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Probable record of Palaeocene–Eocene Thermal Maximum in Southwestern Nigeria: Indication from the Calcareous Nannofossils of Eastern Benin Basin

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ABSTRACT

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The Palaeocene–Eocene Thermal Maximum (PETM) interval has been reported in several calcareous nannofossil studies from Palaeogene basins globally including the Southern Tethys basins of North Africa. The Southern Tethys basins are believed to be connected to the Eastern Benin Basin through the Trans–Saharan Seaway during the Palaeogene. Based on these reports, the present study was carried out from 70 ditch cutting samples in the FA–2 borehole to investigate possible record of the PETM in the Eastern Benin Basin, Southwestern Nigeria. The samples yielded characteristic Palaeocene–Eocene calcareous nannofossils species (e.g. *Coccolithus pelagicus, Sphenolithus moriformis, Pontosphaera multipora, Transversopontis sigmoidalis, Towieus callosus, Discoaster prepentaradiatus, Discoaster deflandrei, Reticulofenestra* spp., *Micrantolithus encraster, Micrantolithus attenuatus, Lophodolithus nanscens, Neochiastozygus perfectus, Neococcolithes dubius, Cruciplacolithus tenuis, Fasculithus tympaniformis* and *Rhomboaster cuspis*) and the Maastrichtian species, *Arkhangeskiella cymbiformis, Micula decussata* and *Micula concava.* The CC 22 (Maastrichtian), NP 5–NP 6 (late Palaeocene) and NP10–NP11 nannofossil zones were identified from the above assemblages. The relatively abundant occurrences of the genus *Coccolithus* and *Sphenolithus* in the borehole section suggest prevailing oligotrophic, warm water condition. The barren interval succeeding the peak nannofossil abundance at sample 159 m correlates with Palaeocene–Eocene thermal maximum (PETM) interval and coincides with the onset of continuous clastic sedimentation in the Palaeogene sequences of the Eastern Benin Basin. This is believed to have resulted from the shoaling of the Calcite Compensation Depth (CCD) and increased clastic input occasioned by the climatic and ocean water perturbations of the PETM interval.

Key–words—Calcite compensation depth, Thermal Maximum, Oligotrophic, Borehole, Tethys.

INTRODUCTION

THE FA–2 Borehole is located in Mowe, within the eastern Benin Basin along Lagos–Ibadan Expressway, Southwestern Nigeria (06º45'41" N and 03º27'17" E) (Fig. 1). The Benin Basin which extends from Ghana through Togo, Republic of Benin to the Okitipupa Ridge in Southwestern Nigeria covers a sizeable portion of the West African Coast. The Benin Basin continues to attract geoscience research works since the past five decades. Research publications on the basin have centred on tectonic evolution, stratigraphy, geochemical evaluations, bitumen and hydrocarbon potential, palaeobiogeography, palaeoecology and biostratigraphy (Adegoke *et al*. 1971; Billman, 1976; Lehner & Ruiter, 1977; Adegoke *et al*., 1980; Omatsola & Adegoke, 1981; Adediran & Adegoke, 1987; Okosun, 1987; Nton, *et al*., 2009; Adekeye *et al*. 2019; Oluwajana *et al*. 2021, Adebambo *et al*., 2022, 2023).

The understanding of biostratigraphy and palaeoenvironmental settings is vital to mineral and oil and gas exploration within the basin. Nannofossils are excellent biostratigraphic and palaeoclimatic tools, providing standard biochronological framework and references for Mesozoic–Cenozoic high resolution biozonation and palaeoclimatic interpretations (Martini, 1971; Perch–Nielsen, 1985; Monechi *et al*., 2000; Bralower, 2002; Mutterlose *et al*., 2007; Chakraborty *et al*., 2021). Calcareous nannofossil studies have been applied to the understanding of certain Cenozoic climatic phenomena, water mass and trophic conditions (Wei & Wise, 1990; Tremolada & Bralower, 2004; Jiang & Wise, 2006; Chakraborty *et al*., 2021).

Calcareous nannofossils have particularly proven to be vital tool in the determination of the drastic global warming during the Palaeocene–Eocene (e.g. Jiang & Wise, 2006; Agnini *et al*. 2007; Mutterlose *et al*., 2007). This climatic perturbation widely known as the Palaeocene–Eocene thermal maximum (PETM) has been recognized in several Palaeogene formations in Southern Tethys basins of North Africa (e.g. Speijer *et al*., 1996; Tantawy, 2006; Morsi *et al*., 2011; Faris *et al*., 2015; Youssef *et al*., 2017;). The Southern Tethys basins are believed to be connected to West African coastal basins through the Trans–Saharan Seaway during the Palaeogene (Keen *et al*., 1994; Elewa, 2002, Speijer & Morsi, 2002). Premised on these studies, we carried out calcareous nannofossil analysis on sediment samples from the FA–2 borehole, Eastern Benin Basin (a West African coastal basin) to investigate the possible record of the PETM in Southwestern Nigeria.

Overview of the evolution, geologic setting and stratigraphy of the Eastern Benin Basin

The basin is one of the West African Coastal basins that evolved from the separation of the African and South American plates and the consequent opening of the Atlantic Ocean during the Mesozoic (Burke *et al*., 1971; Lehner & Ruiter, 1977; Whiteman, 1982; Adediran & Adegoke, 1987; Gebhardt *et al*., 2019). During the Cretaceous–Palaeogene, this basin served as a major site for sediment deposition.

Deposition commenced in an intracratonic setting with immature freshwater sandstone and shaly intercalations. This was followed by a syn–rift stage which resulted in erosion of preexisting deposits and consequent deposition of silt, sandstone and fluvio–lacustrine shales.

The incursion of marine waters into the basin during the Uppermost Cretaceous–Palaeogene times led to the deposition of richly fossiliferous sediments marking the end of the evolutionary development of the basin. The Benin Basin consists of thick sequences of sediments which Omatsola & Adegoke (1981) divided into two chronostratigraphic parts– The Cretaceous Abeokuta Group (comprising Ise, Afowo

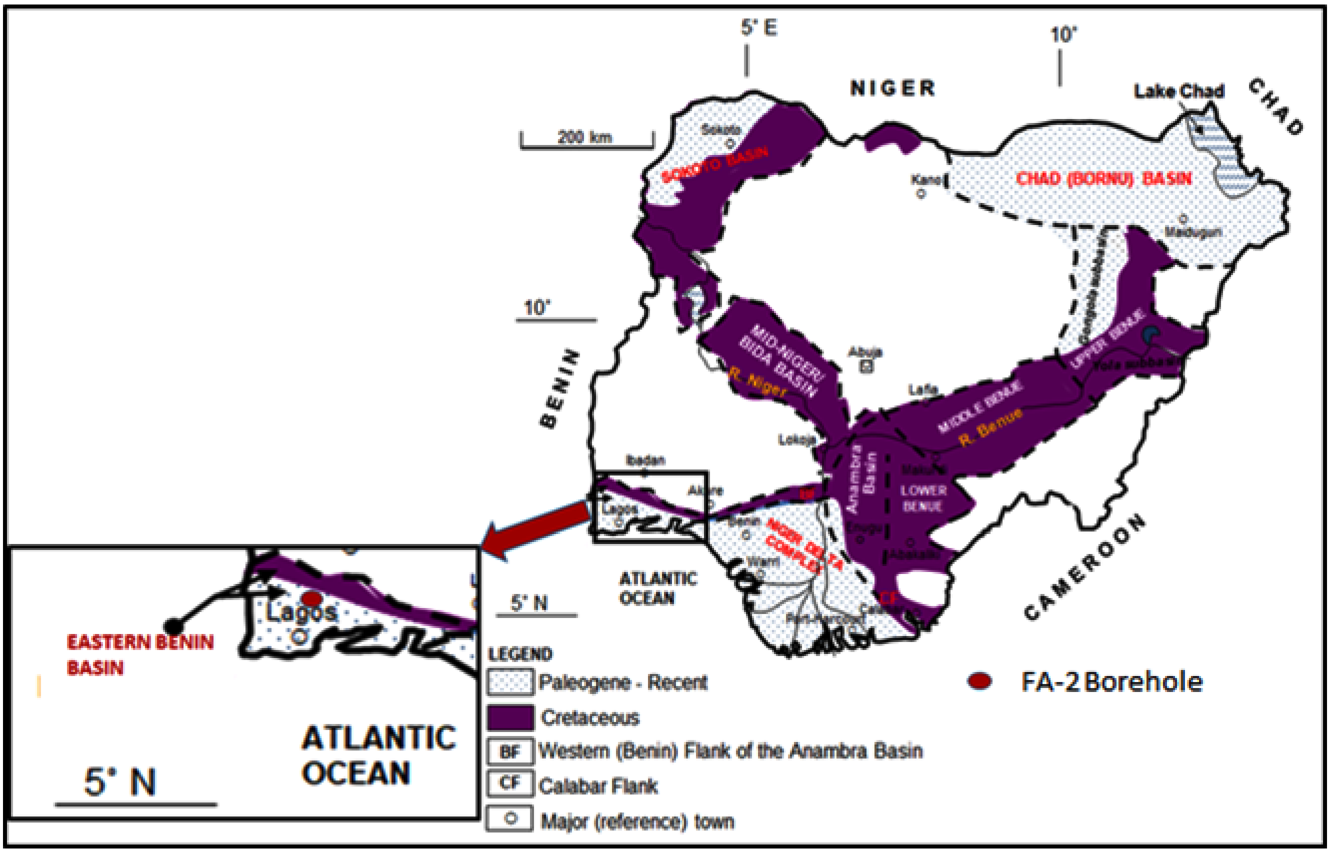

Fig. 1—Map of the sedimentary basins of Nigeria. Inset: Geologic Map of Eastern Benin Basin showing location of the FA–2 Borehole (Modified after Nwajide, 2013).

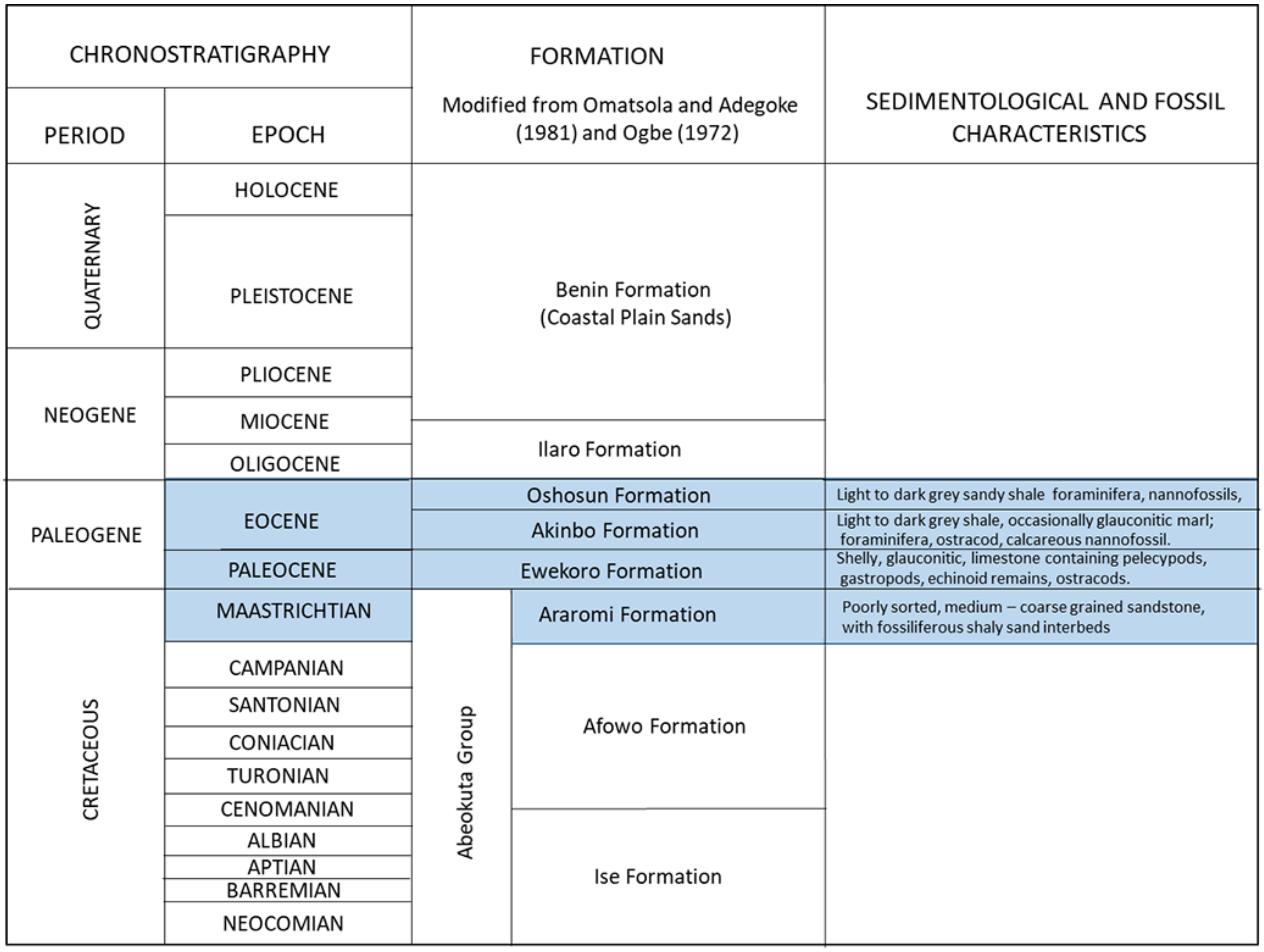

Fig. 2—The stratigraphic setting of the Eastern Benin Basin, modified from Ogbe (1972) and Omatsola & Adegoke (1981). The shaded portion (i.e., Upper Cretaceous–Palaeogene sequence) indicates the formations encountered in the FA–2 borehole.

and Araromi formations) and the Palaeogene–Neogene sediments (comprising the Ewekoro, Akinbo, Oshosun and Ilaro formations) (Fig. 2).

Lithostratigraphy of the Section penetrated by the FA–2 Borehole

The section is composed predominantly of shaly sand at the base followed by limestone which is the dominant lithology in the section. The limestone is overlain by fossiliferous dark shale which is in turn successively overlain by sandy shale at the top (Fig. 3).

Lower shaly sand unit: This unit is about 50 m thick sequence of poorly sorted, medium to coarse, angular grained sandstone with a basal shaly sandstone member. This unit is equivalent to the Araromi Formation of Omatsola & Adegoke (1981).

Limestone unit: Overlying the sand is a 108 m thick, occasionally glauconitic limestone unit with thin shale intercalation. This unit is also characterized by abundance of microfossils such as ostracods, foraminifera, gastropods, pelecypods and calcareous nannofossils. This unit belongs to the Ewekoro Formation (Adegoke *et al*., 1970).

Shale unit: Lying on the limestone is the shale unit consisting of sandy interbeds. The unit is about 66 m thick grades from greenish, light grey to dark grey colour down the borehole and contains abundant glauconitic and pyritized materials with rare carbonaceous detritus. The unit contains a few species of microfossils such as foraminifera, bivalves, ostracods, fish tooth, gastropod, pelecypods and diatom frustules. This unit is believed to be the Akinbo Formation of Ogbe (1972).

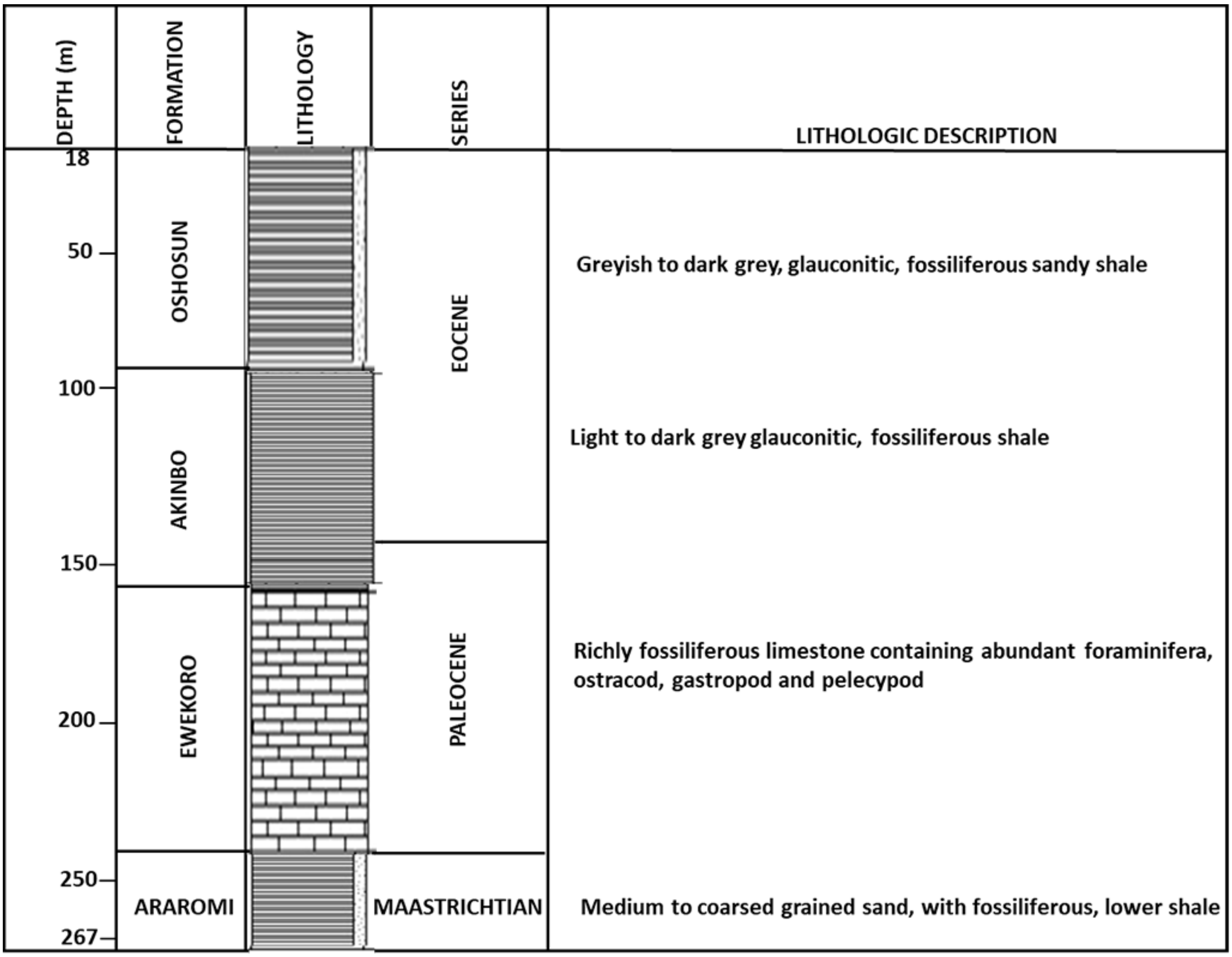

Fig. 3—Lithostratigraphic units of the analyzed section of FA–2 Borehole, Eastern Benin Basin.

mortality associated with the K–Pg boundary. A significant change in nannofossil assemblages at the K–Pg boundary was first reported by Bramlette and Martini (1964). Following this initial observation, the K–Pg boundary event has been reported in several places (Perch–Nielsen, 1981; Jiang & Gartner, 1986; Kasem *et al.*, 2017). Maastrichtian assemblages declined significantly and were replaced by new genera and species in the Palaeocene (Jiang & Gatner, 1986; Alcalá–Herrera *et al.*, 1992; Molina *et al.*, 2006). *Coccolithus pelagicus* occur in very low counts at the basal (Maastrichtian) section of the borehole. Above the interval 210–243 m, the species occur in relatively high abundances.

Coccolithus pelagicus having occurred very sporadically in the Maastrichtian began to blossom after the Cretaceous / Palaeogene biotic mortality (Kasem *et al.*, 2017).

Age: Probable Maastrichtian–early Palaeocene (K–Pg transition).

Nannofossil Zone III: NP5–NP6

Description: The top of the interval is marked by the last occurrence of (LO) *Neochiastozygus perfectus* at 156 m, while the base is placed at the first occurrence (FO) of *Fasciculithus typaniformis* and nannofossil taxa resurgence at 186 m.

Interval: 156–186 m

Assemblage: The nannofossil assemblage within this interval is fairly abundant and diverse comprising typical early to late Palaeocene species; *Transversopontis rectipons*, *Placozygus sigmoides*, *Fasciculithus tympaniformis, Fasciculithus thomasii, Zygodiscus herlynii, Neochiastozygus perfectus, Sphenolithus moriformis, Cruciplacolithus tenuis, Cruciplacolithus frequens,* and *Coccolithus formosus.*

Remark: Species such as *Coccolithus pelagicus*, *Neochiastozygus perfectus*, *Sphenolithus moriformis, Zygodiscus plectopons, Zygodiscus herlynii, Fasciculithus thomasii, Placozygus sigmoides, Cruciplacolithus frequens*

Sandy shale unit: Overlying the shale unit is the greyish, glauconitic, fossiliferous sandy shale referred to as the Oshosun Formation (Adegoke *et al*., 1970).

MATERIALS AND METHOD

Materials for this study are ditch cutting sediment samples from FA–2 borehole located at Mowe, Kilometer 47, Lagos–Ibadan Expressway in the Eastern Benin Basin, Southwestern Nigeria. A total of seventy (70) samples within the interval 18–267 m of the borehole were prepared and analyzed for calcareous nannofossils at approximately 3 m sampling interval.

Samples were processed for nannofossil analysis using the standard smear–slide preparation technique of Bown and Young (1998). About 5 grams of each sample was gently crushed using mortar and pestle. The crushed sample was gently dispersed in distilled water inside a glass vial. A small portion of the suspension was pipetted unto a cover slip (22 x 32 mm), it is later dried at 50º C and mounted on a glass slide with the aid of the Norland adhesive 61 (NOA61) mounting medium. The slides are then cured under ultraviolet light. The prepared slides were examined for nannofossils under cross–polarized and transmitted light with the aid of an Olympus binocular microscope (XZX–INLB2–200) at magnification x 1000.

Species identifications were made in eight traverses across each of the slides and specimens compared with published figures in Perch–Nielsen (1985) and Young (1998). Species counts were recorded and presented in Stratabug 2.0 chart. Photomicrographs of identified calcareous nannofossil taxa were taken with the aid of a DP 12 Olympus camera–adapted transmitted light microscope, and slides are reposited in the Micropalaeontology Laboratory Repository of the Department of Geology, Obafemi Awolowo University, Ile–Ife, Nigeria.

RESULTS

Calcareous Nannofossil Distribution

Five hundred and thirty nine (539) counts of nannofossil belonging to 57 species and 18 genera of calcareous nannofossil were recorded from the FA–2 borehole (Fig. 4). Photomicrographs of the species are shown in Fig. 6. Nannofossils were recovered chiefly from intervals 18–93 m, 147–210 m and 240–267 m, while intervals 96–144 m and 213–237 m are either impoverished or completely barren of calcareous nannofossils (Figs 4 and 5).

The genera *Coccolithus*, *Pontosphaera, Transversopontis* and *Sphenolithus* are the most abundant (Fig. 5) while *Zygodiscus*, *Discoaster*, *Neochiastozygus*, *Lophodolithus, Cyclagelosphaera, Eiffellithus* and *Arkhangeskiella* occurs in subordinate proportions. Also, the genera *Discoaster*, *Transversoponites*, *Toweius*, are restricted to the upper section (early Eocene) of the borehole section. *Micrantolithus* and *Discoaster* began to occur around the Palaeocene–Eocene (P/E) boundary and appear to dominate this interval. Notable Maastrichtian genera, *Arkhangeskiella, Micula* and *Eiffellithus* occur in moderate to low abundance within the basal section. Most genera are fairly represented except *Eiffellithus, Placozygus, Helicosphaera, Reticulofenestra* which are represented by one or two species. The assemblages of the late Palaeocene interval are more diversified than those of the early Eocene. Monechi *et al*. (2000) observed similar distribution pattern in Almedilla, Southern Spain. *Rhomboaster* occurs only at the P / E.

DISCUSSION

Biostratigraphy

The borehole section yielded fairly diverse and moderately abundant calcareous nannofossil assemblages which include characteristic Maastrichtian / Palaeogene diagnostic taxa such as *Cruciplacolithus tenuis*, *Cruciplacolithus primus*, *Lophodolithus nascens*, *Neochiastozygus perfectus*, *Neococcolithes protenus, Micula concava* and *Arkhangeskiella cymbiformis.* These assemblages facilitated nannofossil zonal delineation and recognition of dated events based on the zonation schemes of Martini (1971) and Sissingh (1977). Five biostratigraphic interval (Fig. 7) were delineated as follows:

Nannofossil Zone I: CC22 and possibly older

Description: The CC 22 zone was delineated within the basal shaly sand. The top of the interval is placed at 243 m based on the last occurrence (LO) of *Arkhangeskiella cymbiformis* and abrupt termination of Maastrichtian species.

Interval: 243–267 m

Assemblage: The assemblage within this interval include, *Akhangelskiella cymbiformis, Micula concava, Micula decussata, Eiffelithus turriseiffelii* and *Cyclagelosphaera reinhardtii.*

Age: Maastrichtian

Nannofossil Zone II: Indeterminate

Description: The top is marked by the first occurrence of *Fasciculithus tympaniformis* and nannofossil taxa resurgence at 186 m. The base was delineated based on the last occurrence of *Arkhangelskiella cymbiformis* and abrupt termination of species at 243 m.

Interval: 186–243 m

Assemblage: Rare occurrence of the long ranging species, *Coccolithus pelagicus* was recorded within this interval.

Remark: This over 60 m of almost barren interval is believed to be related to the widely reported biotic mass

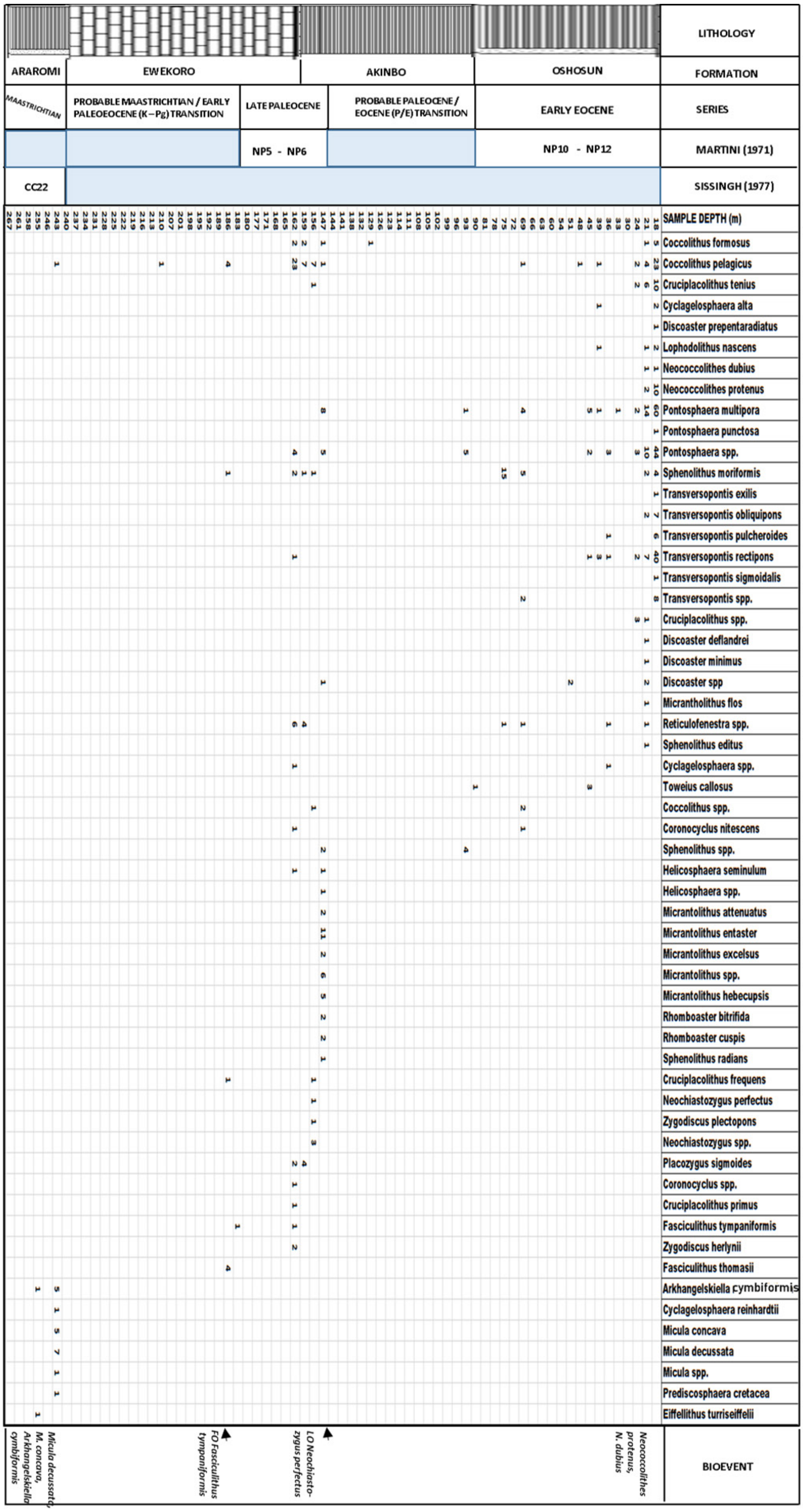

Fig. 4—Calcareous nannofossil zonation, distribution, species abundance and diversity in the FA–2 borehole, Eastern Benin Basin.

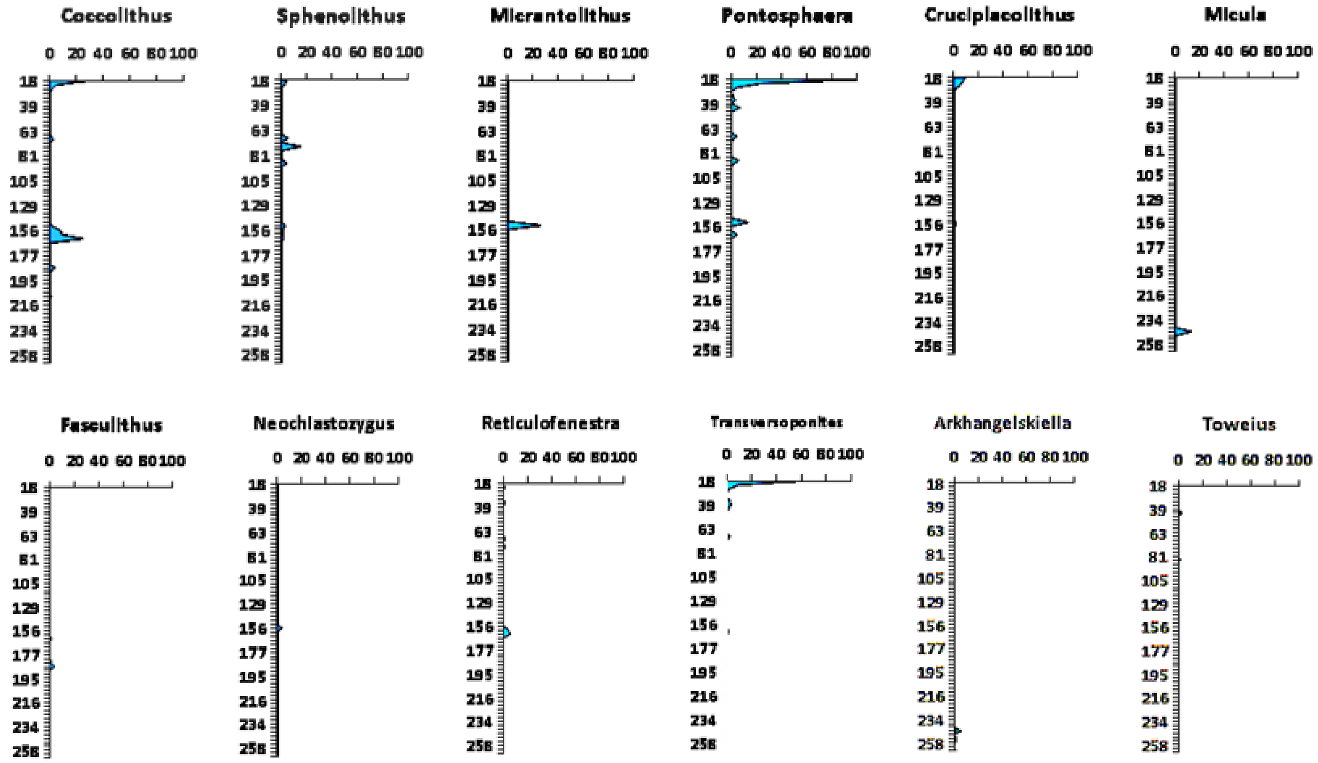

Fig. 5—Graphical representation of the abundances of some calcareous nannofossil genera in the FA–2 borehole, Eastern Benin Basin.

and *Reticulofenestra* spp. appear for the first time within this interval of FA–2 borehole. The Palaeocene / Eocene (P/E) boundary is placed at 156 m based on the last occurrence of *Neochiastozygus perfectus*. This boundary placement is also supported by the *Coccolithus pelagicus* acme at this horizon. Monechi *et al.* (2000) suggested the placement of the P/E boundary interval at *Coccolithus pelagicus* acme in sections where the established boundary markers were not recovered. *Coccolithus pelagicus* was a principal component of nannoplankton communities in low latitudes during the late Palaeocene (Haq & Lohmann, 1976). The Palaeocene boundary in the FA–2 borehole is further evidenced by the marked nannofossil assemblage turnover at 147 m. The Palaeocene / Eocene transition is characterized by faunal and nannofossil assemblage turnover (Speijer *et al*., 1996; Monechi *et al*., 2000; Morsi & Speijer, 2003; Mutterlose *et al*., 2007; Adebambo *et al*., 2022).

Age: Late Palaeocene.

Nannofossil Zone IV: Indeterminate

Description: The top of this interval is marked by nannofossil resurgence at 69 m, while the base is marked by the last occurrence of *Neochiastozygus perfectus* at 156 m.

Interval: 69–156 m

Assemblage: The interval is near barren of nannofossil, with only one (1) count of *Coccolithus formosus* recorded within the interval.

Remark: The approximately 63 meters of near barren interval is related to the calcareous nannofossil and faunal assemblage turnover associated with the Palaeocene–Eocene transition event (Zachos *et al*., 1993; Speijer *et al*., 1996; Monechi *et al*., 2000; Morsi & Speijer, 2003; Mutterlose *et al*., 2007; Adebambo *et al*., 2022.

Age: Probable Palaeocene / Eocene (P / E) Transition.

Nannofossil Zone V: NP10–NP12

Description: The top of this interval is tentatively placed at 18 m, the topmost sample analysed for the FA–2 borehole. The base is marked by the nannofossil resurgence at 69 m.

Interval: 18–69 m

Assemblage: Typical NP10–NP12 early Eocene nannofossil species including *Neococcolithes dubius, Neococcolithes protenus, Coccolithus formosus, Cruciplacolithus tenuis, Lophodolithus nascens, Sphenolithus editus* and *Toweius callosus* occur within this interval.

Remark: The interval especially within 18–51 m show abundant and diverse assemblage of nannofossils. This early

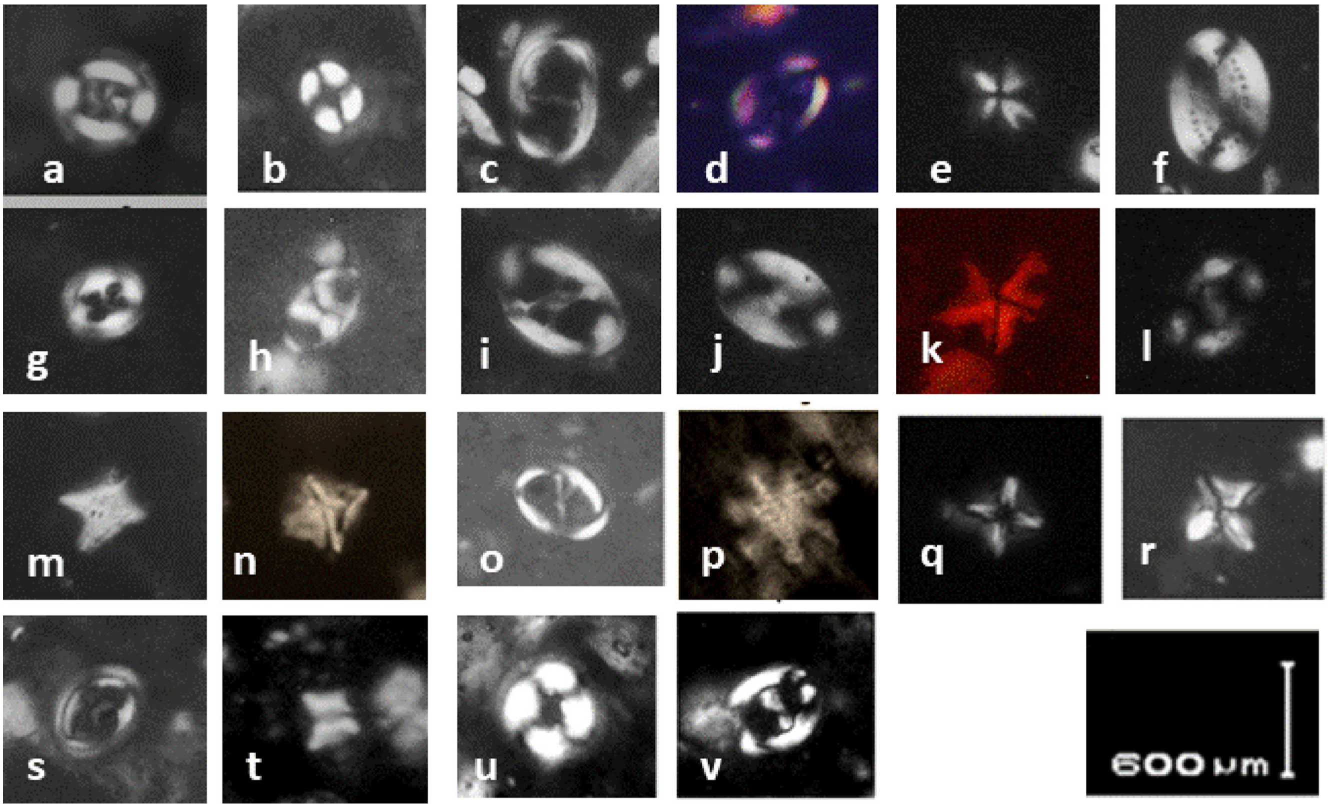

Fig. 6—Photomicrographs of some calcareous nannofossils recovered in the FA–2 Borehole, Eastern Benin Basin. (a) *Cruciplacolithus tenuis* (b) *Coccolithus pelagicus* (c) *Lophodolithus nascens* (d) *Arkhangelskiella cymbiformis* (e) *Sphenolithus moriformis* (f) *Pontosphaera multipora* (g) *Toweius eminens* (h) *Neococcolithus dubius* (i) *Neochiastozygus perfectus* (j) *Tranversopontis rectipons* (k) *Micratholithus hebecupsis* (l) *Zygodiscus plectopons* (m) *Rhomboaster bitrifida* (n) *Rhomboaster cupsis* (o) *Cruciplacolithus primus* (p) *Discoaster minimus* (q) *Micula decussata* (r) *Micula concava* (s) *Neococcolithes protenus* (t) *Fasculithus tympaniformis* (u) *Coccolithus formosus* (v) *Helicosphaera seminulum.*

Eocene section recorded a resurgence in assemblages and the emergence of new taxa after the P / E transition.

Age: Early Eocene.

PALAEOCLIMATIC INTERPRETATION

Calcareous nannofossils are excellent proxies for understanding the palaeoclimatic condition of Palaeogene sequences (Tantawy 2006; Mutterlose *et al.* 2007; Agnini, *et al.*, 2007; Faris, *et al*. 2015; Saxena *et al.*, 2022). Changes in assemblage abundances reflect a response to palaeoecological disturbances (Tremolada & Bralower, 2004). Based on oxygen isotope data and palaeobiogeography of planktic organisms, Haq (1981) noted that a global warming episode prevailed during the Palaeocene–Eocene transition. Oceanic and atmospheric carbon isotope composition declined marginally concomitant with the global temperature rise, suggesting dramatic changes in the global carbon cycle (Kennett & Stott, 1991; Bains *et al*., 1999).

The Palaeocene–Eocene warming episode widely referred to as Palaeocene Eocene Thermal Maximum (PETM) caused abrupt global changes in biotic assemblage compositions (Kelly *et al*., 1996; Speijer & Morsi, 2002; Adebambo *et al.*, 2023). Planktic and meiobenthic communities suffered catastrophic extinction in response to major changes in global oceanic circulation occasioned by the sudden climatic change (Zachos *et al*., 1993; Thomas & Shackleton, 1996; Monechi *et al*., 2000; Adebambo *et al*., 2022).

Surface water, trophic and palaeotemperature conditions of Palaeogene basins have been interpreted based on calcareous nannofossil assemblages (Zachos *et al*., 1989; Wei & Wise, 1990; Aubry, 1998; Monechi *et al*., 2000; Bralower, 2002; Tantawy, 2006; Mutterlose *et al*., 2007).

The calcareous nannofossil assemblages and distribution in the studied section of FA–2 borehole, suggest certain

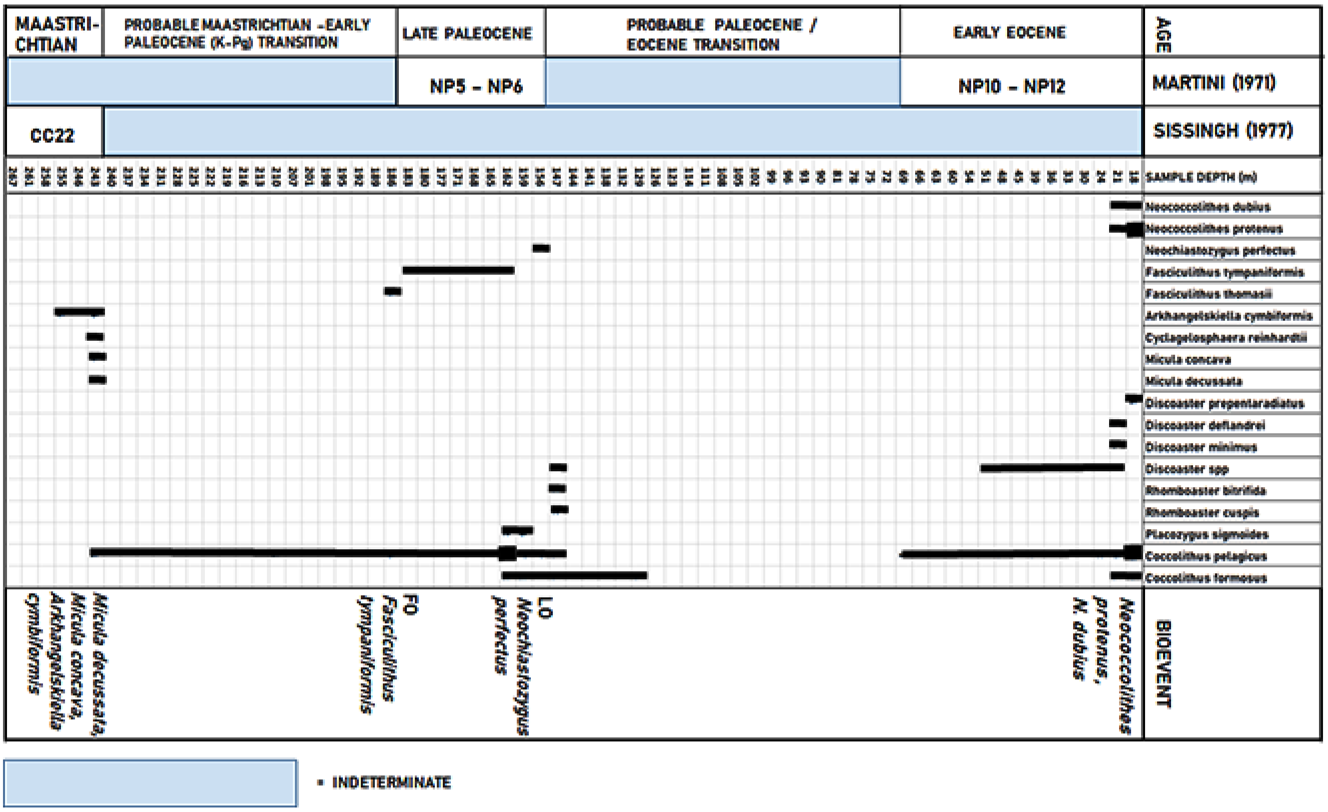

Fig. 7—Stratigraphic distribution of some marker species of the FA–2 borehole.

palaeoclimatic and palaeotrophic conditions of the eastern Benin Basin.

In the FA–2 borehole, peak abundance counts of 23 was recorded for *Coccolithus pelagicus* at 159 m indicating warm water condition. *Coccolithus* has been interpreted to be adapted to warm water condition (Wei & Wise 1990; Kelly *et al*. 1996; Mutterlose *et al*., 2007; Chakraborty *et al*., 2021) and oligotrophic environments (Kahn & Aubry, 2004; Mutterlose *et al*., 2007; Chakraborty *et al*., 2021). *Rhomboaster* and *Discoaster* emerged at 144 m (P / E interval). Mutterlose *et al*. (2007) noted that the onset of PETM in equatorial Atlantic is marked by the emergency of *Discoaster* and *Rhomboaster* and regarded species of these genera as excursion taxa. The *Rhomboaster–Discoaster* spp. excursion nannofossil exhibit remarkable provincialism confined to an equatorial belt in the Atlantic Ocean, Tethys Sea and Pacific Ocean.

The occurrence of *Sphenolithus, Coccolithus*, *Neococcolithes* and *Neochiastozygus* in the FA–2 section suggests oligotrophic to mesotrophic warm waters (Bralower, 2002). Taxa characteristics of cool, mesotrophic conditions (e. g. *Chiasmolithus*) are rare in the section. *Sphenolithus* was also thought to be a k–mode specialist that thrive in warm, oligotrophic waters (Bralower, 2002).

The high abundance of *Coccolithus pelagicus* (23 counts) at 159 m could be an indication of increased productivity associated with upwelling condition. Increased *Coccolithus pelagicus* abundance has been attributed to upwelling off the Coast of Portugal (Monechi *et al*., 2000).

A nannofossil assemblage turnover is recognized between 93 and 159 m in the studied borehole section. Similar assemblage turnover have been reported from several Palaeocene–Eocene localities globally, e.g. West Central Sinai in Egypt (Faris *et al*., 2015), Central Nile Valley, Egypt (Tantawy, 2006), Alamedilla, Southern Spain (Monechi *et al*., 2000) and New Jersey, United States (Bybell & Self–Trail, 1997) and ascribed to the global warming episode, the Palaeocene–Eocene Thermal Maximum. During the PETM, average global temperature rose by 8°C ((Kenneth & Stott, 1991; Bains *et al*., 1999). Foraminifera and ostracod faunal turnover believed to be associated with the PETM have also being reported in the Eastern Benin Basin, Southwestern Nigeria (Adebambo *et al*., 2022, 2023). Species abundance show a significant decreasing pattern from late Palaeocene to early Eocene interval of the studied section as a result of species extinctions. The P / E transition is characterized by extinction of nannofossil taxa (Monechi *et al*., 2000).

The clastic (shale) section above the fairly fossiliferous limestone interval shows rare to barren nannofossil record. This is related to the increased precipitation and run–off from adjacent coastland occasioned by the warm, late Palaeocene climate. The warm climate climaxed during the Palaeocene Eocene Thermal Maximum. Sediments of many PETM sections are depleted in calcium carbonate (Mutterlose *et al.*, 2007) indicating a shoaling of the carbonate compensation depth (CCD) (Zachos *et al*., 2005). Katz *et al*. (1999) reported a prominent decrease in the global ^{13}C / ^{12}C ratio during the PETM (55 Ma) and attributed it to massive release of methane due to dissociation of gas hydrates. There was severe deep sea carbonate dissolution leading to the shoaling of the CCD (Dickens *et al.*, 1995) and a rise in ocean water temperature (Kenneth & Stott, 1991) as a result of the oxidation of methane to CO_2. This acidification and shoaling may be evidenced in the FA–2 section by the emergence of malformed genera such as *Discoaster* and *Rhomboaster* and the disappearance of deep dwelling taxa such as *Fasculithus* (Mutterlose *et al*., 2007) and solution susceptible forms such as *Placozygus sigmoides* (Monechi *et al*., 2000) at 162 m. Surface water acidification occasioned by high CO_2 concentration encourages the development of malformed taxa ((Riebesell *et al*., 2000). *Discoaster* is a k–mode specialist showing preference for warm, oligotrophic waters (Tremolada & Bralower, 2004). Species of *Discoaster* occur in low abundance in the FA–2 section. The taxa (*Discoaster* spp.) are generally sparsely distributed in tropical latitudes in the Palaeogene and appear to show preference for mid–latitude deep water settings (Wei & Wise, 1990).

The PETM interval is a period characterized by warm climate which is expected to favour carbonate deposition due to high surface water carbonate concentration (Broecker & Peng, 1984). However, the period is also believed to be characterized by massive carbon dioxide (CO_2) discharge into the atmosphere causing ocean surface water to be relatively acidic. The relatively acidic waters would significantly prohibit carbonate saturation in spite of the heightened temperature, leading to the shoaling of the CCD (Zachos *et al*., 2005). The CCD rose by >2 km in the South Atlantic (Zachos *et al*., 2005). This event is associated with mass mortality and marked turnover of calcareous nannoplankton assemblages (Bybell & Self–Trail, 1995; Aubry, 1998). This late Palaeocene–early Eocene ocean acidification and reorganization may also be a factor for nannofossil assemblage turnover in the Eastern Benin Basin as indicated by assemblages recovered from FA–2 borehole.

CONCLUSION

The calcareous nannofossil assemblages and distribution within the FA–2 borehole suggest a late Palaeocene warm, tropical climate and palpable evidence of the Palaeocene Eocene Thermal Maximum interval in the Eastern Benin Basin, Southwestern Nigeria. The interval is indicated by a nannofossil assemblage turnover within interval (93–59 m).

The relatively abundant occurrences of the genera *Coccolithus* and *Sphenolithus* suggest a prevalent warm tropical climate and oligotrophic water condition in the basin. The commencement of clastic (shale) deposition in the studied section may be related to the prevailing warm, humid climate of the late Palaeocene and the PETM. The ocean water acidification leading to carbonate dissolution and shoaling of the CCD during the Palaeocene–Eocene (P/E) transition may also be factor for the paucity of nannofossils during this interval. The PETM is characterised by increased clastic sediment input and reduced carbonate accumulation. Ordinarily, the warmer climate of the PETM is expected to favour carbonate deposition. Nonetheless, ocean water acidification during the P/E transition precluded carbonate accumulation in spite of the heightened global temperature that characterised this period. This climatic and ocean water reorganisation would rather favour clastic sedimentation.

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