

# Paleontology, stratigraphy and paleogeography of ninety African Campanian-Neogene planktic and benthic foraminifera of Anan

## Abstract

This study deals with taxonomic consideration of ninety African Campanian-Neogene benthic and planktic foraminiferal species of Anan, which belongs to fifty-five genera. Rich and well-preserved African fauna from Morocco, Tunisia, Egypt, Ivorian Basin, Nigeria and Tanzania, made it possible to correlate them with those previously identified species in different stratigraphic sequence in many Tethyan localities: USA, Trinidad, Spain, France, Germany, Hungaria, Jordan, Iraq, United Arab Emirates (UAE), Qatar and India. Four new benthic foraminiferal genera were erected by the present author: *Leroyia*<sup>1</sup> (3 species), *Lenticuzonaria*<sup>2</sup> (1 species), *Lenticubella*<sup>3</sup> (2 species) and *Percultalina*<sup>4</sup> (2 species). 90 benthic foraminiferal species: 15 agglutinated species, 2 porcelaneous, 34 Lagenid, 33 Rotaliid, and 6 planktic species are added to this assemblage. 70 species of them (~78%) are recorded from Egypt, 9 species (~10%) from Tunisia, 6 species (~7%) from Ivorian Basin,<sup>5</sup> 2 species (~2%) from each of Nigeria and Tanzania, and only one species (~1.5%) from Morocco. One of the recorded species is believed here to be new: *Oolina tunisica*. This study presented also five benthic foraminiferal evolutionary lineages: *Textulariella cretosa* Cushman > *T. sinaensis* Anan, *Leroyia maqfiensis* Anan > *L. aegyptiaca* Anan, *Percultalina misrensis* Anan > *P. sinaensis* Anan, *Uvigerinella tunisica* Anan > *U. nakkadyi* Anan, *Anomalinoides aegyptiacus* (LeRoy) > *A. dababiyaensis* Anan, and another four planktic lineages: *Plummerita safaae* Anan > *P. haggagae* Anan, *P. salimi* > *P. hodae*, Anan, *P. inflata* (Brönnimann) > *P. costata* (Brönnimann), and *P. tunisica* Anan > *P. spainica* Anan lineages. The Campanian *Gaudryina jaffi* Anan<sup>5</sup> and Early Eocene *G. ameeri* Anan,<sup>6</sup> Campanian *Gaudryina lawai* Anan<sup>7</sup> and *G. speijeri* Anan,<sup>6</sup> Campanian *Pseudoclavulina farisi* Anan,<sup>7</sup> and Paleocene *P. hewaidyi* Anan,<sup>8,9</sup> Middle Eocene *Hemirobulina bassiouinii* Anan<sup>10</sup> and Oligocene-Miocene *H. hantkeni* (Bandy) have good examples of Homeomorphy.

**Keywords:** Paleontology, foraminifera, stratigraphy, lineage, homeomorphy, campanian, paleogene, neogene, Africa

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## Introduction

The author analyzed more than 30 years of datasets from local and international sources. The present paper aims to highlight the paleontology, stratigraphy, paleogeography of the 90 Campanian-Neogene benthic and planktic foraminiferal species which were originally erected by the present author from many different localities in Africa: Morocco, Tunisia, Egypt, Ivorian Basin, Nigeria and Tanzania (Figure 1). To offer a comprehensive understanding of the diversity of this assemblage, 4 new benthic foraminiferal genera were erected: *Leroyia*<sup>1</sup> (with its 3 species), *Lenticuzonaria*<sup>2</sup> (1 species), *Lenticubella*<sup>3</sup> (2 species) and *Percultalina*<sup>4</sup> (2 species), including 90 foraminiferal species: 15 agglutinated species, 2 porcelaneous, 34 Lagenid, 33 Rotaliid, and 6 Globigerinid species are added to this assemblage.

## Systematic Paleontology

The taxonomy of Loeblich & Tappan<sup>9</sup> is followed here. Ninety of the erected Campanian-Neogene small benthic and planktic foraminiferal species from six different localities in north and central Africa are illustrated in the Plate (1). The paleontological record has

an important value in the paleogeographic correlations with other Tethyan localities.



**Figure 1** Location map of six African localities: Morocco, Tunisia, Egypt, Ivorian Basin, Nigeria and Tanzania.

Order Foraminiferida Eichwald, 1830

I. Suborder Textulariina Delage & Hérouard, 1896

(1) *Bathysiphon saidi* Anan<sup>10</sup> (Figure 2.2). Middle-Late Eocene. Egypt, UAE, Hungaria.

Remarks: Elongated rough test with constructed of firmly cemented coarse sand grains.

(2) *Anmodiscus tanzanica* Anan<sup>11</sup> (Figure 2.19). Early Oligocene. Tanzania.

Remarks: It has fairly rough surface, and hollow globular proloculus.

(3) *Glomospira moroccoensis* Anan<sup>11</sup> (Figure 2.28). Paleocene. Morocco.

Remarks: It differs from *Glomospira irregularis* in its more enrolled streptospirally coiling.

(4) *Miliammina kenawi* Anan<sup>10</sup> (Figure 2.8. 2). Middle-Late Eocene. Egypt, UAE.

Remarks: It has a fine agglutinated smooth wall in a loose quinqueloculine arrangement with half coil chambers.

(5) *Haplophragmoides aegyptiaca* Anan<sup>12</sup> (Figure 2.2). Paleocene-Eocene. Egypt.

Remarks: It has compressed biumbilicate planispirally enrolled test, finely agglutinated wall with flattened sides, aperture an elongate equatorial slit at the base of the apertural face.

(6) *Trochammina aegyptiaca* Anan<sup>12</sup> (Figure 2.3). Early Eocene. Egypt.

Remarks: This species is characterized by involute trochospiral test, chambers increasing gradually in size as added, sutures radial depressed, and periphery rounded.

(7) *Gaudryina ameeri* Anan<sup>6</sup> (Figure 2.7). Early Eocene. Egypt.

Remarks: The Early Eocene *G. ameeri* Anan resembles the Campanian *Gaudryina jaffi* Anan<sup>7</sup>, but slightly differs by its shorter test, less elongate triserial stage and last chamber, and thicker front carinate rib. These two species have a good example to explain the "Homeomorphy", which an organism simulates an unrelated organism in form and function.

(8) *Gaudryina speijeri* Anan<sup>6</sup> (Figure 2.10). Early Eocene. Egypt, Tunisia, UAE.

Remarks: The two species and *Gaudryina lawai* Anan<sup>7</sup> and *Gaudryina speijeri* Anan consists a good example for the "Homeomorphy".

(9) *Siphogaudryina hafezi* Anan<sup>13</sup> (Figure 2.4). Early Eocene. Egypt.

Remarks: It differs from *G. pyramidata* Cushman by less rectangular apertural face in biserial stage and less acute triserial stage.

(10) *Siphogaudryina strougoi* Anan<sup>14</sup> (Figure 2.2.1). Paleocene. Egypt.

Remarks: It has distinctive 5 longitudinal ridges running nearly parallel to the periphery, 3 of them appear on the apertural view along the test, sutures raised and transverse, subterminal apertural face of the last chamber.

(11) *Textulariella sinaensis* Anan<sup>15</sup> (Figure 2.60). Paleocene. Egypt.

Remarks: This Danian species with cylindrical test, differs from the conical and tapering sharply early stage of the Maastrichtian-Danian *T. cretosa* Cushman. These species represent *Textulariella cretosa* > *T. sinaensis* lineage.

(12) *Textularia fahmyi* Anan<sup>10</sup> (Figure 2.8.3). Middle-Late Eocene. Egypt.

Remarks: It has a large biserial test, 1¼ times as long as broad, tapering toward the initial end, greatest breadth at the end chambers, and rhomboid in cross section, acute periphery, chambers about 8-10 pairs, increasing gradually in size as added, sutures depressed, wall arenaceous, consists of fine sand grains, occasionally rose colored.

(13) *Pseudogaudryina dababiyaensis* Anan<sup>16</sup> (Figure 2.2). Early Eocene. Egypt.

Remarks: One of the biserial stage has a pointed end, while the periphery of the other end is rounded, aperture wide interiomarginal arch. It has a wide triangular triserial portion, while the biserial has parallel edges.

(14) *Pseudoclavulina hewaidyi* Anan<sup>17</sup> (Figure 2.1). Paleocene. Egypt, UAE.

Remarks: The Paleocene *P. hewaidyi* Anan, has resemble form with the Campanian *P. farisi* Anan<sup>7</sup>, but differs by lesser long test, larger triserial early stage, flange shape uniserial chambers than discoidal form, more limbate and depressed sutures in the uniserial stage. These species consists a good example for "Homeomorphy".

(15) *Pseudoclavulina youssefi* Anan<sup>18</sup> (Figure 2.18). Paleocene. Egypt.

Remarks: It belongs to the genus *Pseudoclavulina* not to the genus *Tritaxia*. The Danian Jordanian *P. futyani* Anan differs from the Thanetian Egyptian *P. youssefi* Anan in the flask-shape uniserial chambers of the former than discoidal uniserial chambers of the latter. These two species represent *P. futyani* > *P. youssefi* lineage.

II. Suborder Miliolina Delage & Hérouard, 1896

(16) *Ammossilina misrensis* Anan<sup>18</sup> (Figure 2.22). Late Eocene. Egypt.

Remarks: This species has a quinqueloculine early stage, later chambers are added on the opposite sides of the test in a single plane, wall porcelaneous with a surface layer of agglutinated fine-grains of quartz particles.

(17) *Quinqueloculina tanzanica* Anan<sup>19</sup> (Figure 2.18). Early Oligocene. Tanzania.

Remarks: It differs from *Quinqueloculina carinata-striata* (Weisner) by its ornamented ribs not heavily costate which not parallel to the periphery but meet at it to form a small keel.

III. Suborder Lagenina Delage & Hérouard, 1896

(18) *Awhea africana* Anan<sup>20</sup> (Figure 2.10). Middle Eocene. Ivorian Basin, West Africa.

Remarks: Test calcareous narrow, elongate, uniserial rectilinear, with oval proloculus, followed by elongate subcylindrical chambers, sutures horizontal slightly constricted, surface ornamented with about twenty longitudinal ribs that may be slightly twisted about the vertical axis, aperture not described, probably terminal. It differs from the

holotype *Awhea sinalata* by more width test, and more number of the ribs (20 than 8 ribs).

(19) *Annulofrondicularia bignoti* (Anan<sup>21</sup>) (Figure 2.2.2). Paleocene-Early Eocene. Egypt.

Remarks: It has large proloculus surrounded by four to five uniserial chevron-shaped chambers, and the first one of them completely surrounding the proloculus, smooth surface, and terminal protruding aperture.

(20) *Annulofrondicularia tunisica* Anan<sup>22</sup> (Figure 2.6). Late Paleocene-Early Eocene. Tunisia.

Remarks: This species is closely resemble the Egyptian *A. bignoti*, but differs by larger ornamented proloculus and raised sutures, than smooth smaller proloculus and slightly depressed sutures of the latter.

(21) *Amphimorphina yousefi* Anan<sup>10</sup> (Figure 2.8. 7). Middle Eocene-later Eocene. Egypt, UAE.

Remarks: It has periphery sharply keeled with three keels on either sides running at the whole length of the elongate test, two supplementary raised costae are recognized in the early part on either side, aperture terminal and rounded.

(22) *Pyramidulina leroyi* Anan<sup>23</sup> (Figure 2.10). Late Paleocene-Early Eocene. Egypt.

Remarks: It characterized by its coarse-textured surface and rounded periphery.

(23) *Tristix aubertae* Anan<sup>21</sup> (Figure 2.2.6). Paleocene. Egypt.

Remarks: It has triangular test face, flattened concave triangular chambers and acute periphery.

(24) *Lenticulina ennakhali* Anan<sup>24</sup> (Figure 2.2). Paleocene-Early Eocene. Egypt.

Remarks: The most outstanding characteristics from other members of the genus are the tapering last chamber in an elongate test, flush sutures, and sharp periphery with faint keel.

(25) *Percultazonaria abunnasri* Anan<sup>25</sup> (Figure 2.1). Middle Eocene. Egypt.

Remarks: This species is distinguished by elongate compressed smooth test with raised ornamented costate ridges, closed early stage, 5-7 chambers slightly increased as added, sutures raised strait, terminal aperture.

(26) *Percultazonaria alii* Anan<sup>25</sup> (Figure 2.2). Early Eocene. Egypt.

Remarks: This species differs from early Eocene *P. longiscata* Nakkady by its interrupted ridges at the sutures.

(27) *Percultazonaria allami* Anan<sup>25</sup> (Figure 2.3). Paleocene-Middle Eocene. Egypt.

Remarks: It has inner margin slightly curved, while the outer margin curved with keel.

(28) *Percultazonaria ameeri* Anan<sup>25</sup> (Figure 2.4). Paleocene-Early Eocene. Egypt.

Remarks: It has large size test, conspicuous sutural nodes along the coiled and inclined uniserial portions of the test.

## Genus *Leroyia* Anan1 (Figure 2.8)

Remarks: *Leroyia* has elongate slightly arcuate test, circular in section, early stage slightly coiled but not completely enrolled, later uniserial chambers gradually increased as added, sutures slightly oblique, wall calcareous hyaline radial, surface perforated, smooth without prominent longitudinal costae, aperture radiate, terminal at the dorsal angle and may be produced on a neck. The genus *Leroyia* differs from the other genus *Marginulina* by its smooth wall than ornamented costate surface.

(29) *Leroyia aegyptiaca* Anan<sup>1</sup> (Figure 2.8). Late Paleocene-Early Eocene. Egypt.

Remarks: The Early Eocene *Leroyia aegyptiaca* differs from the Maastrichtian-Pliocene *L. glabra* (d'Orbigny) by its smaller size and number of the uniserial chambers, more lobulate periphery, more perforates test, and different stratigraphic age.

(30) *Leroyia maqfiensis* Anan<sup>1</sup> (Figure 2.10). Maastrichtian. Egypt.

Remarks: The Maastrichtian *Leroyia maqfiensis* differs from the Paleocene-Early Eocene *L. aegyptiaca* by larger test size, and larger uniserial chamber numbers (six than four). These two species explain an evolutionary lineage from the ancestor *L. maqfiensis* Anan to the descendant *L. aegyptiaca* Anan.

(31) *Leroyia tunisica* Anan<sup>1</sup> (Figure 2.13). Paleocene. Tunisia.

Remarks: This species resembles the Egyptian Maastrichtian species *L. aegyptiaca* Anan, but differs in its more elongate test, less lobulate periphery and protrude aperture.

## Genus *Lenticuzonaria* Anan2 (Figure 2.3)

Remarks: The new genus *Lenticuzonaria* Anan has compiled characters between its lenticular test as in the genus *Lenticulina* Lamarck with continuous unbroken sutures, and ornamented spinose surface with mainly elevated sutures that may costate or broken nodes as in the genus *Percultazonaria*. It differs from the Paleocene-Early Eocene *Marginulinopsis tuberculata* (Plummer) in its planispiral to uniserial test.

(32) *Lenticuzonaria misrensis* Anan<sup>2</sup> (Figure 2.5-8). Paleocene. Egypt.

Remarks: It is characterized by planispirally test, and elevated sutures with a row of tubercles.

## Genus *Lenticubella* Anan3 (Figure 2.1)

Remarks: Some representatives of this new genus have been previously assigned to other genera: *Darbyella*, or *Lenticulina*. The new genus has a compiled characters between its lenticular test (genus *Lenticulina* Lamarck (with its symmetrical planispirally enrolled smooth test), and another genus *Darbyella* Howe & Wallace (planispiral-uniserial test with inclined position on the uniserial part on planispiral direction). The genus *Lenticubella* is introduced here to include the Paleocene benthic Lagenid Foraminiferids from Poland and Egypt.

(33) *Lenticubella kurkurensis* Anan<sup>3</sup> (Figure 2.3). Paleocene. Egypt.

Remarks: It has inflated uncoiled stage with prominent umbo, two tapering chambers of the uncoiled part.

**(34) *Lenticubella misrensis* Anan<sup>3</sup>** (Figure 2.4). Paleocene. Egypt.

Remarks: It differs from *Lenticubella kurkurensis* by its smaller size uncoiled tapering chambers, raised early part sutures in the coiled stage, then become depressed in the later part.

**Genus *Percultalina* Anan<sup>4</sup>** (Figure 2.1)

Remarks: Early Paleogene *Percultalina* is the benthic Lagenid foraminiferids from Jordan and Egypt (Southern Tethys) has large lenticular initial portion followed by two or more uniserial elongate erected or inclined inflated rounded chambers, ornamented surface by elevated sutures with a row of tubercles or nodes along the sutures, and spinose surface. This genus has been previously assigned to different genera *Vaginulinopsis* Reuss, or *Percultazonaria* Loeblich & Tappan, or *Marginulinopsis* Silvestri.

**(35) *Percultalina misrensis* Anan<sup>4</sup>** (Figure 2.2). Late Paleocene. Egypt.

Remarks: The *P. misrensis* differs from the Jordanian *P. wadiarabensis* (Futyán) by inclined uniserial portion than rectilinear chambers, coarser knobs in the early coiled portion, and lesser depressed sutures.

**(36) *Percultalina sinaensis* Anan<sup>4</sup>** (Figure 2.3). Middle Eocene. Egypt.

Remarks: *Percultalina sinaensis* differs from *P. misrensis* by less inclined uniserial portion, and thinner row of tubercles or nodes along the sutures, and represent *P. misrensis* Anan > *P. sinaensis* Anan lineage.

**(37) *Saracenaria leroyi* Anan<sup>10</sup>** (Figure 2.8.14, 15). Middle-Late Eocene. Egypt, UAE.

Remarks: It triangular in cross section planispiral smooth test, acute dorsal side, and broad and flat apertural face.

**(38) *Neoflabellina misrensis* Anan<sup>11</sup>** (Figure 2.71b). Paleocene. Egypt.

Remarks: Test elongate, tapering terminal last chamber, fewer coiled early chambers in a planispiral rectilinear, higher elevated sutures, aperture terminal on neck.

**(39) *Vaginulinoides africana* Anan<sup>20</sup>** (Figure 2.5). M. Eocene. Ivorian Basin, West Africa.

Remarks: This species has elongate compressed slightly curved test, ornamented mainly by a longitudinal ribs on the test surface extended along and covered the chambers, but not crossing the sutures.

**(40) *Palmula ansaryi* Anan<sup>10</sup>** (Figure 2.8.14, 15). Eocene. Egypt.

Remarks: It has large palmate smooth test, height and width in the uniserial stage has 8-12 chevron-shaped chambers, sutures slightly raised, with one or more raised ribs in the coiled stage, terminal radial aperture.

**(41) *Palmula berggreni* (Anan<sup>26</sup>)** (Figure 2.2). Paleocene. Egypt.

Remarks: Loeblich & Tappan<sup>9</sup> considered the genus *Planularia* as a junior synonym of the genus *Palmula*. This species has large compressed test, semicircular in outline, chambers increasing very gradually in size, sutures extending backward, raised and beaded in the umbilical area but depressed in the last chambers, surface smooth except for the raised sutures, slit-like aperture at the peripheral angle.

**(42) *Palmula salimi* Anan<sup>21</sup>** (Figure 2.2. 7). Paleocene. Egypt.

Remarks: This species has large elongate palmate smooth test with greatest width toward the middle, semi-circular early planispiral stage, while the rhomboidal uniserial stage has four to seven broad chevron-shaped chambers, truncated periphery slightly depressed suture, and terminal aperture.

**(43) *Hemirobulina bassiounii* Anan<sup>10</sup>** (Figure 2.8.16). Middle Eocene. Egypt.

Remarks: This species has large elongate smooth test, circular in cross section, four to six chambers closely coiled and rapidly increasing in size as added in a slight curve at the base, but later becoming rectilinear, the last globose chamber occupies about  $\frac{2}{3}$  of the test, slightly depressed sutures, and radiate aperture on neck. The middle Eocene *H. bassiounii* Anan and Oligocene-Miocene *H. hantkeni* (Bandy) have another example of benthic Homeomorphy.

**(44) *Citharina plummerae* Anan<sup>26</sup>** (Figure 2.1). Paleocene. Egypt.

Remarks: It has wing-shaped flattened elongate test with thin acuminate, globular to ovate proloculus and later uniserial chambers increasing gradually in breadth, with numerous regular spaced longitudinal striae parallel to the direction of growth, raised oblique suture and somewhat curved, protruding aperture at the dorsal angle.

**(45) *Vaginulina boukharyi* (Anan<sup>27</sup>)** (Figure 2.12). Paleocene. Egypt.

Remarks: This species is characterized by large smooth test, early stage planispirally enrolled and involutes, but later uncoiled with gradually increased chambers, laterally compressed, septa horizontal slightly thickened and raised, elevated septa, terminal aperture at dorsal end.

**(46) *Lagena rawdhae* Anan<sup>28</sup>** (Figure 2.23). Late Paleocene-Early Eocene, Egypt.

Remarks: It differs from *L. sulcata* (Walker & Jacob) by its not extended ribs all over the test's surface.

**(47) *Lagena tunisica* Anan<sup>29</sup>** (Figure 2.20). Maastrichtian. Tunisia.

Remarks: It differs from Maastrichtian-Miocene *L. sulcata* by less number longitudinal costae, and short neck terminal apertural.

**(48) *Ramulina ismaili* Anan<sup>30</sup>** (Figure 2.2.6). Maastrichtian-Paleocene. Egypt, Trinidad, Germany.

Remarks: It differs from *R. tubensis* Ismail by less thick, elongate tapering tubular projection, and one of the three tubes is longer than the others. It differs from *R. arkadelphiana* Cushman by its more globular test chamber

**(49) *Ramulina orabii* Anan<sup>30</sup>** (Figure 2.3.1). Paleocene-Early Eocene. Egypt and USA.

Remarks: It differs from *R. elongata* Ismail by its more globular central test chamber and comparatively thicker arms, and from Maastrichtian *R. navarroensis* Cushman in having less arms and a less globular central chamber.

**(50) *Ramulina shreiffae* Anan<sup>31</sup>** (Figure 2.20). Early Eocene. Egypt.

Remarks: This new species differs from *R. pseudoaculata* (Olsson) in having a smooth surface and not concentric two ends arms of the chamber, then ornamented surface and concentric two arms.

**(51) *Oolina tunisica* Anan, n. sp.** (= *Oolina* sp. 2 - Figure 2.12. 4). Maastrichtian. Tunisia.

Remarks: This species is characterized by globular smooth test, with rounded aperture on short neck. It differs from *Oolina laevigata* d'Orbigny by more globular test without very fine longitudinal striae.

IV. Suborder Rotaliina Delage & Hérourard, 1896

(52) *Bolivinooides aegyptiacus* Anan<sup>32</sup> (Figure 2.1). Late Maastrichtian. Egypt.

Remarks: It differs from the other members of *B. draco* group (*B. d. draco* and *B. d. dorreeni*) by its no reticulate ornamented surface, and the Early Maastrichtian *B. miliaris* is not related to the *B. draco* group.

(53) *Bolivinooides ayyadi* Anan<sup>33</sup> (Figure 2.1). Maastrichtian. Egypt.

Remarks: This new species differs from the other species of the genus *Bolivinooides* by its discontinuous acute periphery and irregular rows of raised oblong lobes.

(54) *Bolivinooides zikoi* Anan<sup>34</sup> (Figure 2.11). Late Maastrichtian. Egypt.

Remarks: This species differs from other members of the genus *Bolivinooides* by its discontinuously irregular rows of raised oblong lobes. It was recorded from Wadi EdDakhl section, Egypt.

(55) *Stainforthia abdelkarimi* Anan<sup>35</sup> (Figure 2.26). Paleocene. Egypt.

Remarks: This species is characterized by its nearly parallel elongate test.

(56) *Stainforthia eddakhensis* Anan<sup>35</sup> (Figure 2.2). Early Eocene. Egypt.

Remarks: It differs from *S. farafraensis* (LeRoy) by fusiform elongate test than mainly conical shape.

(57) *Stainforthia taramsaensis* Anan<sup>35</sup> (Figure 2.3). Late Paleocene. Egypt.

Remarks: It is characterized by elongate small test, more tight arranged chambers than the new species *S. eddakhensis*, and more lager elongated apertural opening at the apertural face.

(58) *Euloxostomum mouradi* Anan<sup>36</sup> (Figure 2.9). Late Maastrichtian. Egypt.

Remarks: It is characterized by its perpendicular successive enlarged uniserial chambers as added without short spine at the basal part of the test.

(59) *Orthokarstenia nakkadyi* Anan<sup>37</sup> (Figure 2.7). Paleocene-Middle Eocene. Egypt, Tunisia, USA, Spain, France

Remarks: This species has longitudinal costae only in the lower half of the test, while it is smooth without ornamentation in the upper half test.

(60) *Bulimina dababiyaensis* Anan<sup>33</sup> (Figure 2.4). Early Eocene. Egypt.

Remarks: This species differs from *B. midwayensis* Cushman & Parker by its perforated test than very characteristic costae ornamentation at the base of the chambers.

(61) *Globobulimina misrensis* Anan<sup>33</sup> (Figure 2.5). Early Eocene. Egypt.

Remarks: This species is characterized by its smooth ovate test, and loop shaped aperture.

(62) *Buliminelloides aegyptiaca* Anan<sup>38</sup> (Figure 2.2). Early Eocene. Egypt.

Remarks: The whole test shows wrinkles ornamentation, but the upper part smooth and imperforated.

(63) *Buliminelloides africana* Anan<sup>38</sup> (Figure 2.3). Middle Eocene. Ivorian Basin.

Remarks: It is characterized by apiculate end of the test, an elongate aperture of the last chamber.

(64) *Euuvigerina ahmadi* Anan<sup>33</sup> (Figure 2.6). Late Maastrichtian. Egypt.

Remarks: This species is characterized by its low inflated and closely appressed biserial twisted chambers, and aperture terminal on the last chamber with short neck.

(65) *Euuvigerina helali* Anan<sup>33</sup> (Figure 2.7). Early Eocene. Egypt.

Remarks: This species differs from *E. ahmadi* by its smaller early chambers and inflated regular last chambers, aperture terminal on the last chambers with short cylindrical neck.

(66) *Uvigerina conica* Anan<sup>39</sup> (Figure 2.5.2). Miocene. Nigeria, Bering Sea.

Remarks: It is characterized by conical shape, with pointed initial part of the first chambers.

(67) *Uvigerina globosa* Anan<sup>39</sup> (Figure 2.5.5). Miocene. Nigeria.

Remarks: This species is characterized by its large globose ended chambers. It differs from *U. bifurcata* by its relatively globular test, less number of regular longitudinal ribs.

(68) *Uvigerinella nakkadyi* Anan<sup>10</sup> (Figure 2.9.5). Middle-Late Eocene. Egypt, UAE.

Remarks: Elongate smooth test, circular in cross section, tapering in initial part, chambers triserial increasing in height as added tending to become uniserial, depressed sutures, slit-like aperture in final chamber.

(69) *Uvigerinella tunisica* Anan<sup>40</sup> (Figure 2.29). Paleocene-Early Eocene. Tunisia.

Remarks: This species is characterized by small coarse papillae surface, and diagnostic apertural neck. It differs from *U. nakkadyi* by more depressed sutures and aperture no neck. These two species present another example of evolutionary lineage: *Uvigerinella tunisica* > *U. nakkadyi* lineage.

(70) *Fursenkoina misrensis* Anan<sup>33</sup> (Figure 2.8). Early Eocene. Egypt.

Remarks: This species differs from other members of the genus by its more inflated test, and narrow elongate aperture and extending up the face of the final chamber

(71) *Fursenkoina sinaensis* Anan<sup>33</sup> (Figure 2.9). Maastrichtian. Egypt.

Remarks: This species belongs here to the genus *Fursenkoina* due to its sigmoid arrangement of the early biserial chambers, and its loop shaped elongate aperture. It is distinguished by elongate smooth biserial test, four times as long as broad and twisted, periphery

rounded about the test axis, sutures oblique and depressed, aperture loop shaped elongate and narrow running from the inner margin of the last-formed chamber to apex.

(72) *Pseudobuliminella africana* Anan<sup>20</sup> (Figure 2.20). Middle Eocene. Ivorian Basin.

Remarks: It regards to the genus *Pseudobuliminella* de Klasz et al., not *Rectuvigerina* Mathews with triserial to uniserial elongate ornamented test by longitudinal costae, and aperture terminal on a neck.

(73) *Caucasina africana* Anan<sup>20</sup> (Figure 2.36). Middle Eocene. Ivorian Basin.

Remarks: The species is closely related to the genus *Caucasina*. It differs from the holotype *Caucasina oligocenica* Khalilov by small granular calcareous angled to semi-rounded granules (not smooth) surface.

(74) *Ellipsoglandulina arafati* Anan<sup>41</sup> (Figure 2.2). Early Eocene. Egypt.

Remarks: It has smooth flaring test, circular in section and in apertural view, widest in the middle ( $l/w=1.37$ ), pointed initial end, uniserial throughout and strongly overlapping chambers increase rapidly in size, last chamber comprising greater part ( $\sim 3/4$ ) of the test, slightly depressed straight horizontal sutures, terminal semilunate aperture.

(75) *Nodosarella africana* Anan<sup>20</sup> (Figure 2.30). Middle Eocene. Ivorian Basin.

Remarks: It differs from *N. advena* by curvature test (not rectilinear), and a greater number of chambers.

(76) *Pleurostomella osmani* Anan<sup>42</sup> (Figure 2.15). Maastrichtian. Egypt.

Remarks: It is distinguished from other species of the genus by lax biserial to nearly uniserial, sutures depressed, aperture subterminal elliptical with overhanging hood and without teeth.

(77) *Siphonodosaria misrensis* Anan<sup>43</sup> (Figure 2.76). Early Eocene. Egypt.

Remarks: It differs from *S. hispidula* Cushman with smooth chambers enlarging gradually strongly overlapping.

(78) *Nonionella dababiyaensis* Anan<sup>33</sup> (Figure 2.13). Early Eocene. Egypt.

Remarks: It differs from *N. africana* LeRoy by larger elongated test and chambers, more closed umbilicus.

(79) *Anomalinooides dababiyaensis* Anan<sup>43</sup> (Figure 2.4). Early Eocene. Egypt.

Remarks: The Paleocene-Ypresian *A. aegyptiacus* (LeRoy) regards as ancestor of Ypresian *A. dababiyaensis*.

(80) *Anomalinooides leroyi* Anan<sup>44</sup> (Figure 2.12). Maastrichtian-Paleocene. Egypt and Tunisia.

Remarks: This species is distinguished from other species of the genus by its nearly planoconvex test, deep wide umbilicus, raised sutures on both sides, rounded periphery, and peripheral aperture with distinct lip.

(81) *Anomalinooides masrensis* Anan<sup>43</sup> (Figure 2.10). Early Eocene. Egypt, Iraq.

Remarks: This species is characterized by its perforated surface and raised limbate sutures.

(82) *Gyroidinooides africana* Anan<sup>45</sup> (Figure 2.2). Maastrichtian. Ivorian Basin, Tanzania.

Remarks: It has smooth biconvex trochospiral test, highly convex umbilical side, sutures curved, periphery rounded, umbilicus closed, aperture a low interiomarginal tight slit extending from the periphery to the umbilicus.

(83) *Gyroidinooides luterbacheri* Anan<sup>46</sup> (Figure 2.13). Paleocene. Egypt.

Remarks: This species characterized by its wide but without deep umbilicus, aperture slit-like, extending from umbilicus to the dorsal edge along the base of the broad apertural face.

(84) *Gyroidinooides tunisica* Anan<sup>45</sup> (Figure 2.10). Paleocene. Tunisia.

Remarks: It has conical ventral side, wide rounded umbilical area, flush sutures, wide pore perforated wall.

#### V. Suborder Globigerinina Delage & Hérouard, 1896

(85) *Plummerita haggagae* Anan<sup>17</sup> (Figure 2.2-3). Maastrichtian. Egypt, Iraq.

Remarks: It has last four-chambered volution, originally recorded from the Maastrichtian of Duwi section of Egypt, and from Duhok area, NE Iraq.

(86) *Plummerita safaae* Anan<sup>47</sup> (Figure 2.3). Maastrichtian. Egypt.

Remarks: *Plummerita safaae* differs from *P. haggagae* with three spine-like prolongation of the last four inflated chamber, and from four inflated chamber of *P. elkefensis* with four spine-like prolongations.

(87) *Plummerita salimi* Anan<sup>47</sup> (Figure 2.5). Maastrichtian. Egypt.

Remarks: This species is closely related with *P. hodaie*, but differs by its axially pointed spine-like prolongations of the second chamber than the third one of the latter.

(88) *Plummerita tunisica* Anan<sup>48</sup> (Figure 2.3). Maastrichtian. Tunisia.

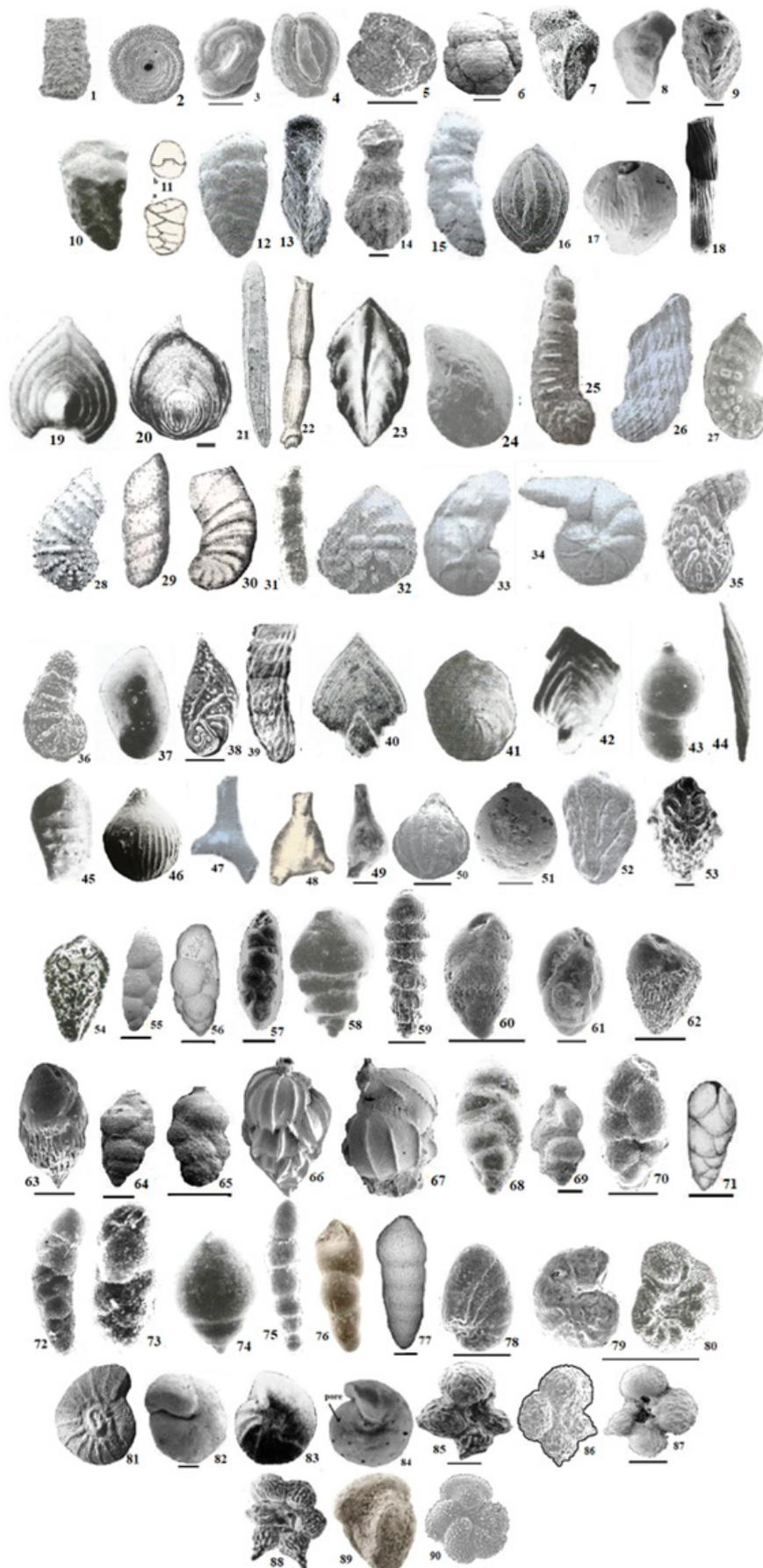
Remarks: It has last six chambered volutions with spine-like prolongation of ultimate and penultimate chambers. *P. tunisica* Anan most probably developed from *P. inflata* (Brönnimann).

(89) *Turborotalia semicunialensis* Anan<sup>49</sup> (Figure 2.9). Late Eocene. UAE, Egypt, Tanzania, India.

Remarks: The *Turborotalia semicunialensis* Anan with its raised keel in the first two chambers of the last whorl was recorded recently from the *Globigerinatheca index* Zone (E16) of Jabal Hafit, UAE. Other forms of it, were recorded from northwest of India southern Tanzania and Wadi Hiton, Fayum, Western Desert of Egypt.

(90) *Morozovella tunisica* Anan<sup>50</sup> (Figure 2.3). Danian. Tunisia.

Remarks: The species *Morozovella tunisica* differs from *M. angulata* by is nearly biconvex test, more elongate curved with nearly banana shape chamber and curved sutures, than flat dorsal side, inflated triangular chambers and straight sutures of the latter species.



**Figure 2.1.** *Bathysiphon saidi* Anan,<sup>10</sup> 2. *Ammodiscus tanzanica* Anan,<sup>11</sup> 3. *Glomospira moroccoensis* Anan,<sup>11</sup> 4. *Miliammina kenawyi* Anan,<sup>10</sup> 5. *Haplomagmoides aegyptiaca* Anan,<sup>12</sup> 6. *Trochammina aegyptiaca* Anan,<sup>12</sup> 7. *Gaudryina ameerii* Anan,<sup>6</sup> 8. *Gaudryina speijeri* Anan,<sup>6</sup> 9. *Siphogaudryina hafezi* Anan,<sup>13</sup> 10. *Siphogaudryina strougoi* Anan,<sup>14</sup> 11. *Textulariella sinaensis* Anan,<sup>15</sup> 12. *Textularia fahmyi* Anan,<sup>10</sup> 13. *Pseudogaudryina dababiyaensis* Anan,<sup>16</sup> 14. *Pseudoclavulina hewaidyi* Anan,<sup>17</sup>, 15. *Pseudoclavulina youssefi* Anan,<sup>18</sup> 16. *Ammomassilina misrensis* Anan,<sup>18</sup> 17. *Quinqueloculina tanzanica* Anan,<sup>19</sup> 18. *Awhea africana* Anan,<sup>20</sup> 19. *Annulofrondicularia bignoti* Anan,<sup>21</sup> 20. *Annulofrondicularia tunisica* Anan,<sup>22</sup> 21. *Amphimorphina youssefi* Anan,<sup>10</sup> 22. *Pyramidulina leroyi* Anan,<sup>23</sup> 23. *Tristix aubertae* Anan,<sup>21</sup> 24. *Lenticulina ennakhali* Anan,<sup>24</sup> 25. *Percultazonaria abunnasri* Anan,<sup>25</sup> 26. *Percultazonaria alii* Anan,<sup>25</sup> 27. *Percultazonaria allami* Anan,<sup>25</sup> 28. *Percultazonaria ameerii* Anan,<sup>25</sup> 29. *Leroyia aegyptiaca* Anan,<sup>1</sup> 30. *Leroyia maqfiensis* Anan,<sup>1</sup> 31. *Leroyia tunisica* Anan,<sup>1</sup> 32. *Lenticuzonaria misrensis* Anan,<sup>2</sup> 33. *Lenticubella kurkurensis* Anan,<sup>3</sup> 34. *Lenticubella misrensis* Anan,<sup>3</sup> 35. *Percultalina misrensis* Anan,<sup>4</sup> 36. *Percultalina sinaensis* Anan,<sup>4</sup> 37. *Saracenaria leroyi* Anan,<sup>10</sup> 38. *Neoflabellina misrensis* Anan,<sup>11</sup> 39. *Vaginulinoides africana* Anan,<sup>20</sup> 40. *Palmula ansaryi* Anan,<sup>10</sup> 41. *Palmula berggreni* (Anan,<sup>26</sup>) 42. *Palmula salimi* Anan,<sup>21</sup> 43. *Hemirobulina bassiouinii* Anan,<sup>10</sup> 44. *Citharina plummerae* Anan,<sup>26</sup> 45. *Vaginulina boukharyi* (Anan,<sup>27</sup>) 46. *Lagena rawdhae* Anan,<sup>28</sup> 47. *Lagena tunisica* Anan,<sup>29</sup> 48. *Ramulina ismaili* Anan,<sup>30</sup> 49. *Ramulina orabii* Anan,<sup>30</sup> 50. *Ramulina shreifae* Anan,<sup>31</sup> 51. *Oolina tunisica* Anan, n. sp., 52. *Bolivinoides aegyptiacus* Anan,<sup>32</sup> 53. *Bolivinoides ayyadi* Anan,<sup>33</sup> 54. *Bolivinoides zikoi* Anan,<sup>34</sup> 55. *Stainforthia abdelkarimi* Anan,<sup>35</sup> 56. *Stainforthia eddakhensis* Anan,<sup>35</sup> 57. *Stainforthia taramsaensis* Anan,<sup>35</sup> 58. *Euloxostomum mouradi* Anan,<sup>36</sup> 59. *Orthokarstenia nakkadyi* Anan,<sup>37</sup> 60. *Bulimina dababiyaensis* Anan,<sup>33</sup> 61. *Globobulimina misrensis* Anan,<sup>33</sup> 62. *Buliminelloides aegyptiaca* Anan,<sup>38</sup> 63. *Buliminelloides africana* Anan,<sup>38</sup> 64. *Euuvigerina ahmadi* Anan,<sup>33</sup> 65. *Euuvigerina helali* Anan,<sup>33</sup> 66. *Uvigerina conica* Anan,<sup>39</sup> 67. *Uvigerina globosa* Anan,<sup>39</sup> 68. *Uvigerinella nakkadyi* Anan,<sup>10</sup> 69. *Uvigerinella tunisica* Anan,<sup>40</sup> 70. *Fursenkoina misrensis* Anan,<sup>33</sup> 71. *Fursenkoina sinaensis* Anan,<sup>33</sup> 72. *Pseudobuliminella africana* Anan,<sup>20</sup> 73. *Caucasina africana* Anan,<sup>20</sup> 74. *Ellipsoglandulina arafati* Anan,<sup>41</sup> 75. *Nodosarella africana* Anan,<sup>20</sup> 76. *Pleurostomella osmani* Anan,<sup>42</sup> 77. *Siphonodosaria misrensis* Anan,<sup>43</sup> 78. *Nonionella dababiyaensis* Anan,<sup>43</sup> 79. *Anomalinoides dababiyaensis* Anan,<sup>43</sup> 80. *Anomalinoides leroyi* Anan,<sup>44</sup> 81. *Anomalinoides masrensis* Anan,<sup>43</sup> 82. *Gyroidinoides africana* Anan,<sup>45</sup> 83. *Gyroidinoides luterbacheri* Anan,<sup>46</sup> 84. *Gyroidinoides tunisica* Anan,<sup>45</sup> 85. *Plummerita haggagae* Anan,<sup>17</sup> 86. *Plummerita safae* Anan,<sup>47</sup> 87. *Plummerita salimi* Anan,<sup>47</sup> 88. *Plummerita tunisica* Anan,<sup>48</sup> 89. *Turborotalia semicunialensis* Anan,<sup>49</sup> 90. *Morozovella tunisica* Anan.<sup>50</sup>

## Paleogeography

The recorded ninety benthic and planktic foraminiferal species were originally recorded from North Africa (Morocco, Tunisia, Egypt), and Central Africa (Ivorian Basin, Nigeria, Tanzania). Some remarks are presented:

- I. *Orthokarstenia nakkadyi* Anan has a wide geographic distribution, which recorded from: USA (North America), Spain, France (West Europe), Tunisia and Egypt (North Africa).
- II. *Bathysiphon saidi* (Anan) is recorded from: Hungaria (Central Europe), Egypt (N. Africa), and UAE (SW Asia).
- III. *Ramulina ismaili* Anan is recorded from: Trinidad (S. America), Germany (N. Europe) and Egypt (N. Africa).
- IV. *Ramulina orabii* Anan is recorded from: USA (N. America) and Egypt (N. Africa).
- V. *Miliammina kenawyi* Anan, *Pseudoclavulina hewaidyi* Anan and *Amphimorphina youssefi* Anan are recorded from: Egypt (N. Africa) and UAE (SW Asia).
- VI. *Anomalinoides leroyi* Anan is recorded from Tunisia and Egypt (N. & E. Africa).
- VII. *Anomalinoides masrensis* Anan is recorded from Egypt (N. Africa) and Iraq (SW Asia).

VIII. *Anomalinoides masrensis* Anan is recorded from Ivorian Basin and Tanzania (C. Africa). *Plummerita haggagae* Anan is recorded from Egypt (N. Africa) and Iraq (SW Iraq). 10. *Turborotalia semicunialensis* is recorded from Egypt and Tanzania (Africa), UAE and India (Asia).

IX. 11. The other recorded species are endemic to their original erection.

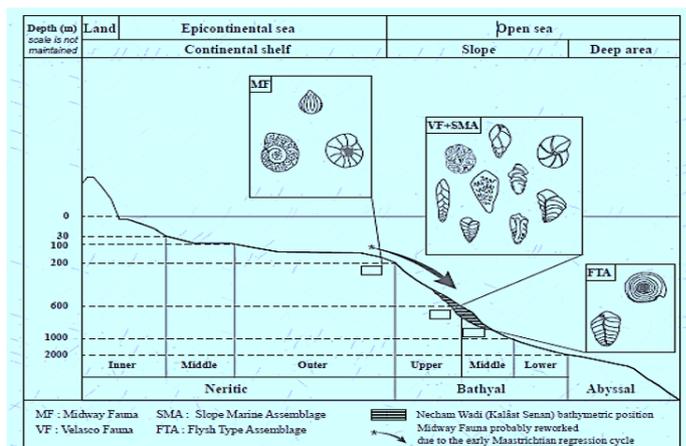
## Paleoenvironment

Major environmental parameters affecting the abundance and distribution of foraminiferal species include: water depth, type of substrate, temperature, oxygenation, nutrition, organic matter, current patterns TCC (Figure 3).



**Figure 3** The Neo-Tethys Ocean during the Late Cretaceous-Neogene times showing the open flow direction of the Tethyan Circumglobal Current (TCC) in all directions.<sup>51</sup>

Moreover, the benthic foraminifera groups: Midway Fauna (MF), Velasco Fauna (VF), Slope Marine Assemblage (SMA), Flysh Type Assemblage (FTA) can be used as paleobathymetric markers (Figure 4). These groups range from middle to outer shelf environment (50–200m water depth) for Midway Fauna (MF), continental slope and the abyssal plain (from the upper bathyal of 200–600m depth to the lower bathyal of 1000–2000m and even deeper) for Velasco Fauna (VF), Slope Marine Assemblage (SMA) and Flysh-type Assemblage (FTA) for many agglutinated species (Figure 4).



**Figure 4** Estimated palaeodepths of different benthic foraminiferal groups.<sup>52</sup>

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## Conflict of interest

The author certifies that they have no conflict of interest or affiliations with or involvement in any organization or entirely with any financial interest, of non-finical interest in the subject matter or materials discussed in this manuscript.

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