

## CALCAREOUS NANNOPLANKTONS BIOSTRATIGRAPHIC ZONATION AND PALEOENVIRONMENTAL RECONSTRUCTION OF AJ WELL, OFFSHORE EASTERN DAHOMEY BASIN

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### ABSTRACT

A comprehensive analysis was conducted on fifty-one ditch-cutting samples from the AJ Well, collected at 30-meter intervals between depths of 2850 m and 4380 m, to examine calcareous nannoplankton assemblages. The primary objectives were to establish a detailed biostratigraphic framework and to reconstruct the paleoenvironmental conditions of the sedimentary sequence penetrated by the AJ Well in the offshore eastern Dahomey Basin. Calcareous nannofossil analysis was conducted using standard smear slide preparation and light microscopy to identify biostratigraphic zones and constrain the age of the sedimentary sequence. Biostratigraphic examination identified two zones: NP24 or younger and NN11 or older, corresponding to the Late Oligocene to Late Miocene epochs. The nannofossil assemblage, comprising species such as *Coccolithus pelagicus*, *Discoaster berggrenii*, *Discoaster brouweri*, *Helicosphaera carteri*, *Pontosphaera multipora*, *Reticulofenestra* spp., *Sphenolithus moriformis*, *Cyclicargolithus abisectus*, *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, and *Zygrhablithus bijugatus*, served as proxies for interpreting past marine conditions. Both warm-water indicators (*Discoaster* spp, *Sphenolithus moriformis*) and cooler-water taxa (*Coccolithus pelagicus*) suggested fluctuations in sea surface temperatures over time. Additionally, the occurrence of *Helicosphaera carteri* pointed to intervals of increased nutrient availability, possibly due to upwelling or terrestrial input. These findings generally reflect a dynamic interplay of oceanographic and climatic factors influencing the depositional environment in the offshore Dahomey Basin during the Late Oligocene to Late Miocene Epoch.

**Keywords:** Calcareous nannofossils; Paleoenvironment; Biostratigraphic zonation; Offshore Dahomey Basin

### INTRODUCTION

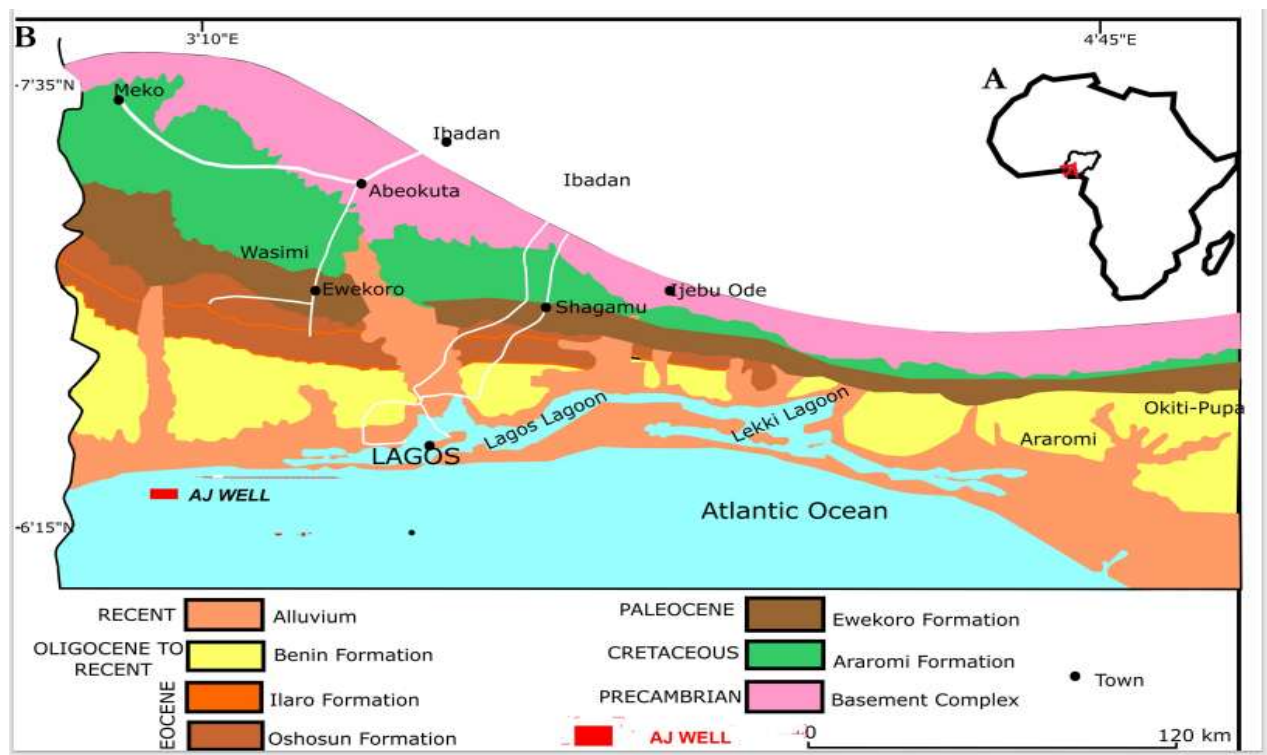
The Dahomey Basin, an extensive sedimentary province along the West African margin, spans from southeastern Ghana through Togo and Benin to southwestern Nigeria. The stratigraphy of the basin incorporates different depositional environments that span from the continental to

the deep marine settings. Previous studies have employed various microfossil groups to unravel this history. For instance, Alege *et al.*, (2024) conducted biostratigraphic and paleoecological analyses of the Late Cretaceous to Tertiary sediments in the basin utilizing foraminiferal assemblages to interpret depositional environments. Similarly,

Olayiwola *et al.* (2022) investigated the upper Eocene to lower Oligocene sediments through palynological methods, providing insights into paleoenvironments and depositional sequences.

Despite these contributions, there is a paucity of research specifically focusing on calcareous nannoplankton within the Dahomey Basin. Calcareous nannofossils are microscopic algae whose assemblages in sedimentary records provide valuable insights into past marine environments. Due to their rapid evolutionary rates and widespread distribution, calcareous nannoplankton are excellent biostratigraphic markers and invaluable for paleoenvironmental reconstructions. A notable study by Aturamu *et al.*, (2024) analysed calcareous nannofossils from Well

Uche 1 in the offshore eastern Dahomey Basin, identifying key species and establishing biostratigraphic zones corresponding to the Early Miocene. Building upon these foundational works, the present study aimed to comprehensively analyse calcareous nannoplankton from the AJ Well, located offshore in the eastern Dahomey Basin (Figure 1). It seeks to achieve the through the following objectives: (a) conduct a thorough taxonomic analysis to identify and document calcareous nannoplankton species present in the AJ Well samples, (b) determine the vertical distribution of identified species to establish biostratigraphic zones and correlate them with established zonation schemes, and (c) analyze the composition and abundance of nannoplankton assemblages to infer past environmental conditions.



**Figure 1.** (A) Location of Dahomey Basin in the Gulf of Guinea area of West Africa (B) Geological map of Dahomey Basin, southwestern Nigeria, showing the location of the AJ well (Modified after Alege *et al.*, 2024)

### Geology of the Study Area

The Eastern Dahomey Basin, located along the Gulf of Guinea in southwestern Nigeria (Figure 1), is a significant sedimentary basin with a complex geological history. Its

evolution is closely linked to the opening of the South Atlantic during the Mesozoic era, leading to the deposition of a diverse sequence of sedimentary rocks (Alege *et al.*, 2014; Adamu *et al.*, 2018b; Njoku *et al.*, 2021;). The

development of the basin was influenced by rifting associated with the separation of the African and South American plates. This tectonic activity led to basement fragmentation, block faulting, and subsidence, creating accommodation space for sediment accumulation (Omatsola & Adegoke, 1981; Adamu *et al.*, 2018a; Saadu *et al.*, 2022; Alege & Joseph, 2024).

The stratigraphic framework of the basin comprises both the Cretaceous and Tertiary sediments. The Abeokuta Group represents the Cretaceous sequence, subdivided into three formations: the Ise Formation, unconformably overlying the basement complex. This formation comprises coarse conglomerates and sandstones, indicating fluvial depositional environments (Mosuro *et al.*, 2021). The Afowo Formation is characterized by transitional to marine sands and sandstones with interbedded shales and siltstones, suggesting a shift towards a more marine-influenced setting. The youngest of the Cretaceous Abeokuta group is the Araromi Formation, comprising shales and siltstones with interbeds of limestone and sands. This formation reflects deeper marine conditions during its deposition. The Tertiary sequence includes the Ewekoro, Akinbo, Oshosun, Ilaro, and Benin (Coastal Plain Sands) Formations, each representing various depositional environments ranging from shallow marine to continental settings (Njoku *et al.*, 2021; Oyeyemi *et al.*, 2021; Alege *et al.*, 2024).

The Ewekoro Formation is the oldest of the Tertiary formations of the Paleocene age. It is characterized by well-bedded, fossiliferous limestone, indicating deposition in a shallow marine environment. Overlying the Ewekoro Formation, the Akinbo Formation comprises flaggy, grey-to-black shales. It is from the Late Paleocene to the Early Eocene in age (Olabode & Mohammed, 2016). The Oshosun Formation (Eocene) overlies the Akinbo and is composed of flaggy shales similar to the Akinbo Formation. It is of Eocene age. Overlying the Oshosun is the Ilaro Formation, predominantly consisting of coarse, sandy estuarine and deltaic deposits; the Ilaro

Formation reflects a shift to more proximal depositional settings, with sediments indicative of higher energy environments. The Benin Formation, also known as the coastal plain sands, caps the stratigraphic sequence. It is characterised by coarse, unconsolidated sands with minor clay interbeds, representing continental depositional environments such as fluvial and deltaic systems. It ranges from Oligocene to Recent in age (Olabode & Adekoya, 2008)

### Materials and Methods of Study

Fifty-one (51) ditch-cutting samples from AJ well in the offshore Eastern Dahomey Basin were collected at 30-foot intervals to analyse for calcareous nannofossil assemblages. Each sample underwent meticulous cleaning to eliminate contaminants, followed by smear slide preparation using Brasier's standard techniques (1980). The slides were examined under a polarised-light microscope at a magnification of 400, employing cross-polarized (Alege & Joseph, 2025) and phase-contrast illumination to enhance the visibility of the nannofossil structures. Identifications were made to the species level, adhering to the established taxonomic framework of Paul (1990). A systematic scan of each slide was conducted to assess species diversity and abundance, recording the relative abundance of each species using a semi-quantitative scale. Detailed identification of forms (to species level where possible) is made of all taxa encountered in each slide. Eight traverses are studied in each slide. The cascading counting method (Styzen, 1997) was employed to determine the relative abundance and diversity of the assemblages.

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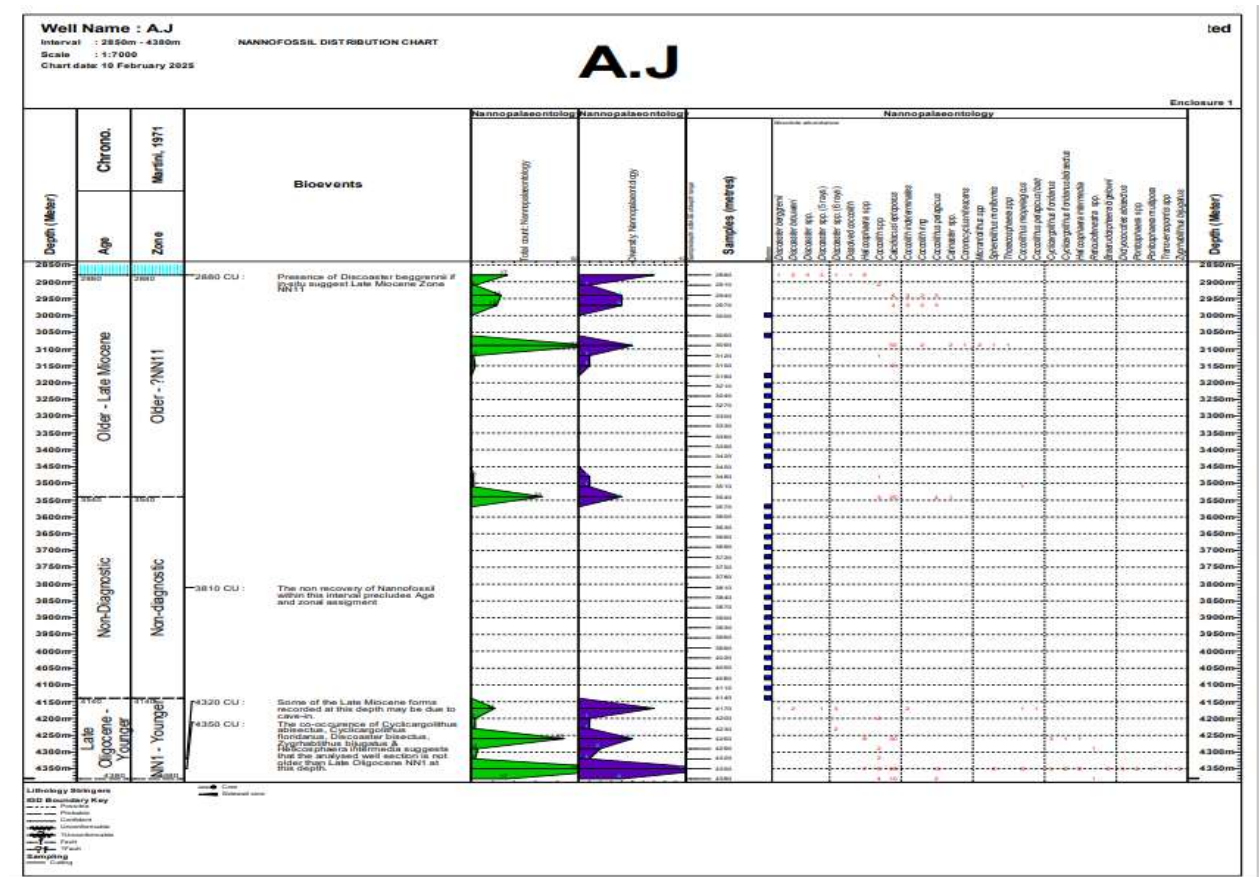
prepared for all samples using the Stratabug biostratigraphic software. The first and last occurrences of key nannofossil species were utilized to establish biostratigraphic zones, correlating them with standard zonation schemes of Martini (1971). Variations in species diversity and abundance provided insights into paleoenvironmental conditions, including sea-level changes, productivity, and water temperature.

## RESULTS AND DISCUSSION

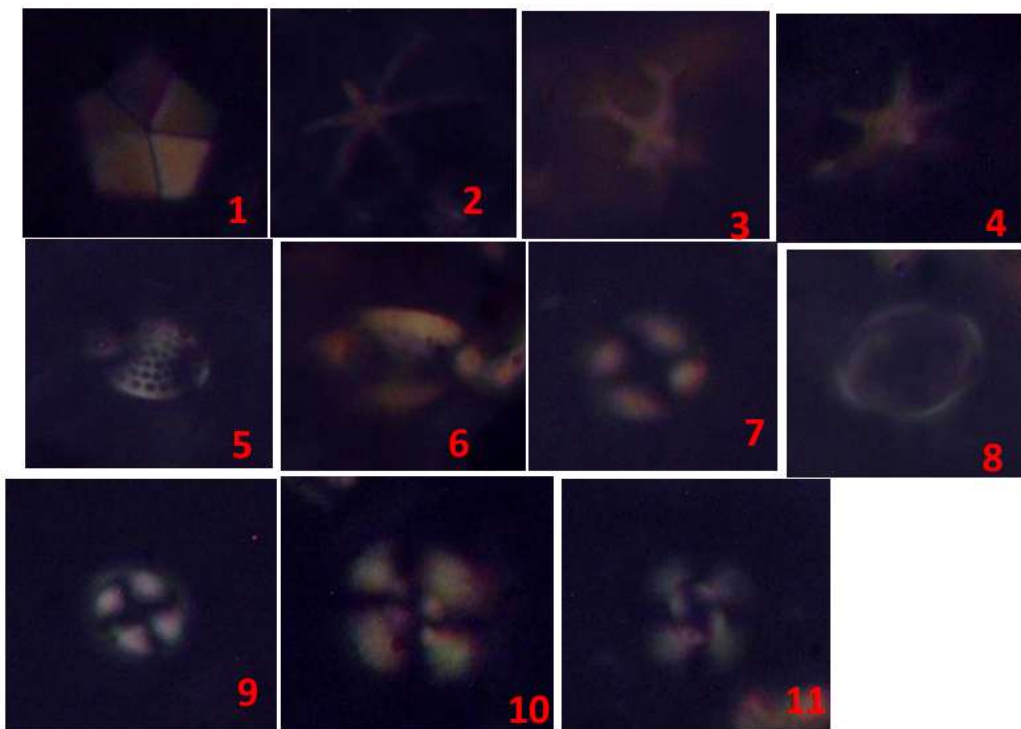
### Nannoplankton occurrence and distribution

Fifty-one ditch-cutting samples were analyzed from the AJ well across an interval of 2850m to 4380m at 30m intervals, focusing on calcareous nannoplankton. A total of twenty

(20) species of calcareous nannoplanktons were recorded (Fig. 2; Plate 1), namely *Discoaster bergrenii*, *Discoaster brouweri*, *Discoaster* spp. *Discoaster* spp. (5 rays), *Discoaster* spp. (6 rays), *Dissolved coccolith*, *Helicosphaera* spp., *Coccolith* spp. *Calcidiscus leptoporus*, *Coccolith indeterminates*, *Coccolith ring*, *Coccolithus pelagicus*, *Catinaster* spp., *Coronocylus nitescens*, *Micrantolithus* spp, *Sphenolithus moriformis*, *Thoracosphaera* spp, *Coccolithus miopelagicus*, *Coccolithus pelagicus* (bar) *Cyclicargolithus floridanus*, *Cyclicargolithus floridanus/abisectus*, *Helicosphaera intermedia*, *Reticulofenestra* spp., *Braarudosphaera bigelowii*, *Dictyococcites abisectus*, *Pontosphaera* spp. *Poritosphaera multipora*, *Transversoportis* spp., and *Zygrhablithus bijugatus*.



**Figure 2.** Nannoplankton distribution chart of AJ well showing their abundance and depths of occurrences



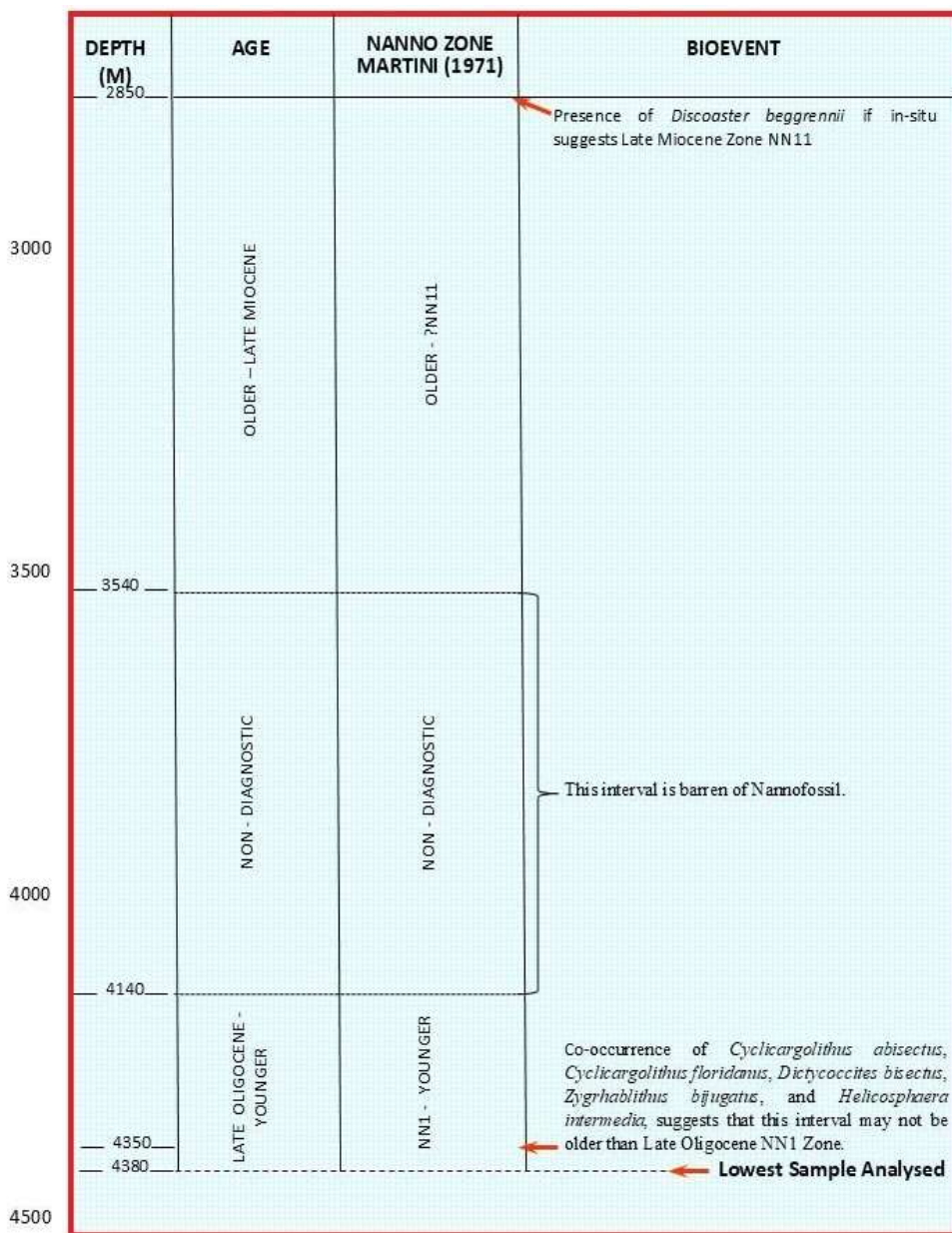
**Plate 1.** Photomicrographs of nannofossils for AJ well

1. *Braarudosphaera bigelowi* 2. *Discoaster brouweri* 3. *Discoaster prepentariatus*  
 4. *Discoaster* sp. (6 rays) 5. *Pontosphaera multipora* 6. *Pontosphaera discopora*  
 7. *Coccolithus miopelagicus* 8. *Coccolith Indeterminate* 9. *Coccolithus pelagicus*  
 10. *Cyclagelosphaera reinhardtii* 11. *Cyclicargolithus floridanus* (mag. X 400)

### Calcareous Nannoplankton Zonation

The calcareous nannofossil zones recognized in this study were based on the zonation scheme of Martini (1971) while the chronostratigraphic subdivisions were based on the revised Cenozoic Geochronologic and Chronostratigraphic scheme of Berggren *et al.*, (1995).

The analysis identified nannofossils in the upper (2850m – 3540m) and lower (4140m – 4380m) depth intervals, while the middle section (3540m – 4140m) was barren of calcareous nannoplankton (Figure 3). The presence of these nannofossils in the upper and lower depth intervals allowed for the delineation of zones according to the zonation scheme of Martini (1971).



**Figure 3.** Nannofossil biozonation chart of AJ well

**Stratigraphic Depth Interval: 2850 – 3540m**

**Nannoplankton Zone: ?NN11 & Older**

**Age: ?Late Miocene**

The presence of *Discoaster beggrenii* at 2880m depth marked the top of this zone and the base is tentatively placed at 3540m depth. This depth interval exhibited moderate occurrences of calcareous nannofossils, although some samples were barren. The nannofossils identified include *Cocolithus* spp., *Cocolithus pelagicus*, *Discoaster*

*berggrenii*, *Discoaster broweri*, *Discoaster* spp. (5 rays), *Helicosphaera carteri*, *Helicosphaera* spp., *Pontosphaera multipora*, *Reticulofenestra* spp., *Sphenolithus moriformis*, among others.

**Stratigraphic Depth Interval: 3570 – 4110m**

**Age: Non-diagnostic**

**Nannoplankton Zone: Non-diagnostic**

This depth interval was barren of nannofossils. The barren nature of this interval may be due

to the sandy lithology or an environment unsuitable for nannofossil preservation

**Stratigraphic Depth Interval: 4140 – 4380m**

**Age: NP24 or Younger**

**Nannoplankton Zone: Late Oligocene or Younger**

The base of the depth interval was marked by the co-occurrence of *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, *Zygrhablithus bijugatus*, and *Helicosphaera intermedia* at 4350m depth, with the interval tentatively extending down to 4380m, the deepest sample analyzed.

The co-occurrence of *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, *Zygrhablithus bijugatus*, and *Helicosphaera intermedia*, suggested that this interval belonged to the Late Oligocene NN1 Zone or possibly a younger period. The interval was characterized by high abundance and diversity of nannofossils. The peak abundance and diversity observed from 4140m to 4380m depth intervals may indicate a Maximum Flooding Surface (MFS) Condensed Section. However, the absence of age-diagnostic nannofossils prevented a precise age assignment for the MFS. The nannofossils recovered from this interval included *Brarudosphaera bigelowi*, *Calcidiscus leptoporus*, *Coccolithus miopelagicus*, *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Discoaster* spp., *Dictyococcites bisectus*, *Helicosphaera intermedia*, *Helicosphaera carteri*, *Reticulofenestra* spp., *Zygrhablithus bijugatus*, among others.

### Paleoenvironmental conditions

The presence and distribution of the recovered nanofossils assemblages in the AJ well have been used to reconstruct the paleoenvironmental conditions of the offshore eastern Dahomey Basin. At 2850m depth, the presence of *Discoaster berggrenii*, if in situ, along with *Discoaster broweri*, indicated a Late Miocene Zone NN11 in the upper interval of the AJ well (Adeigbe *et al.*, 2013). *Coccolithus pelagicus* also suggested periods

of reduced sea surface temperatures typically associated with cooler water conditions (Pratiwi & Sato, 2016).

The co-occurrence of *Sphenolithus piriformis* and *Discoaster* spp species, such as *Discoaster berggrenii* and *Discoaster Broweri*, indicated warm, oligotrophic (nutrient-poor) surface waters. Their abundance pointed to periods of elevated sea surface temperatures and stratified water columns. On the contrary, the presence of *Helicosphaera carteri* suggested environments with higher nutrient availability compared to those dominated by *Discoaster* species. Therefore, the co-occurrence of warm-water indicators (*Discoaster* spp. and *Sphenolithus moriformis*) with cooler water taxa (*Coccolithus pelagicus*) in AJ well suggested fluctuations in sea surface temperatures over time. The presence of *Helicosphaera carteri* pointed to intervals of increased nutrient availability, possibly due to upwelling or terrestrial input (Adeigbe *et al.*, 2013; Le Gouv   *et al.*, 2024).

The presence of *Cyclicargolithus abisectus* (Figure 2) found at the lower section (4140-4380m depth intervals) of the AJ well indicated the Late Eocene to Early Oligocene periods (Aturamu *et al.*, 2024). Its presence is often associated with cooler sea surface temperatures and increased nutrient availability, suggesting mesotrophic conditions during deposition. Studies have reported the occurrence of *C. abisectus* in association with other species indicative of eutrophic environments, reflecting a shift towards cooler and more nutrient-rich conditions during the Eocene-Oligocene transition (Oszczypko-Clowes & Żydek, 2012).

The presence of *C. floridanus* and *Dictyococcites bisectus* indicated temperate water conditions. Its abundance suggested stable, open marine environments with moderate nutrient levels, which infers mesotrophic conditions in temperate marine settings. The occurrence of *Z. bijugatus* was indicative of warm, stable marine environments with low nutrient levels. Its

association with warm, oligotrophic (nutrient-poor) surface waters suggested periods of elevated sea surface temperatures and stratified water columns (Raffi & Blackman, 2022).

In summary, the nannofossil assemblages from the AJ well reflect changes that indicated a marine setting that experienced fluctuations in sea surface temperatures and nutrient levels, with periods of stratified and mixed water column conditions from the Late Miocene to Early Oligocene.

## CONCLUSION

A total of fifty-one ditch-cutting samples from the AJ well, spanning the interval between 2850 m and 4380 m at 30 m sampling intervals, were analyzed for calcareous nannoplankton content. Biostratigraphic analysis identified two distinct zones—NP24 and younger, and NN11 and older—corresponding to an age range from the Late Oligocene to the Late Miocene.

The identified species, including *Coccolithus pelagicus*, *Discoaster berggrenii*, *Discoaster brouweri*, *Helicosphaera carteri*, *Pontosphaera multipora*, *Reticulofenestra* spp., *Sphenolithus moriformis*, *Cyclicargolithus abisectus*, *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, and *Zygrhablithus bijugatus*, serve as proxies for interpreting past marine conditions.

The nannofossil assemblage from the AJ well indicated a marine setting characterised by climate variability, shifts in nutrient levels, and changes in water column structure. This reflected an interplay of oceanographic and climatic factors influencing the depositional environment in the offshore Dahomey Basin during this geologic period.

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