biostratigraphic precision, it is best to record them as such. In addition, isolated rays and pairs of rays are common; care is sometimes needed to avoid misidentifying these.

5.1.2. Genus: *Catinaster*

As described by [21], this form is basket shaped nannolith formed by fusion of the bifurcations of a small *discoaster* [20].

Range: NN8-NN10

1) *C. coalitus*. (Plate 1, photograph number: 20)

Description: They have their 6 rays confined to basket and according to [20] short pseudo-rays are often formed where the tips of bifurcations meet. *C. coalitus* holotype is nearly circular and many specimens that are usually assigned to it are hexagonal in outline. These forms are somewhat smaller and are found in the older part of the short range of *C. coalitus* in the Middle Miocene.

5.1.3. Genus: *Helicosphaera* [18]

The *Helicosphaera* identified in this study include:

1) *H. carteri* (Plate 1, photograph number: 26)

This is the most common *Helicosphaera* species. It is medium to large in size and flange ends in wing with two pores in central-area.

Range: NN1-NN21

2) *H. intermedia* (Plate 1, photograph numbers: 25)

Description: According to [25], it is like *H. euphratis* but with the central-area open, spanned by curved and disjunctive bar [20]. The *Helicoliths* of *Helicosphaera intermedia* are symmetrically elliptical with a wing that terminates gradually at the beginning of the metapterygial side. The proximal plate is of type II with a large central opening transversed by a sigmoid bridge, which is inclined in a normal direction. A diagonal suture divides the bridge into two roughly triangular segments consisting of equidimensional elements without apparent orientation. The suture of the bridge is visible only in proximal view. The blanket covers the entire distal surface of the *helicolith*. The ratio of the double edge to the single edge is approximately 3:1. It is S-shaped and its first occurrence is in the Oligocene zone CP16.

5.1.4. Genus: *Pontosphaera*

They are coccoliths whose central areas have variable number of perforations.

i.) *P. multipora* (**Plate 1**, photograph numbers: 28)

Description: Its central area protrudes above rim, 3 or more cycles of large pores in other words, its floor are pierced by many perforations or thinned by large depressions.

Range: Paleogene-NN21

2) *P. discopora*

Description: The rim is elevated with 3 or more cycles of pores.

5.1.5. Genus: *Syracosphaera* Lohmann, 1902

This genus is responsible for much of the diversity of modern coccolithophores (>50 species) but most species produce small coccoliths with low preservation potential and which are difficult to identify under the microscope [20]. The ones identified in this well are the common larger (>3 µm) species. They are:

1) *S. pulchra* (**Plate 1**, photograph number: 29)

Description: It is a coccolith with an oblong or irregularly elliptical with bright rim and central-area of radial laths showing tangential c-axis orientation [20].

Range: Paleogene-NN21

5.1.6. Genus: *Cyclicargolithus*

These are forms which have circular to sub-circular central area [20].

1) *C. floridanus*. They are common forms with sizes usually less than 10 µm.

5.1.7. Genus: *Reticulofenestra*

They are circular to elliptical in shape with an opened or closed central-area and no special structures.

1) *R. pseudoumbilicus* (>7 micron): (**Plate 1**, photograph number: 23)

Description: The size of the central opening is relatively large and greater than 7 micron.

2) *R. haqii*

Description: Distinguished by the size of the central opening of size 0.1 to 1.5 µm (micron meters).

3) *R. minuta*

Description: Used for forms smaller than 3 µm (3 micron meter).

Range: Paleogene-NN21 *i.e.* it ranges from the early Oligocene through the Pliocene.

4) *R. minutula*

Description: Used to describe forms that range between 3 - 5 µm.

Range: NN15-NN18

5.1.8. Genus: *Coccolithus*

1) *C. pelagicus* (**Plate 1**, photograph number: 27)

Description: The size ranges between 3 - 16 µm and has a central-area open or with transverse bar.

Range: Paleogene-NN21

5.1.9. Genus: *Calcidiscus*

Calcidiscus recovered from this study have circular to sub-circular proximal shield and are birefringent and the distal shields are non-birefringent with curved sutures. Shields are easily separated [20]. They include:

1) *C. leptoporus* (Plate 1, photograph number: 22)

Description: [20] described this form as being circular to sub-circular, closed central-area, default name covering a wide range of variation. It is fan shaped and has a closed central slit.

Range: NN2-NN21

2) *C. macintyreii* (Plate 1, photograph number: 21)

Description: Large placoliths with sub elliptical outline and an elliptical tube which has a relatively large opening and usually lacks calcareous central filling. The placoliths have a non-birefringent distal shield and a birefringent proximal one as the extinction bands of the birefringent proximal shield curve sinistrally in proximal view.

Range: NN7-NN19, but usually only distinguished in the Upper Pliocene and Quaternary [20].

5.1.10. Genus: *Minylitha*

1) *M. convallis*

Description: This form has a Rhomb-shaped nannoliths with elevated rim [20]. In other words, it's a thick plate-like individual calcite element with polygonal outline, depressed central area, and raised rim. It appears only moderately bright in polarized light as it is the only species of the *Minylitha* family.

Range: NN9-NN11A

5.1.11. Genus: *Sphenolithus*

Two groups of this were recovered:

1) Species without prominent apical spines

a) *Sphenolithus abies* (Plate 1, photograph numbers: 1 and 2)

Description: A representative of the latter type of the sphenoliths distinguishable by its wide proximal shield. It is slightly conical in shape and can be viewed parallel to crossed nicols and also at 45° to crossed nicols. According to [20], it is similar to *S. moriformis* but more elevated and with cupsate outline.

Range: NN7-NN15

b) *S. moriformis* (Plate 1, photograph number: 3)

Description: Generalized form with no spine, and upper and lower parts of similar size. It has an obtuse proximal column.

Range: Lower Eocene-NN10

1) Species With Prominent, Monocrystalline Apical Spines [20].

a) *S. heteromorphus* (Plate 1, photograph numbers 4 and 5)

Description: This form has well developed apical spine. Both Its lateral ele-

ments and proximal elements are large.

Range: NN4-NN5

5.1.12. Genus: *Thoracosphaera*

1) *Thoracosphaera* spp.

Description: Some of the species assigned to the *Thoracosphaera* are calcareous dinoflagellates. The width, shape and outline of archaeopyle vary in the various species. Also, the skeletal ultrastructure showing size, shape and arrangement of skeletal elements in the species vary with the test size which is used with some reservations, is spherical and prolate spheroidal.

***Crenalithus* spp.**

Description: This form belongs to the *Crenalithus* family.

5.2. Age Determination

Considering the age range of the recovered taxa from a section of a well in the Coastal depobelt of Niger delta, the following nannofossil zones could be defined: NN11, NN10, NN9, NN8 and NN5. Zone NN11 which is late Miocene belongs to the Messinian stage. Zones NN10 (Late Miocene), NN9 (Late Miocene) belong to the Tortonian stage, NN8 (Middle Miocene) belong to the Serravallian stage, NN5 (Middle Miocene) belong to the Langhian stage based on [25] All these ages fall within Middle-Late Miocene ages.

6. Conclusion

In this study the Genus, *Discoaster*, was found divisible into six sub-groups: 6-rayed *discoaster* with bifurcations, 6-rayed *discoasters* without bifurcation, 5-rayed *discoasters*, 5-rayed *discoaster* with acute bifurcations, 5-rayed nannolith and the Indeterminate Forms. Genus *Catinaster*, *Cyclicargolithus*, *Coccolithu*, *Minylitha* and *Syracosphaera* have one sub-group each while *Helicosphaera*, *Pontosphaera* and *Calcidiscus* have two and *Reticulofenestra* four. Two groups of *Sphenolithus* were recovered. They are species without prominent apical spines and species with prominent, monocrystalline apical spines. All the nannofossils fall within the following zones NN11, NN10, NN9, NN8 and NN5 belonging to the Middle-Late Miocene age.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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