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Calcareous Nannofossils Biostratigraphy and Paleoecology of Well 03, Shallow Offshore, Niger Delta, Nigeria

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ABSTRACT

This study presents the calcareous nannofossils biostratigraphy of well 03, shallow offshore, Niger Delta, Nigeria using ditch cuttings samples analyzed for nannofossils to determine age, biozonation, and paleoecological interpretation. A quantity (5 g) each of the cuttings were subjected to standard smear slide preparation technique for nannofossils using Norland adhesive and the slides examined under light microscope at 1000 × magnification. Lithologically the studied sequences were composed of shale, siltstone /mudstone which are grey with intercalation of sandstones belonging to Agbada Formation. A fairly diverse 37 species of nannofossils assemblage was recovered. Two major nannofossil zones of *Helicosphaera ampliaperta* and *Sphenolithus heteromorphus* were delineated. Establishment of these zones aided the assignment of the early Miocene - late Miocene age range to the section. Paleoecology of the studied section reveals fluctuations between warm and cool climates evidenced from the variation in the assemblages of diagnostic species across the intervals, *Sphenolithus heteromorphus* predominates intervals 7900 – 12420 ft *and the occurrence of Discoaster* berggrenii *between* 9300 -9420 ft suggest intervals under warm climate conditions while *Coccolithus pelagicus and coccolithus miopelagicus strives between* 7000 -10780 ft, between 6670 -10980 ft, respectively indicating cooler environmental conditions.

KEYWORDS: Calcareous nannofossil, Biostratigraphy, Biozonation, Paleoecological, Shallow offshore, assemblage, Miocene

INTRODUCTION

Calcareous nannofossils are a group of ancient unicellular autotrophic marine algae with calcareous test, generally smaller than 30 μm in size. These unicellular, planktonic organisms are the most abundant calcifying organisms on our planet (Baumann *et al.,* 2004, Sudeep *et al.,* 2017). This is a diverse group of organisms, but the only ones that are fossilized to any great extent are coccoliths, the calcareous plates of Coccolithophores. Calcareous nannoplankton is the living equivalent of nannofossil widely distributed in marine environments from the shelf to the open ocean and constitutes a significant part of the phytoplankton community, along with diatoms, dinoflagellates, and cyanobacteria Sudeep *et al.* (2017).

As a photosynthesizing group, nannoplanktons live in the photic zone of the water column. They reach maximum diversity in tropical and subtropical latitudes and are less diverse, though more abundant in temperate and sub-Arctic waters, but tend to be very rare or absent at latitudes higher than 70_. The majority of species have broad ecological tolerances for a wide range of temperatures and salinities. Nannoplankton distribution patterns are strongly related to surface water temperature and macronutrient availability (nitrate and phosphate), which, in turn, are linked to oceanographic features such as circulation and water masses. Seasonally stable, oligotrophic (low-nutrient), tropical, and subtropical oceanic environments support the highest diversities, but standing populations tend to be very low, reflecting nutrient limitation. Eutrophic (nutrient-rich) conditions, associated with the continental shelf, or in upwelling zones, support high-standing populations dominated by a distinctive assemblage of one or a few species (Andruleit, *et al*., 2004, Sudeep *et al*. (2017).

The Niger Delta region in the southern part of Nigeria is an oil province of Nigeria in West Africa, also known as the Niger Delta basin. The Niger Delta basin lies between longitudes 3º E and 9º E and latitudes 4º N and 7º N (Figure 1).

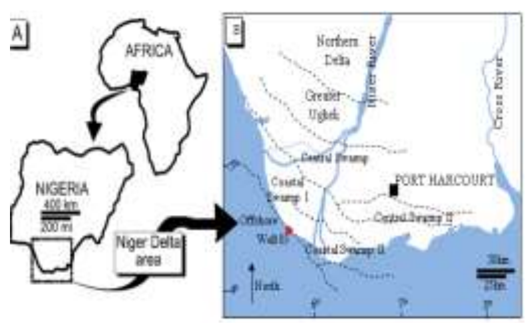

Figure 1: Location of Niger Delta along the west coast of Central Africa B**.** location of well-03, shallow offshore.

The importance of calcareous nannofossils in the relative dating of marine sediments is due to their abundance (millions of specimens per gram carbonate-bearing sediment), taxonomic diversity, rapid evolution, wide distribution in marine environments and preservation potential (slightly less susceptible to dissolution than planktonic foraminifers. Nannofossils find their application in petroleum geology in the provision of critical data on geologic age and sedimentary facies of source and reservoir rocks (Isabella, *et al*., 2022;

Sudeep *et al*., 2017). Nannofossils belongs to an excellent group in providing real-time data, due to minimal set-up required for their recovery and examination. For example, they have been used for well-site biostratigraphy extensively in offshore deep-water Nigeria to aid exploration and production (Fadiya, 2014).

Early studies on Calcareous nannofossils early research in the Niger Delta began in the 1990s to complement foraminifera and palynomorphs research before other studies were carried out in the Niger Delta (Fadiya and Salami, 2012; Osterloff *et al*., 2013). Early Pliocene to late Miocene age was assigned to sediments investigated due to the occurrence of *Ceratolithus rugosus* Zone, *Discoaster berggrenii – Discoaster quinqueramus* Zone, *Catinaster coalithus* Zone and *Discoaster hamatus* (Boboye and Adeleye,2009; Alkali *et al*., 2014).

Also, Miocene age for the Akata field, Eastern Niger Delta was described based on the presence of the *Sphenolithus heteromorphus* zone with an assigned age of 15.0 Ma equivalent to the Neogene nannofossil (NN)5 zone (Okosun *et al*., 2012). As with other microfossil groups, many unpublished proprietary reports on calcareous nannofossils from wells in the Niger Delta still exist, emphasising the need for more data sets on calcareous nannofossils and other fossil groups for the Niger Delta to be published. In addition, biostratigraphic data aid biostratigraphers in correlating sedimentary sequence and paleoecologic dynamics.
However, zonation schemes by oil companies' biostratigraphers are kept secret and rarely published because of confidentiality. A few known nannofossil zonation schemes from industries include the work of (Bowman *et al*., 2009 and Guerra *et al*., 2012) on the Miocene of Gulf of Mexico and the Cretaceous of the Pelotas basin respectively. These schemes were based on bioevents (top, acme) rather than bases due to caving-in well cuttings. In essence, zonation's by companies are usually suited for specific basins and lack global applicability. This present study establishes the age and paleoecology of the studied section of well 03 shallow offshore, Niger Delta, Nigeria

MATERIALS AND METHODS

One hundred and twelve ditch-cutting samples for nannofossil investigations were retrieved from well-03 within the range of 6000 - 12420 ft at 30ft intervals from shallow offshore, Niger Delta, Nigeria. The standard smear slide preparation method for nannofossil was employed. 5g of cuttings were washed to remove the drilling mud. The subsample was gently crushed using mortar and pestle. The crushed material was dispersed in distilled water in a tube. A disposable glass pipette was employed to pipette the suspension for final slide making. The pipetted solvent was dried on a 22 × 40 mm coverslip at a slightly hot temperature of between 50ºC and 60ºC. The dried cover slip was then mounted on a glass slide using Norland adhesive cured under UV light. Eight traverses were studied in each slide.

Detailed identification of forms (to species level where possible) was made of all taxa encountered in each slide based on morphological features especially the presence or absence of a central area and an appendage. The photomicrographs of some of the microfossils were taken with the aid of a polarising microscope of 1000 × magnification (Plate 1) and the data from the slides and others were plotted on nannofossil distribution charts on a scale of 1:5000 using StrataBug Biostratigraphic software (Figure 2).

Data Analysis

Biofacies data from the slides and others were plotted on nannofossil distribution charts on a scale of 1:5000 using StrataBug Biostratigraphic software (Figure 2).

RESULTS AND DISCUSSION

Rich and diverse assemblages of Nannofossils were recovered from the samples. The identified calcareous nannofossils have been presented in a distribution chart (Figure 2). The important bio-events were used to decipher zonal boundaries and the age (Figure 3). The samples analysed yielded fairly rich and well-preserved species.

Calcareous Nannofossils Biozones

The stratigraphic interval studied in Well 03 has been subdivided into biostratigraphic zones based on their calcareous nannofossil content. The well was zoned using the globally recognized calcareous nannofossil zonation scheme of (Martini, 1971). Three major zones were identified belonging to the middle Miocene to late Miocene. These are the NN4, NN5, and NN6-7 zones (Martini, 1971). (Figure 3).

Helicosphaera ampliaperta Zone

Stratigraphic interval: 10060 - 12420 ft.
Age: Early Miocene
Definition: The top of this zone is recognized in the well and is placed as the top of *Helicosphaera ampliaperta* at 10060 ft. The base is assumed as the base of the studied interval. The zone is also characterized by the top occurrence of *Sphenolithus dissimilis* and base occurrence of *Helicosphaera intermedia* and is the lowermost biostratigraphic zonal event in the sections. The zone corresponds to NN4 zone of Martini (1971) and CN3 of Okada and Bukry (1980).

Sphenolithus heteromorphus Zone

Stratigraphic interval: 7090 - 10060 ft.
Age: Middle Miocene

Definition: The zone is defined by the top of *Sphenolithus heteromorphus* at 7090 ft. and the top of *H. ampliaperta* as the base at 10060 ft. The zone is also characterized by the LDO of *H. intermedia* and *H. obliqua*. The zone is equivalent to NN5 of Martini., (1971); Okada and Bukry, 1980).

Undiagnostic Zone

Stratigraphic interval: 6010 - 7090 ft.

Age: Late Miocene.

The zone lies between the top of the *Sphenolithus heteromorphus* at 7090 ft. and the top of the studied interval. The zone is correlated to NN6 - NN7 of (Martini., 1971 and Okada and Bukry., 1980).

Paleoecology

Nannoplankton inhabit the surface waters of the ocean and as such is greatly affected by surface water temperature changes. The Discoasters are well known to favour and predominate warm waters and several earlier workers have conducted paleotemperature studies using the low ratio of warm water *Discoasters* to *Coccolithus* to suggest cool water conditions. Coccolithus is a good indicator of a cool climate, (Bukry, 1981)., Discoasters were well known to prefer warm waters (Bukry, 1981).

The *Sphenolithus heteromorphus, Discoaster brouweri* and *Discoasters berggrenii*are also considered to be paleobio indicators for warm oceanic waters (Aubry, 1984). *Coccolithus pelagicus, Coccolithus miopelagicus* prefers cold (7-14°C) and nutrient-rich surface waters (McIntyre and Be, 1967) and therefore it is a good paleoclimatic indicator (Haq, 1977).

Recovered Nannofossils species distribution across the studied section reveals fluctuations between warm and cool climates, evidenced by the variation in the assemblages of diagnostic species such as *Sphenolithus heteromorphus* between *intervals* 7900 – 12420 ft*, Discoaste rbrouweri* between 6100 -7180 ft, *Discoaster berggreni* between 9300 -9420 ft *and Coccolithus pelagicus* between 7000 -10780 ft*, and Coccolithus miopelagicus* between 6670 -10980 ft *(*Figure 2). *Braarudo sphaerid* depositional events within the section suggested low salinity, shallow coastal to brackish Pontosphaerid (*P.multipora, P. discopora*) neritic environments *Helicosphaerid* (*H. carteri, H. intermedia, H. stalis, H. mediteranea, H. scissura, H. ampliaperta, H.euphratis*), which can be common in Paleogene and Neogene assemblages, are generally considered to prefer warm to temperate waters and increased .nutrient availability (Auer *et al*. 2014).

CONCLUSION

A lithological analysis of the well shows that the bulk of the lithofacies is made up of shale, silty mudstones, and sandy mudstones which are grey to dark grey in colour, with intercalations of coarse -medium - fine-grained sandstone beds. 37 species of nannofossils were recovered, the recovery was mainly on shaly samples. Three nannofossil zones (NN4, NN5, NN6- NN7) belonging to the late early Miocene - late Miocene age were identified following the standard zonation schemes. These zones are *Helicosphaera ampliaperta*, *Sphenolit husheteromorphus,* and *Catinaster coalitus* zones.

Paleoecology of the studied section reveals fluctuations between warm and cool climates during the early Miocene to late Miocene periods evidenced by the variation in the assemblages of diagnostic species across the intervals, *Sphenolithus heteromorphus* predominates intervals 7900 – 12420 ft *and the occurrence of Discoaster* berggrenii *between* 9300 -9420 ft suggest intervals under warm climate conditions while *Coccolithus pelagicus and coccolithus miopelagicus strives between* 7000 -10780 ft*,* between 6670 -10980 ft respectively indicating cooler environmental conditions.

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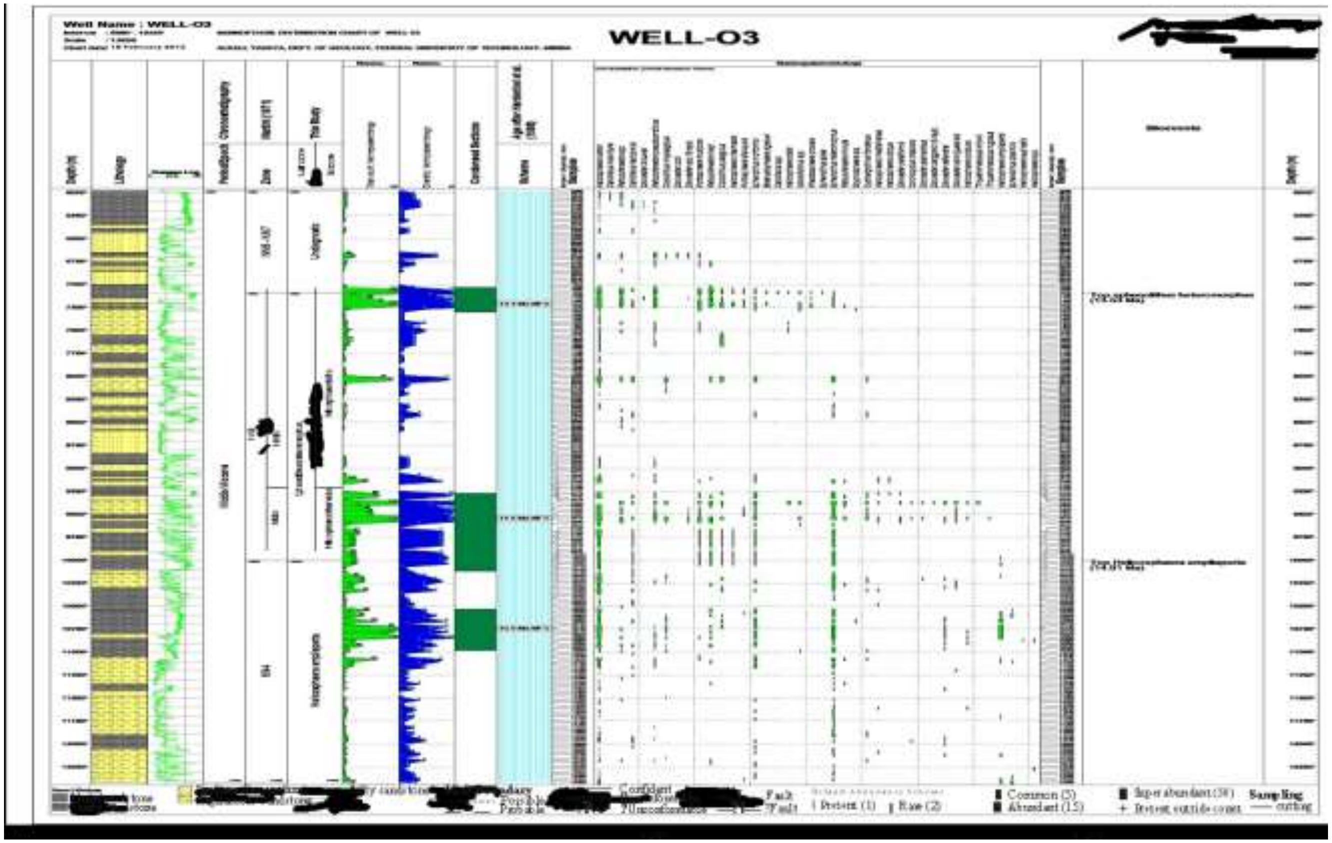

Figure 2: Nannofossils distribution chart of Well 03, Shallow Offshore, Niger Delta, Nigeri

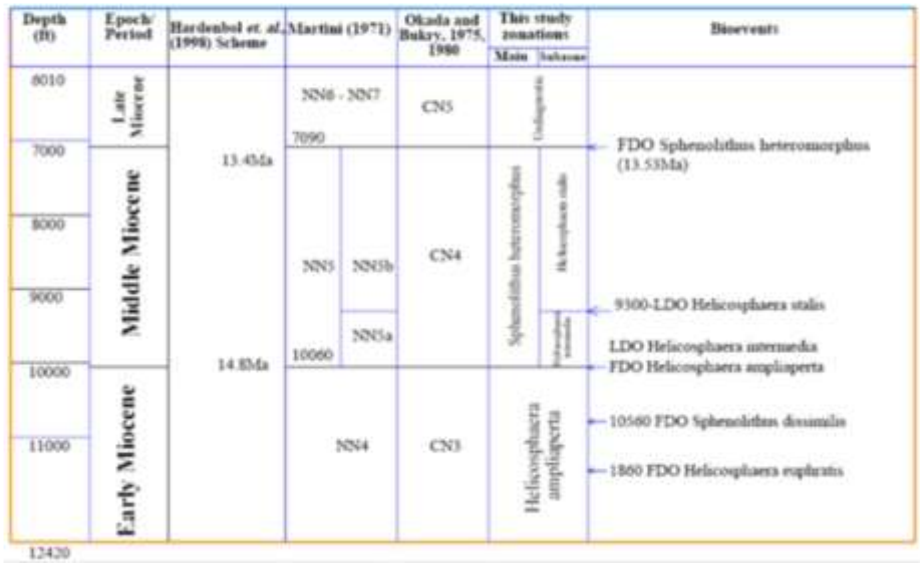

Figure 3: Calcareous nannofossils zones recognized in well 03, shallow offshore, Niger Delta

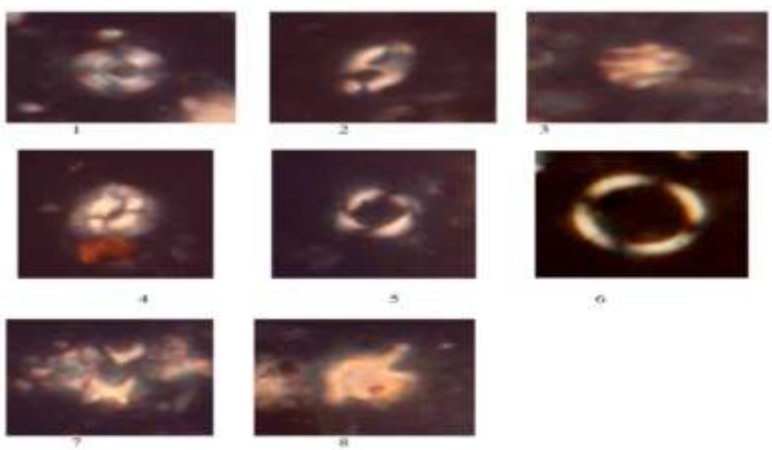

Plate I (Nannofossils)
Explanation of Plate I (× 1000)

1. *Calcidiscus macintyrei* Loeblich and Tapan 2. *Helicosphaera oblique* Bramlette and Wilcoxon 3. *Catinaster coalitus* Martini and Bramlette 4. *Cocolithus pelagicus* Wallich, Schiller 5. *Reticulofenestra pseudoumbilicus* Gartner 6. *Coronocyclus nitescens* (Kamptner) Bramlette and Wilcoxon 7. *Mynilitha convalis* Bukry, 8. *Discoasterbollii*Martini and Bramlette

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