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MAASTRICHTIAN-PALEOCENE FORAMINIFERA FROM NW NIGERIA AND THEIR PALEOGEOGRAPHY

Abstract. — Maastrichtian and Paleocene beds of southeastern Iullemmeden basin contain rich but poorly preserved foraminiferal microfaunas. Twelve species are described, none of which is new. Although foraminiferal species were noted in these sediments by other workers, no previous attempt has been made to figure and describe them. The Paleocene benthic foraminifera assemblage of the Saharan epicontinental sea that flooded the Iullemmeden Basin has many taxa in common with the European Boreal and Meridional epicontinental faunas. The ancient Tethys Sea served as a corridor for this faunal exchange. However, the benthic foraminiferal microfaunas of the Iullemmeden Basin are very distinct from those of the Southern Nigerian Sedimentary Basin. This suggests that the two basins were not directly connected during the Paleocene.

INTRODUCTION

Maastrichtian and Paleocene marine beds outcrop extensively in central West Africa, in the Sokoto region of northwestern Nigeria, and continue northeastward in the neighbouring Niger Republic. These deposits which consist of siltstones, shales and organogenic marls were laid down in and around the Saharan epeiric sea that flooded the central Sahara during Latest Cretaceous and Early Tertiary times. An embayment of the Saharan sea extended into Sokoto in northwestern Nigeria. A large syneclise, the Iullemmeden Basin (fig. 1), subsided during time and received over 2000 m of predominantly clastic sediments which had started to accummulate under continental conditions during Late Jurassic to Early Cretaceous times (Kogbe and Lemoigne 1976). The lithostratigraphy of the Iullemmeden Basin has been presented by Jones (1948), Greigert (1966), and Kogbe (1973). The first known detailed foraminiferal analysis of any part of the basin is that of Krasheninnikov and Trofimov (1969) which was based on Mali Republic. Asseez and Fayose (1972) reported several Paleogene benthonic foraminifera from boreholes in the Sokoto province. Preliminary foraminiferal paleoecologic and paleogeographic interpretations on the southeastern part of the Iullemmeden Basin were presented by Petters (1977).

The foraminiferal microfaunas of the Iullemmeden Basin are predominantly benthic. The assemblages are rich but not diverse and individuals are generally moderate to small in size and very poorly preserved. In spite of these problems the assemblages are quite distinctive and furnish a reliable criterion for age correlation (Petters, in press), and

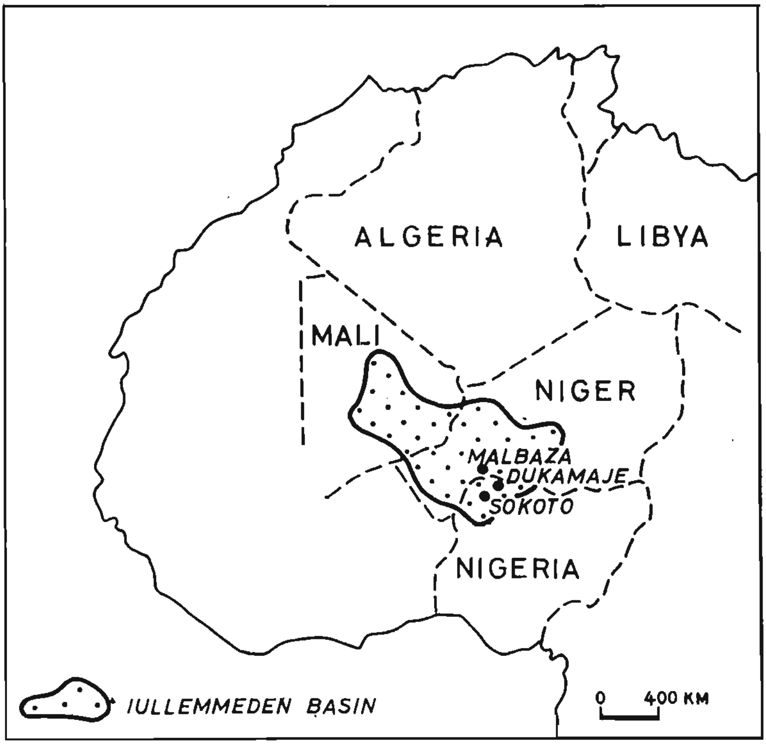

Fig. 1. Localities of Maastrichtian-Paleocene age in Southeastern Iullemmeden Basin.

for making paleoecologic and paleobiogeographic deductions. The aim of the present paper is to present, for the first time, an illustrated documentation of some of the foraminiferal taxa that occur in this remote and very poorly known region. Since most paleobiogeographical maps published so far (e. g. in Hallam 1973) suffer from the lack of adequate faunal distribution data from Africa, an attempt is made to assess the paleobiogeographical meaning of the Paleocene benthic foraminiferal assemblage. This assemblage is chosen partly because the local material is sufficiently rich and representative, and also because summaries of the distribution of Paleocene benthic foraminifera from other parts of the world have been recently published (Pożaryska and Szczechura 1968; Szczechura and Pożaryska 1974; Berggren 1974*a*; Berggren and Aubert

1975), hence regional comparisons of Paleocene assemblages can be attempted with a good amount of confidence.

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GEOLOGICAL FRAMEWORK AND FORAMINIFERAL MICROFAUNAS

Exposed marine and marginal marine sediments in the southeastern edge of the Iullemmeden Basin are over 120 m thick. This sedimentary wedge thickens northwestward and attains its maximum thickness outside Nigeria, in the Republic of Niger and Mali. These marine deposits consist of two depositional cycles of Maastrichtian and Paleocene age.

The basal unit of the Maastrichtian cycle is the Taloka Formation, with a thickness of over 50 m in outcrop. This formation is a sequence of horizontally bedded siltstones, carbonaceous mudstones, and fine--grained sandstone lenses. In the middle and top parts the Taloka Formation has abundant *Ophiomorpha* burrows and is also shelly in the middle part suggesting a beach environment. The molluscan assemblage of the middle shelly siltstone of the Taloka Formation consists of species of *Anadra*, *Modiolus*, *Cardium*, *Cyprimeria*, and *Baroda*, according to Jones (1948). The Taloka Formation constitutes a coastal plain complex, and has yielded no foraminifera.

Conformably overlying the Taloka Formation is the Dukamaje Formation which is a 10 m unit comprising a basal gypsiferous and nodular, fissile shale; a middle gypsiferous marl band; and a top shale (fig. 2). The basal shale is rich in vertebrate fossils such as crocodiles, turtles, and mosasaurus. It also contains an abundant, entirely arenaceous foraminiferal assemblage, comprising *Ammobaculites* sp., *Ammodiscus* cf. *siliceus*, *Haplophragmoides excavata*, *Miliammina* sp., *Textularia* sp., *Trochammina* sp., and traces of *Orbignyna inflata*. The marl band has an admixture of predominantly calcareous taxa, together with a subsidiary content of arenaceous species. Calcareous forms include *Guembelitria cretacea*, *Gavelinella* sp., *Nonion* sp., and *Nonionella* sp. There is a recurrence of an entirely arenaceous assemblage in the top shale of the Dukamaje Formation. The presence of *Guembelitria cretacea* supports a Late Maastrichtian age for the Dukamaję Formation.

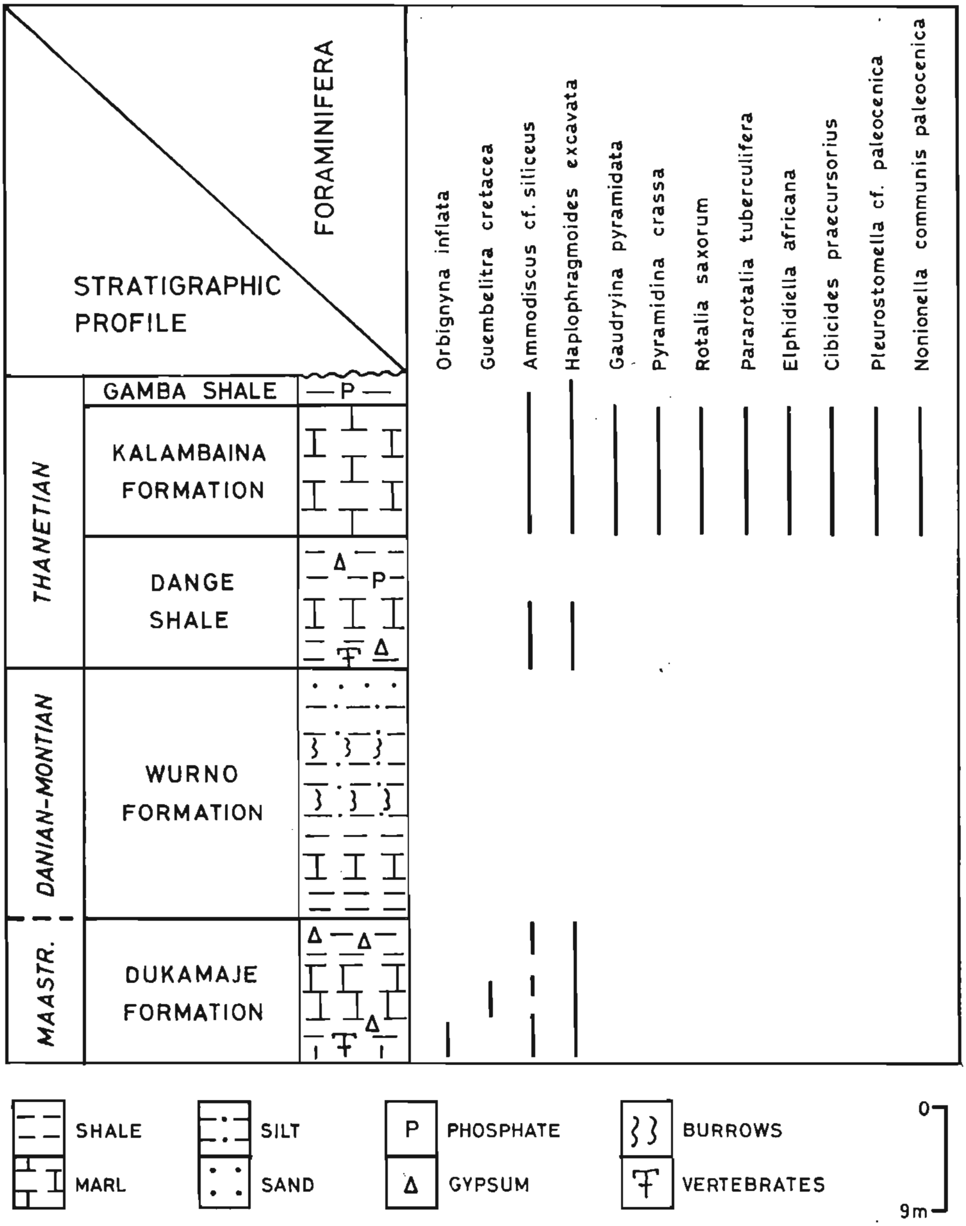

Fig. 2. Composite stratigraphic profile for marine and marginal marine sediments in the Sokoto embayment showing the ranges of the foraminifera described in this study.

The Wurno Formation marks the end of the Late Maastrichtian depositional cycle and a renewed phase of coastal plain sedimentation. It is very similar to the Taloka Formation in physical characteristics in that it is horizontally bedded, burrowed, and composed of muddy siltstones, mudstones and fine-grained sandstones. The base of the Wurno

Formation is not exposed. An arenaceous foraminiferal assemblage occurs in the lower and middle parts of the Wurno Formation at its type section. This includes *Miliammina* sp., *Textularia* sp., *Ammobaculites* sp., and *Trochammina* sp. With this evidence of marine influence, most of the Wurno Formation can be placed with the Paleocene marine cycle. The Wurno Formation attains a maximum thickness of about 20 m at the type section.

The Wurno Formation is succeeded by about 10 m of gypsiferous paper shale, the Dange Formation. The Dange Formation is rich in Paleocene vertebrate remains, and also contains a sporadic arenaceous foraminiferal assemblage. However, there is a 1 — m marl band in the lower part that is shelly in places and also contains abundant *Cibicides simplex*, in addition to arenaceous foraminifera.

The Kalambaina Formation of over 10 m thickness in outcrop is a highly fossiliferous marl with limestone nodules, and some very argillaceous parts. Its rich but low diversity molluscan and echinoid megafossil assemblage was described by Parker (1964). The Kalambaina Formation was deposited during the maximum extent of the last Saharan epeiric sea. Its deposits overstep those of the Maastrichtian transgression, and contain a rich, warm, and shallow-water benthic foraminiferal assemblage comprising mainly rotaliids, cibicidids, nonionids, *Pararotalia*, *Elphidiella* and the larger foraminifera *Operculinoides bermudezi*. In terms of biostratigraphic correlation, the association of *Operculinoides bermudezi, Thalmannita madrugaensis*, and *Boldia cubensis* is diagnostic, and was correlated by Berggren (1974*a*) with the planktonic foraminiferal *Planorotalites pseudomenardii* Zone (P_4). This is because in the Paleocene sections of Senegal, Cuba, Libya and apparently Pakistan, this benthic foraminiferal association occurs together with planktonic foraminifera such as *Morozovella velascoensis*, *M. acuta*, *Planorotalites elongatus*, and *P. pseudomenardii.*

The youngest fossiliferous marine strata in southeastern Iullemmeden Basin are those of the Gamba Formation, which is a greenish grey phosphatic paper shale with sharks' teeth and arenaceous foraminifera. The Gamba Formation is about 2 m thick in outcrop but is missing in places due to a disconformity. The Gamba shale is thus regressive and marks the final withdrawal of the sea from the region.

REGIONAL FORAMINIFERAL CORRELATION OF THE PALEOCENE IN THE IULLEMMEDEN BASIN

The most significant contribution to Paleocene foraminiferal biostratigraphic correlation in the Iullemmeden Basin to date, is that of Krasheninnikov and Trofimov (1969), a partial English translation and elaboration of which was incorporated in Berggren (1974*a*). Four benthic foraminiferal biostratigraphic units were recognized in the Paleocene of Mali from bottom to top, as shown below with their approximate correlative planktonic foraminiferal zones: *Laffitteina bibensis* (= *Globoconusa daubjergensis-G. pseudobulloides* Zone), *Elphidiella africana* (= *Morozovella angulata-M. pusilla* Zone), *Operculinoides bermudezi* (= *Planorotalites pseudomenardii* Zone), and *Lockhartia haimei* (= *Morozovella velascoensis* Zone). This zonation furnishes a framework within to reconstruct the geological history of the Iullemmeden Basin. Such a reconstruction for the southeastern part of the basin was made recently by Petters (1977).

The four biostratigraphic units recognized in Mali span the entire Paleocene and occur in a limestone and marl sequence. This is due to the fact that Mali is located in the centre of the Iullemmeden Basin where a more complete succession of marine sediments is preserved. This is unlike the stratigraphic situation on the southeastern part of the basin, in northwestern Nigeria, where only the *Operculinoides bermudezi* Zone is represented by marine sediments. The two older zones of Danian — Montian age represent a time of coastal plain sedimentation in northwestern Nigeria and neighbouring Niger, when the full marine influence of the Paleocene transgression was not yet felt in the southeastern portion of the basin. These coastal plain sediments are those of the Wurno Formation. This paleogeographic picture, and stratigraphic correlation casts serious doubts on the position of Cretaceous-Tertiary boundary as drawn by earlier workers. Parker (1964) drew this boundary at the top of the Wurno Formation; Parker and Carter (1965) placed it at the top of the Dange Formation, while Reyment (1965), and Kogbe (1973, 1976) again drew it at the top of the Wurno. On the above stratigraphic and paleogeographic considerations, and the absence of a clearly demonstrable unconformity between the Wurno and Dange Formations, Petters (in press) placed the Cretaceous-Tertiary boundary in southeastern Iullemmeden Basin at the base of the Wurno Formation.

The Latest Paleocene is missing from the exposed parts of northwestern Nigeria. This may be due to the fact that the regression may have started before the end of the Paleocene or the Latest Paleocene may be missing due to the disconformity at the top of the Kalambaina and Gamba Formations. However, the absence of *Lockhartia haimei* from the top of the Kalambaina Formation in outcrop suggests that this zone may be missing from northwestern Nigeria due to the regression. The *Lockhartia haimei* Zone is present in the Niger Republic. Thus, the stratigraphic picture of the extensive, regional organic-rich calcareous lithotype in which the marine Paleocene is represented in the Iullemmeden Basin, is one of considerable diachronity.

PALEOBIOGEOGRAPHIC SIGNIFICANCE OF LATE PALEOCENE BENTHIC FORAMINIFERA FROM THE IULLEMMEDEN BASIN

In recent years the stratigraphic, geographic, depth, and facies distribution of Paleocene benthic foraminifera have been well elucidated. Excellent reviews and syntheses of regional distribution data can be found in Pożaryska and Szczechura (1968), Szczechura and Pożaryska (1974), Berggren (1974*a*), and Berggren and Aubert (1975). In all these works, the cosmopolitan distribution of many Paleocene benthic species has been acknowledged. Berggren and Aubert (1975) attributed this to equitable climatic conditions and warmer, more uniform thermal structure of the oceans and different paleogeographic and paleo-oceanographic conditions. The paleogeographic framework for the distribution of Paleocene benthic species was discussed by Szczechura and Pożaryska (1974) who stressed the strong bathymetric dependence of small benthic forms. Thus, there is a marked difference between strictly epicontinental and strictly geosynclinal assemblages, to which Berggren (1974*a*) and Berggren and Aubert (1975) gave the names Midway-type and Velasco-type faunas respectively. The Boreal, and the Meridional or Transitional (embracing the Paris Basin, Belgium, Holland and Germany) provinces in Europe were epicontinental, the former being characterised by a cool climate while the latter was subtropical.

Within the epicontinental areas of the Mediterranean and circum--Atlantic regions Berggren (1974*a*) and Berggren and Aubert (1975) distinguished two types of benthic assemblages: a shallow-water, inner to middle shelf assemblage that developed only in a carbonate environment; and a middle to outer shelf assemblage which developed in a shale and marl environment. The former was termed the Tethyan Carbonate Fauna, and the latter the Midway-type faunal assemblage. The Tethyan Carbonate Fauna is characterised by various cibicidids, nonionids, rotaliids, discorbids, elphidiellids and especially larger foraminifera such as *Operculinoides*, *Lockhartia*, *Miscellanea*, and *Discocyclina*. The Midway-type assemblage is characterized by various textulariids, polymorphinids, and anomalinids.

The presence of *Operculinoides bermudezi* in the outcropping part of the Kalambaina marl and limestone, and *Rotalia hensoni*, and species of *Lockhartia*, *Sakesaria* and *Daviesina* in the younger more basinal parts of the Kalambaina equivalents in Niger and Mali, places the Kalambaina microfauna among the Tethyan carbonate assemblage. Although the Tethyan carbonate fauna of the Saharan epeiric sea became well differentiated during the Thanetian, it has many elements in common with the Boreal and Meridional provinces of mainland Europe where the Thanetian is regressive and represented by fresh-water, and lagoonal environments. This is because some of these cosmopolitan benthic species range throughout the Paleocene, with some extending into the Eocene. Such cosmopolitan elements include *Rotalia trochidiformis, R. saxorum, Thalmannita madrugaensis, Boldia cubensis, Nonion graniferum, Elphidiella prima, Cibicides simplex, C. reinholdi, Rosalina koeneni, Pyramidina crassa, Pararotalia perclara*, and *P. tuberculifera*. Most of these taxa were reported from the Carpathian Paleocene where there is an admixture of epicontinental and geosynclinal Paleocene elements (Szczechura and Pożaryska 1974). Some also occur in the Danian-Montian of Belgium and the Netherlands, the Paris Basin, the Polish lowlands, and the Crimea Peninsula of the Soviet Union.

Figure 3 is a plot of the world-wide distribution of the two principal groups of benthic foraminifera that occur in the Kalambaina Formation. First is the endemic element, *Operculinoides bermudezi* which is restrict-

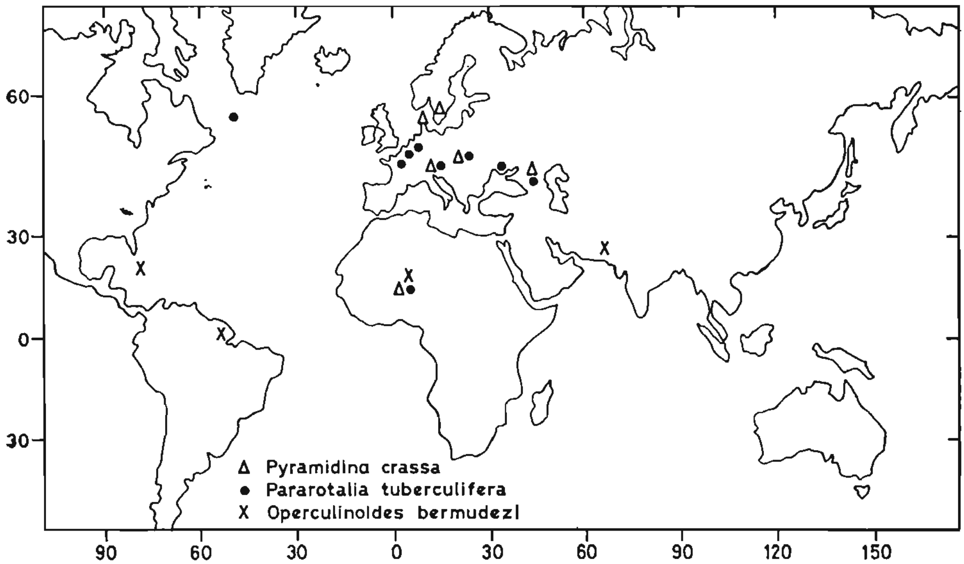

Fig. 3. World map showing the distribution of *Pyramidina crassa, Pararotalia tuberculifera*, and *Operculinoides bermudezi*.

ed to the shallow-water tropical and classical Tethyan province like the normal types of rudistid pelecypods (Kummel 1970:547, fig. 15—4). Second are the more cosmopolitan elements, *Pyramidina crassa*, and *Pararotalia tuberculifera* which also occur in the Boreal region. The known distribution of *Pyramidina crassa* shows that this Paleocene index form probably did not cross the Atlantic into the New World. *Pararotalia tuberculifera* was more wide-ranging both geographically and stratigraphically and occurred where there was a very shallow-water carbonate substrate in the North Atlantic, Europe, the Sahara, and North Africa. Another taxon which has not been reported from North America (Plummer 1926; Cushman 1951; Olsson 1960), but which occurs in the Kalambaina Formation and in Europe is *Rosalina koeneni*. Thus, there are certain benthic taxa which seem to be restricted to the Sahara, North Africa, Europe, and the USSR.

The above differences between the Saharan Paleocene benthic foraminifera and those of North America also apply to the Southern Nigerian Sedimentary Basin, including the Niger Delta. Ogbe (1974), in his comprehensive study of Lower Tertiary foraminifera in southern Nigeria, recorded about 300 benthic species and subspecies from many boreholes in the Niger Delta, and also from the Ewokoro Formation. The difference between Ogbe's faunal list and that of the Kalambaina Formation is very striking. Even in the coeval carbonate facies of the Ewokoro Formation, the distinctive Tethyan shallow-water carbonate benthic association does not occur. Other important elements of the Iullemmeden Basin that have not been recorded from southern Nigeria include *Rotalia trochidiformis*, *R. saxorum*, *Pararotalia tuberculifera*, *Thalmannita madrugaensis*, *Boldia cubensis*, *Laffitteina bibensis*, *Nonion graniferum*, *Elphidiella prima*, *Rosalina koeneni*, and *Pyramidina crassa*. Only the ubiquitous Paleocene elements which are of no paleobiogeographic significance, such as *Cibicides*, *simplex*, and *C. reinholdi* occur in both the Iullemmeden Basin and the southern sedimentary basin.

Based on the present state of knowledge of the Paleocene of Nigeria, it is evident the Southern Nigerian Sedimentary Basin did not derive its fauna through the so-called trans-Saharan seaway. Foraminiferal data do not suggest any direct faunal exchange between the Iullemmeden Basin and the southern basin. The faunas of the Southern Nigerian Sedimentary Basin came direct from the Atlantic, which explains the strong affinity with the Midway faunas of the U.S. Gulf Coast.

SUMMARY

Analysis of the benthic foraminiferal microfaunas of southeastern Iullemmeden Basin reveals not only the occurrence of Maastrichtian--Paleocene age diagnostic species, but also the existence of paleobiogeographically significant forms during the Paleocene. There is a close similarity between the Paleocene benthic assemblages of the Iullemmeden Basin and those of the epicontinental Boreal and Meridional provinces of Europe. Similar faunal elements include large, thick-walled species of the rotaliids, *Laffitteina* and *Elphidiella*. Other forms common to both regions include *Nonion graniferum*, *Rosalina koeneni*, and *Pyramidina crassa*. Thus, there was an extensive fauna exchange within the contiguous Mediterranean region during the Paleocene.

Benthic foraminifera which were restricted to carbonate facies along the margins of the Tethys Sea, such as *Operculinoides bermudezi*, *Rotalia hensoni*, and species of *Lockhartia*, *Daviesina* and *Sakesaria*, occur abun-

dantly in the Late Paleocene of the Iullemmeden Basin. Of these forms which were reported from Mali and Niger by Krasheninnikov and Trofimov (1969) and Greigert (1966), only *Operculinoides bermudezi* was observed in the outcropping part of the Kalambaina marl and limestone in the area between Sokoto and Malbaza.

Whereas the Paleocene benthic foraminiferal microfaunas of the Iullemmeden Basin have much in common with mainland Europe and the Mediterranean, those of the Southern Nigerian Sedimentary Basin show close affinity with the Gulf Coastal Region of the United States. The distinctiveness of the two major West African Paleocene foraminiferal microfaunas supports the recognition of the two areas as separate paleogeographic provinces, between which was no faunal interchange.

DESCRIPTIONS

Family **Ammodiscidae** Reuss, 1862
Genus *Ammodiscus* Reuss, 1862
Ammodiscus cf. *siliceus* (Terquem, 1862)
(pl. 5: 2)

Material. — Very abundant, over 100 specimens, most of them well preserved.

Dimensions of figured specimen (in mm):

Maximum diameter	0.22
Minimum diameter	0.18

Description. — Test very small; planispiral, evolute; single tube increasing gradually in size, biconcave; outline some-what quadrate to triangular; periphery rounded. About 4 whorls which may partially overlap. Wall smooth, arenaceous with very fine particles. Aperture is semicircular at the end of the long tubular chamber.

Variation. — Some variation occurs in outline, many specimens being somewhat triangular, others quadrate, a few are circular. Also, the walls of some specimens have fairly coarse cemented material, while others show a very fine texture.

Remarks. — The Nigerian specimens are compared with hypotypes of *Ammodiscus siliceus* reported from the Paleocene of the Polish Carpathians by Szczechura and Pożaryska (1974). Points of similarity include the smooth wall, biconcave test, and lack of transverse growth constructions. The Polish forms are, however, larger and consist of more whorls which do not overlap.

Occurrence — This species occurs abundantly at some intervals in the lower and upper shales of the Dukamaje Formation. *Ammodiscus siliceus* is known from the Jurassic — Paleocene of the European Tethys as summarized by Szczechura and Pożaryska (1974).

Family **Lituolidae** de Blainville, 1825
Genus *Haplophragmoides* Cushman, 1910
Haplophragmoides excavata Cushman and Waters, 1927
(pl. 6: 3, 4)

1927. *Haplophragmoides excavata* Cushman and Waters: 82, pl. 10: 3*a*, *b*.
1971. *Haplophragmoides excavata* Cushman and Waters, forma *alpha*; Mello: C32, pl. 4: 1*a*-*b*.

Material. — Common well preserved specimens.

Dimensions of figured specimen (in mm):

Maximum diameter	0.52
Minimum diameter	0.44

Description. — Test medium to large; planispirally involute, may be slightly evolute showing few chambers of previous whorl; slightly ovate in outline, with faintly lobulate periphery; rounded axial periphery, occasionaly narrowly rounded due to secondary compression of test. About 7 wedge-shaped chambers in last whorl, chambers increase gradually in size, slightly inflated. Wall texture exhibits a smooth finish due to moderate to fine constituent grains. Sutures straight, flush to slightly depressed, radial to poorly oblique, may become indistinct depending on granularity of wall. Umbilicus small and shallow. Aperture low, equatorial, interiomarginal, triangular, at centre of apertural face.

Variation. — This taxon exhibits a large degree of morphological variability. The most striking aspect of variation is the surface texture of the test. Depending on the grain size of the substrate, this species can incorporate fairly coarse quartz sand grains into its test. This in turn tends to obscure morphologic details such as sutures and chamber outline.

Remarks. — Mello (1971) recognized several morphological variants of *Haplophragmoides excavata* in the Campanian — Maastrichtian Pierre Shale Formation of the Western Interior of the United States. He erected 5 morphological subgroups based on grain size, degree of test compression, chamber shape and number, and degree of involution. The Nigerian forms described here can be placed under *Haplophragmoides excavata* Cushman and Waters forma *alpha* of Mello. Both forms have a smoothly finished, fine-grained wall texture, medium to large size, involute planispiral coiling 6 to 8 chambers in the last whorl, commonly visible sutures and slightly inflated chambers. Detailed study of the rich Nigerian material in future, will enable recognition of other morphovariants.

Occurrence. — *Haplophragmoides excavata* is a commonly occurring form especially in the Campanian — Maastrichtian sequence of the Western Interior Seaway of North America (Mello 1971). In northwestern Nigeria this taxon was recovered mainly from the Maastrichtian Dukamaje Formation. A sporadic occurrence of some variants of this group was also noted in the Paleocene of north-western Nigeria and neighbouring Niger.

Family **Ataxophragmiidae** Schwager, 1877

Genus *Gaudryina* d'Orbigny, 1839

Gaudryina pyramidata Cushman, 1930

(pl. 5:6)

1930. *Gaudryina (Pseudogaudryina) pyramidata* Cushman: 87, pl. 12:13.
1956. *Gaudryina pyramidata* Cushman; Said and Kenawy: 124, pl. 1:26.

Material. — Rare; fair preservation.

Dimensions of figured specimen (in mm):

Length	0.80
Maximum width	0.54

Description. — Test large, triangular, rapidly tapering; triserial in early portion, late biserial, acute angles, concave sides. Chambers broad, triangular and slightly inflated especially in later part of test; indistinct in early triserial part. Sutures depressed where visible. Wall smooth, apparently fine — to medium-grained. Aperture at base of ultimate chamber, semicircular depression, often filled by secondary calcite.

Remarks. — The material described in this study is very typical of *Gaudryina pyramidata* as figured by Le Roy (1953), and Said and Kenawy (1956). The angles in the Nigerian specimens are, however, truncate in addition to being acute. Morphologic details are much obscured by secondary calcite in-filling.

Occurrence. — This species was first described from the Paleocene Velasco Shale of Mexico and the Lizard Springs Formation of Trinidad by Cushman (1930). Later Le Roy (1953) observed it in the upper part of his Maastrichtian unit A in Egypt. Said and Kenawy (1956) extended the stratigraphic range of *Gaudryina pyramidata* into the lower Maastrichtian and Danian of Egypt. Haynes (1962) also recorded this species from the Paleocene of Libya. In the Sokoto embayment *G. pyramidata* occurs only in the Kalambaina Formation of Late Paleocene age. Thus, the known range of this species so far is from Early Maastrichtian to Late Paleocene.

Genus *Orbignyna* Hagenov, 1842

Orbignyna inflata (Reuss, 1850)

(pl. 6:6)

1850. *Spirolina inflata* Reuss: 16, pl. 2:5, 6.
1965. *Orbignyna inflata* (Reuss); Pożaryska: 58, pl. 3:6*a-c*.

Material. — About 10 specimens in excellent state of preservation.

Dimensions of figured specimen (in mm):

Maximum diameter	1.3
Minimum diameter	1.0

Description. — Test large, ovate, inflated to slightly compressed, planispiral early stage, involute, later somewhat uncoiling but not completely; periphery distinctly lobulate especially in the later part of last whorl; axial periphery narrowly rounded to nearly sharp, broad apertural face. Chambers elongate and curved, increasing rapidly in size; 8 chambers in last whorl. Wall coarsely arenaceous with transparent quartz grains randomly embedded in porous siliceous cement; abundant matrix. Sutures mostly distinct, depressed and wide, more pronounced toward periphery, curved; somewhat faint where wall texture is very coarse, but generally more prominent in later part of last whorl. Aperture an elongate slit centrally located on apertural face.

Variation. — Only the degree of test compression seems to vary.

Remarks. — The Nigerian material is strikingly similar to hypotypes figured by Pożaryska (1965). But scanning electron micrographs reveal that *O. inflata* is coarsely arenaceous.

Occurrence. — In this study *O. inflata* was recovered only from the shale lithologies of the Maastrichtian Dukamaje Formation, where it shows sporadic occurrence. The occurrence of *O. inflata* in the Polish Danian is due to reworking; this species is common in the Upper Cretaceous of the USSR (Pożaryska, 1965). However, it is also known from the Middle Danian of Denmark.

Family **Turrilinidae** Cushman, 1927

Genus *Pyramidina* Brotzen, 1940

Pyramidina crassa Brotzen, 1948

(pl. 5:1)

1948. *Pyramidina crassa* Brotzen: 63, pl. 6:8.
1965. *Pyramidina crassa* Brotzen; Pożaryska: 99, pl. 15:5*a-c*.
1974. *Pyramidina crassa* Brotzen; Szczechura and Pożaryska: 47, pl. 5:14, 15.

Material. — Eighty-three well preserved specimens.

Dimensions of figured specimen (in mm):

Length	0.71
Maximum width	0.44

Description. — Test gradually tapering, triserial, maximum width toward apertural end, triangular in transverse section, concave sides; peripheral margin narrowly truncate in initial part of test, later becoming broad. Chambers about 5—6 with moderate increase in size, broad and low. Wall calcareous, smooth and finely perforate. Sutures depressed, curved and very distinct, overarched by succeeding chambers. Aperture terminal, elongate to nearly loop-shaped.

Variation. — The only variation observed was in the length/width ratio. Some specimens are twice as long as broad, whereas in others the ratio is much lower. The length/width ratio may in future studies prove to be a useful index for separating different populations, if not morphotypes, of *Pyramidina crassa.*

Remarks. — Scanning electron micrographs reveal small rounded pores on *P. crassa.* Most of the Nigerian specimens tend to show a lower length/width ratio than the forms reported from Sweden by Brotzen (1948), and Poland by Pożaryska (1965). Otherwise, the Nigerian forms are identical to the holotype figured by Brotzen (1948).

Occurrence. — The foraminiferal microfaunas of the Kalambaina Formation is characterized by *Pyramidina crassa,* among others. This species was also reported from the subsurface Late Paleocene of Mali by Krasheninnikov and Trofimov (1969). It co-occurs with the larger foraminifera *Operculinoides bermudezi,* and other distinctive calcareous benthic foraminifera such as *Thalmannita madrugaensis,* and *Boldia cubensis.* Berggren (1974*a*) correlated this biostratigraphically important shallow-water benthic foraminiferal assemblage with the planktonic foraminiferal *Planorotalites pseudomenardii* Zone (P_4) of Middle Thanetian age.

However, *P. crassa* is known from the Danian of Sweden (Brotzen 1948), the Danian-Montian of Polish Lowlands and Pamiętowo boring (Pożaryska 1965; Pożaryska and Szczechura 1968), the Thanetian of the Polish Carpathians (Szczechura and Pożaryska 1974), and from the Paleocene of Denmark, Austria, and USSR. *Pyramidina crassa* can therefore be regarded as a useful Paleocene index benthonic foraminifera.

Family **Rotaliidae** Ehrenberg, 1839

Genus *Rotalia* Lamarck, 1804

Rotalia saxorum d'Orbigny, 1850

(pl. 5:4)

1850. *Rotalia saxorum* d'Orbigny: 407, fig. 5.
1882. *Rotalia perovalis* Terquem: 70, pl. 6:5.
1946. *Rotalia saxorum* d'Orbigny; van Bellen: 64, pl. 8:17—19.
1952. *Rotalia perovalis* (Terquema); Le Calvez: 49, pl. 4:47—48.
1966. *Rotalia saxorum* d'Orbigny; Hofker: 263, pl. 55:94; 246, pl. 47:20*a-c*.
1966. *Rotalia perovalis* (Terquem); Hofker: 263, pl. 55:97.
1968. *Rotalia saxorum* d'Orbigny; Pożaryska and Szczechura: 61, pl. 5:1, 3, 4; pl. 18:5—9.

Material. — Abundant and fairly well preserved.

Dimensions of figured specimen (in mm):

Maximum diameter	0.68
Minimum diameter	0.62

Description. — Test medium to large, trochospiral, lenticular to plano-convex, conical on spiral side, flat to very slightly bulging on umbilical side; circular in outline; periphery round, not lobulate, heavily thickened and acute peripheral margin. All chambers visible on spiral side, only 7 chambers of last whorl visible on umbilical side. Wall calcareous, granular, coarsely perforate. Sutures on umbilical side distinct, deep, becoming deeper toward umbilicus, curved, terminating before reaching thickened periphery, last three umbilical sutures exhibit short branches that seem to merge with nearby pores; spiral sutures broad, flush to faintly limbate, often indistinct due to poor preservation. Umbilicus covered with large, central, well defined plug surrounded by deep groove into which sutures merge. Aperture a horizontal slit at the base of last chamber, completely umbilical.

Variation. — This species does not seem to exhibit much morphological variation.

Remarks. — The Nigerian forms are closely similar to hypotypes of *Rotalia saxorum* figured by Pożaryska and Szczechura (1968: pl. 18:9), and Szczechura and Pożaryska (1974: pl. 12:5—7). The morphovariant with a highly lobulate periphery figured by Pożaryska and Szczechura (1968: pl. 18:5) was not observed in the present study. The surface texture of *R. saxorum* as revealed by SEM is one in which the thickened peripheral margin is smooth to sparingly perforate, with minute pores, while the remainder of the test exhibits large and rounded pores.

Occurrence. — This form occurs in the Paleocene Kalambaina Formation and its equivalents in the subsurface of Mali. In Europe the stratigraphic range of *R. saxorum* is Maastrichtian to Eocene. It is characteristic of the warm, shallow-water deposits that surrounded the Tethys Sea.

Genus *Pararotalia* Le Calvez, 1949
Pararotalia tuberculifera (Reuss, 1862)
(pl. 5:5)

1862. *Rotalia tuberculifera* Reuss: 313, pl. 2:2.
1965. *Pararotalia tuberculifera* (Reuss); Pożaryska: 118, pl. 20:3*a-c*.
1974. *Pararotalia tuberculifera* (Reuss); Szczechura and Pożaryska: 67, pl. 13:1, 2, 4.

Material. — Extremely rich and variable state of preservation.

Dimensions of figured specimens (in mm):

Maximum diameter	0.46
Minimum diameter	0.37

Description as given by Pożaryska (1965).

Variation. — Pożaryska and Szczechura (1968) and Szczechura and Pożaryska (1974) have demonstrated the large degree of morphologic variation shown by *Pararotalia tuberculifera.* Their observations are applicable to the Nigerian population as well. Thus, forms with lobulate to strong serrate outline are common in the present study, as well as spinose forms and those with various umbilical modifications.

Remarks. — The Nigerian specimen here figured is one of the variants of *P. tuberculifera*, and is not at all representative of the range of morphologic variation shown by the population studied. Spinose forms with circular and serrate outline are common among the Nigerian material, as well as ovate forms with more evenly lobulate periphery.

Occurrence. — *Pararotalia tuberculifera* is a commonly occuring warm, shallow-water species in the Paleocene carbonates of the Iullemmeden Basin and is best developed in the Kalambaina Formation. It is known in the Late Cretaceous — Paleogene of most parts of Europe and USSR. Although *P. tuberculifera* is of limited use in age correlation, its paleoecologic significance was emphasized by Berggren (1974*a*). Berggren assigned a shallow inner neritic depth of less than 10 metres to the basal section of Late Paleocene age at Rockall Bank (Site 117). The association of *P. tuberculifera* and *Cibicides simplex* with larger foraminifera at Rockall Bank was found to denote very shallow depths based on lithologic and other paleontological criteria.

Family **Elphidiidae** Galloway, 1933
Genus *Elphidiella* Cushman, 1936
Elphidiella africana (Le Roy), 1953
(pl. 6:7)

1953. *Elphidium africanum* Le Roy: 28, pl. 3:11—12.

Material. — Common but very poorly preserved.

Dimensions of figured specimen (in mm):

Maximum diameter	0.40
Minimum diameter	0.36

Description and variation as given by Le Roy (1953).

Remarks. — The specimens reported here are similar to the holotype in being circular, biconvex, with numerous and moderately distinct chambers which increase gradually in size, and in having somewhat raised sutures. It is mainly in this latter respect that the Nigerian specimens differ from the related and co-occurring form *Elphidiella prima*. However, the specimens of *E. africana* discussed here are generally smaller than the holotype figured by Le Roy (1953). Rectal processes are not evident on the Nigerian specimens because of poor preservation.

Occurrence. — *Elphidiella africana* was first described from the uppermost part of Esna Shale in Egypt, an interval which correlates with Early Eocene age. In the Iullemmeden Basin this species occurs throughout most of the Paleocene carbonate facies and is restricted to the Kalambaina Formation in northwestern Nigeria and nearby Niger Republic.

Family **Heterohelicidae** Cushman, 1927
Genus *Guembelitria* Cushman, 1933
Guembelitria cretacea Cushman, 1933
(pl. 5:7)

1933. *Guembelitria cretacea* Cushman: 37, pl. 4:12*a-b*.
1936. *Guembelitria cretacea* Cushman; Jennings: 28, pl. 3:12*a-b*.
1960. *Guembelitria cretacea* Cushman; Olsson: 27, pl. 4:8.
1964. *Guembelitria cretacea* Cushman; Said and Sabry: 390, pl. 3:32.
1973. *Guembelitria cretacea* Cushman; Smith and Pessagno: 15, pl. 1:1—8.

Material. — Very abundant, 250 specimens, poorly preserved.

Dimensions of figured specimen (in mm):

Length	0.13
Maximum width	0.11

Description and variation as given by Smith and Pessagno (1973).

Remarks. — Specimens from southeastern Iullemmeden Basin are generally short and dwarfish; there are fewer chambers in each row, and a very rapid rate of chamber expansion. Otherwise, the materials presented here are very typical. Because of the poor state of preservation no observation can be made regarding the wall topography of this species.

Occurrence. — This well known species has been reported from the Middle to Late Maastrichtian in the Gulf Coastal Plain of the United States by numerous authors including Pessagno (1967) and Smith and Pessagno (1973). It has also been reported from the Atlantic Coastal Plain of the USA where it occurs in the Maastrichtian (Olsson 1960; Petters 1975), and from the Maastrichtian of Egypt (Said and Sabry 1964).

In northwestern Nigeria *Guembelitria cretacea* occurs in the marl member of the Dukamaje Formation, thus supporting a Maastrichtian age for this formation. Its occurrence in this region is, however, very unique in that there are no truly planktonic foraminifera associated with it, except extremely rare and diminutive ?*Rugoglobigerina*. Shallow to middle neritic marine environments has been suggested for this species by Smith and Pessagno (1973). However, Davids (1966) and others postulated a benthic habit for *G. cretacea*. This was because the distribution of this species, unlike other heterohelicids (*Gublerina, Heterohelix, Planoglobulina, Pseudoguembelina, Pseudotextularia*, and *Racemiguembelina*), was most abundant under apparently shallow-water conditions and very rare or absent in deep-water assemblages. Davids found that higher numbers of this genus appeared where other planktonics were reduced in numbers. He therefore suggested a nerito-pelagic or benthic mode of life for the genus *Guembelitria*.

In the Dukamaje Formation *Guembelitria cretacea* occurs in a gypsiferous lithofacies which suggests very poor communication of the restricted interior Saharan sea, with the open Tethys Sea. This biofacies is therefore extremely shallow. The very abundant occurrence of this species under such conditions is strongly suggestive of a benthic habit. At some intervals in the Dukamaje marl *G. cretacea* constitutes over 40 percent of the entire assemblage suggesting its strong tolerance of extreme ecologic conditions.

Family **Cibicididae** Cushman, 1927

Genus *Cibicides* Montfort, 1808

Cibicides praecursorius (Schwager, 1883)

(pl. 6:1, 2)

1833. *Discorbina praecursoria* Schwager: 125, pl. 27:12*a-d*, 13*a-d*; pl. 29:16*a-d*.
1941. *Cibicides praecursoria* (Schwager); Toulmin: 610, pl. 82:19—21.
1953. *Cibicides praecursorius* (Schwager); Le Roy: 25, pl. 10:12—14.

Material. — Common and fairly well preserved.

Dimensions of figured specimens (in mm):

Maximum diameter	0.30
Minimum diameter	0.26

Description. — Test trochospiral, plano-convex, spiral side flat or nearly flat, umbilical side moderately convex; periphery acute, fairly lobulate. Chambers 6—7 in last whorl, distinct, wedge-shaped, inflated on umbilical side, increasing rapidly in size. Wall calcareous, smooth and polished; moderately perforate, large pores. Sutures distinct, depressed, more strongly depressed and slightly curved on umbilical side and radiate. Umbilicus small. Aperture a low slit at base of final chamber on umbilical side, arching across the periphery onto the spiral side, bordered by narrow, thick lip.

Variation. — Not very pronounced.

Remarks. — The specimens from southeastern Iullemeden Basin are very similar to those figured by Said and Kenawy (1956) from Sinai, Egypt. Points of similarity include the number of chambers in the final whorl, and the fairly rapid rate of chamber size increase. However, specimens figured by Toulmin (1940) from the Paleocene of Alabama, and those figured by le Roy have more chambers (7—9) in the final whorl; these chambers show a slower rate of size increase. Furthermore, the Saharan and Sinai specimens are more inflated umbilically than those from Alabama and from the western Egyptian desert.

Occurrence. — *Cibicides praecursorius* is known from the Maastrichtian (Said and Kenaway, 1956), mid-Paleocene (Toulmin 1941), and Late Paleocene (Le Roy 1953). In this study *C. praecursorius* is restricted to the Kalambaina limestone.

Family **Pleurostomellidae** Reuss, 1860

Genus *Pleurostomella* Reuss, 1860

Pleurostomella cf. *paleocenica* Cushman, 1947

(pl. 6:5)

Material. — Rare and poorly preserved.

Dimensions of figured specimen (in mm):

Length	0.40
Maximum width	0.15

Description. — Test gradually tapering, cuneate, nearly circular in transverse section. Chambers few, inflated, nearly as wide as high, alternating. Wall calcareous, costate. Sutures distinct, later ones strongly depressed. Aperture on upper part of ultimate chamber, deep, wide, an oval depression that occupies most of apertural face.

Variation. — Very insignificant.

Remarks. — The materials from southeastern Iullemmeden Basin are similar to *Pleurostomella paleocenica*. The principal difference between the specimens reported here, and *P. paleocenica* figured by Plummer (1926) and Cushman (1951) from the Midway Formation of Texas lies in the finely costate ornamentation of the present material, whereas *P. paleocenica* has a smooth test.

Occurrence. — This species is rare in the Kalambaina Formation.

Family **Nonionidae** Schultze, 1854

Genus *Nonionella* Montfort, 1808

Nonionella communis paleocenica Pożaryska and Szczechura, 1968

(pl. 5:3)

1968. *Nonionella communis paleocenica* Pożaryska and Szczechura: 83, pl. 9:7—9.

Material. — Rare and poorly preserved.

Dimensions of figured specimen (in mm):

Maximum diameter	0.20
Minimum diameter	0.14

Description and variation as given by Pożaryska and Szczechura (1968).

Remarks. — Althought its morphologic details are lost due to poor preservation, the present specimens are very similar to those figured by Pożaryska and Szczechura (1968) in having an ovate and narrow test, with radial and slightly curved sutures, and an umbilical depression. The aperture is visible in the present material and is a narrow low arch or slit at the base of the ultimate chamber on the umbilical side.

Occurrence. — The present material comes from the Kalambaina Formation. *Nonionella communis paleocenica* is common in the Paleocene (Montian) of the Pamiętowo boring of Poland (Pożaryska and Szczechura 1968).

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SUNDAY W. PETTERS

OTWORNICE MASTRYCHTU I PALEOCENU Z NW NIGERII I ICH PALEOGEOGRAFIA

Streszczenie

Na terenie Nigerii osady z pogranicza kredy i trzeciorzędu są szczególnie dobrze rozwinięte w regionie Sokoto i Dukamaje, stanowiącym południowe peryferie wielkiego, środkowo-saharyjskiego basenu Iullemmeden. W basenie tym osady kredy i paleocenu osiągnęły znaczne miąższości. Analiza mikrofauny wykazała duże bogactwo otwornic, głównie bentonicznych, nie najlepiej zresztą zachowanych. Umożliwiły one jednak autorowi przeprowadzenie korelacji poprzez teren Sahary z obszarami Tetydy i mórz epikontynentalnych Europy. Autor zajął się bliżej paleocenem w obrębie którego stwierdził szereg gatunków wspólnych dla wyżej wymienionych regionów. Gatunki te są w tym samym stopniu charakterystyczne dla osadów paleocenu Nigerii, co i dla osadów paleocenu północnej Afryki (Tunezji), a pewne elementy dla paleocenu Europy poczynając od Basenu Paryskiego, przez Belgię, Holandię, Polskę po Krym. Z drugiej strony autor przeprowadził porównanie z osadami paleocenu S obrzeżenia Nigerii, gdzie mikrofauna tegoż wieku okazała się nieco odmienna od północno-nigeryjskiej, a zbliżona do środkowo-amerykańskiej. Tak więc zapewne istniało nader słabe połączenie tych dwóch basenów nigeryjskich między sobą. Basen południowy, Ewokoro, musiał mieć w tym czasie połączenie z basenem środkowo-amerykańskim (Texas, Meksyk) poprzez Atlantyk bezpośrednio, a nie drogą śródsaharyjską.

САНДЭЙ В. ПЭТТЭРС

МААСТРИХТО-ПАЛЕОЦЕНОВЫЕ ФОРАМИНИФЕРЫ СЕВЕРО-ЗАПАДНОЙ НИГЕРИИ И ИХ ПАЛЕОГЕОГРАФИЯ

Резюме

На территории Нигерии отложения границы мелового и третичного периодов особенно хорошо проявляются в районе Сокото и Дукамайэ, являющимся южной периферией большого центрально-сахарийского бассейна Иуллэммэдэн. В этом бассейне меловые и палеоценовые отложения достигли значительных мощностей. Анализ микрофауны указал на большое богатство фораминифер, главным образом, бентонных и не очень хорошо сохранившихся. Однако это позволило автору провести корреляцию района Сахары и территории Тетиды, а также территории эпиконтинентальных морей Европы. Автор детально изучил палеоцен, где он обнаружил для выше названных районов ряд общих видов. Эти виды являются в такой же самой степени характерными для отложений палеоцена Нигерии, как и для отложений палеоцена северной Африки (Тунезия), а некоторые элементы характерны для отложений палеоцена Европы, начиная от Парижского Бассейна, через Бельгию, Голландию, Польшу до Крыма. С другой стороны автор сравнил эти отложения с отложениями палеоцена южного побережья Нигерии, где микрофауна такого же возраста оказалось несколько иной по сравнению с северо-нигерийской, и близкой с центрально-американской. Это означает, что существовала связь может быть слабая, этих двух нигерийских бассейнов. Южный бассейн Эвокоро должен быть в это время соединён с центрально-американским бассейном (Тексас, Мексико) непосредственно через Атлантику, а не центрально-сахарийским путём.

EXPLANATION OF THE PLATES

Plate 5

All magnifications are approximate

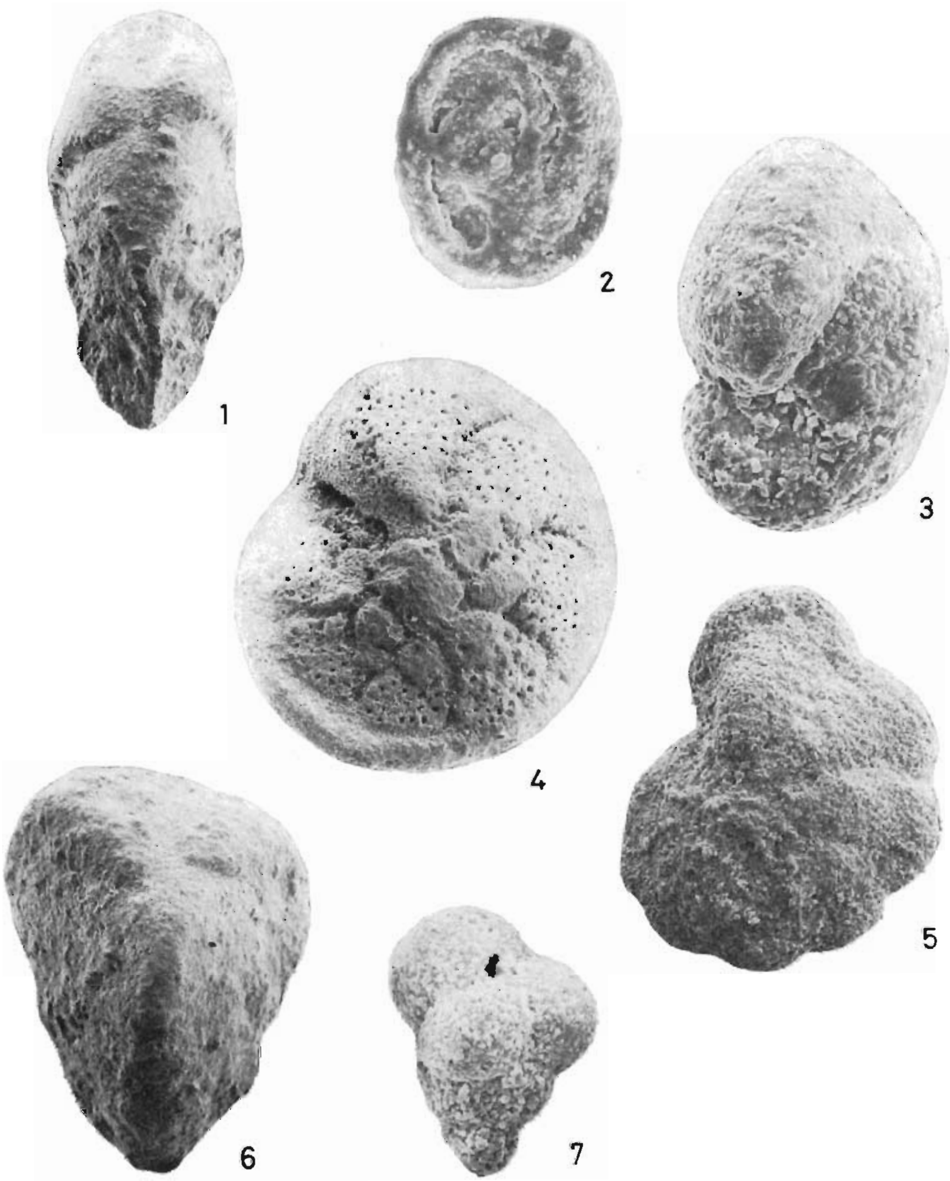
1. *Pyramidina crassa* Brotzen. Kalambaina Formation, near Tsoga, 4 m, side view, × 60.
2. *Ammodiscus* cf. *siliceus* (Terquem). Dukamaje Formation, type locality, 1 m, side view, × 240.
3. *Nonionella communis paleocenica* Pożaryska and Szczechura. Kalambaina Formation, near Tsoga, 4 m, umbilical view, × 240.
4. *Rotalia saxorum* d'Orbigny. Kalambaina Formation, Malbaza quarry, 8 m, umbilical view, × 72.

5. *Pararotalia tuberculifera* (Reuss). Kalambaina Formation, type locality, 8 m, umbilical view, × 100.
6. *Gaudryina pyramidata* Cushman. Kalambaina Formation, near Tsoga, 4 m, side view, × 66.
7. *Guembelitria cretacea* Cushman. Dukamaje marl, type locality, 5 m, side view, × 240.

Plate 6

All magnifications are approximate

1, 2. *Cibicides praecursorius* (Schwager). Kalambaina Formation, type locality, 8 m, *1* umbilical view; *2* spiral view, both × 150.
3, 4. *Haplophragmoides excavata* Cushman and Waters. Dukamaje Formation, lower shale, near Tsoga, 3 m, *3* edge view; *4* side view, both × 60.
5. *Pleurostomella* cf. *paleocenica* Cushman. Kalambaina Formation, type locality, 5 m, side view, × 120.
6. *Orbignyna inflata* (Reuss). Dukamaje Formation, lower shale, near Tsoga, 3 m, spiral view, × 30.
7. *Elphidiella africana* (Le Roy). Kalambaina Formation, type locality, 8 m, side view, × 120.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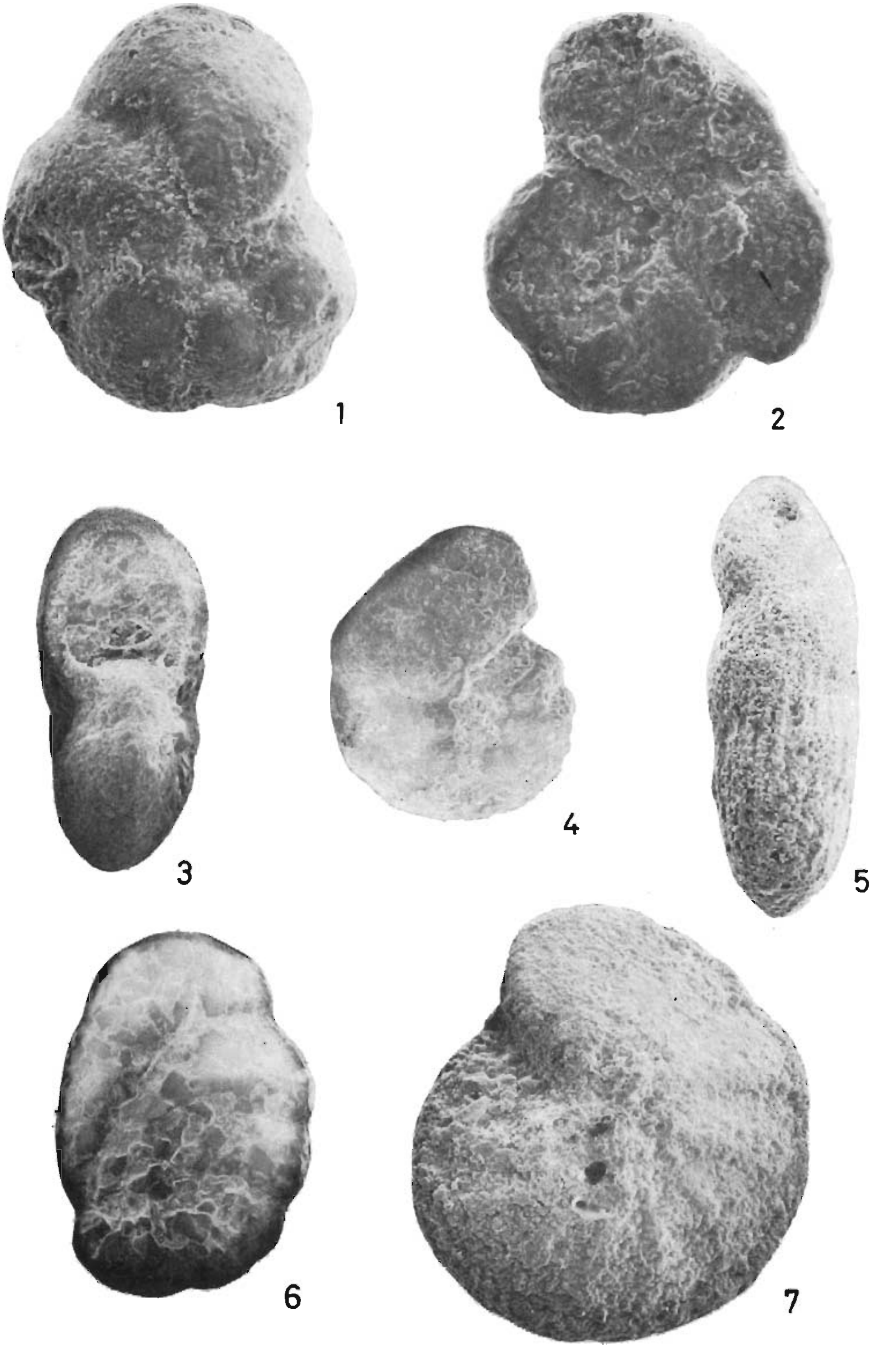
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