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TAXONOMIC NOTES ON SELECTED LATE PALEOCENE TO EARLY EOCENE FORAMINIFERA FROM EASTERN BENIN BASIN, SOUTHWESTERN NIGERIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author EAO designed the study, wrote the protocol and interpreted the data. Author WGA compiled the photomicrographs of relevant foraminiferal species and the charts. Authors USO and YBA managed the literature searches and produced the initial draft. Author SOO anchored the systematic paleontology for the species while the wall textures were described by author EAO. All authors read and approved the final manuscript.

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ABSTRACT

The taxonomy and morphological features of selected Late Paleocene to Early Eocene foraminifera from southwestern Nigeria (eastern Dahomey basin) have been studied from boreholes and outcrops. Fourteen benthic and planktic species were identified while two were placed in open nomenclature. The described and illustrated features include costae, anastomosing costae, smooth, fine and coarse granular textures, apertures, pores, pustules and pseudospines. In the planktic foraminifera, normal perforate cancellate and pseudospinose wall texture was identified in *Subbotina* cf. *triloculinoides*, *Acarinina pseudotopilensis, A. tribulosa, A*. aff. *Pentacamerata* while *Morozovella aequa* has a strong pustulose (muricate) wall texture. The benthic foraminifera *Lagena* cf. *L. shoponnai* and *Nonionoyae* display fine granular and coarse surface topography respectively. The described and illustrated features will be useful in the taxonomy of the species.

Keywords: Foraminifera; Eastern Benin; paleocene –eocene; benthic; planktic; SW Nigeria.

1. INTRODUCTION

The Paleogene strata form an arcuate pattern in the Benin basin (previously known as the Dahomey Embayment) which extends from Lome in Togo through Benin Republic to southwestern Nigeria (Fig. 1). Southwestern Nigeria basin represents the eastern part of the Benin basin. Several workers have studied the geology and biostratigraphy of the Paleogene sequences in southwestern Nigeria [1-17]. Haynes and Nwabufor-Ene [14] described and illustrated some foraminifera from the Paleocene of southwestern Nigeria. The morphological characteristics of some of the species have been updated in the current study. Okosun [18] reviewed the early Tertiary stratigraphy of the basin (Table 1)

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while Okosun and Alkali [17] studied the Late Paleocene-Early Eocene foraminiferal biostratigraphy of the basin and identified six planktic and two benthic foraminiferal zones. Researchers have also investigated the systematic of Paleocene trochospiral planktic foraminifera [19]. The objective of this study is to undertake a morphological and taxonomic study of selected Paleogene foraminifera from southwestern Nigeria basin. The morphological features described for the species will enable their easy identification and usage in biozonation, stratigraphic correlation and biochronology in the coastal and central West African basins.

2. MATERIALS AND METHODS

Sixty samples were collected for the study from four Geological Survey of Nigeria (GSN) boreholes: Araromi – 1(GSN 1131), Gbekebo– 1 (GSN 1132), Akinside – 1 (GSN 1582), GSN BH 4925 and a phosphate exploration pit at Ifo. The samples were collected at 2 – 3 meters intervals from the boreholes.

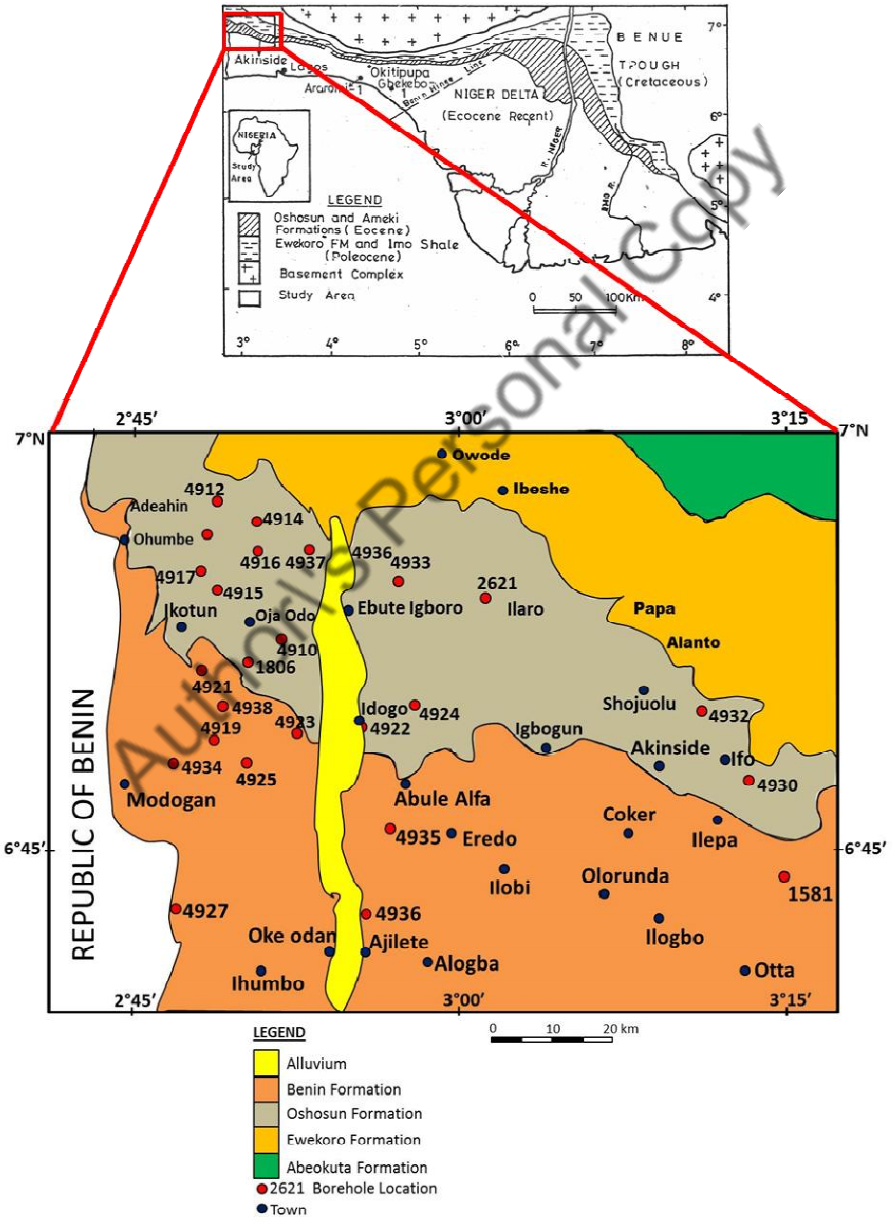

Fig. 1. Simplified geological map of Southwestern Nigeria (Eastern Benin Basin) showing borehole locations

Table 1. Tertiary stratigraphy of Southwestern Nigeria [18]

Age	Inland	Coastal
Post Eocene to recent	Benin Fm	Benin Fm
Eocene	Oshosun Fm	Oshosun Fm
	Imo Shale	Imo Shale
Paleocene	Ewekoro Fm	Araromi Fm
	Imo Shale	

Fm = Formation

The samples were disaggregated in a solution of 10% H_2O_2 overnight and boiled in water with a pinch of soda ash. They were then washed through a 63 µm sieve. The washing procedure was repeated until foraminifera with clean surfaces were obtained.

All the foraminifera recovered from the residue were counted and studied using a reflected light Olympus microscope. Further details of the morphological features including wall surface topography to unravel the wall texture were carried out with a scanning electron microscope (SEM). Generic classification was based on Loeblich and Tappan [20], Olsson et al. [21] and other relevant foraminiferal literature. The species identification was based mainly on Toumarkine and Luterbacher [22].

3. BIOSTRATIGARAPHY

The sixteen (16) foraminiferal species were recovered from four boreholes: Araromi – 1 (GSN 1131), BH 4925 (GSN 4925), Akinside – 1 (GSN 1582), Gbekebo – 1 (GSN 1132) borehole and a shallow phosphate exploration pit at Ifo town (Fig. 1). The foraminiferal distribution charts of three of the boreholes are shown in Figs. 2 to 4 below. The data on planktic and benthic foraminiferal zones and ages of the boreholes have been provided in an earlier paper by two of the present authors [17].

4. SYSTEMATIC PALEONTOLOGY

4.1 Planktic Foraminifera

Order GLOBIGERINIDA
Superfamily GLOBIGERINACEA Carpenter, Parker & Jones [23].
Family GLOBOROTALIDAE Cushman, 1927

Genus *Acarinina* Subbotina, 1954
Acarinina tribulosa Loeblich and Tappan
Pl. 1b, Figs. 14 – 17

1957 *Globorotalia tribulosa* Loeblich and Tappan, p. 195, pl. 56, figs. 3a – c, 7a – c.
1970 *Globorotalia tribulosa* Loeblich and Tappan, Fayose, p. 68/ pl. 15, Fig. 3.
1983 *Acarinina tribulosa* (Loeblich & Tappan), Petters, p. 30, pl. 4, Fig. 2.
1987 *Globorotalia (Acarinina) tribulosa* Loeblich & Tappan, Haynes and Nwabufo-Ene, p. 4, pl.1, Figs. 1 – 3.

Occurrence and Stratigraphic Range: Common in the Paleocene to early Eocene strata of southwestern Nigeria, it was found at 30 m, 40 m, 50 m and 70 m in Borehole No 4925. The species has a late Paleocene-early Eocene age in Africa, N.W. Europe, and Gulf Coast of U.S.A.

Morphological Note: The species ornament is coarsely perforate, strongly pustulose and cancellate (pl. 1, Figs. 16, 17).

Acarinina pseudotopilensis Subbotina
Pl. 1a, Figs. 6 – 10**.**
1953 *Acarinina pseudotopilensis* Subbotina, p. 227, Figs. 8, 9, pl. 22, Figs. 1 – 3.
1971 *Truncorotaloides pseudotopilensis* Subbotina, Jenkins, p. 135, pl. 13, Figs. 382 – 387.
1975 *Globorotalia pseudotopilensis* Subbotina, Stainforth et al., p. 217, Fig. 78.
1987 *Globorotalia (Acarinina) pseudotopilensis* Subbotina, Haynes and Nwabufo-Ene, p. 5, pl.1, Figs. 4-6.

Occurrence and Stratigraphic Range**:** Scanty in Borehole 4925 at 40 m, 60 m and 70 m. also present in Araromi– 1 (GSN 1131) at 295 – 296 m and 336 341 m in Akinside -1 (GSN 1582) at 66 – 73 m [17]. The species has a Late Paleocene to Early Eocene range globally.

Morphological Note**:** Species has four inflated chambers in the last whorl, spiral side slightly elevated, planoconvex in edge view, ventral margins rounded to anguloconical. Wall is normal perforate, nonspinose, densely muricate with blunt triangular muricae. The ventral side is broad with a deeper umbilicus and highly arched aperture when compared to the designated types for the species. The ornament is coarsely perforate, strongly pustulate and cancellate (pl. 1, Fig. 9).

Acarinina aff. *pentacamerata* Subbotina
Pl. 1b, Figs. 18 – 22.

1947 *Globorotalia pentacamerata* Subbotina p. 128, pl. 9, Figs. 24 – 26.
1981 *Acarinina pentacamerata sensu* (Subbotina) Petters, p. 225, pl. 17.2, Fig. 16.

1987 *Globorotalia (Acarinina) pentacamerata* Subbotina, Haynes and Nwabufo-Ene, p. 4, pl. 1, Figs. 7 – 8.

2012 *Acarinina pentacamerata* Subbotina, Okosun and Alkali, p. 7, 8, pl. 1, Fig. 20.

Occurrence and Stratigraphic Range: Species occurs sparsely in Borehole 4925 at 30 m, 40 m, 50 m, 60 m and 70 m. It has an Early Eocene age in southwestern Nigeria.

Morphological Note**:** The species has four and a half to five globular chambers. This is in contrast to the five chambers described for the species by Subbotina [24]. The species has deeply channeled radial sutures and coarsely perforate and cancellate (pl. 1, figs. 18 – 20).

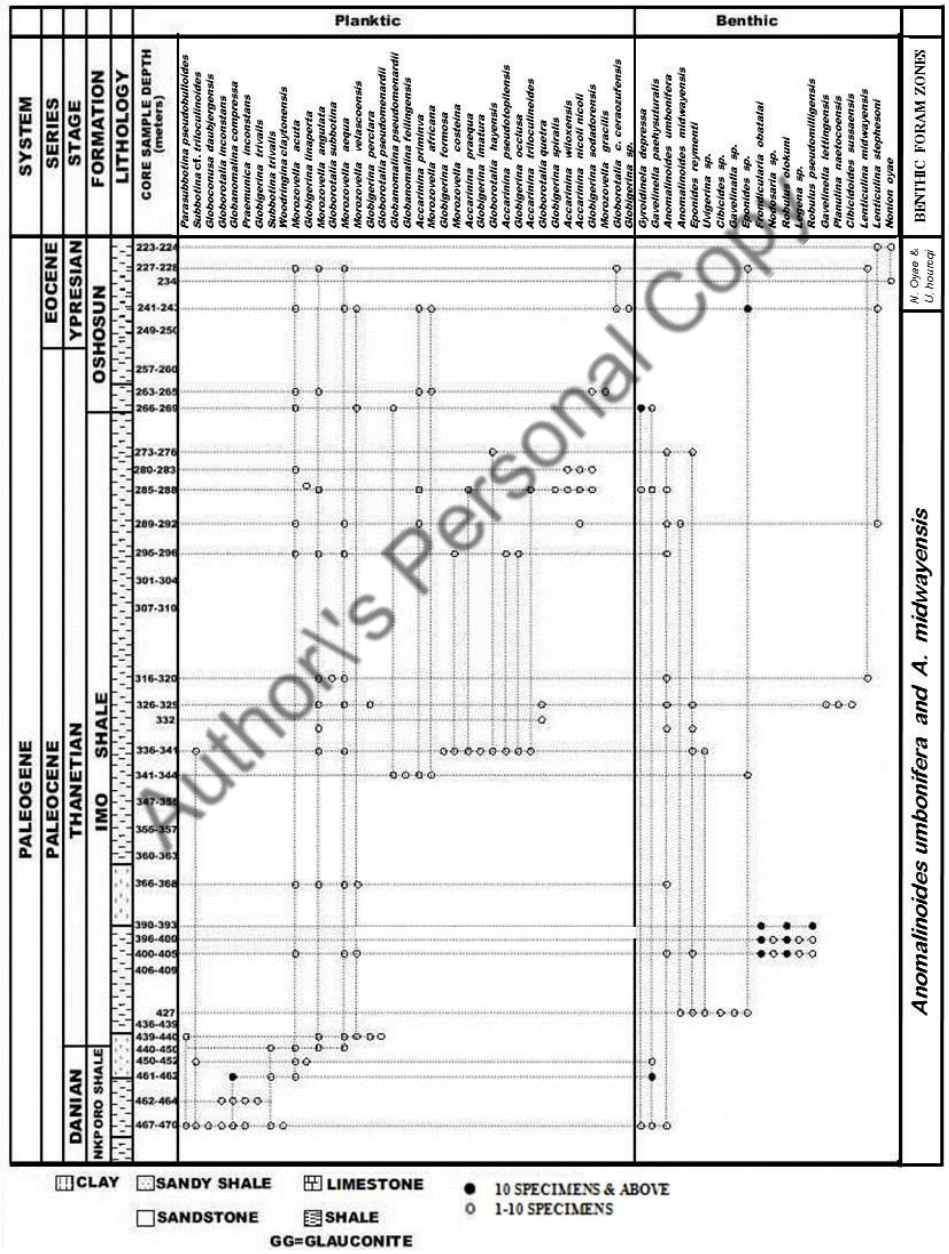

Fig. 2. Stratigraphic distribution of foraminifera in Araromi Borehole, GSN BH 1131 (modified after Okosun and Alkali [17])

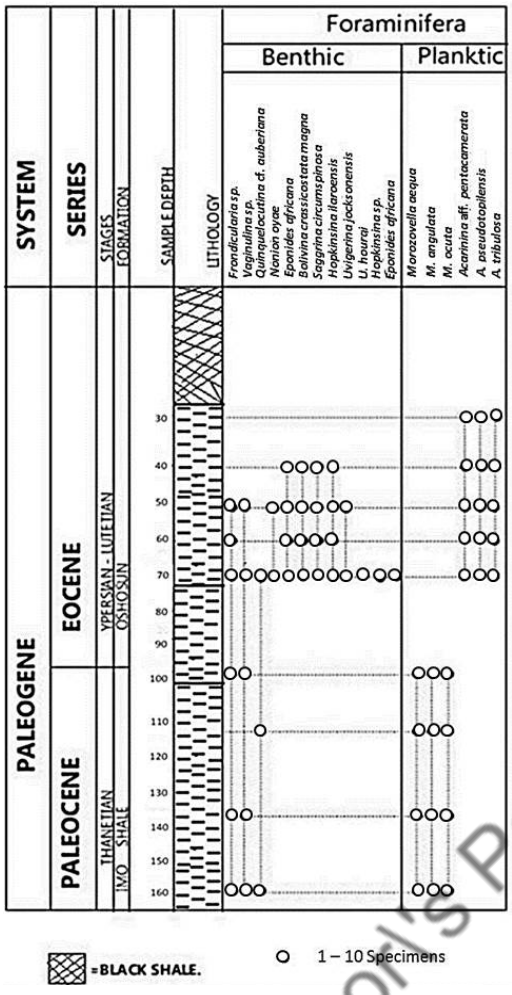

Fig. 3. Distribution chart of foraminifera in GSN BH 4925. Legend as in Fig. 2 above (modified after Okosun and Alkali [17])

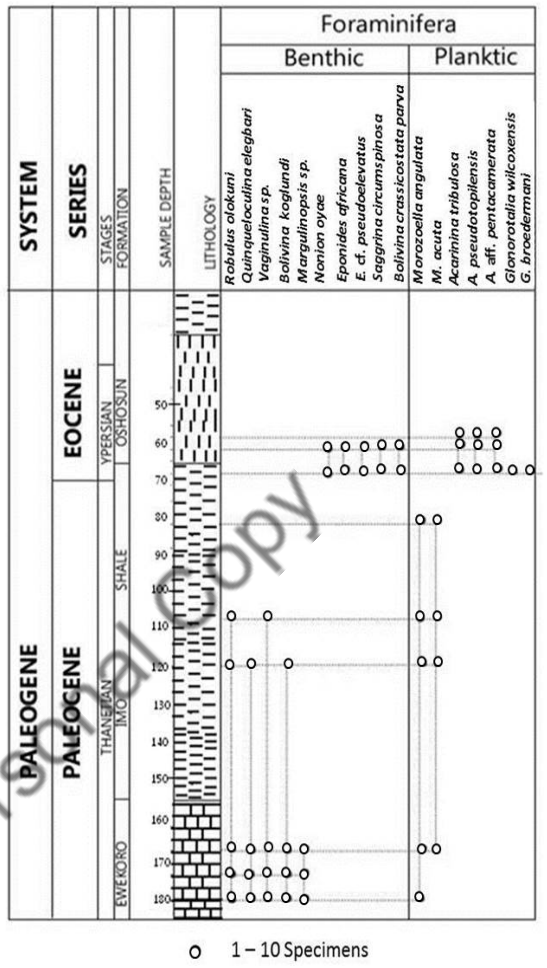

Fig. 4. Stratigraphic distribution of foraminifera in Akinside Borehole [BH 1582] Legend as in Fig. 2 above (modified after Okosun and Alkali[17])

Genus *Morozovella*
Morozovella aequa (Cushman and Renz)
Pl. 1a, Figs. 10 – 13.

1942 *Globorotalia crassata* Cushman var. *aequa* (Cushman and Renz) p. 12, pl. 3, Fig. 3.
1975 *Globorotalia aequa* (Cushman and Renz) Stainforth et al., p. 163, Fig. 31.
1983 *Morozovella aequa* (Cushman and Renz) Petters, p. 52, pl. 5, Fig. 3.
1987 *Globorotalia (Morozovella) aequa* Haynes and Nwabufo-Ene, p. 6, pl. 1, Figs. 9 – 11.

Occurrence and Stratigraphic Range: Majority of specimens were poorly preserved. About 15 specimens were recorded from Araromi Borehole (GSN1131), Gbekebo Borehole (GSN1132) and Borehole 4925 at 450 – 227 m, 740 – 672 m and 168 – 94 m respectively [17]. The range of the species is Paleocene to Early Eocene in Nigeria.

Morphological Note: The species is planoconvex, with a flat dorsal side (pl. 1, Fig. 10) and a strongly convex ventral side (pl. 1, Fig. 12). Keel weakly to strongly developed and pustulate (pl. 1, Figs. 11 and 12). Test is perforate with both small and large round pores (pl. 1, Fig. 13).

Genus *Subbotina*1953
Subbotina cf. *triloculinoides* (Plummer)
Pl. 1a, Figs. 1 – 5

1953 *Globigerina triloculinoides Plummer*, Subbotina, p. 82, pl. 11, Fig. 15.
1957 *Globigerina triloculinoides* Plummer, Reyment, p. 74, pl. 15, Figs. 4, 20.

Occurrence and Stratigraphical Range: The species was found in Araromi -1 (GSN1131) at 470 – 336 m and in Gbekebo -1 (GSN1132) at 877 - 878 m. The species has a Paleocene age in southwestern Nigeria.

Morphological Note: The material displays both dextral and sinistral coiling. Three globular chambers are visible on the ventral side. The final chamber is much larger than the other chambers. The aperture is large with a prominent lip. The surface is pseudospinose (pl.1a, Fig. 5), coarsely perforate, pores funnel-shaped with large throat and cancellate (pl. 1a, Figs. 3).

4.2 Benthic Foraminifera

Superfamily BOLVINITACEA Cushman, 1927
Family BOLIVINITIDAE Cushman, 1927

Genus *Bolivina* d'Orbigny, 1839
Bolivina crassicostataparva (de Klasz, Lecalvez and Rerat)
Pl. 2, Figs. 3 – 8

1981 *Bolivina crassicostata* de Klasz, Lecalvez and Rerat, Petters, p. 223, pl. 17.1, Figs. 13, 17.
1987 *Bolivina crassicostata parva* de Klasz, Lecalvez and Rerat, Haynes and Nwabufo-Ene, p. 9, pl.2, Figs. 8, 9, pl. 3, Fig. 6.

Occurrence and Stratigraphic Range: More than 10 specimens were recorded from Borehole 4925 at 40, 50, 60 and 70 meters. Poorly preserved specimens were also recovered from pits at Ifo. The subspecies was also reported by Haynes and Nwabufo-Ene from some boreholes in southwestern Nigeria. The species has a Late Paleocene to Early Eocene age in southwestern Nigeria. Species occurs in the phosphate beds of southwestern Nigeria and Togo.

Morphological Note: About 9 sinuous costae run longitudinally on both sides of the specimens. The costae bifurcate occasionally, they may anastomose. The wall is coarsely perforate (pl. 2, Figs. 3 – 8). The pores are evenly distributed (pl. 2, Figs. 4, 5). The aperture is a narrow slit with a raised collar on one side (pl. 2, Fig. 6). The subspecies is usually smaller in size compared to *Bolivina crassicostata magma.* Pronounced size differences have been reported between the 2 subspecies [14].

Bolivina crassicostata magma (de Klasz, Lecalvez and Rerat)
Pl. 2, Figs. 9 – 16

1964 *Bolivina crassicostata* de Klasz, Lecalvez and Rerat p.

1987 *Bolivina crassicostata magma,* de Klasz, Lecalvez and Rerat, Haynes and Nwabufo-Ene,
Pl. 8, pl. 2, Figs. 6, 7.

Occurrence and Stratigraphic Range**:** About 12 specimens were recorded Akinside -1(GSN 1582) and GSN 1805 at 50, 60 and 85 m respectively. Six specimens were recorded from BH 4925 from 40 to 60 m (Fig. 3). The subspecies occurs in the Paleocene to Eocene strata in southwestern Nigeria. Haynes and Nwabufo-Ene [14] reported its presence in the Paleocene – Eocene strata of West Africa.

Morphological Note**:** The subspecies has an elongate, ovate test composed of 9 pairs of chambers. The surface is adorned with prominent longitudinal costae that develop cross-branches which tend to form rhombs and triangles (pl. 2, Figs. 9–11). The intercostal areas are coarsely perforate (pl. 2, Figs. 13 – 16). The aperture is a broad slit in a medium line.

Order BULIMINIDA
Superfamily BULIMINACEA Jones, 1875
Family UVIGERRINIDAE Hackel, 1894

Genus *Uvigerna* d'Orbigny, 1826.
Uvigerina jacksonensis Cushman
Pl. 3, Figs. 25, 26

1925 *Uvigerina jacksonensis* Cushman, p. 67, pl. 10, Fig. 13
1987 *Uvigerina jacksonensis* Cushman, Haynes and Nwabufo-Ene, p. 7, pl. 2, Figs. 3 to 5, pl. 3, Fig. 5.

Occurrence and Stratigraphic Range: The species was recovered from GSN Borehole 1581 at 15 m, 45 m and 76 m. it is a Late Eocene index species in southern Nigeria, U.S.A and Mexico.

Morphological Note: Species is large, stout and robust with a maximum of 12 globular chambers. Its greatest width is at midpoint. Prominent and discontinuous costae run across 2 or 3 chambers (pl. 3, Fig. 25). Aperture is terminal with a short neck and a thin rounded lip.

Genus *Hopkinsina* Howe & Wallace, 1932
Hopkinsina ilaroensis Petters*, 1981*
Pl. 3, Figs. 1 – 5.

1981 *Hopkinsina danvilensis sensu* Petters, p. 223, pl. 17.1, Figs. 14, 15
1987 *Hopkinsina ilaroensissensu* Petters, Haynes and Nwabufo-Ene.

Occurrence and Stratigraphic Range: Twelve specimens of the species were recovered from GSN

Borehole 4925 at 40 m and 60 m. the species occurs at the latest Paleocene to early Eocene.

Morphological Note: The species is characterized by about 16 globose chambers which have an early triserial trochospiral and later biserial arrangement. The sutures are deeply impressed. The ornament is composed 10–14 blade-like costae which are discontinuous. They are broken at the sutures (pl. 3, Figs. 1, 2). Intercostal areas densely and evenly perforate. Aperture round, located on a short neck with a rounded lip (pl. 3, Figs. 3, 4, 5).

Genus *Sagrina* d'Orbigny, 1839
Sagrina circumspinosa (de Klasz and Rerat), 1962 [25].
Pl. 2, Figs. 1 – 2.

1962 *Bitubulogenerina circumspinosa* de Klasz and Rerat, p. 186, pl. 3, Figs. 3a-c, 4a, b.
1981 *Sagrina circumspinosa* (de Klasz and Rerat), Petters, p. 224, pl. 17.1, Fig. 16.
1987 *Sagrina circumspinosa* (de Klasz and Rerat), Haynes and Nwabufo-Ene, p. 8, pl. 2, Figs. 10, 11.

Occurrence and Stratigraphic Range: About 8 specimens were recorded from GSN Borehole 4925 at 50 m and 60 m. The species has been reported from the Lower and Middle Eocene from Gabon, Togo and southwestern Nigeria.

Morphological Note: The species is elongate with triserial and biserial early and late chamber arrangement stages. The biserial chambered adult stage is usually composed of about 6 pairs of chambers. About 6 or 7 downward projecting tubulospines are on each of the chambers (pl. 2, Figs. 1, 2).

Suborder MILIOUNA Delage and Herouard 1896
Superfamily MILIOLACEA Ehrenberg 1839
Subfamily QUINQUELOCULINA Cushman 1927.

Genus *Quinqueloculina* d'Orbigny 1826
Quinqueloculina cf *Q. seminulum* (Linne) 1759
Pl. 3, Fig. 16
1778 *Serpula seminulum* Linne, 1978 p. 786
1826 *Quinqueloculina seminulum* (Linne), d'Orbigny, 1826, p. 301
1929 *Quinqueloculina* cf. *seminulum,* Linne p. 24, pl. 2, Figs. 1, 2.

Description: Test free, outline ovate, apex truncated, wall calcareous and porcelaneous. Four chambers visible on one side and three visible on opposite side. Aperture terminal, ovate with a bifid tooth.

Occurrence and Stratigraphic Range: Five specimens from phosphate exploration pit at Ifo. The species probably has an Eocene age.

Morphological Note: The genus *Quinqueloculina* d'Orbigny 1826 comprises morphologically highly variable species that numerous authors usually group as *Quinqueloculina* spp. The species are common in shallow marine environments and brackish water.

Quinqueloculina cf. *auberiana*
Pl. 3, Figs. 12, 13, 14.

1884 *Quinqueloculina aubereana* Brady, pl. 5

Occurrence and Stratigraphic Range: Four specimens from phosphate exploration pit at Ifo. The species probably has an Eocene age.

Morphological Note: Free test that is composed of globose chambers with a robust outline. The wall is calcareous, porcelaneous and imperforate. Three chambers visible exteriorly (pl. 3, Fig. 12). The aperture is terminal and ovate with a simple straight tooth.

Superfamily DISCORBACEA Ehrenberg 1838
Family DISCORBIDAE Ehrenber, 1838
Superfamily BAGGININAE Cushman 1927

Genus *Cancris* de Montfort 1808
Cancris?sp
Pl. 3, Figs. 6 – 8.

Occurrence and Stratigraphic range**:** Four specimens of the species were recovered from Eocene phosphate exploration pit at Ifo.

Morphological Note: The material is biconvex, trochospiral, evolute and elongate on the spiral side. There are about 13 regularly curved ribs on the spiral side. Although no apertural lip was observed, the material has been tentatively referred to the genus *Cancris* because of the above features.

Family NONIONIDAE Schultze 1854
Subfamily NONIONINAE Schultze 1854

Genus *Nonion* de Montfort 1808
Nonion oyae (Reyment) 1966
Pl. 3, Figs. 21 – 24.

1966 *Planulina oyae* Reyment, p. 287, pl.1, Figs. 45 – 48.

1982 *Nonion oyae* (Reyment), Petters, p. 80, pl. 12, Figs. 6 – 7.

Occurrence and Stratigraphic Range: Four specimens were recovered. The species is an endemic marker for the Eocene in the Niger delta and the Benin basin (Dahomey embayment). *Nonion oyae* was recovered from GSN 4925 (Fig. 1). The species was transferred from the trochospiral genus *Planulina* to the genus *Nonion* because of its planispiral growth form [13].

Morphological Note: The species is strongly biumbonate, very finely perforate, strongly flattened with indented sutures (pl. 3, Figs. 21 – 23). There are 15 – 17 chambers in the last whorl (pl. 3, Fig. 21) in contrast to the 14 – 15 reported for the species by Reyment [26].

Superfamily NODOSARIACEA Ehrenberg 1938
Family NODOSARIIDAE Ehrenberg 1838
Subfamily NODOSARIINAE Ehrenberg 1838

Genus *Lagena* Walker and Jacob in Kanmacher 1798
Lagena cf. *L. shoponnai* Reyment 1966
Pl. 3, Figs. 9, 10, 11.

1965 *Lagena* sp. nov., Reyment, pl. 17, Fig. 5.
1966 *Lagena shoponnai* Reyment, p. 284, pl. 1, Fig. 44.

Occurrence and Stratigraphic Range: Four specimens of the species were recovered from a phosphate exploration pit at Ifo within the Oshosun Formation. The species also occurs in the phosphate mine at Hahoto in Togo. *Legena* cf. *shoponnai* has an Early to Middle Eocene age.

Morphological Note: The present material has an ornament of about 13 to 14 prominent coarse costae. The costae run from the neck to the bottom of the species (pl. 3, Figs. 9 – 11). This differentiates the species from other species of the genus *Lagena*. It is different from *Lagena shoponnai* Reyment which is characterized by about 16 costae and has a much smaller size.

Superfamily ROTALIACEA Ehrenberg, 1839
Family ROTALIIDAE Ehrenberg, 1839
Subfamily ROTALIINAE Ehrenberg, 1839

Genus *Rotalia* (Lamarck) 1804
Rotalia sp
Pl. 3, Figs. 17 – 20.

Description: Test trochospiral biconvex ventral side involute and dorsal side evolute with angular poreless periphery. About 4 whorls with up to 14 chambers in the last whorl, sutures curving backwards, coarsely perforate (pl. 3, Figs. 17 – 20). The apertural features were not discernible in the present material.

Occurrence and Stratigraphic Range**:** Five specimens of the species were recovered from the phosphate pit at Ifo in the Eocene Oshosun Formation. Details of apertural features could not be observed.

Morphological Note: Foramen and foramina passage were observed in a broken test of the species (pl. 3, Fig. 19). The coarse perforate nature of the test is shown in pl. 3, Figs. 20, 27.

5. DISCUSSION

From a total of 16 foraminiferal species of this study, 14 were fully identified while 2 were placed in open nomenclature due to the limited number of specimens available for detailed taxonomic study. *Planulina oyae* was emended to *Nonion oyae* based on observed involute and planispiral characteristic of the test [13]. The genus *Planulina* is characterized by the following features: Trochospiral, evolute, biumbonate, rounded and lobulate peripheral outline, depressed and slightly curved radial sutures. These morphological features which are in agreement with the diagnosis of the genus [20,27]) were observed in the specimens of the species. They further support the emendation of Petters [13]. *Bolivina crassicostata* de Klasz and Rerat 1964 [28] was subdivided into two subspecies, *B. crassicostata magma* and *B. crassicostata parva* by Haynes and Nwabufor-Ene [14]. The subdivision was based on size, pores and ornamentation differences. *B. crassicostata magma* is large, nearly 2 mm in length, with about 9 nearly straight continuous costae. The costae develop cross branches that tend to form triangles and rhombs (pl. 2, Figs. 9-11).The subspecies is coarsely perforate with pores up to 40 microns in diameter (pl. 2, Figs. 13-16). *B. crassicostata parva*, the small subspecies reaches a maximum length of 0.45 mm. It has about 9 sinuous costae which usually branch and join together particularly at the mid-point of the test. Pores on the test are of smaller diameter, reaching about 3 – 4 microns in diameter. The aperture in the 2 subspecies is a broad slit in the median line with a thick collar on one side of the test and a curved internal tooth plate (pl.2, Fig. 6). There is also a pronounced difference in the length of the aperture of the two subspecies, *B. crassicostata magma* has a length of 72 microns while that of *B. crassicostata parva* is 40 microns. The subdivision of *Bolivina crassicostata* into two subspecies can also be validated by the remarkable differences in their pore diameter indicated above.

This is supported by the differentiation of 6 generic groups of planktic foraminifera based on pore diameter, pore concentration and shell porosity [29]. *Globigerinoides* and *Globorotalia* were differentiated based on the possession of 2 – 4 microns and 4 – 7 microns pore diameters respectively [30].

Researchers have investigated the wall textures of planktic foraminifera [21,30-35]. Pustules and spines are important microstructures on the wall textures of planktic foraminifera. Although their systematic significance has been given varied interpretations, their distinction has taxonomic value. Pustules can be pointed, rounded or branched microstructures which are direct outgrowths of the chamber wall. They have no conical mounds or spine bases. Spines on the other hand are secondary microstructures composed of elongate single crystals that have been grown on the outside surface of the chamber wall. Spines usually have conical mounds at their bases where it makes contact with the surface of the test. The conical mounds have central perforations to accommodate the spinous rod. Pustules when long and pointed are referred to as pseudospines [32,33,34].

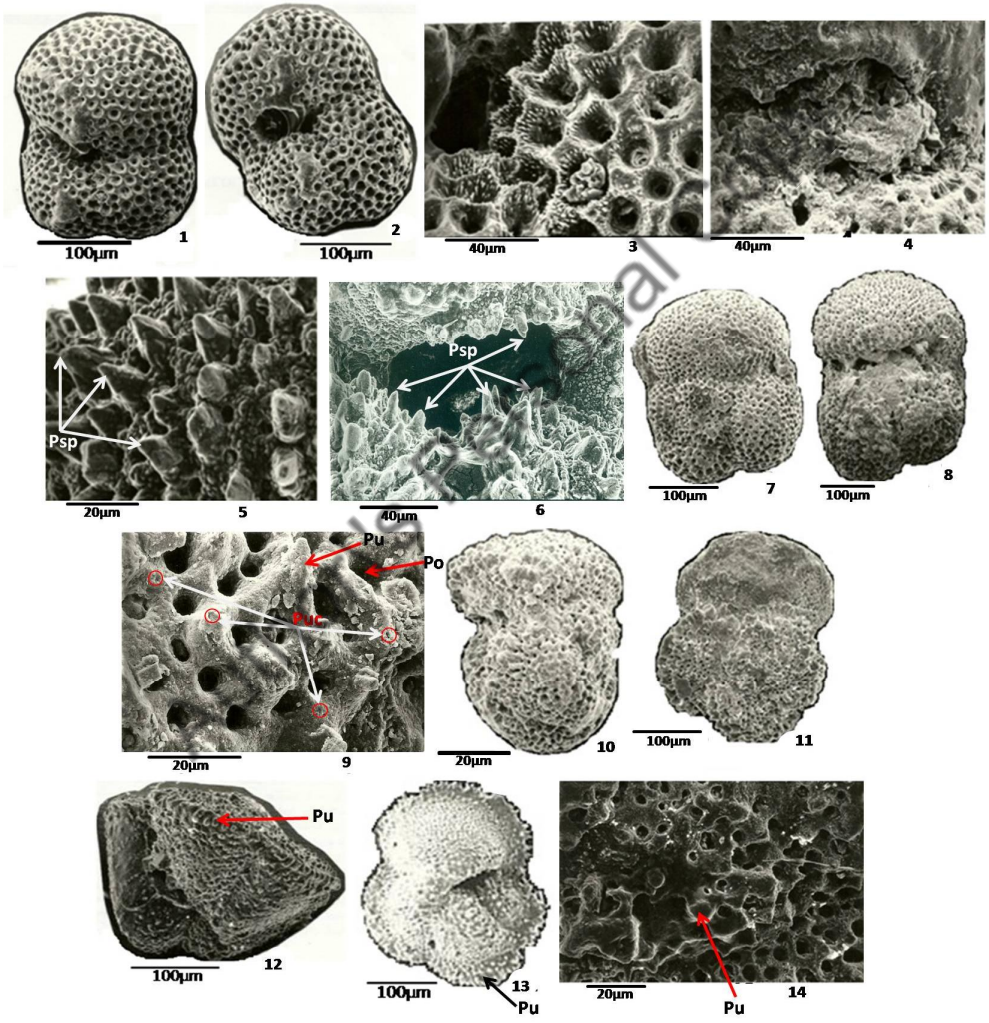

Plate 1a

1 – 5. Subbotina cf. *S. triloculinoides (Plummer), 1953*
1 & 2. Ventral views, X 200.
3. Close-up view of texture showing deep funnel shaped pores, X 1000.
4. Close-up view of aperture, X 500.
5. Close-up view of wall texture X 1000, note the pointed pustules (Ppu). Pointed pustules were referred to as pseudospines([32,33&34]).

6 – 7: Acarinina pseudotopilensis Subbotina, 1953. Dorsal view, X 200 and ventral view, X 100, 8.Side view, X 100.
9. Close-up view of ornament, X 1000, note pustules (Pu), corroded pustules (Puc) and pores (Po).
10. Side view, X 200.
11 – 12: Morozovella aequa (Cushman and Renz), 1942, dorsal and ventral views, X 200, note pustules on fig. 11.
13. Ventral view with keeled margin, X 200.
14. Close-up view of texture showing pustule (Pu) development, X 1000.

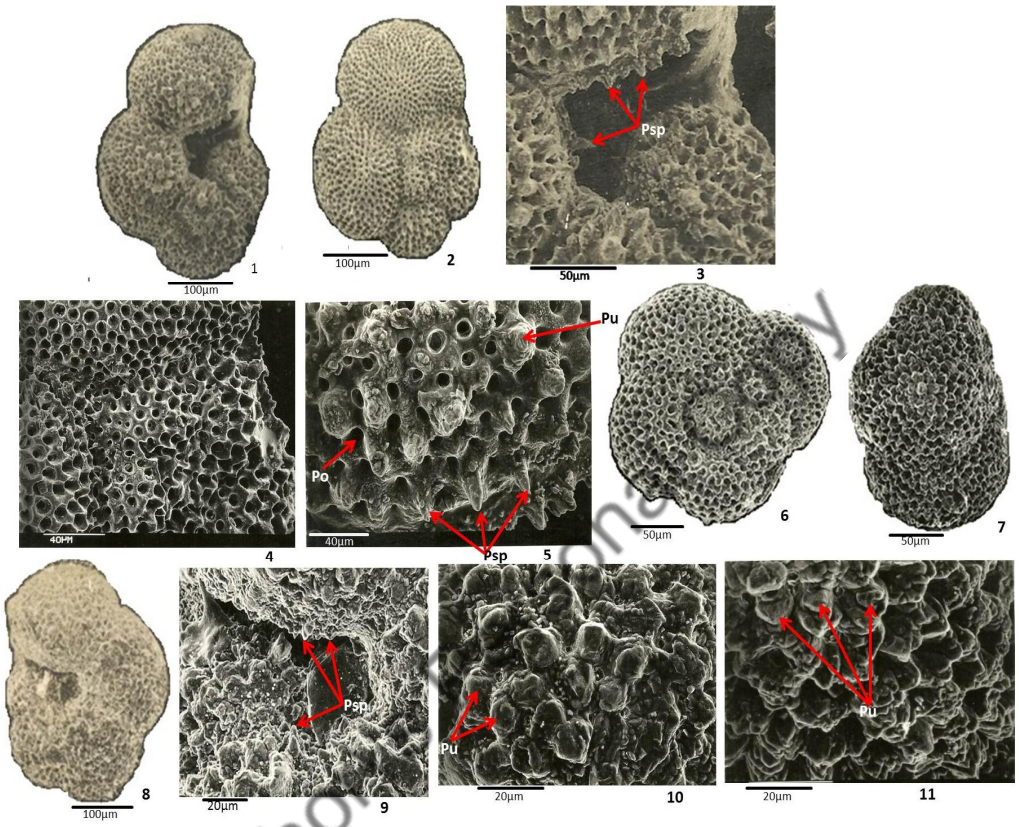

Plate 1b

Figs. 1- 5.Acarinina tribulosa (Loeblich and Tappan), 1957[37]
1, 2, ventral, dorsal views, X 200, note pustular development on test.
3. Close- up view of aperture, X 500, note presence of round and pointed pustules (Ppu)
4. Close-up view of dorsal texture, X500.
5. Close-up view of texture showing pores (Po) and pustules (Pu).
Figs. 6-11. Acarinina aff. *Pentacamerata (Subbotina), 1947*
6, 7 and 8.dorsal, side and ventral views X 200.
9.Close-up view of aperture showing development of pustules (Pu), X 1000.
10, 11.Close-up views of ventral and dorsal texture, X 1000, note development of blunt pustules (Pu).

Four basic types of wall textures have been recognized from the lower Danian planktic foraminifera as follows: Microperforate, normal perforate cancellate spinose, normal perforate cancellate non- spinose and normal perforate smooth walled [21]. In the current study of selected Paleocene planktic foraminifera, the normal perforate cancellate non-spinose and a normal perforate, cancellatespinose wall textures have been recognized. *Subbotina* cf. *triloculinoides* [36] displays a normal perforate, cancellate pseudospinose wall texture (pl.1a, Fig. 5). *Acarinina pseudotopilensis* (Subbotina) 1953 and *Acarinina* cf. *A. pentacamerata* (Subbotina) 1947 exhibit normal perforate, cancellate non-spinose wall texture. Pustules are present in the umbilical area of these Acarinina species particularly at and close to the aperture (pl.1a, Fig. 9 and pl.1b, Fig. 9). *Acarinina tribulosa* [37] shows pointed pustules at the aperture (pl. 1b, Figs. 3, 5). The occurrence of pustules at the umbilicus and close to the aperture further goes to

support the suggestion that pustules form supporting elements for pseudopodia attachment in the capture and transport of food [32]. Pseudospines were noted in *Subbotina* cf. *S. triloculinoides* while both pseudospines and round pustules were observed in *Acarinina tribulosa* in this study.

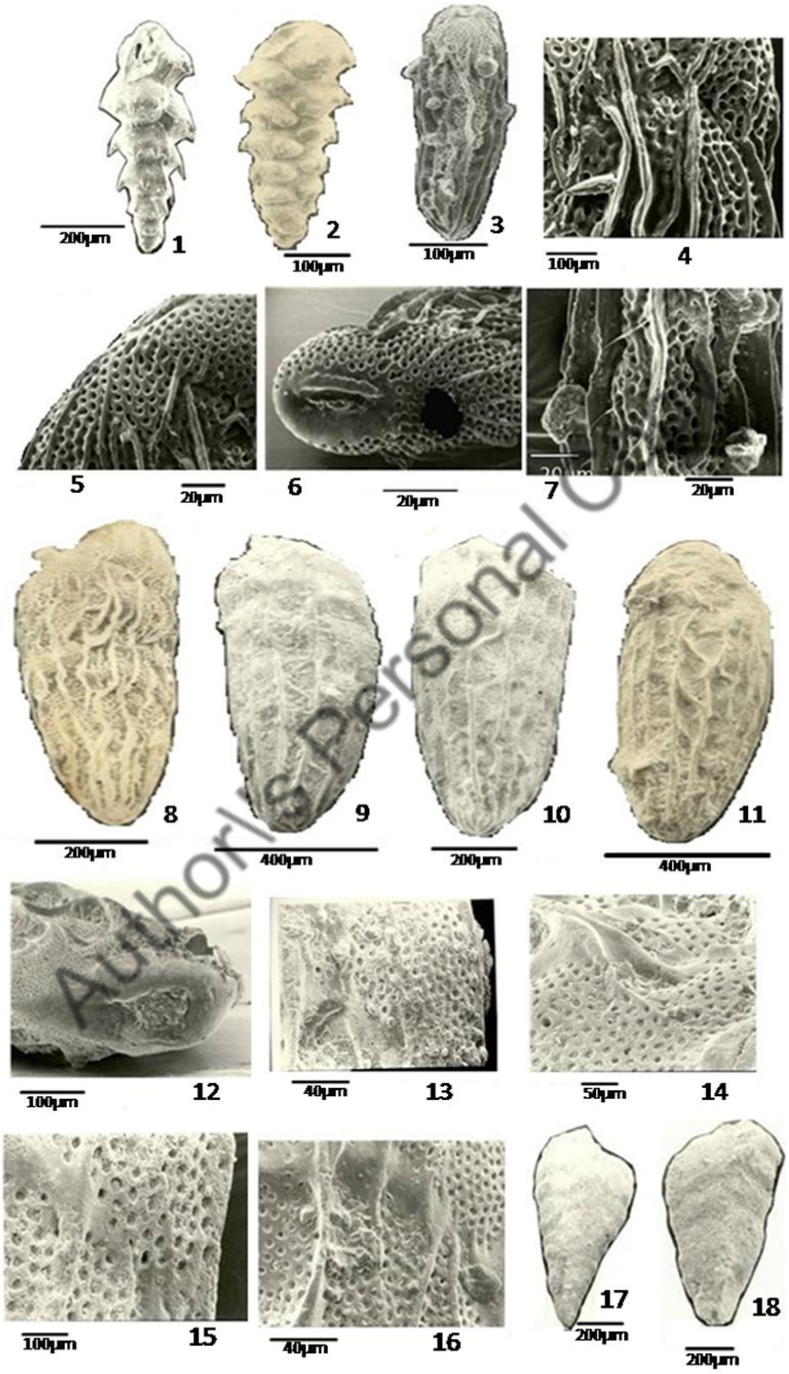

Plate 2

Figs. 1 – 2.Sagrina circumspinosa (de Klasz and Rerat), 1962[25]
1. Edge view, X 70

2. Side view, X 100.
Figs. 3 – 8.Bolivina crassicostata parva (de Klasz, Lecalvex and Rerat), 1964 [28] Haynes and Nwabufo-Ene [14].
3. Edge view, X 55.
4. Close-up of ornament, note sinuous and prominent costae and reticulate intercostals areas, X 1,000
5. Close-up view of texture on last chamber, X 1,000.
6. Close-up of view of aperture, note prominent longitudinally drawn lip on I side of the aperture, X 500.
7. Close-up view of ornament, note the prominent sinuous and blade-like costae, X 1000
8. Side view, X 200.
Figs. 9 – 16.Bolivina crassicostata magma (de Klasz, Lecalvex and Rerat), 1964[28] Haynes and Nwabufo-Ene[14].
9 – 11. Side views, X 100.
12. Close-up of aperture,
13, 14, 16, close-up of ornament, note coarse pores, X 500.
15. Close-up of pores, X 500
Figs. 17, 18.Textularia sp.*, 17, 18. Side views, X 50*

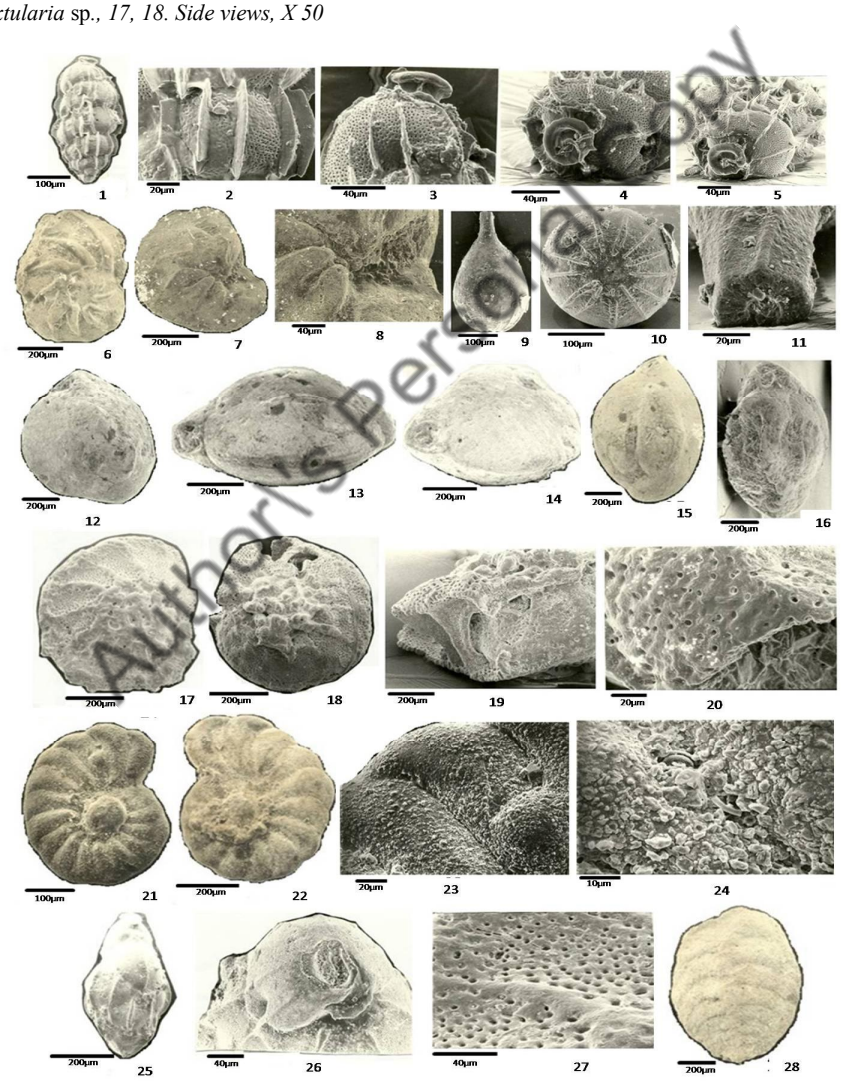

Plate 3

Figs. 1 – 5.Hopkinsina ilaroensis Haynes and Nwabufo-Ene [14].
1. Side view, X 40. 2. Close-up view of costae, note discontinuous and blade-like

nature of the costae, X 500. 3. Aperture and last chamber, note the pyaline lip, X 500.
4 - 5. Apertural views, note the round lip.
Figs. 6 – 8.Cancris sp.
6. Dorsal view, X 100. 7. Ventral view, X 100. 8. Close-up view of Aperture, X 500
Figs. 9 – 11.Lagenasp
9. Side view, 10. Basal view, note 12 costae, X 200. 11.Close-up of aperture, note visible costae, X 1,000.
Fig. 12.Quinqueloculina cf. *auberiana Side view, X 100.*
Figs. 13, 14Quinqueloculina cf. *seminulum (Linne)*
Close-up of aperture
Fig. 15.Quinqueloculina cf. *seminulum*
Side view
Fig. 16.Quinqueloculina sp
Close-up view of aperture
Figs. 17 – 20, 27.Rotalia sp
17. Dorsal view, X 100.
18. Ventral view, X 100.
19. Close-up view of foramen, X 150
20. Close-up of pores, X 1,000.
27. Close-up view of ornament, X 1,000.
Figs. 21 – 24.Nonion oyae
21. Dorsal view, X 100.
22. Ventral view, X 100.
23. Close-up view of sutural slits,X 2,000.
24. Close-up view of sutural slit, X 2,500.
Fig. 25.Uvigerina jacksonensis Cushman
Side view, 100.
Fig. 26.Uvigerina jacksonensis Cushman
Close-up view of aperture, X 100.
Fig. 27.Valvulina sp
Side view, note curved chambers, X 100.

Large pores were found on Acarinina and Subbotina species (pl. 1a, Figs. 3, 9, 14). They have been classified as large because they are on the average nearly equal in diameter to the interpore areas [33].

6. CONCLUSION

Early Danian planktic foraminifera have been classified into four groups based surface wall texture which are: Normal perforate cancellate spinose, normal perforate non-spinose, microperforate and normal perforate smooth-walled. *Subbotina* cf. *triloculinoides, Acarinina tribulosa*, *A*. *pseudotopilensis* and *A*. aff. *pentacamerata* were encountered from the Danian and Thanetian in the current study. Three morphological elements: pores, pustules and pseudospines were observed in *Acarinina* species while large pores and pseudospines were noted in *Subbotina* cf. *triloculinoides*. The observation of pustules on *S.* cf. *triloculinoides* is in contrast to the report on the species by previous workers. *S.* cf. *triloculinoides* has normal perforate, cancellate and pseudospinose texture while the surface topography of *A. tribulosa, A. pseudotopilensis* and *A*. aff. *pentacamerata* is normal, perforate pustulose and non-spinose. The studied species of planktic foraminifera have large pores. The production of the scanning electron microscope micrographs of the foraminiferal species by Prof. J. Haynes is also acknowledged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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