Palaeontologia Electronica
http://palaeo-electronica.org

RE-ILLUSTRATION AND REVISED TAXONOMY FOR SELECTED DEEP-SEA BENTHIC FORAMINIFERS

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ABSTRACT

In this article we present new illustrations together with updated taxonomic, biostratigraphic and paleoecological coverage for 36 deep-water benthic foraminiferal species, including ten holotypes, four paratypes, three syntypes, and one lectotype from collections at The Natural History Museum, London, the Smithsonian Institution, and Krakow University. High-resolution digital photography and an image manipulation application were used to produce completely focused colour composite images of these taxa. These images represent the closest representation of what the micropalaeontologist actually 'sees' through the microscope during the species-identification process. We focus on selected agglutinated and calcareous taxa that are of stratigraphical and/or paleoecological significance for ODP/IODP studies to highlight morphologic features, such as wall texture, grain and cement composition, test colour and opacity, shape of sutures, chamber arrangement, and inner structure including early ontogenic stages. These features represent important taxonomic criteria that are not readily detectable in SEM illustrations or conventional light photomicrographs.

Keywords: foraminifera, palaeoceanography, taxonomy, digital imaging, micropalaeontology, Ocean Drilling Program, Integrated Ocean Drilling Program

INTRODUCTION

Benthic foraminifers play a central role in deep-sea paleoceanographical research because of their geographic ubiquity, their abundance in Cretaceous to Recent deep-sea sediments, and because of their utility as indicators of environmental conditions both at and below the sediment-water interface. Additionally, stable isotopes and geochemical tracers obtained from the foraminiferal tests provide environmental information that is of major significance in studies of global climatic change. Nevertheless, the taxonomy of benthic foraminifers remains extremely unwieldy. The standard of published illustrations and descriptions of

Holbourn, Ann E. and Andrew S. Henderson. 2002. Re-illustration and Revised Taxonomy for Selected Deep-sea Benthic Foraminifers. **Palaeontologia Electronica** 4(2):34pp, 628KB; http://palaeo-electronica.org/paleo/2001_2/foram/issue2_01.htm

type specimens in major museum collections, which serve as the basis of benthic foraminiferal taxonomy, varies enormously in both quality and accessibility. This is mainly due to the fact that taxonomic terminology is not standardized, and that descriptions and illustrations are dispersed in a wide range of publications that have strong historical or regional connotation. Because of these factors, taxonomic work with benthic foraminifers all too often represents a cumbersome task, that prohibits real evaluation and data synthesis, as well as severely compromising the use of benthic foraminifers for paleoceanographical research.

Line drawings have been used to illustrate benthic foraminiferal morphology since the late eighteenth century. While some of these illustrations are true works of art, most benthic foraminiferal line drawings are simplistic and often neglect to include important taxonomic characters. Light micrographs are, in principle, superior to line drawings in the sense that they provide a more accurate record of the morphology. This type of illustration also has the advantage of closely resembling what is actually seen in the microscope. However, there are inherent limits on the resolving power of the microscope due to the wavelength of light. At the relatively high magnifications required to resolve many of the structural elements of the benthic foraminiferal test, the focal plane is often much narrower than the size of the structures being examined. This means that the entire structure cannot be brought into focus simultaneously. Taxonomists compensate for this by adjusting the microscope's focus so that they are able to scan the structure and construct a composite image in their mind. Nevertheless, even at relatively low magnifications, light micrographs of benthic foraminifers appear blurred and out of focus.

The development of the Scanning Electron Microscope (SEM) in the late 1950s held the promise of solving the focal plane depth problem for micropaleontological imaging. Even at the highest conceivable magnifications employed for benthic foraminiferal taxonomic study, SEM photomicrographs usually exhibit adequate focal depths, and have become the standard mode of micropaleontological illustration. However, as the SEM collects electrons emitted from a thin metallic film deposited on the surface of the benthic foraminiferal test, it is unable to image any of the taxonomically important characters (e.g., suture patterns, chamber numbers) that lie below the test surface.

First attempts to overcome this problem were made in the 1980s with the development of a technique that used a Scanning Light Microscope (Scott et al., 2000). This allowed a composite photograph of the specimen to be taken as it moved through a lighted focal plane with a bandwidth of 50-100 microns. However, this system has several limitations: 1) smaller specimens may be of smaller width than the light bandwidth; 2) the magnification of the system is limited (i.e., to x40 for the system used by Scott et al**.** 2000); 3) the horizontal narrow band lighting may fail to illuminate some parts of the test, resulting in an unequally lighted illustration with markedly darker areas; and 4) the images obtained still have to be digitized.

Over the past several years, researchers at The Natural History Museum, London have been investigating and developing techniques that employ digital images to overcome the limitations of light micrographs. These digital imaging techniques involve taking a number of images per specimen. This image set constitutes a series of 'slices' taken sequentially at different focal plane depths such that all aspects of the specimens' morphology are captured within an in-focus slice for the set in aggregate. A composite image is then built up by combining the areas in each image slice that are in focus. The resulting composite image is a true-colour image of specimen viewed in transmitted and/or reflected light with full focus throughout the field of view. These images, while not completely replacing other methods of illustrating foraminifers, are the most realistic and representative view of what the micropalaeontologist actually 'sees' through the microscope tube. They are particularly useful when illustrating previously un-illustrated or poorly illustrated type specimens, and the technique has the added benefit of not altering the original specimen.

We have compiled a digital database of deep-water benthic foraminifers which comprises sets of fully focused, composite images and standardized, taxonomic descriptions that consolidate previous taxonomic efforts by individuals and research groups. The use of consistent morphological descriptors (Appendix) also provides a structured and searchable framework, that facilitates comparison between species and identification. We present here a selection of records from the database, and document 36 benthic foraminiferal taxa including ten holotypes, four paratypes, three syntypes and one lectotype. We illustrate whenever possible type specimens, mainly deposited in collections of the Smithsonian Institute; The Natural History Museum, London (Challenger foraminifera), and Krakow University, for which only drawings or black and white illustrations are available. We additionally illustrate well-preserved material, mainly topotypic, from deep-sea cores, commercial wells, and land sections. For selected species, SEM micrographs are given for comparison.

We have focused on agglutinated taxa to highlight morphologic features such as wall texture, grain and cement composition, test colour and opacity, chamber arrangement, shape of sutures, and inner structure including early ontogenic stages, as these represent important taxonomic criteria that are not otherwise detectable in SEM illustrations. We have additionally focused on some calcareous groups that are of stratigraphical and/or paleoecological significance for Ocean Drilling Program (ODP)/Integrated Ocean Drilling Program (IODP) studies, but had a particularly confused taxonomic history including the genera **Stilostomella, Planulina,** and **Cibicidoides,** in the hope that the new illustrations and descriptions might contribute to the clarification of their taxonomy.

Digital Imaging Equpment Used At The Natural History Museum, London

The specimens were imaged using either a Kontron Electronic ProgRes 3012 camera scanner, attached to a Leica Diaplan Microscope or an Allen Compact Video Microscope. Using an image manipulation application (e.g., Adobe Photoshop) a fully in focus composite image was produced. By applying further standard digital processing techniques (e.g., sharpening, colour and level balance, brightness/contrast and the addition of a uniform background colour), the final image was completed.

TAXONOMY

We present systematic data (descriptions, synonymies, biogeographic, paleoecologic and stratigraphic ranges) that were assembled from primary research, from the micropaleontological literature, and from consultation with specialists. The taxonomic classification follows Loeblich and Tappan (1987) with a few exceptions which mainly reflect taxonomic updates published subsequently. The revised timescale of Berggren et al**.** (1995) was used for the Cenozoic, and the timescale of Gradstein et al**.** (1995) was used for the Mesozoic.

Genus Ammobaculites

Ammobaculites jarvisi Cushman and Renz, 1946
Figure 1.1.

1946 **Ammobaculites jarvisi** Cushman and Renz: p. 46, pl. 19, fig. 6.
1988 **Ammobaculites jarvisi** Cushman and Renz; Kaminski et al**:** p. 188, pl. 4, fig. 4.
1990 **Ammobaculites jarvisi** Cushman and Renz; Kuhnt and Kaminski: p. 462, pl. 3, fig. d.
1994 **Bulbobaculites jarvisi** Cushman and Renz; Bolli **et al: p.** 81, fig. 21.25.

Original Designation:

Ammobaculites jarvisi Cushman and Renz, 1946.

Type Specimen:

Holotype (CC46514) and paratypes (CC46515 and 46516) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Upper Paleocene (P5).

Type Locality:

Lizard Springs Formation in Ravine Ampelu, Trinidad.

Description:

Test forms a relatively small initial planispire followed by a large, elongate, broad, rectilinear or slightly arched uniserial series, usually with four chambers. Chambers are moderately inflated and separated by depressed sutures. Chamber walls are non-alveolar, well-cemented, finely to coarsely agglutinated, and occasionally includes carbonate grains. The primary aperture is a terminal round opening.

Remarks:

Ammobaculites jarvisi Cushman and Renz may agglutinate carbonate material and is characteristic of marly slope environments (Kuhnt and Kaminski 1990). The holotype has an attached test of **Ammolagena clavata**.

Biogeography:

North and South Atlantic, Caribbean.

Bathymetry and Paleoecology:

Common in upper to middle bathyal deposits in Trinidad, the North African paleomargin and the updip wells on the Labrador Margin (Kuhnt and Kaminski 1990).

Stratigraphic Range:

Cretaceous (Maastrichtian) – Eocene (Ypresian).

Genus Ammobaculoides

Ammobaculoides carpathicus Geroch, 1966
Figure 1.2.

1966 **Ammobaculoides carpathicus** Geroch: p. 479, pl. 13, figs 13-22.
1984 **Ammobaculoides carpathicus** Geroch; Geroch and Nowak: pl. 1, figs 15-16; pl. 6, figs 8-11.

Original Designation:

Ammobaculoides carpathicus Geroch, 1966.

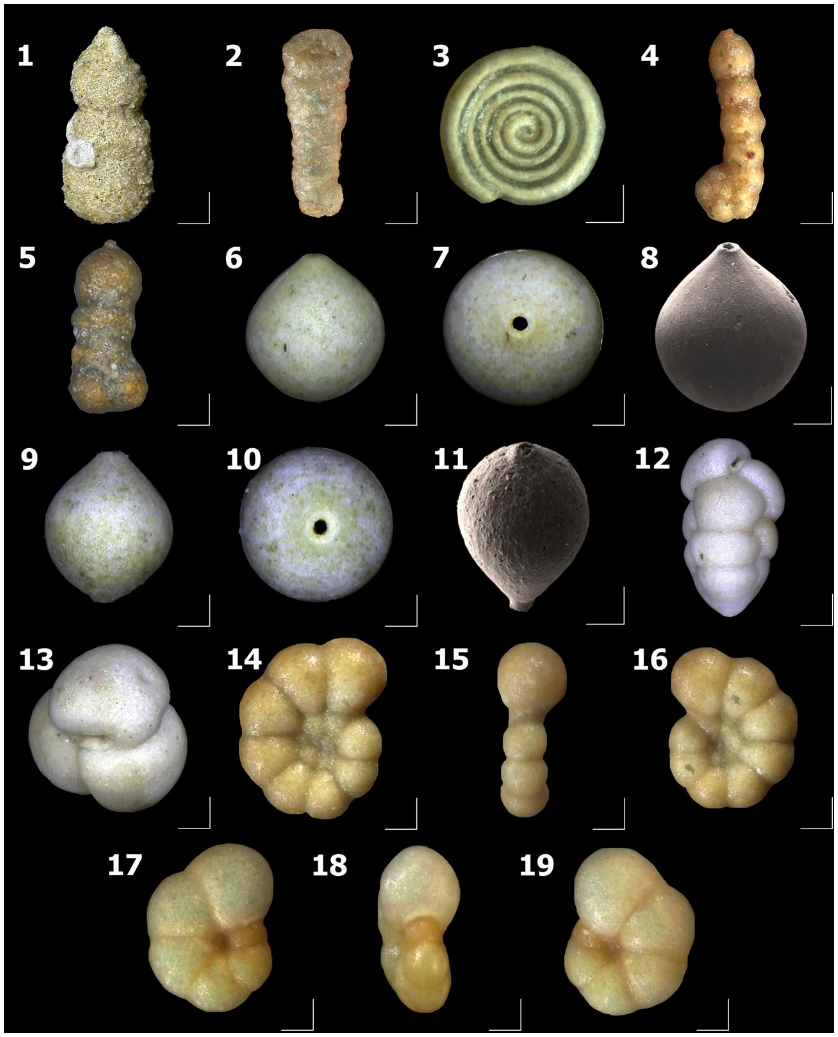

Figure 1.1-19. 1. Ammobaculites jarvisi Cushman and Renz, 1946. **1.** Side view. Holotype. Late Paleocene. Lizard Springs Formation in Ravine Ampelu, Trinidad. Smithsonian Collection. CC 46514. Scale Bar = 298 microns. **2. Ammobaculoides carpathicus** Geroch, 1966. **2.** Side view. Paratype. Cretaceous, Barremian? Subsilesian Unit, Sample 115/57, Black shales. Verovice, Poland. Smithsonian Collection. USNM 460972. Scale Bar = 113 microns. **3. Ammodiscus latus** Grzybowski, 1898. **3.** Side view. Late Eocene. Silesian Unit. Green shales, Karas Stream 48, Biecz near Gorlice, Poland. Geroch Collection, Jagiellonian University, Krakow, Poland. Scale Bar = 176 microns. **4-5. Bulbobaculites problematicus** (Neagu), 1962. **4.** Side view. Cretaceous, Turonian. Sub-Silesian Unit. Red shale. Borehole 130, 230 m, Wyglówka, near Krosno, Poland. Geroch Collection, Jagiellonian University, Krakow, Poland. Scale Bar = 276 microns. **5.** Side view. Holotype of **Ammobaculites luckei** Cushman and Hedberg, a suspected synonym **Bulbobaculites problematicus**. Late Cretaceous. Smithsonian Collection. CC 37905. Scale Bar = 77 microns. **6-8. Caudammina ovulum gigantea** (Geroch), 1960. **6.** Side view. Late Cretaceous. DSDP Leg 47, Hole 398D, Core 48, Section 5, 112-115 cm. Scale Bar = 97 microns. **7.** Apertural view of specimen 6. Scale Bar = 110 microns. **8.** Side view. Late Cretaceous. ODP Leg 103, Hole 641A, Core 1X, CC. **9-11. Caudammina ovulum ovulum** (Grzybowski), 1896. **9.** Side view. Late Cretaceous. DSDP Leg 47, Hole 398D, Core 48, Section 5, 112-115 cm. Scale Bar = 70 microns. **10.** Apertural view of specimen 9. Scale Bar = 58 microns. **11**. Side view. Late Cretaceous. ODP Leg 103, Site 641A, Core 2X, CC. **12-13. Eggerella bradyi** (Cushman), 1911. **12.** Side view. Syntype. Recent. Challenger Station 23, off Sombrero Island, West Indies (450 fm). Natural History Museum, London. NHM ZF2605. Scale Bar = 197 microns. **13**. Apertural view of specimen 12. Scale Bar = 124 microns. **14-16. Haplophragmoides multicamerus** Krasheninnikov, 1973. **14.** Umbilical view. Late Cretaceous. DSDP Leg 20, Site 196, Core 2, Section 1, 1-4 cm. Scale Bar = 116 microns **15.** Apertural view of specimen 14. **16**. Umbilical view of specimen 14. **17-19. Haplophragmoides pervagatus** Krasheninnikov, 1973. **17.** Umbilical view. Late Cretaceous. DSDP Leg 93, Hole 603B, Core 303, 88-91 cm. Scale Bar = 104 microns. **18.** Apertural view of specimen 17. **19.** Umbilical view of specimen 17.

Type Specimen:

Paratype (USNM 460972) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

?Barremian, lower Verovice Shales; in black shale. Also occurs in the upper Cieszyn Shale (Valanginian), and the Grodziszcze Shale (Hauterivian).

Type Locality:

Stepina near Strzyzow, Silesia, Poland. Also found at Sulkowice-Ubionka; Lipnik, near Bielsko; and Leszna Gorna, near Goleszow.

Description:

Test forms an initial planispire followed by a short biserial series and (finally) elongate uniserial series with numerous chambers. The moderately-inflated chambers are separated by depressed sutures in the uniserial part. This uniserial portion usually forms half to three-quarters of the total length of the test. Uniserial chambers are low and rounded in cross-section, increase gradually in size initially and then become almost constant in size in the (presumptive) adult stage. Wall chambers are medium to coarsely agglutinated with organic cement. The primary aperture is a terminal opening in the uniserial part.

Remarks:

One of the few stratigraphic indicators in Lower Cretaceous sub CCD sediments. Geroch (1966) noted that immersed specimens reveal interiors of chambers, cup-like in the uniserial portion and joined by tubes.

Biogeography:

First described from the Polish Carpathians by Geroch (1966). Kaminski et al. (1992) recorded specimens from ODP Site 765 in the Argo Abyssal Plain off northwestern Australia, that were similar in size, outline, and shape of chambers. However, as the wall structure of the Site 765 specimens was not determined, these authors adopted the designation **Ammobaculoide** cf**. carpathicus**.

Bathymetry and Paleoecology:

Bathyal to abyssal. Characteristic of sub CCD environments. Lower Cretaceous sub CCD sediments are rare because the CCD was extremely deep in the Tethys and Atlantic Ocean during the Early Cretaceous.

Stratigraphic Range:

Lower Cretaceous (Valanginian – Aptian) in the Polish Carpathians (Geroch and Nowak 1984).

Genus Ammodiscus

Ammodiscus latus Grzybowski, 1898
Figure 1.3.

1895 **Ammodiscus cf**. **tenuis** Brady; Rzehak: p. 214, pl. 7, fig. 5.
1898 **Ammodiscus latus** Grzybowski: p. 282, pl. 10, figs 27-28.
1898 **Ammodiscus umbonatus** Grzybowski: p. 283, pl. 10, figs 29-30.
1948 **Lituotuba eocenica** Cushman and Renz: p. 7, pl. 1, figs 20-21.
1950 **Lituotuba navetensis** Cushman and Renz, new name: p. 45.
1981 **Ammodiscus latus** Grzybowski; Morgiel and Olszewska: p. 8, pl. 1, figs 8-9.
1984 **Ammodiscus latus** Grzybowski; Geroch and Nowak: pl. 1, figs 12-13; pl. 5, figs 9-12.
1993 **Ammodiscus latus** Grzybowski; Kaminski and Geroch: p. 254, pl. 5, figs 4a-6.
1994 **Ammodiscus latus** Grzybowski; Gradstein et al**:** pl. 9, figs 23-25.
1994 **Ammodiscus latus** Grzybowski; Bolli et al**:** p. 68, fig. 18.25.

Original Designation:

Ammodiscus latus Grzybowski, 1898.

Type Specimen:

Depository not given. Lectotype from red clay outcropping in the right bank of the Wislok River at Kroscienlo Nizme, designated and illustrated by Kaminski and Geroch (1993). Lectotype and original syntypic material (No. UJ-132-P, 1/38) deposited in the Grzybowski collection, Jagiellonian University, Krakow, Poland.

Type Level:

Uppermost Eocene; red and grey clay.

Type Locality:

Not designated. Localities given: Hanover-Galicia Company wells no. 33 and 34, at Potok; Duniecki well no.1 at Toroszówka; grey clay (rare) and red clay (common) in the bed of the Wislok River at Kroscienlo Nizme; all in the vicinity of Krosno, Poland.

Description:

Test forms a robust, thick, evolute, planispiral coil increasing in size very slowly, with a distinct coil suture. In megalospheric individuals, the test consists of two to three whorls with an umbilicus that is depressed on one or both sides. In microspheric individuals, the test comprises up to five whorls, and the umbilicus is usually not depressed. Some specimens display irregular coiling in the last whorl or exhibit a tendency to uncoil. Chamber walls are medium to coarsely agglutinated with organic cement. The primary aperture is simple, at the end of the open tube.

Remarks:

Extremely variable in size.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Bathyal to abyssal. Common in flysch-type and sub CCD assemblages. The size of tests is probably related to the available carbon flux. For instance, specimens from green organic rich clays of Labrador may exceed 2 mm in diameter, whereas specimens from abyssal ODP Site 647 are smaller, between 600 and 800 microns in diameter.

Stratigraphic Range:

Eocene (Bartonian) – Miocene (Messinian). The first common occurrence of **A. latus** marks the base of the **Ammodiscus latus** Zone of Geroch and Nowak (1984).

Genus Bulbobaculites

Bulbobaculites problematicus (Neagu), 1962
Figure 1.4-5.

1962 **Ammobaculites agglutinans** (d'Orbigny) ssp**. problematicus** Neagu: p. 61, pl. 2, figs 22-24.
1966 **Haplophragmium aequicameratum** Huss: p. 68-69.
1974 **Haplophragmium lueckei** (Cushman and Hedberg); Krasheninnikov: p. 639, pl. 4, figs. 3a-b, 4a, 5a.
1984 **Ammobaculites problematicus** Neagu; Geroch and Nowak: pl. 1, figs 17-18; pl. 6, fig. 23.
1988 ?**Haplophragmium lueckei** (Cushman and Hedberg); Moullade et al**:** p. 363, pl. 3, figs 1-6.
1990 **Ammobaculites problematicus** Neagu; Kuhnt and Kaminski: p. 465, fig. 5A.
1990 **Haplophragmium problematicum** (Neagu); Kuhnt: p. 312, pl. 4, figs 3-9.

Original Designation:

Ammobaculites agglutinans (d'Orbigny) ssp**. problematicus** Neagu, 1962.

Type Specimen:

Depository not given.

Type Level:

Upper Cenomanian-lower Turonian.

Type Locality:

Pîrîul Fetii (valea superioara a Buzaului), Carpatii de curbura, red clay.

Description:

Test forms a small, initial, streptospiral stage, followed by a uniserial, rectilinear portion of variable length, cylindrical in cross-section. The inflated chambers are separated by markedly-depressed sutures. Chamber walls are finely or coarsely agglutinated with organic cement. The last chamber tapers towards a rounded, terminal aperture, generally possessing a smooth collar.

Remarks:

Bulbobaculites problematicus (Neagu) (including the type specimens in the Neagu collection) displays a wide range of morphologic variability (see Kuhnt and Kaminski1990, Figures 5, 5A). These authors suggested that the degree of variability was substrate dependent. Specimens from abyssal settings are usually fine-grained, whereas specimens found in turbidites are coarser-grained.

Ammobaculites lueckei Cushman and Hedberg (1941), which is the type species of the Genus **Bulbobaculites** Maync (1952) is most likely a synonym of **Bulbobaculites problematicus** (Neagu). However, the only specimen available for taxonomic comparison in the collections of the Smithsonian Institution is the holotype. Although Cushman and Hedberg (1941) reported in the initial description and illustration that the holotype possessed an elliptical aperture at the end of a short neck, a re-examination of the holotype showed that it has a rounded aperture, with a smooth collar. The holotype of **A. lueckei** has a red colour confirming its fossilization in deep-sea red clay. **Ammobaculites lueckei** probably represents one growth stage of **B. problematicus.**

Bulbobaculites problematicus (Neagu) is a very useful maker in the Atlantic, indicating a post Cenomanian/ Turonian boundary age.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Bathyal to abyssal. Common in flysch-type assemblages (Kuhnt, personal commun., 2001).

Stratigraphic Range:

Cretaceous (Cenomanian – Coniacian) in the Polish Carpathians (Geroch and Nowak 1984). However, the first occurrence of **Bulbobaculites problematicus** (Neagu) in the North Atlantic occurs after the Cenomanian/Turonian boundary (see Kuhnt and Kaminski, 1990, Figure 8). In the marginal basins of Zumaya, Gubbio, and the Penibetic the stratigraphic range of **Bulbobaculites problematicus** (Neagu) extends into the Santonian (see Kuhnt and Kaminski 1990, Figure 8).

Genus Caudammina

Caudammina ovulum gigantea (Geroch), 1960
Figure 1.6-8.

1955 **Hormosina ovulum** (Grzybowski); Geroch and Gradzinski: pl. 5, fig. 3.
1960 **Hormosina ovulum** (Grzybowski) var. **gigantea** Geroch: p. 43, pl. 2, figs 18-19; pl. 11, fig. 6.
1984 **Hormosina ovulum gigantea** Geroch; Geroch and Nowak: pl. 1, fig. 20; pl. 5, figs 15-16.
1988 **Hormosina gigantea** Geroch; Moullade et al**:** p. 365, pl. 2, fig. 11.
1990 **Hormosina ovulum gigantea** Geroch; Kuhnt and Kaminski: p. 474, pl. 1, figs a-b.

1992 **Hormosina ovulum gigantea** Geroch; Wightman and Kuhnt: p. 256, pl. 1, fig. 17.

Original Designation:

Hormosina ovulum (Grzybowski) var**. gigantea** Geroch, 1960.

Type Specimen:

Depository not given.

Type Level:

Not designated. One figured specimen (Figure 18) from the Upper Cretaceous, Senonian, Lower Istebna Beds; other figured specimens (Figure 19) from beds transitional from the Godula Beds (Aptian-Albian to Senonian) – the Lower Istebna Beds. Also occurs in the Upper Istebna Beds (uppermost Cretaceous?-Paleocene) and Ciezkowice Beds (Paleocene).

Type Locality:

Not designated. Figured specimen from the Rudnik, near Wadowice (Figure 18), Czarne (Figure 19) and along the Czarna Wiselka stream (Figure 6), all in the Silesian Beskids, Poland.

Description:

Test composed of large, spherical chambers arranged in a rectilinear or arcuate series but typically found as single chamber fragments. Chamber size often exceeds 400 microns in width. Chamber wall is multilayered in contrast to stolon connections that are thin, consisting mostly of a single layer often of coarse quartz grains. The difference in wall structure between the chambers and stolons probably accounts for the isolated occurrence of single chamber fragments. The primary aperture is terminal and produced on a tubular neck. Chamber walls are thick, finely agglutinated, and smoothly cemented with organic cement.

Remarks:

Useful stratigraphic marker with a distinct range from the base of the Campanian to the latest Maastrichtian. In the Carpathian flysch, the first occurrence of **Caudammina ovulum gigantea** marks the base of the early Campanian-Maastrichtian **Hormosina ovulum gigantea** Zone of Geroch and Nowak (1984).

Caudammina ovulum gigantea exhibits great variability in size, and intergrades with **Caudammina ovulum ovulum** are common.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Bathyal and abyssal. Common in flysch-type assemblages.

Stratigraphic Range:

Cretaceous (Campanian-latest Maastrichtian) in the Polish Carpathian Flysch, according to Geroch and Nowak (1984). Cretaceous (Campanian-Maastrichtian) in the North Atlantic and Labrador (Kuhnt and Kaminski 1990), in the Indian Ocean (Krasheninnikov 1974), and in the Pacific (Wightman and Kuhnt 1992).

Caudammina ovulum ovulum (Grzybowski), 1896
Figure 1.9-11.

1896 **Reophax ovulum** Grzybowski: p. 276, pl. 8, figs 19-21.
1973 **Hormosina ovulum** (Grzybowski); Krasheninnikov: pl. 7, fig. 12.
1988 **Hormosina ovulum** (Grzybowski); Moullade et al**:** p. 364, pl. 2, figs 7-9.
1988 **Hormosina ovulum ovulum** (Grzybowski); Kaminski et al**:** p. 186, pl. 2, fig. 10.
1990 **Hormosina ovulum ovulum** (Grzybowski); Kuhnt and Kaminski: p. 474, pl. 1, figs c-e.
1992 **Hormosina ovulum ovulum** (Grzybowski); Wightman and Kuhnt: p. 257, pl. 2, fig. 2.
1994 **Hormosinella ovulum** (Grzybowski); Bolli et al**:** p. 72, figs 19.17-19.

Original Designation:

Reophax ovulum Grzybowski, 1896.

Type Specimen:

Depository not given.

Type Level:

Erroneously reported as Lower Oligocene, lower Tongrian in Ellis and Messina catalogue. The type level is an Upper Cretaceous red clay.

Type Locality:

Between 64 and 70 m below the top of an exploratory coal shaft, about 500 m southwest of the courthouse at Wadowice near Krakow, Poland.

Description:

Test composed of ovate chambers arranged in a rectilinear or arcuate series, but usually found as single chamber fragments. Chamber wall is multilayered in contrast to stolon connections that are thin, consisting mostly of a single layer often of coarse quartz grains. Differences in wall structure between chambers and stolons probably account for the isolated occurrence of single chamber fragments. The primary aperture is terminal produced on a tubular neck. Chamber walls are thick, finely agglutinated, and smoothly cemented with organic cement.

Remarks:

Caudammina ovulum (Grzybowski) is similar to **Caudammina gigantea** Geroch in its very smooth surface and narrow connections between the chambers, but has a smaller size (200-400 microns) and more elongated chambers. **Caudammina gigantea** (Geroch) has a more restricted stratigraphic range (Geroch 1960; Geroch and Nowak 1984; Moullade et al. 1988), and is a useful marker for the end of the Paleocene. Extremely elongated forms show similarities to **Hormosina ovuloides** (Grzybowski), but can be distinguished from this species by their narrow connections between the chambers and a more symmetrical eggshape.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Bathyal and abyssal. Common in flysch-type assemblages.

Stratigraphic Range:

Cretaceous to Paleocene; given as Hauterivian to Paleocene by Geroch and Nowak (1984).

Genus Eggerella

Eggerella bradyi (Cushman), 1911
Figure 1.12-13.

Type species of the genus **Eggerella** Cushman, 1933.

1884 **Verneuilina pygmaea** (Egger) (non Egger); Brady: p. 385, pl. 47, figs 4-7.
1911 **Verneuilina bradyi** Cushman: p. 54, fig. 87, p. 67, fig. 107.
1951 **Eggerella bradyi** (Cushman); Phleger and Parker: p. 6, pl. 3, figs 1, 2.
1960 **Eggerella bradyi** (Cushman); Barker: p. 96, pl. 47, figs 4-7.
1994 **Eggerella bradyi** (Cushman); Jones: p. 51-52, pl. 47, figs 4-7.
1998 **Eggerella bradyi** (Cushman); Robertson: p. 24, pl. 3, fig. 4.

Original Designation:

Verneuilina bradyi Cushman, 1911.

Type Specimen:

Depository not given.

Type Level:

Recent.

Type Locality:

Not designated. Localities mentioned are scattered stations in the North Pacific Ocean, over 1000 fm.

Description:

Test nearly conical, oval in cross-section, initially trochospiral, later (in adult portion) reduced to three, and occasionally two chambers per whorl. The highly-inflated chambers increase rapidly in size and are separated by thin, depressed sutures. Chamber walls are finely agglutinated, canaliculate, and smoothly cemented with calcareous cement. The primary aperture is an elongate slit at the base of final chamber, bordered by a narrow lip.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Typically occurs in deep-water, oligotrophic environments (Altenbach et al. 1999; Kuhnt et al. 1999, 2000, in press). However, it has calcareous cement and is not found in sub CCD sediments. Recorded in water depth of 129-3125 fm at Challenger stations (Jones 1994).

Stratigraphic Range:

Oligocene (Rupelian) – Recent.

Genus Haplophragmoides

Haplophragmoides multicamerus Krasheninnikov, 1973
Figure 1.14-16.

1973 **Haplophragmoides multicamerus** Krasheninnikov: p. 207, pl. 1, figs 1-2.
1974 **Haplophragmoides pervagatus** Krasheninnikov; Krasheninnikov: p. 635, pl. 1, figs. 4a, b.
1988 **Haplophragmoides multicamerus** Krasheninnikov; Moullade et al: p. 364, pl. 5, figs 1-2.
1992 **Haplophragmoides multicamerus** Krasheninnikov; Wightman and Kuhnt, 1992: p. 256, pl. 3, figs 3-5.

Original Designation:

Haplophragmoides multicamerus Krasheninnikov, 1973.

Type Specimen:

Holotype (No 4011/1) deposited in the collections of the Micropaleontological Laboratory, Geological Institute, Academy of Sciences of the USSR, Moscow.

Type Level:

Upper Cretaceous, Santonian-Campanian.

Type Locality:

Holotype from Deep Sea Drilling Project (DSDP) Leg 20, Hole 196, Core 2, Section 1, 38-40 cm interval; 6194 m depth on the abyssal floor, west of the Izu-Bonin Trench, Latitude 30° 06.97'N, Longitude 148° 34.49'E.

Description:

Test small, planispiral, flattened, evolute, slightly lobulate in outline, oval in cross-section with rounded periphery. Chambers of previous whorls are partly visible through wide, shallow umbilicus. Lateral sides are slightly concave to flat. Eight to 11 inflated, trapeziform chambers in the last whorl, increasing relatively rapidly in height, are separated by straight, depressed sutures. Chamber walls are finely agglutinated with organic cement and show a smooth, glassy finish. The primary aperture is an elongate equatorial slit at the base of the last chamber.

Remarks:

Width of umbilicus varies but inner coil is always partially visible. According to Loeblich and Tappan (1987), this species belongs to the genus **Evolutinella**.

Useful stratigraphic marker for the Late Cretaceous and bathymetric indicator for abyssal paleoenvironments.

Biogeography:

Worldwide.

Recorded from the Pacific Ocean (Krasheninnikov1973; Wightman and Kuhnt1992), the Indian Ocean (Krasheninnikov 1974), and the North Atlantic (Moullade et al. 1988).

Bathymetry and Paleoecology:

Abyssal, below CCD.

Stratigraphic Range:

Cretaceous (Santonian-Maastrichtian).

Campanian in the Pacific Ocean (Krasheninnikov 1973). Santonian to Campanian in the Indian Ocean (Krasheninnikov 1974), Santonian to Maastrichtian in the North Atlantic (Moullade et al. 1988).

Haplophragmoides pervagatus Krasheninnikov, 1973
Figure 1.17-19.

1973 **Haplophragmoides pervagatus** Krasheninnikov: p. 208, pl. 1, fig. 7.

Original Designation:

Haplophragmoides pervagatus Krasheninnikov, 1973.

Type Specimen:

Holotype (No 4011/7) deposited in the collections of the Micropaleontological Laboratory, Geological Institute, Academy of Sciences of the USSR, Moscow.

Type Level:

Upper Cretaceous, Santonian-Campanian.

Type Locality:

Holotype from DSDP Leg 20, Hole 196, Core 2, Section 1, 38-40 cm interval; 6194 m depth on the abyssal floor, west of the Izu-Bonin Trench, Latitude 30° 06.97'N, Longitude 148° 34.49'E.

Description:

Test small, planispiral, flattened, slightly evolute, slightly lobulate in outline, oval in cross-section with rounded periphery. Previous chambers of penultimate whorl are partly visible through small, open umbilicus. Lateral sides are slightly concave, almost flat. Approximately six inflated, trapeziform chambers in the last whorl, increasing gradually in size, are separated by straight, depressed sutures. Chamber walls are finely agglutinated with organic cement and show a smooth, glassy finish. The primary aperture is an elongate equatorial slit at the base of the last chamber.

Remarks:

Wightman and Kuhnt (1992) observed transitional forms between **Haplophragmoides pervagatus, Haplophragmoides perexplicatus,** and **Haplophragmoides constrictus**, and suggested that these forms may represent end members of a continuous morphologic lineage.

Width of umbilicus varies, but inner coil is always partially visible. According to Loeblich and Tappan (1987), this species belongs to the genus **Evolutinella**.

Useful stratigraphic marker for the Late Cretaceous and bathymetric indicator for abyssal paleoenvironments.

Biogeography:

Worldwide.

Recorded from the Pacific Ocean (Krasheninnikov 1973) as **Haplophragmoides perexplicatus** from the North Atlantic (Moullade et al. 1988), and as **Haplophragmoides** ex gr. **perexplicatus-constrictus** in the Pacific (Wightman and Kuhnt 1992).

Bathymetry and Paleoecology:

Abyssal, below CCD.

Stratigraphic Range:

Cretaceous (Santonian-Campanian).

Campanian in the Pacific Ocean (Krasheninnikov 1973), Santonian-Maastrichtian in the Atlantic Ocean (Moullade et al. 1988' Wightman and Kuhnt, 1992).

Genus Hippocrepina

Hippocrepina depressa Vasicek, 1947
Figure 2.1

1947 **Hippocrepina depressa** Vacisek: p. 243, pl. 1, figs 1-2.
1960 **Hippocrepina depressa** Vacisek; Geroch: pl. 6, fig. 1.
1974 **Hippocrepina depressa** Vacisek; Bartenstein: p. 684, pl. 2, figs 23-26.
1989a **Jacullela depressa** (Vacisek); Riegraf and Luterbacher: p. 1085, pl. 1, figs 4-6.
1992 **Hippocrepina depressa** Vacisek; Kaminski et al: p. 254, pl. 1, figs 7-8.
1994 **Hippocrepina depressa** Vacisek; Reicherter et al: pl. 7A, figs E-F.
1995 **Hippocrepina depressa** Vacisek; Kuhnt: pl. 1, fig. 5.
1997 **Hippocrepina depressa** Vacisek; Holbourn and Kaminski: p. 34, pl. 4, figs 1-2.

Original Designation:

Hippocrepina depressa Vasicek, 1947.

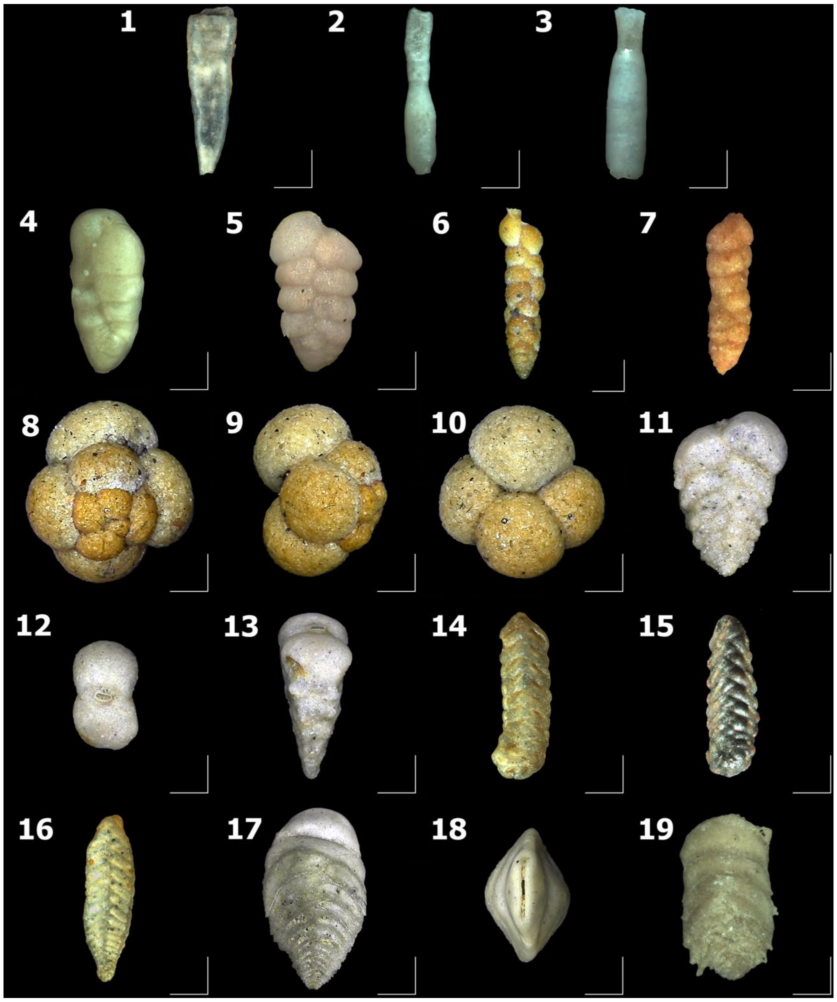

Figure 2.1 - 2.19. 1. Hippocrepina depressa Vasicek, 1947. **1.** Side view. Barremian-Aptian. Silesian Unit. MK 260, Black shales, Verovice Beds. Wilkowisko, east of Myslenice, Poland. Geroch Collection, Jagiellonian University, Krakow, Poland. Scale Bar = 225 microns. **2.3. Kalamopsis grzybowskii** (Dylàzanka), 1923. **2.** Side view. Late Cretaceous. Wyglówka borehole 5: 384.6-319.6 m. Variegated marls, Subsilesian Unit, Poland. Geroch Collection, Jagiellonian University, Krakow, Poland. Scale Bar = 446 microns. **3.** Side view. Late Cretaceous. Wyglówka borehole 5: 384.6-319.6 m. Variegated marls, Subsilesian Unit, Poland. Geroch Collection, Jagiellonian University, Krakow, Poland. Scale Bar = 353 microns. **4-5. Karreriella bradyi** (Cushman), 1911. **4.** Side view. Holotype. Recent. Albatross Station D2806, Galapagos Islands (1379 fm). Smithsonian Collection. USNM 26307. Scale Bar = 137 microns. **5.** Side view. Barra Fan, Seep Study. R.W. Jones' Collection. Scale Bar = 165 microns. 6-7. Karrerulina conversa (Grybowski), 1901. 6. Side view. Recent Challenger Station 346, South Atlantic Ocean (2350 fm). Natural History Museum, London. NHM ZF1416. Scale Bar - 184 microns. 7. Side view. Late Cretaceous. Specimen from the Geroch Collection at the Smithsonian Institution. Scale Bar - 210 mircrons. **8-10. Paratrochammina challengeri** Brönnimann and Whittaker, 1988. **8.** Spiral view. Recent. Challenger Station 323, South Atlantic Ocean (1900 fm). Natural History Museum, London. NHM ZF1538. **9.** Side view of specimen 8. **10.** Umbilical view of specimen 8. Scale Bar = 291 microns. **11-13. Siphotextularia concava** (Karrer), 1868. **11.** Side view. Recent. Challenger Station 308, West of Patagonia, East Pacific Ocean (175 fm). Natural History Museum, London. NHM ZF2443. **12.** Apertural view of specimen 11. **13.** End view of specimen 11. Scale Bar = 191 microns. **14-16. Spiroplectammina spectabilis** (Grzybowski), 1888 emend. Kaminski, 1984. **14.** Macrospheric specimen. Side view. Karas Potok, Poland. Geroch Collection, Jagiellonian University, Krakow, Poland. Scale Bar = 444 microns. **15.** Macrospheric specimen. Side view. Karas Potok, Poland. Geroch Collection, Jagiellonian University, Krakow, Poland. Scale Bar = 435 microns. **16.** Microspheric specimen. Side view. Karas Potok, Poland. Geroch Collection, Jagiellonian University, Krakow, Poland. Scale Bar = 440 microns. **17-18. Vulvulina pennatula** (Batsch), 1791. **17.** Side view. Recent. Challenger Station 24, off Culebra Island, West Indies (390 fm). Natural History Museum, London. NHM ZF1126. Scale Bar = 432 microns. **18.** Apertural view of specimen 17. Scale Bar = 341 microns. **19. Vulvulina spinosa Cushman, 1927.** Side view. **19.** Holotype. Late Eocene. From the Alaxan Clay, Rio Buena Vista, just South of crossing of Alazan to Moyutla Road, Vera Cruz, Mexico. Collected by T. W. Vaughan, Smithsonian Collection. CC 901. Scale Bar = 234 microns.

Type Specimen:

Depository not given.

Type Level:

Cretaceous (definitely older than Senonian), lower part of the Magura flysch, lower Bigenerina zone. Associated with numerous Radiolaria and fish teeth.

Type Locality:

Exploratory boring no. 12R, near Hluk, 5 miles southeast of Uherske Hradiste, which is on the Morava River about 40 miles east-southeast of Brno, in central Moravia, Czechoslovakia.

Description:

Small, elongate, laterally compressed, conical test, which may be arched and may have annular constrictions at irregular intervals. Chamber walls are thick, agglutinated with fine to medium particles and smoothly finished with an organic cement. The primary aperture is terminal and rounded.

Remarks:

One of the few species that became extinct at the Cenomanian/Turonian boundary.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Bathyal to abyssal. Common in flysch-type sediments.

Stratigraphic Range:

Cretaceous (Hauterivian-Cenomanian).

Genus Kalamopsis

Kalamopsis grzybowskii (Dylàzanka), 1923
Figure 2.2-3.

1923 **Hyperammina grzybowskii** Dylàzanka: pl. 1, p. 65.
1955 **Hyperammina grzybowskii** Dylàzanka; Geroch and Gradzinski: pl. 5, fig. 1.
1974 **Kalamopsis grzybowskii** (Dylàzanka); Bartenstein: pl. 1, figs 31-34; pl. 2, figs 27-35.
1984 **Kalamopsis grzybowskii** (Dylàzanka); Geroch and Nowak: pl. 1, figs 2-3.
1989b **Kalamopsis grzybowskii** (Dylàzanka); Riegraf and Luterbacher: p. 1019, pl. 1, fig. 4-5.
1993 **Kalamopsis grzybowskii** (Dylàzanka); Kaminski and Geroch: p. 281, pl. 17, figs 5-8.
1997 **Kalamopsis grzybowskii** (Dylàzanka); Holbourn and Kaminski: p. 37, pl. 7, figs 1-3.

Original Designation:

Hyperammina grzybowskii Dylàzanka, 1923.

Type Specimen:

Depository not given. Lectotype designated by Kaminski and Geroch (1993), deposited in the Grzybowski Collection at the Jagiellonian University, Krakow, Poland (UJ-133-P, 4/18a).

Type Level:

Upper Cretaceous, Inoceramus beds. Sixteen meters series of alternating sandstones and shales, divisible into six horizons. Occurs also in gray shales in the Inoceramus beds at Siary.

Type Locality:

Quarry about 0.5 km from the Grybów-Gorlice Creek near the place where the road leading to the village of Bielanka crosses the creek from left to right for the first time, near the bottom of a 340 m hill in Szymbark, near Gorlice, eastern part of Krakow Department, Poland. Found also opposite the Chapel, near the inn, in Siary, near Gorlice.

Description:

Cylindrical test comprised of a rounded proloculus followed by elongate tubular chambers in a rectilinear series. Chambers are separated by internal partitions, which may correspond to points of constriction. Chamber walls are thin, finely agglutinated with organic cement, finely finished, occasionally with some coarser grains. The primary aperture is simple and terminal.

Remarks:

Mostly found as broken fragments. Type specimens in the Grzybowski Collection can be up to 1 mm in length (Kaminski and Geroch 1993).

Biogeography:

Worldwide

Bathymetry and Paleoecology:

Bathyal to abyssal. Typically found in flysch-type assemblages.

Stratigraphic Range:

Cretaceous (Oxfordian?) - Eocene (Priabonian?).

Riegraf and Luterbacher (1989b) reported its range as Kimmeridgian to Eocene in the North Atlantic (Sites 105, 367, 368, 370, and 398). Kuhnt et al. (in press) reported its occurrence in Oligocene sediments from Site 1148 in the South China Sea.

Genus Karreriella

Karreriella bradyi (Cushman), 1911
Figure 2.4-5.

1884 **Gaudryina pupoides** d'Orbigny; Brady: p. 378, pl. 46, figs 1-4.
1911 **Gaudryina bradyi** Cushman: p. 67, fig. 107.

1921 **Gaudryina bradyi** Cushman; Cushman: p. 149, pl. 29, fig. 3.
1986 **Karreriella bradyi** (Cushman); Schröder: p. 55, pl. 22, fig. 8-9.
1988 **Karreriella bradyi** (Cushman); Zheng: p. 94, pl. 45, fig. 10, pl. 46, fig. 1, pl. 54, fig. 6, text-fig. 21.
1991 **Karreriella bradyi** (Cushman); van Marle: p. 235, pl. 25, figs 2-4.
1994 **Karreriella bradyi** (Cushman); Loeblich and Tappan: p. 25, pl. 30, figs 8-16.
1998 **Karreriella bradyi** (Cushman); Robertson: p. 26, pl. 4, fig. 1.

Original Designation:

Gaudryina bradyi Cushman, 1911, p. 67, fig. 107.

Type Specimen:

Holotype deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Recent.

Type Locality:

Not designated.

Description:

Test free, elongate, megalospheric generation and early stage of the microspheric generation trochospiral, with up to five chambers per whorl, later reduced to triserial and microspheric adult becoming biserial. Chamber walls are finely agglutinated with calcareous cement and are canaliculate. The aperture is areal, surrounded by a distinct lip. It is a rounded opening slightly above the base of the apertural face in the trochospiral stage; and is subterminal in the biserial adult.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Bathyal to abyssal above CCD. Typically occurs in deep-water, oligotrophic environments (Kuhnt et al., 1999, in press). It has calcareous cement and is not found in sub CCD sediments.

Stratigraphic Range:

Paleocene (Selandian?) - Recent.

Genus Karrerulina

Karrerulina conversa (Grzybowski), 1901
Figure 2.6-7.

Type species of the genus **Karrerulina** Finlay, 1940 (by synonomy with **G. apicularis).**

1901 **Gaudryina conversa** Grzybowski: p. 285, pl. 7, figs 15, 16.
1911 **Gaudryina apicularis** Cushman: p. 68, figs 110.
1940 **Karreriella (Karrerulina) apicularis** (Cushman); Finlay: p. 450.
1940 **Karreriella aegra** Finlay: p. 451, pl. 62, figs 21-22.
1953 **Plectina apicularis** (Cushman); Phleger et al**:** p. 27, pl. 5, fig. 10.
1970 **Karreriella indigena** Mjatliuk: p. 116, pl. 34, figs 10-14.
1978 **Plectina conversa** (Grzybowski); Krasheninnikov and Pflaumann: p. 569, pl. 3, figs 4a, b.
1984 **Plectina** aff. **conversa** (Grzybowski); Hemleben and Tröster: p. 521, pl. 4, fig. 24.
1987 **Karrerulina apicularis** (Cushman); Loeblich and Tappan: p. 130, pl. 139, figs 7-13.
1988 **Karreriella conversa** (Grzybowski); Kaminski et al**:** p. 196, pl. 9, figs 17-18b.
1988 **Plectina conversa** (Grzybowski); Moullade et al**:** p. 365, pl. 9, figs 1-3.
1990 **Karrerulina conversa** (Grzybowski); Charnock and Jones: p. 195, pl. 12, fig. 19; pl. 25, fig. 10.
1993 **Gerochammina conversa** (Grzybowski); Kaminski and Geroch: p. 279, pl. 13, figs 5-11.
1994 **Karrerulina conversa** (Grzybowski); Jones: p. 51, pl. 46, figs 17-19.

Original Designation:

Gaudryina conversa Grzybowski, 1901.

Type Specimen:

Depository not given. Lectotype designated and illustrated by Kaminski and Geroch (1993). Lectotype (No. UJ-133-P, 2/105b) deposited in the Grzybowski collection, Jagiellonian University, Krakow, Poland.

Type Level:

Eocene, Ropianka formation = beds with Inoceramus (possibly reworked); grey clay and clay shale (Bartne); red clay (Ropica Polska).

Type Locality:

Ropica Polska U (40).

Description:

Test elongate initially trochospiral, then becoming triserial and finally biserial. The trochospiral portion, which makes up about a third of the test, has three to four whorls of four or five chambers and a circular cross-section. The triserial portion generally consists of one to two whorls. The biserial portion is of variable length, somewhat flattened with subparallel or lobulate outline. Chambers increase rapidly in size and sutures are indistinct in the multiserial portion. Chambers are low, increasing slowly in size with distinct, fine, and depressed sutures in the biserial stage. The final chamber is often distinctly inflated. Chamber walls are agglutinated with fine to medium quartz grains and abundant silicified cement. The primary aperture is terminal, round, at the end of a short neck.

Remarks:

Biserial stage may be twisted along the long axis of the test (Kaminski and Geroch 1993). Triserial stage is often indistinct or may be absent.

Biogeography:

Worldwide.

Bathymetry & Paleoecology:

Bathyal to abyssal, with upper water depth limit of 3000 m (Kuhnt et al**.** 2000). Mobile, deep infaunal species, restricted to oligotrophic deep-water settings with well-oxygenated bottom and interstitial waters (Kuhnt et al**.** 2000).

Stratigraphic Range:

Cretaceous (Santonian?, Campanian) – Recent.

Genus Paratrochammina

Paratrochammina challengeri Brönnimann and Whittaker, 1988
Figure 2.8-10.

1884 **Haplophragmium globigeriniforme** (Parker and Jones); Brady (pars): p. 312, pl. 35, figs. 10a-c only (**non** fig. 11) (**non Lituola nautiloiudea** var. **globigeriniformis** Parker and Jones, 1865).
1988 **Paratrochammina challengeri** Brönnimann and Whittaker: p. 43, figs 16H-K.
1988 **Trochammina altiformis** (Parker & Jones); Moullade et al**:** p. 366, pl. 8, figs 1-3.
1990 **Trochamminopsis challengeri** (Brönnimann & Whittaker); Charnock and Jones: p. 189, pl. 11, figs 7-10; pl. 22, fig. 6.
1994 **Paratrochammina challengeri** Brönnimann and-Whittaker; Jones: p. 41, pl. 35, fig. 10.

Original Designation:

Paratrochammina challengeri Brönnimann and Whittaker, 1988.

Type Specimen:

Holotype is housed in the micropaleontological collections of the Natural History Museum, London, and is registered in slide ZF 4135.

Type Level:

Recent.

Type Locality:

“Challenger” Station 323, 450 miles north of South Georgia, South Atlantic (50° 47' W, 35° 39' S), depth 1900 m.

Description:

Test trochospiral, concavo-convex with evolute, convex spiral side, concave, involute umbilical side, and rounded periphery. Approximately four highly inflated chambers in the last whorl, increasing gradually in size, are separated by straight, markedly depressed sutures. The wall is finely agglutinated with abundant cement. The aperture is a low interiomarginal arch with an umbilical flap covering all previous flaps.

Remarks:

This long-ranging taxon is widely reported in the literature, under the name **Trochammina globigeriniformis**. Brönnimann and Whittaker (1988) considered **Trochammina globigeriniformis** to be a **nomen dubium** and proposed the new name **Paratrochammina challengeri.**

Bathymetry and Paleoecology:

Cosmopolitan.

Bathymetry:

Bathyal to abyssal, including sub CCD.

Stratigraphic Range:

Late Cretaceous - Recent.

Genus Siphotextularia

Siphotextularia concava (Karrer), 1868
Figure 2.11-13.

1868 **Plecanium concavum** Karrer: p. 129, pl. 1, fig. 3.
1991 **Siphotextularia concava** (Karrer); van Marle: pl. 25, fig. 11.
1994 **Siphotextularia concava** (Karrer); Jones: p. 47, pl. 42, figs 13-14.
1998 **Siphotextularia concava** (Karrer); Cicha et al**:** p. 127, pl. 10, figs 3-4.

Original Designation:

Plecanium concavum Karrer, 1868.

Type Specimen:

Depository not given.

Type Level:

Miocene, Gainfahrn Marl, very sandy calcareous clay.

Type Locality:

Kostej im Banat, Rumania.

Description:

Test forms an elongate, tapered, slightly lobulate, slightly compressed, biserial series, sub-quadrate in cross-section. The moderately inflated chambers increase gradually in size and are separated by oblique, slightly depressed sutures. Chamber walls are finely agglutinated with calcareous cement and canaliculate. The primary aperture is an areal slit, bordered by a lip, produced on a short neck.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Recorded from 17 fm and 175 fm at Challenger stations in the Pacific (Jones1994).

Stratigraphic Range:

Late Miocene (Tortonian) – Recent.

Genus Spiroplectammina

Spiroplectammina spectabilis (Grzybowski), 1888
emend. Kaminski, 1984
Figure 2.14-16.

1898 **Spiroplecta spectabilis** Grzybowski: p. 293, pl. 12, fig. 12.
1898 **Spiroplecta brevis** Grzybowski: p. 293, pl. 12, fig. 13.
1898 **Spiroplecta costidorsata** Grzybowski: p. 294, pl. 12, fig. 11.
1898 **Spiroplecta foliacea** Grzybowski: p. 293, pl. 12, fig. 14-15.
1898 **Spiroplectoides clotho** Grzybowski: p. 224, pl. 8, fig. 18.
1934 **Spiroplectoides californica** Cushman and Campbell: p. 70, pl. 9, figs 13-14.
1935 **Spiroplectammina mexiaensis** Lalicker: p. 43, pl. 6, figs 5-6.
1939 **Spiroplectoides directa** Cushman and Siegfus: p. 26, pl. 6, figs 7-8.
1943 **Spiroplectammina grzybowskii** Frizzel: p. 339, pl. 55, figs 12a-13.
1951 **Spiroplectammina perplexa** Israelsky: p. 12, pl. 3, figs 9-14.
1952 **Spiroplectammina brunswickensis** Todd and Kniker: p. 6, pl. 1, fig. 16.
1984 **Spiroplectammina spectabilis** (Grzybowski); Kaminski: p. 29-49, pls 12-13.
1990 **Spiroplectammina (Spiroplectinella) spectabilis** (Grzybowski); Charnock & Jones: p. 182, pl. 9, figs 15-18; pl. 21, fig. 5.
1990 **Spiroplectammina spectabilis** (Grzybowski); Kaminski et al: p. 369, pl. 6, figs 5-6.
1993 **Spiroplectammina spectabilis** (Grzybowski); Kaminski and Geroch: p. 267, pl. 12, figs 4a-5c.
1994 **Spiroplectammina spectabilis** (Grzybowski); Gradstein et al: pl. 2, figs 14-18.

Original Designation:

Spiroplecta spectabilis Grzybowski, 1898.

Type Specimen:

Depository not given. Lectotype from 170 m depth in Hanover-Galicia well no. 33, deposited in the Grzybowski Collection at the Jagiellonian University, Krakow, Poland (UJ-132-P, 1/82c).

Type Level:

Uppermost Eocene; red and gray clay.

Type Locality:

Hanover-Galicia well no. 3 at Potok, near Krosno, Poland.

Description:

Test forms an initial planispire, later becoming a biserial series. In megalospheric forms, the planispiral portion, consisting of four to seven chambers, may be wider than the subsequent biserial portion. In microspheric forms, the planispiral portion is smaller. In both generations, the biserial part is rhomboidal in cross-section with nearly parallel sides. However, in microspheric forms, it may increase in breadth initially then decrease distally. Chambers in the biserial part are low and numerous with flush or slightly depressed sutures, inclined approximately 60° to the long axis of the test. The peripheral margin is acute and may be weakly keeled. Chamber walls are imperforate, finely agglutinated with organic cement and smoothly finished. The primary aperture is a narrow interiomarginal slit.

Remarks:

Spiroplectammina spectabilis (Grzybowski) is one of the most widely recognized Paleogene species and figures prominently in a number of zonal schemes.

This species may be considered as a plexus of forms that differ in length and thickness, with significant differences between end members (Kaminski 1984).

Biogeography:

Worldwide. It was first described from the Paleogene of the Carpathian flysch (Grzybowski 1898) and has been subsequently found in the Caribbean (Cushman and Jarvis 1928), along the Pacific margin of North and South America (Cushman and Campbell 1934; Todd and Kniker1952), in the Northwest Pacific (Serova 1987), South Pacific (Webb 1975), North Atlantic (Kaminski et al. 1990), and South Atlantic (Widmark 1997).

Bathymetry and Paleoecology:

Bathyal – abyssal, including sub CCD.

Stratigraphic Range:

Cretaceous (Maastrichtian) – Eocene (Priabonian).

In its type area, the first frequent occurrence of this species marks the base of the late Paleocene **Spiroplectammina spectabilis** Zone of Geroch and Nowak (1984). However, **Spiroplectammina spectabilis** has a diachronous first occurrence, which may reflect the immigration of the species into various ocean basins. For instance, it occurs in the Maastrichtian in Trinidad (Kaminski et al. 1988; Beckmann 1994), on Sakhalin Island (Serova 1987), and in the lower Paleocene of other areas of the Atlantic. At many localities, **Spiroplectammina spectabilis** displays a distinctive abundance maximum immediately after the K/T boundary in Zone P0.

Genus Vulvulina

Vulvulina pennatula (Batsch), 1791
Figure 2.17-18.

Type species of the genus **Vulvulina** d'Orbigny, 1826.

1791 **Nautilus (Orthoceras) pennatula** Batsch: pp 3, 5, pl. 4, fig. 13a-e.
1826 **Vulvulina capreolus** d'Orbigny, p. 264.
1987 **Vulvulina pennatula** (Batsch); Loeblich and Tappan: p. 113, pl. 120, figs 19-21.
1994 **Vulvulina pennatula** (Batsch); Jones: p. 49, pl. 45, figs 1-8.

Original Designation:

Nautilus (Orthoceras) pennatula Batsch, 1791.

Type Specimen:

Depository not given.

Type Level:

Not given ? (?)Recent.

Type Locality:

Shores of Italy [exact locality not given]. [Probably Rimini, on the Adriatic Coast (Cushman, 1931)].

Description:

Test is elongate, flattened, flaring with an acute periphery. Microspheric generation with initial planispire, later becomes biserial, then uniserial in well-developed specimens. The numerous, broad, low chambers are slightly inflated, increase rapidly in size and curve strongly downwards. Sutures are curved and depressed. Chamber walls are finely agglutinated with calcareous cement and smoothly finished. The primary aperture is a broad low interiomarginal arch in the early stage later becoming a narrow, elongate, terminal slit in the adult stage.

Remarks:

Vulvulina nicobarica (Schwager) may be conspecific with **Vulvulina pennatula** (Batsch). Brady (1884) included **V. nicobarica** in the synonymy of **V. pennatula.** However, Srinivasan and Sharma (1980) considered them to be different species.

Biogeography:

Worldwide.

Bathymetry and Paleoecology::

350-675 fm (Jones 1994).

Stratigraphic Range:

Eocene (Ypresian?) – Recent.

Vulvulina spinosa Cushman, 1927
Figure 2.19.

1927 **Vulvulina spinosa** Cushman: p. 111, pl. 23, fig. 1.
1932 **Vulvulina jarvisi** Cushman: p. 84, pl. 10, fig. 20.
1983 **Vulvulina spinosa** Cushman; Tjalsma and Lohmann: p. 38, pl. 10, figs 4-5.
1987 **Vulvulina spinosa** Cushman; Miller and Katz: p. 140, pl. 1, fig. 2.
1989 **Vulvulina spinosa** Cushman; Hermelin: p. 29.
1990 **Vulvulina spinosa** Cushman; Boersma: pl. 2, fig. 2.
1990 **Vulvulina spinosa** Cushman; Thomas: p. 590.
1994 **Vulvulina spinosa** Cushman; Bolli et al: p. 325, figs 87.3, 3a.

Original Designation:

Vulvulina spinosa Cushman, 1927.

Type Specimen:

Holotype (No. 901) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Upper Eocene. Alazan Clay.

Type Locality:

Rio Buena Vista, just south of crossing of Alazan to Moyutla Road, Vera Cruz, Mexico.

Description:

Test is elongate, flattened, lozenge-shaped or rhomboidal with an acute periphery. Microspheric generation with initial planispire, later becomes biserial, then uniserial in well-developed specimens. The broad, low chambers are slightly inflated, increasing rapidly in size and curving strongly downwards. Chambers possess a prominent projecting spine at the outer margins and are separated by curved, depressed sutures. Chamber walls are coarsely agglutinated with calcareous cement and roughly finished. The primary aperture is a broad, low interiomarginal arch in the early stage, later becoming a narrow, elongate, terminal slit.

Remarks:

Tjalsma and Lohmann (1983) considered **Vulvulina spinosa** Cushman and **Vulvulina jarvisi** Cushman to be conspecific.

Biogeography:

Worldwide. Reported from Trinidad, Venezuela, and Barbados (Bolli et al. 1994). Atlantic, (Tjalsma and Lohmann 1983). Weddell Sea, Antarctic, (Thomas 1990). North Atlantic (Miller and Katz 1987), and Western Pacific (Hermelin 1990).

Bathymetry and Paleoecology:

Restricted to shallower sites (bathyal) during the early Eocene, expanding to deeper sites (abyssal) during the late middle Eocene (Tjalsma and Lohmann 1983). Lower bathyal (Thomas 1990). Abyssal, >3.5 km (Miller and Katz 1987). Lower bathyal and abyssal (Boersma 1990).

Stratigraphic Range:

Paleocene – Miocene (Serravillian). Common to abundant in Oligocene to middle Miocene, last occurrence in Serravillian with questionable occurrence in Tortonian (Miller and Katz 1987). First occurrence at or near the early/late Paleocene boundary in the southern Indian Ocean (Mackensen and Berggren 1992).

Genus Cibicides

Cibicides lobatulus (Walker and Jacob), 1798
Figure 3.1-3.

1798 **Nautilus lobatulus** Walker and Jacob: p. 642, pl. 14, fig. 36.
1994 **Cibicides lobatulus** (Walker and Jacob); Jones: p. 97, pl. 92, fig. 10; pl. 93, figs 1, 4-5; p.114, pl. 115, figs 4-5.

Original Designation:

Nautilus lobatulus Walker and Jacob, 1798.

Type Specimen:

Depository not given.

Type Level:

Recent. Shore sand.

Type Locality:

Whitestable, Kent, England. Not common.

Description:

Test forms a low trochospire; slightly lobulate (last chambers) in outline, and planoconvex in cross-section, with an involute, convex umbilical side, a flattened or slightly-convex, evolute spiral side, and a subacute, imperforate periphery. Seven to nine moderately inflated chambers increase gradually in size and are separated by broad, curved, flush, or slightly depressed sutures. Chamber walls are calcareous, thick, and coarsely perforate on both sides of the test. The primary aperture is a narrow, equatorial slit bordered by a thin lip, extending on the spiral side.

Remarks:

Cibicides lobatulus is commonly used for stable isotope studies, as it provides a reliable record of bottom water $\delta^{18}O$ and $\delta^{13}C$ values in intermediate water masses, where **Planulina wuellerstorfi** is absent (Weinelt et al. 2000).

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Cibicides lobatulus is a typical epibenthic species that occurs over a wide range of organic flux rates in relatively shallow water (less than 1000 m) and appears to be closely linked to near-bottom currents for its nutritional needs (Altenbach et al. 1999). Reported from shallow water to 3000 fm at Challenger stations (Jones 1994).

Stratigraphic Range:

Miocene (Langhian) – Recent.

Genus Cibicidoides

Cibicidoides barnetti (Bermúdez), 1949
Figure 3.4-8.

1949 **Cibicides barnetti** Bermúdez: p. 295, pl. 24, fig.7-9.
1986 **Cibicidoides barnetti** (Bermúdez); van Morkhoven et al: p. 187, pl. 63.
1993 **Cibicidoides barnetti** (Bermúdez); Katz and Miller: pl. 2, fig. 1.

Original Designation:

Cibicides barnetti Bermúdez, 1949.

Type Specimen:

Holotype (USNM 62546) and paratypes deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Lower Miocene, Sombrerito Formation; tan, massive fossiliferous clay shale. Given as middle Oligocene by Bermúdez (1949).

Type Locality:

Sample H-1066 from the Cañada Gerinaldo, Benefactor Province, Dominican Republic.

Description:

Test forms a trochospire; biconvex in cross-section, with a partially evolute, more convex umbilical side, and an acute, imperforate periphery. The (approximately) 14 moderately inflated chambers in the last whorl increase gradually in size and are separated by curved, raised, limbate sutures extending along the periphery to form a "pseudokeel." On the umbilical side, the sutures converge towards a large, glossy, clear umbo; on the spiral side the early sutures coalesce to form irregular seams. Chamber walls are calcareous, thick and uniformly perforate on both sides of the test. The primary aperture is a narrow, equatorial slit bordered by a thin lip and extends onto the spiral side.

Remarks:

Often confused with **Cibicidoides trinitatensis** (Nuttall). **Cibicidoides barnetti** (Bermúdez) is distinguished by its characteristic "pseudokeel" formed by circumperipheral extensions of the sutures, whereas **C. trinitatensis** has a more rounded periphery and more prominent, thicker sutures (van Morkhoven **et al.**, 1986).

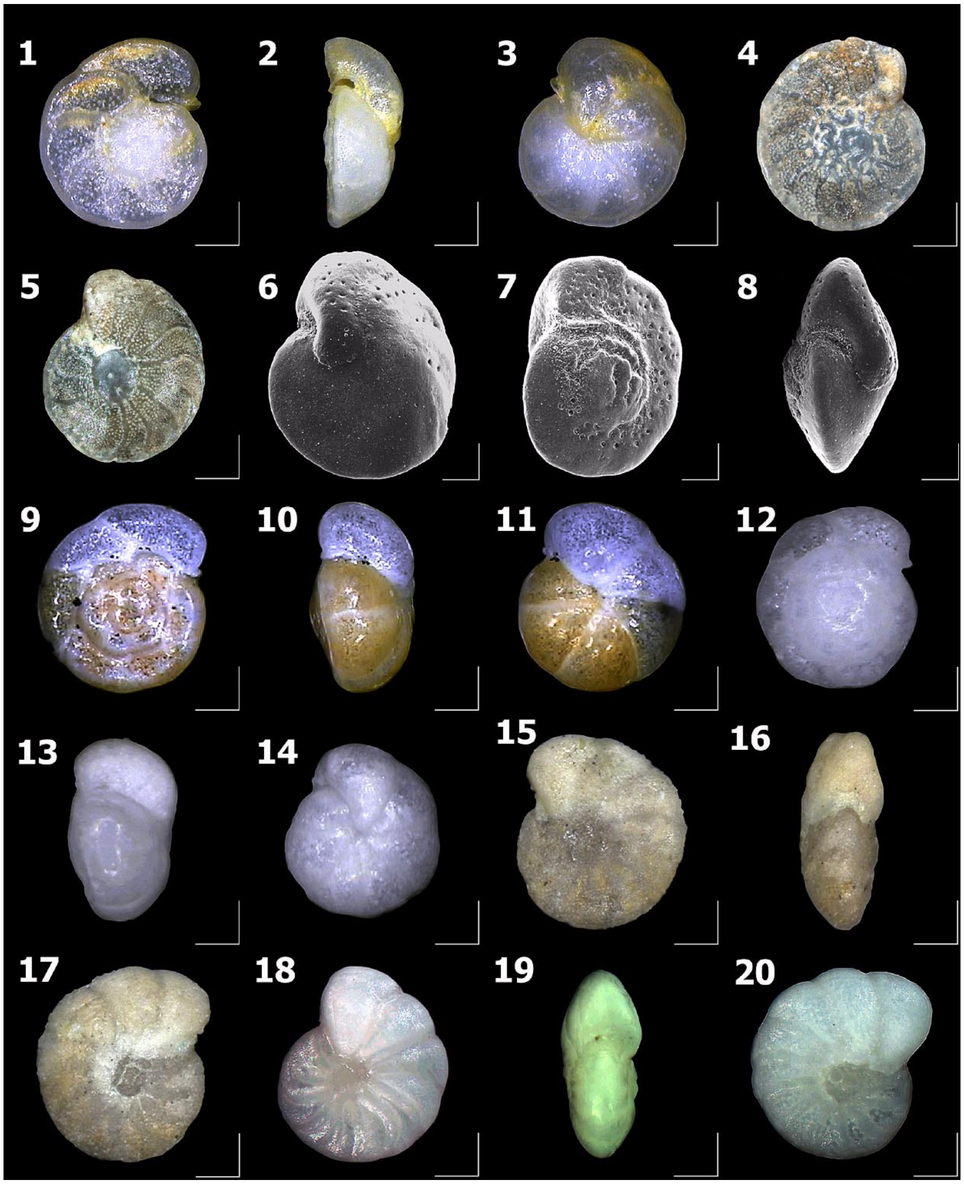

Figure 3. 1-3. Cibicides lobatulus (Walker and Jacob), 1798. **1.** Spiral view. Middle Pleistocene. Slindon Sands Member, Eartham Formation. Boxgrove Quarry 2, GTP13, West Sussex, England. J. E. Whittaker's collection, The Natural History Museum, London. **2.** Apertural view of specimen 1. **3.** Umbilical view of specimen 1. Scale Bar = 54 microns. **4-8. Cibicidoides barnetti** (Bermúdez), 1949. **4.** Spiral view. Holotype. Middle Oligocene. Sombrerito Formation, Dominican Republic, Benefactor Province, Canada Gerinaldo. Smithsonian Collection. USNM 62546. **5.** Umbilical view. Holotype. Scale Bar = 190 microns. **6.** Umbilical view. Oligocene. ODP Leg 184, Site 1148A, 33X-3, 70-72 cm(cm?). Scale Bar = 117 microns. **7.** Spiral view. Oligocene. ODP Leg 184, Site 1148A, 33X-3, 70-72 cm. Scale Bar = 112 microns. **8.** Apertural view. ODP Leg 184, Site 1148A, 33X-3, 70-72 cm. Scale Bar = 111 microns. **9-14. Cibicidoides bradyi** (Trauth), 1918. **9.** Spiral view. Recent. Challenger Station 323, South Atlantic Ocean (1900 fm). Natural History Museum, London. NHM ZF2523. Scale Bar = 62 microns. **10.** Apertural view of specimen 9. **11.** Umbilical view of specimen 9. **12.** Spiral view. Early Oligocene. ODP Leg 114, Site 703A, Core 10, Section 5, 88-92 cm. Scale Bar = 55 microns. **13.** Apertural view of specimen 13. **14.** Umbilical view of specimen 13. **15-20. Cibicidoides micrus** (Bermúdez), 1949. **15.** Spiral view Holotype. Early Eocene. Abuillot Formation, Haiti Central Plain, Abuillot River Traverse. Smithsonian Collection. CC 62431. **16.** Apertural view. Holotype. **17.** Umbilical view. Holotype. Scale Bar = 60 microns.**18.** Spiral view. Eocene. DSDP Leg 48, Hole 402A, Core 2, Section 1, 18-22 cm. Scale Bar = 113 microns. **19.** Apertural view of specimen 18. **20.** Umbilical view of specimen 18.

Biogeography:

Worldwide. Recorded in the Pacific and Atlantic (van Morkhoven et al. 1986), in the South China Sea (Kuhnt et al. in press).

Bathymetry and Paleoecology:

Bathyal to abyssal.

Stratigraphic Range:

Eocene (Priabonian) – Miocene (Serravillian). Doubtful in the Eocene Lutetian – Bartonian interval (van Morkhoven et al. 1986).

Cibicidoides bradyi (Trauth), 1918

Figure 3.9-14.

1918 **Truncatulina bradyi** Trauth: p. 235.
1884 **Truncatulina dutemplei** (d'Orbigny) (**non** d'Orbigny); Brady: p. 665, pl. 95, fig. 5.
1893 **Truncatulina dutemplei** (d'Orbigny) (**non** d'Orbigny); Egger: p. 208, figs 22-23, 30, 54-56.
1926 **Pulvinulina umbonata** (Reuss) var. **multisepta** Koch: p. 749, 737, pl. 25.
1951 **Cibicides hyalina** Hofker: p. 359, figs 244-245.
1976 **Cibicidoides bradyi** (Trauth); Pflum and Frerichs: pl. 3, figs 6, 7.
1983 **Cibicidoides haitiensis** (Coryell and Rivero) (**non** Coryell and Rivero); Tjalsma & Lohmann: p. 26, pl. 17, figs 6.
1983 **Cibicidoides haitiensis** (Coryell & Rivero) (**non** Coryell and Rivero); Miller: p. 433, pl. 2, fig. 5.
1986 **Cibicidoides bradyi** (Trauth); van Morkhoven et al: p.100, pl. 30.
1987 **Cibicidoides bradyi** (Trauth); Miller and Katz: p. 126, pl. 7, figs 2.

Original Designation:

Truncatulina bradyi Trauth, 1918, p. 235 (type reference) illustrated by figures of **Truncatulina dutemplei** (**non** d'Orbigny) in Brady 1884, p. 665, pl. 95, fig. 5 and in Egger, 1893, p. 208, figs 22-23, 30, 54-56.

Type Specimen:

Depository not given. Specimen illustrated by Brady (1884) is deposited in the collections of the Natural History Museum, London, UK.

Type Level:

Recent.

Type Locality:

Not designated.

Description:

Test forms a trochospire; unequally biconvex in cross-section, with an involute umbilical side and an evolute, more convex spiral side with an imperforate, rounded periphery. The nine to 10 inflated chambers in the last whorl increase gradually in size and are separated by radial sutures on the umbilical side and oblique or slightly curved sutures on the spiral side. On the umbilical side, the sutures converge towards an open umbilicus, that may be covered by a clear umbilical plug. Chamber walls are calcareous, coarsely perforate on the spiral side and smooth, finely perforate on the umbilical side. The primary aperture is a narrow equatorial slit, bordered by a thin lip and extends onto the spiral side.

Remarks:

Cibicidoides bradyi has a smaller test size, fewer chambers per whorl and a more rounded periphery than **Cibicidoides robertsonianus**. **Cibicidoides bradyi** may be the ancestral form of **Cibicidoides robertsonianus**. Intergrades between these two species occur in the Miocene when their stratigraphic ranges overlap (Kuhnt et al., in press).

Biogeography:

Worldwide. Recorded from the Indian Ocean, the Pacific, the North and South Atlantic, the Mediterranean, the Gulf of Mexico and Papua New Guinea (van Morkhoven et al. 1986) and the South China Sea (Kuhnt et al., in press).

Bathymetry and Paleoecology:

Bathyal to abyssal (Katz, personal commun., 1998).

Stratigraphic Range:

Eocene (Ypresian) – Recent.

Cibicidoides micrus (Bermúdez), 1949

Figure 3.15-20.

1949 **Cibicides micrus** Bermúdez: p. 302, pl. 24, figs 34-36.

Original Designation:

Cibicides micrus Bermúdez, 1949.

Type Specimen:

Holotype (No. 62431) and paratypes deposited in the collections of the United States National Museum, Washington, D.C. Topotypes deposited in the collections of the Standard Oil Company of Cuba at the University of Havana; the University of Santo Domingo, Ciudad Trudillo, Dominican Republic; the Dorothy K. Palmer Collection at the Paleontological Research Institution, Ithaca, New York; and in the author's personal collection, now housed in the Paleontological Laboratory of INTEVEP, Los Teques (suburb of Caracas), Venezuela.

Type Locality:

Sample H-843, from a cut in a bluff along the Abuillot River, a confluent of the Canot River, Hinche area, Central Plain, Haiti (Type Locality of the Abuillot Formation). Frequent.

Type Level:

Lower Eocene, Abuillot Formation; highly calcareous, slightly sandy shale.

Description:

Test forms a lenticular trochospire; subcircular in outline and unequally biconvex with a slightly convex, evolute spiral side, a more flattened, partially-evolute umbilical side, and a subacute, imperforate periphery. The (approximately) 12 slightly-inflated chambers in the last whorl increase gradually in size and are separated by distinct, slightly-curved sutures. Spiral sutures are markedly depressed and the umbilicus is closed. Chamber walls are calcareous, thick, finely perforate, and smooth. The primary aperture is a narrow equatorial slit bordered by a thin lip and extends onto the spiral side.

Remarks:

Specimens illustrated as **Cibicidoides micrus** (Bermúdez) by van Morkhoven et al**.** (1986) are topotypes of **Cocoarota cocoaensis**, the type species of the genus **Cocoarota** Loeblich and Tappan, 1986 (Loeblich and Tappan 1987; Revets 1996).

Mophotypes from lower bathyal depths are generally larger, whereas abyssal forms are more rounded and distinctly evolute on the spiral side (Tjalsma and Lohmann 1983).

Biogeography:

Worldwide. Found in the North and South Atlantic, the Pacific Ocean, and the Indian Ocean (van Morkhoven et al**.** 1986).

Bathymetry and Paleoecology:

Bathyal to abyssal.

Stratigraphic Range:

Eocene (Ypresian) – Oligocene (Chattian?).

Cibicidoides mundulus (Brady, Parker, and Jones), 1888

Figure 4.1-9.

Type species of the genus **Cibicidoides** Thalmann, 1939.

1888 **Truncatulina mundula** Brady, Parker and Jones: p. 228, pl. 45, fig. 25a-c.
1951 **Cibicides** sp. 2 Phleger and Parker: p. 32, pl. 18, figs 1-2.
1953 **Cibicides kullenbergi** Parker in Phleger et al**:** p. 49, pl. 11, figs 7-8.
1955 **Cibicidoides mundulus** (Brady, Parker & Jones); Loeblich and Tappan: pl. 25, fig. 4.
1986 **Cibicidoides mundulus** (Brady, Parker and Jones); van Morkhoven et al**:** p. 65, pl. 21.
1987 **Cibicidoides mundulus** (Brady, Parker and Jones); Loeblich and Tappan: p. 572, pl. 626, figs 1-3.
1987 **Cibicidoides mundulus** (Brady, Parker and Jones); Miller and Katz: p. 130, pl. 7, fig. 3.
1994 **Cibicidoides mundulus** (Brady, Parker and Jones); Jones: p. 99, pl. 95, fig. 6.
1996 **Cibicidoides mundulus** (Brady, Parker and Jones); Revets: pl. 1, figs 9-12.

Original Designation:

Truncatulina mundula Brady, Parker, and Jones, 1888.

Bathymetry:

Depository of holotype not given. Lectotype (ZF 3585) deposited in the micropaleontological collections of the Natural History Museum, London, UK.

Type Level:

Recent. Olive-brown clay.

Type Locality:

Plumper Station, Latitude 22°, 54'S, Longitude 40°, 37'W, over Abrolhos Bank, off the coast of Brazil; 4260 fm.

Description:

Test forms a biumbonate trochospire; subcircular in outline and nearly biconvex in cross-section with an involute, slightly more convex umbilical side, an evolute spiral side, and a subacute, imperforate periphery. The 10 to 12 moderately inflated chambers in the last whorl increase gradually in size and are separated by flush, curved sutures. Chamber walls are calcareous and finely perforate on the umbilical side; coarsely perforate on the spiral side. A coil of coarse perforations is visible through the clear umbo on the spiral side. The primary aperture is a narrow equatorial slit, bordered by a thin lip, and extends onto the spiral side.

Remarks:

We follow van Morkhoven et al**.** (1986) in considering **C. kullenbergi** (Parker) to be a junior synonym of **C. mundulus** (Brady, Parker, and Jones). The original figure shows that **C. kullenbergi** has strongly curved sutures on the umbilical side, in contrast to **C. mundulus**, which has straighter sutures. However, direct comparison between the lectotype of **C. mundulus** and the holotype of **C. kullenbergi** revealed that **C. kullenbergi** also had straight sutures on the umbilical side. The two taxa exhibit a similar range of variability in the degree of curvature of their sutures and in the size of their test and cannot, therefore, be distinguished as separate species on the basis of these criteria.

Cibicidoides mundulus (Brady, Parker, and Jones) can be distinguished from **Cibicidoides pachyderma** (Rzehak) by looking at the peripheral view: **Cibicidoides pachyderma** has an asymmetrical appearance, reminiscent of the central saucer of the Starship Enterprise, whereas **C. mundulus** exhibits a more symmetrical character reminiscent of a flying saucer from a 1950s sci-fi film (Katz, personal commun., 1998). **Cibicidoides mundulus** intergrades with **Cibicidoides praemundulus** Berggren and Miller over the last two zones of the Oligocene (Katz, personal commun., 1998).

Figure 4. 1-9. Cibicidoides mundulus (Brady, Parker, and Jones), 1888. **1.** Spiral view. Lectotype designated by Loeblich and Tappan, 1955. Recent. Plumper Station 4, 260 fm, Latitude 22° 54' South, Longitude 40° 37' West, over Abrahlos Bank, off coast of Brazil, South America. Natural History Museum, London. NHM ZF 3585. Scale Bar = 226 microns. **2.** Apertural view. Lectotype. **3.** Umbilical view. Lectotype. **4.** Spiral view. Paratype of **Cibicides kullenbergi** Parker. Recent. Rehabeh Station 3-38, 260 fm, Latitude 36° 34' North, Longitude 38° 15' West, in the central part of the North Atlantic, 3109 m. Smithsonian Collection. **5.** Apertural view. Paratype of **Cibicides kullenbergi** Parker. **6.** Umbilical view. Paratype of **Cibicides kullenbergi** Parker. Scale Bar = 225 microns. **7.** Spiral view. Recent. As **C. kullenbergi**, Lutze Collection no. 198, Lutze 1978, West Africa M25, GIK. **8.** Apertural view of specimen 7. **9.** Umbilical view of specimen 7. Scale Bar = 232 microns. **10-12. Cibicidoides robertsonianus** (Brady), 1881. **10.** Spiral view. Syntype. Recent. Challenger Station 24, West Indies, 390 fm. Natural History Museum, London. NHM ZF 2547. **11.** Apertural view of specimen 10. **12.** Umbilical view of specimen 10. Scale Bar = 239 microns. **13-15. Cibicidoides subhaidingerii** (Parr), 1950. **13.** Spiral view. Recent. Challenger Station 185, Torres Strait, Pacific Ocean (155 fm). Natural History Museum, London. NHM ZF2528. **14.** Apertural view of specimen 13. **15.** Umbilical view of specimen 13. Scale Bar = 209 microns. **16-18. Epistominella exigua** (Brady), 1884. **16.** Spiral view. Syntype. Recent. Challenger Collection no. 160, Southern Ocean, 2600 fm. Natural History Museum, London. NHM ZF2214. **17.** Apertural view of specimen 16. **18.** Umbilical view of specimen 16. Scale Bar = 115 microns. **19-20. Laticarinina pauperata** (Parker and Jones), 1865. **19.** Umbilical view. Late Miocene. DSDP Leg 82, Site 558, Core 1, Section 2, 90-94 cm. **20.** Spiral view of specimen 19. Scale Bar = 123 microns.

Biogeography:

Recorded from the Antarctic, the Bahamas, the Peru-Chile Trench, the North and South Atlantic, the Mediterranean, the Gulf of Mexico, the Pacific, the Tasman Sea, the Coral Sea, and the Indian Ocean (van Morkhoven et al**.** 1986).

Bathymetry and Paleoecology:

Bathyal to abyssal.

Stratigraphic Range:

Oligocene (Chattian) – Recent.

Cibicidoides robertsonianus (Brady), 1881
Figure 4.10-12.

1881 **Planorbulina robertsoniana** Brady: p. 65.
1884 **Truncatulina robertsoniana** Brady: p. 664, pl. 95, figs 4a-c.
1940 **Cibicides robertsonianus** var**. haitensis** Coryell and Rivero: p. 335, pl. 44, figs 4-6.
1945 **Gyroidina jarvisi** Cushman and Stainforth: p. 62, pl. 11, fig. 3.
1976 **Cibicides robertsonianus** (Brady); Pflum and Frerichs: pl. 3, figs 3-5.
1986 **Cibicidoides robertsonianus** (Brady); van Morkhoven et al**:** p.41, pl. 11.
1987 **Cibicidoides robertsonianus** (Brady); Miller and Katz: p. 132, pl. 7, fig. 1.
1994 **Cibicidoides robertsonianus** (Brady); Jones: p. 99, pl. 95, fig. 4.
1998 **Cibicidoides robertsonianus** (Brady); Robertson: p. 206, pl. 81, fig. 3.

Original Designation:

Planorbulina robertsoniana Brady, 1881, p. 65 (type reference) and **Truncatulina robertsoniana** Brady, 1884, p. 664, pl. 95, figs 4a-c (type figure).

Type Specimen:

Depository not given. Figured specimen deposited in the micropaleontological collections of the Natural History Museum, London, UK.

Type Level:

Recent.

Type Locality:

Not given. Figured specimen from Challenger Station 24, off Culebra Island, north of St. Thomas, West Indies; 390 fm.

Description:

Test forms a trochospire; subcircular in outline and unequally biconvex in cross-section with a partially evolute, more convex umbilical side, an involute, convex umbilical side slightly depressed at the umbilicus, and a subacute, imperforate periphery. The 13 to 14 moderately inflated chambers in the last whorl (final chambers slightly more inflated) increase gradually in size and are separated by curved sutures; flush or slightly depressed on the umbilical side, thickened and flush on the spiral side. Sutures converge towards a large, glossy umbo on the umbilical side. Chamber walls are calcareous, thick and smooth, coarsely perforate on the spiral side, finely perforate on the umbilical side. Well- preserved specimens have distinctive rich brown-colored chambers visible through the transluscent wall. The primary aperture is a narrow equatorial slit, bordered by a thin lip, and extends onto the spiral side.

Remarks:

Cibicidoides robertsonianus (Brady) differs from **Cibicidoides bradyi** (Trauth) by its larger test, more angular periphery and more prominent imperforate periphery (van Morkhoven et al**.** 1986). Specimens from the middle Miocene intergrade with **C. bradyi**, which may be the ancestral form.

Biogeography:

Worldwide. Recorded from the Pacific, Tasman Sea, Atlantic, Mediterranean, and Gulf of Mexico (van Morkhoven et al**.** 1986).

Bathymetry and Paleoecology:

Bathyal to abyssal.

Stratigraphic Range:

Miocene (Serravillian) – Recent.

Cibicidoides subhaidingerii (Parr), 1950
Figure 4.13-15.

1884 **Truncatulina haidingerii** (d'Orbigny) (non d'Orbigny); Brady: p. 663, pl. 95, fig. 7.
1950 **Cibicides subhaidingerii** Parr: p. 364, pl. 15, fig. 7.
1963 ?**Cibicidoides yoitaensis** Matsunaga: p. 117, pl. 52, figs 3a-c.
1986 **Cibicidoides subhaidingerii** (Parr); van Morkhoven et al**:** p. 95, pl. 28.
1994 **Cibicidoides subhaidingerii** (Parr); Jones: p. 99, pl. 94, fig. 7.
1998 **Cibicidoides subhaidingerii** (Parr); Robertson: p. 208, pl. 81, fig. 4.

Original Designation:

Cibicides subhaidingerii Parr, 1950.

Type Specimen:

Holotype and other specimens deposited temporarily at the University of Adelaide.

Type Level:

Recent.

Type Locality:

B.A.N.Z.A.R.E. Station 115, latitude 41°03'S, longitude 148°42'E, off northeastern Tasmania, in 128 m water depth (frequent). Other localities given: Station 113, off

Maria Island, off the east coast of Tasmania, in 122-155 m water depth (one good specimen); and Station 76, in the Indian Ocean, east of Albany, on the south coast of Western Australia, on the continental shelf, in 62 m water depth (less well-developed specimens). Common along the east coast of Australia.

Description:

Test forms a low trochospire; unequally biconvex in cross-section, with an involute, strongly convex umbilical side, a slightly convex, evolute spiral side, and a sub-rounded, imperforate periphery. The eight to 10 moderately inflated chambers in the last whorl increase gradually in size and are separated by limbate, flush, or slightly depressed sutures; radial, straight or slightly curved on the umbilical side, curved on the spiral side. Chamber walls are calcareous, thick, and coarsely perforate on both sides of the test. The primary aperture is a narrow equatorial slit bordered by a thin lip and extends onto the spiral side.

Remarks:

Specimens may differ from the holotype by having a more acute periphery, thus resembling the Early Miocene to mid-Pliocene **Cibicidoides dutemplei** (d'Orbigny). However, they differ from **C. dutemplei** by their large umbonal boss and lack of strongly curved, limbate umbilical sutures. They also resemble the Late Eocene to Early Miocene **Cibicidoides mexicanus** (Nuttall) but differ from it by having an umbonal boss, instead of an umbonal depression, and by more elongated last chambers on the spiral side.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Neritic-lower bathyal.

90-1775 fm (Jones 1994).

Stratigraphic Range:

Oligocene (Rupelian) – Recent.

Genus Epistominella

Epistominella exigua (Brady), 1884
Figure 4.16-18.

1884 **Pulvinulina exigua** Brady: p. 696, pl. 103, figs 13-14.
1951 **Pseudoparrella exigua** (Brady); Phleger and Parker: p. 28, pl. 15, fig. 6 (not fig. 7).
1951 **Pulvinulinella exigua** (Brady); Hofker: p. 322, text figs 219-221.
1987 **Epistominella exigua** (Brady); Miller and Katz: p. 132, pl. 5, figs 6a-b.
1989 **Epistominella exigua** (Brady); Hermelin: p. 67.
1990 **Epistominella exigua** (Brady); Thomas: p. 590.
1994 **Alabaminoides exiguus** (Brady); Jones: p. 103, pl. 103, figs 13-114.
1994 **Pseudoparrella exigua** (Brady); Loeblich and Tappan: p. 146, pl. 307, figs 1-7.

Original Designation:

Pulvinulina exigua Brady, 1884.

Type Specimen:

Figured specimens (ZF2214, ZF2215) deposited in the micropaleontological collections of the Natural History Museum, London, UK.

Type Level:

Recent.

Type Locality:

Not designated. Localities given: 12 stations in the North Atlantic (64-2740 fm); four in the South Atlantic (1025-2475 fm); three in the Southern Ocean (1300-2600 fm); ten in the South Pacific (129-2350 fm), and five in the North Pacific (15-2300 fm).

Description:

Test forms a small trochospire; slightly lobulate in outline and unequally biconvex in cross-section, with an evolute, slightly-convex spiral side, an involute, convex to nearly conical umbilical side, and an acute, keeled periphery. The five moderately-inflated chambers in the last whorl increase gradually in size and are separated by flush, oblique, thickened sutures on the spiral side, and by curved, slightly-depressed sutures on the umbilical side. Chamber walls are calcareous, finely perforate, and smooth. The primary aperture is an interiomarginal slit extending up the face of the final chamber on the umbilical side.

Remarks:

In Recent sediments, the initial chambers characteristically have a brownish colour. Useful indicator of pulsed organic matter paleofluxes.

Biogeography:

Worldwide. Timor Sea (Loeblich and Tappan 1994); Weddell Sea, Antarctic (Thomas 1990); North Atlantic (Miller and Katz 1987); Indian Ocean, Atlantic, Pacific, and Gulf of Mexico (see references in Hermelin1989).

Bathymetry and Paleoecology:

Bathyal to abyssal. Predominantly lower bathyal to abysssal. Deep water (Brady 1884), lower bathyal (Thomas 1990), abyssal, >3.5 km (Miller and Katz 1987), reported from 15-2600 fm at Challenger stations (Jones 1994).

Characteristically occurs in areas of seasonally pulsed phytodetritus flux, where abundant food is episodically available (Smart et al**.** 1994; Gooday 1996).

Stratigraphic Range:

Eocene (Lutetian) – Recent. Middle Eocene to late Eocene (rare), topmost Eocene to Pleistocene (common) according to Thomas (1990). Rare in early Oligocene, common to abundant in late Oligocene to Miocene (Miller and Katz1987).

Genus Laticarinina

Laticarinina pauperata (Parker and Jones), 1865
Figure 4.19-20.

Type species of the genus **Laticarinina** Galloway and Wissler, 1927.

1865 **Pulvinulina repanda** var. **menardii** d'Orbigny, subvar. **pauperata** Parker and Jones: p. 395, pl. 16, figs 50-51b.
1942 **Laticarinina bulbrooki** Cushman and Todd: p. 19, pl. 4, figs 8-9.
1942 **Laticarinina crassicarinata** Cushman and Todd: p. 18, pl. 4, figs 11-12.
1949 **Laticarinina pauperata** (Parker and Jones); Bermúdez: p. 309, pl. 23, figs 43-45.
1953 **Laticarinina pauperata** (Parker and Jones); Phleger et al: p. 49, pl. 11, figs 5-6.
1986 **Laticarinina pauperata** (Parker and Jones); van Morkhoven et al: p. 89, pl. 26.
1987 **Laticarinina pauperata** (Parker and Jones); Loeblich and Tappan: p. 578, pl. 631, figs 1-13.
1987 **Laticarinina pauperata** (Parker and Jones); Miller and Katz: p. 134, pl. 3, fig. 7.
1998 **Laticarinina pauperata** (Parker and Jones); Robertson: p. 210, pl. 84, figs 1-2.

Original Designation:

Pulvinulina repanda Fichtel and Moll, var. **menardii** d'Orbigny, subvar. **pauperata** Parker and Jones, 1865.

Type Specimen:

Depository not given.

Type Level:

Recent.

Type Locality:

Not designated.

Description:

Test strongly compressed, trochoid planoconvex in cross-section with evolute, flattened spiral and evolute, slightly convex umbilical side. Very broad, transparent, imperforate, peripheral keel projecting beyond the last chamber and showing sinuous growth lines. Twelve to 13 slightly inflated chambers in the last whorl in megalospheric forms and up to 22 chambers in microspheric forms. Chambers become loosely coiled, cuneiform on the umbilical side and reniform on the spiral side, and are separated by sutures, radial and slightly depressed on the umbilical side and indistinct on the spiral side. Chamber walls are calcareous, smooth, and finely perforate on both sides of the test. Earlier chambers often have a thin lining of chitin. The primary aperture is a subequatorial slit, or a supplementary opening that is present beneath the posterior umbilical margin.

Remarks:

Laticarinina is most probably a monospecific genus. Distinctive deep-water indicator. Occurs in relatively low numbers in assemblages.

Biogeography:

Worldwide. Recorded from the North and South Atlantic, the Gulf of Mexico, the Caribbean, the Pacific, the Indian Ocean, the Arabian Sea, the Tasman Sea, the Ross Sea, the Weddell Sea, the Scotia Sea, the Mediterranean, and Europe and India (van Morkhoven et al. 1986).

Bathymetry and Paleoecology:

Bathyal to abyssal. Most abundant in lower bathyal depths (Katz, personal commun., 1998).

Stratigraphic Range:

Oligocene (Rupelian) – Recent. Doubtful in Oligocene Zone P18 (van Morkhoven et al. 1986).

Genus Planulina

Planulina renzi Cushman and Stainforth, 1945
Figure 5.1-5.

1945 **Planulina renzi** Cushman and Stainforth: p. 72, pl. 15, fig. 1.
1928 **Truncatulina wuellerstorfi** (Schwager) (**non** Schwager); Nuttall: p. 98, pl. 7, fig. 12.
1945 **Planulina marialana** Hadley var. **gigas** Keijzer: p. 206, pl. 5, fig. 77.
1986 **Planulina renzi** Cushman and Stainforth; van Morkhoven et al: p. 133, pl. 43.
1987 **Planulina renzi** Cushman and Stainforth; Miller andKatz: p. 136, pl. 6, fig.1.
1993 **Planulina renzi** Cushman and Stainforth; Katz and Miller: pl. 3, fig. 6.
1994 **Planulina renzi** Cushman and Stainforth; Bolli et al: p. 369, fig. 57.3; fig. 88.12.
1998 **Planulina renzi** Cushman and Stainforth; Robertson: p. 214, pl. 85, fig. 2.

Original Designation:

Planulina renzi Cushman and Stainforth, 1945.

Type Specimen:

Holotype (USNM 44002) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Middle Miocene, Cipero Formation, **Globorotalia fohsi** Zone, light coloured marls. Originally given as upper Oligocene by Cushman and Stainforth (1945).

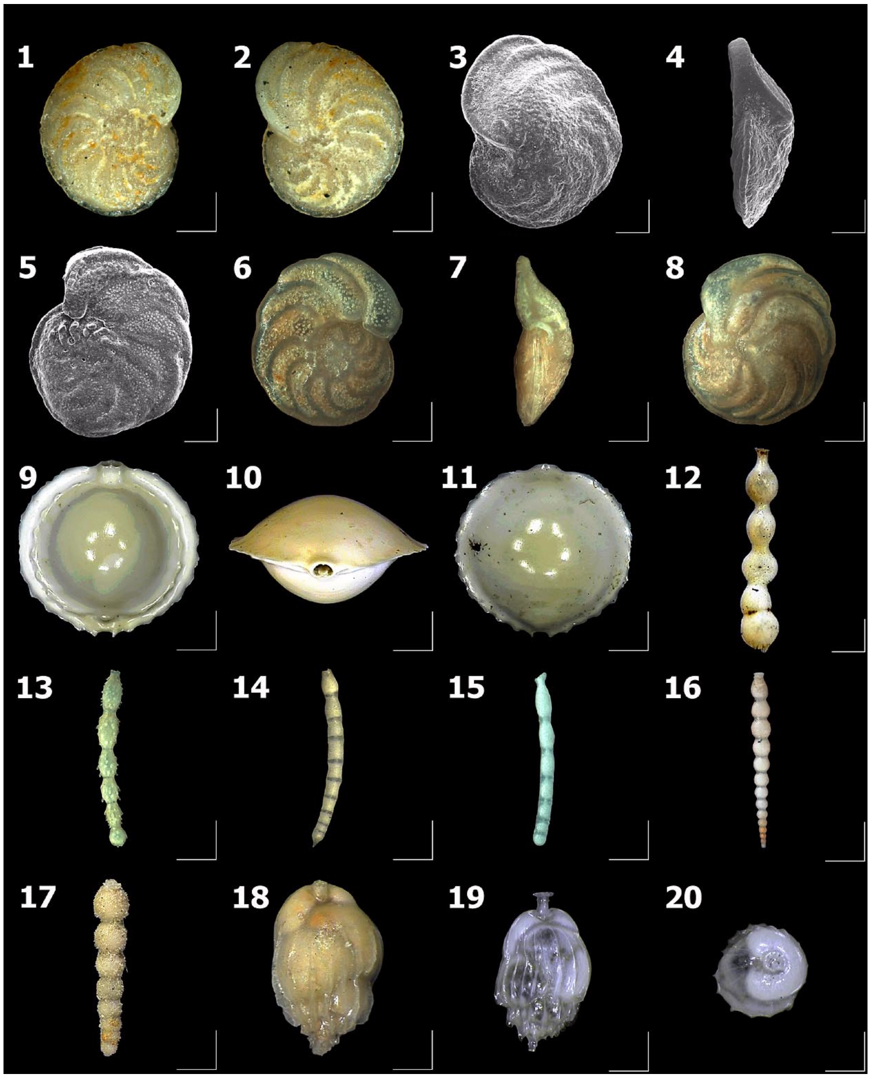

Figure 5. 1-5. Planulina renzi Cushman and Stainforth, 1945. **1.** Spiral view. Holotype. Middle Miocene. Cipero zone VII (upper), Sample Rz.425, Trinidad B.W.I. Smithonian Colllection. USNM 44002. Scale Bar = 112 microns**. 2.** Umbilical view. Holotype. Scale Bar = 109 microns. **3.** Umbilical view. Oligocene. ODP Leg 184, Site 1148A, 76X-3, 75-80cm. Scale Bar = 131 microns. **4.** Apertural view of specimen 3. Scale Bar = 127 microns. **5.** Spiral view. Oligocene. ODP Leg 184, Site 1148A, 76X-2, 70-72cm.Scale Bar = 190 microns. **6-8. Planulina wuellerstorfi** (Schwager), 1866. **6.** Spiral view. Recent. Lutze collection no. 200, Lutze 1978, West Africa M25, GIK. **7.** Apertural view of specimen 6. **8.** Umbilical view of specimen 6. Scale Bar = 161 microns. **9-11. Pyrgo serrata** (Bailey), 1861. **9.** Side view. Recent. Challenger Station 168, NE coast of New Zealand, South Pacific Ocean (1100 fm). Natural History Museum, London. NHM ZF1148. Scale Bar = 337 microns. **10.** Apertural view of specimen 9. Scale Bar = 302 microns. **11.** Side view of specimen 9. Scale Bar = 331 microns. **12. Stilostomella abyssorum** (Brady), 1881. **12.** Side view. Paratype (designated by Loeblich and Tappan, 1964 from unfigured syntypes). Recent. Challenger Station 296, South Pacific Ocean (1825 fm). Natural History Museum, London. NHM ZF 1926. Scale Bar = 226 microns. **13. Stilostomella alexanderi** (Cushman), 1936. **13.** Side view. Holotype. Late Cretaceous. Taylor Marl, road cut 14.4 mi S of Paris, 0.9 mi N of Lake City, Delta Co., Texas. Collected by C.T. Alexander, Smithsonian Collection. CC 23254. Scale Bar = 62 microns. **14-15. Stilostomella annulifera** (Cushman and Bermúdez), 1936. **14.** Side view. Paratype. Middle Eocene? Under the library of Havana University. Bermúdez Station 257, Cuba. Smithsonian Collection. CC 23100. Scale Bar = 237 microns. **15.** Side view. Oligocene. DSDP Leg 85, Site 573B, 26-CC. Scale Bar = 192 microns. **16. Stilostomella paleocenica** (Cushman and Todd), 1946. **16.** Side view. Holotype. Paleocene. Loc 1 NE 1/4 NW1/4 sec. 16, T.1N. R.12W., Little Rock, Arkansas. Smithsonian Collection. CC 46415. Scale Bar = 569 microns. **17. Stilostomella subspinosa** (Cushman), 1943. **17**. Side view. Holotype. Early Middle Miocene. From the Green clay, Cipero Section #14. San Fernando, Trinidad, British West Indies. Smithsonian Collection. CC 21484. Scale Bar = 443 microns. **18-20. Uvigerina basicordata** Cushman and Renz, 1941. **18.** Side view. Holotype. Early Miocene. From the Lower Agua Salada Formation, Tocuyo, 18.7 km S (202°45') of San Juan de los Cayos, District of Acosta, State Falcon, Venezuela. Smithsonian Collection. CC 35924. Scale Bar = 114 microns. **19**. Side view. Early Miocene. Eureka borehole E68-151A, 4588', Gulf of Mexico. Scale Bar = 137 microns. **20.** Apertural view of specimen 19. Scale Bar = 132 microns.

Type Locality:

Sample Rz.425, Trinidad Leaseholds Catalogue No. 61418, Trinidad Government Cadastral coordinates: N 228,300 links, E 353,600 links, situated at the base of the cliff in the southern (North-dipping) limb of the syncline, 120 ft northeastward from the boundary between the upper and middle zones, 880 ft in a straight line southwestward from Rz.108 (“Cipero Nose”), along the coast between the mouth of the Cipero River, at the point where the Trinidad Government railway turns inland, south of San Fernando, Trinidad, B.W.I.

Description:

Test forms a compressed, discoidal, very low trochospire; unequally biconvex in cross-section, with a strongly evolute, nearly flat or slightly convex spiral side, a partially evolute, more convex unbilical side, and an acute, keeled periphery. The 12 to 14 narrow, curved, slightly-inflated chambers in the final whorl increase gradually in size and are separated by broad, limbate, raised, strongly-curved sutures. Chamber walls are calcareous, coarsely perforate, and granular in appearance. The central area of the spiral side is ornamented by several bosses that coalesce with the raised sutures. The primary aperture is an equatorial slit with a narrow lip extending beneath the umbilical folium.

Remarks:

Planulina renzi Cushman and Stainforth differs from **Planulina wuellerstorfi** (Schwager) by its less flattened, more robust, generally larger test and its granular wall texture. Intergrades between **P. renzi** and **P. wuellerstorfi** are common in the Miocene, when the stratigraphic range of the two species overlaps. **Planulina renzi** may be the ancestral form of **P. wuellerstorfi.**

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Primarily bathyal. Occurs at abyssal depths from the Oligocene to early middle Miocene. Became restricted to bathyal depths in the later part of its range (N10-N17).

Stratigraphic Range:

Oligocene (Rupelian) – Miocene (Messinian). van Morkhoven et al**.** (1986) noted that a small form occurs in the upper Eocene (P16 and P17), which is probably related.

Planulina wuellerstorfi (Schwager), 1866

Figure 5.6-8.

1866 **Anomalina wuellerstorfi** Schwager: p. 258, pl. 7, figs 105, 107.
1949 **Planulina wuellerstorfi** (Schwager); Bermúdez: p. 293, pl. 23, figs 37-39.
1953 **Planulina wuellerstorfi** (Schwager); Phleger et al**:** p. 26, pl. 11, figs 1-2.
1976 **Cibicides wuellerstorfi** (Schwager); Pflum and Frerichs: p. 116, pl. 4, figs 2-4.
1986 **Planulina wuellerstorfi** (Schwager); van Morkhoven et al**:** p. 48, pl. 14.
1987 **Planulina wuellerstorfi** (Schwager); Miller and Katz: p. 136, pl. 6, figs 2.
1998 **Planulina wuellerstorfi** (Schwager); Robertson: p. 216, pl. 86, fig. 2.

Original Designation:

Anomalina wuellerstorfi Schwager, 1866.

Type Specimen:

Depository not given. Neotype (Mf 18) designated by Srinivasan and Sharma (1980) deposited in the Micropalaeontology Section, Department of Geology, Banaras Hindu University, Banaras, India.

Type Level:

Upper Tertiary. Lower and upper clays.

Type Locality:

Car Nicobar, Andaman Sea.

Description:

Test forms a compressed, discoidal, very low trochospire; planoconvex in cross-section, with a flattened, evolute spiral side, a slightly convex, partially evolute, umbilical side and a truncate, keeled periphery. The (approximately) 10 narrow, curved, slightly inflated chambers in the final whorl increase rapidly in size and are separated by thickened, strongly curved sutures, slightly-depressed in final chambers on the spiral side, and sinuoid or hooked in final chambers on the umbilical side. Chamber walls are calcareous and coarsely perforate on the spiral side, finely perforate on the umbilical side. The primary aperture is an equatorial slit with a narrow lip extending beneath the umbilical folium.

Remarks:

See Remarks for **Planulina renzi** Cushman and Stainforth.

Planulina wuellerstorfi has been previously referred to several other genera including **Anomalina, Cibicides, Cibicidoides** and **Fontbotia**. We follow van Morkhoven et al**.** (1986) in placing the species into the genus **Planulina**. We feel that subsequent reassignments to **Cibicidoides** (Whittaker 1988) **Fontbotia** (González-Donoso and Linares 1970), or **Cibicides** (Sen Gupta 1989) did not fully resolve the generic assignation of this species.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Planulina wuellerstorfi is a low-intermediate (2.5-9 g/m^2y) carbon flux indicator (Altenbach et al**.** 1999) that is generally used as a bathymetric indicator for water depths over 1000 m. Although **Planulina wuellerstorfi**

occurs mainly in lower bathyal and abyssal depths, it was reported in upper Pleistocene sediments from ODP Sites 1129, 1131 and 1132, situated on the shelf break and upper slope of the Great Australian Bight (Feary, Hine, and Malone et al. 2000). Bandy (1967) observed that specimens of **P. wuellerstorfi** from depths over 1000 m tend to have hooked or sigmoid sutures, whereas specimens from shallower environments have smoother, curved sutures.

Planulina wuellerstorfi generally has an epifaunal mode of life. It is one of the most commonly used benthic foraminifers for stable isotope studies, as it provide a reliable record of bottom water $\delta^{18}O$ and $\delta^{13}C$ values. However, **P. wuellerstorfi** may exhibit significant negative shifts in $\delta^{13}C$ values in areas of strong seasonal productivity, where fluffy layers develop at the seafloor. For an in-depth evaluation of stable carbon isotopes in benthic foraminifers see Mackensen and Bickert (1999).

Stratigraphic Range:

Miocene (Langhian) – Recent.

Genus Pyrgo

Pyrgo serrata (Bailey), 1861
Figure 5.9-11.

1861 **Biloculina serrata** Bailey: p. 350, pl. 8, fig. E.
1884 **Biloculina depressa** var. **serrata** Brady: p. 146, pl. 3, fig. 3.
1994 **Pyrgo serrata** (Bailey); Jones: p. 19, pl. 3, fig. 3.

Original Designation:

Biloculina serrata Bailey, 1861, p. 350, pl. 8, fig. E.

Type Specimen:

Depository not given.

Type Level:

Recent.

Type Locality:

United States Coast Survey, Position 14, 150 fm, Gulf Stream.

Description:

Test forms a slightly compressed, biloculine series in the adult form; subcircular in outline and elliptical in cross-section, with an acute, extended, keeled periphery. Keel is distinctly serrate. Chamber walls are calcareous, porcelaneous, smooth, and imperforate. The primary aperture is oval and terminal with a short bifid tooth.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

580-1750 fm (Jones 1994).

Stratigraphic Range:

Miocene (Aquitanian) – Recent.

Genus Stilostomella

Stilostomella abyssorum (Brady), 1881
Figure 5.12.

1881 **Nodosaria (?) abyssorum** Brady: p. 63, pl. 63, figs 8-9.
1987 **Siphonodosaria abyssorum** (Brady); Loeblich and Tappan: p. 540, pl. 585, figs 5-7.
1989 **Siphonodosaria abyssorum** (Brady); Hermelin: p. 61, pl. 11, figs 2-5.
1994 **Stilostomella abyssorum** (Brady); Jones: p. 74, pl. 63, figs 8-9; supplementary pl. 2, figs 8-9.
1998 **Siphonodosaria abyssorum** (Brady); Robertson: p. 178, pl. 66, fig. 7.

Original Designation:

Nodosaria (?) abyssorum Brady, 1881.

Type Specimen:

Figured specimens (ZF1926, ZF3649) deposited in the micropalaeontological collections of the Natural History Museum, London, UK. Lectotype (from slide ZF3649) designated by Loeblich and Tappan (1964).

Type Level:

Recent.

Type Locality:

Not given. Found only at "Challenger" Sta. 296, Latitude 38°06'S, Longitude 88°02'W in the South Pacific Ocean, southwest of Juan Fernandez Island; 1825 fm.

Description:

Test forms an elongate, large, robust, uniserial series; rectilinear or slightly arcuate in shape and circular in cross-section. The (approximately) five subspherical, inflated chambers are separated by constricted, slightly-limbate sutures. Chambers may vary in shape and size (first chamber is often the largest). Chamber walls are calcareous, finely perforate, and smooth, with a ring of short, stout spines on the initial chamber. The primary aperture is an arcuate or V-shaped terminal opening on a short, broad neck with a phialine lip and small tooth-like projection.

Remarks:

Hermelin (1989) considered the species named **Ellipsonodosaria nuttalli** by Cushman and Jarvis (1934) to be a junior synonym of **Stilostomella abyssorum**. Specimens of **Ellipsonodosaria nuttalli** Cushman and Jarvis var. **aculeata** Cushman and Renz, 1948, which are virtually smooth, closely resemble **Stilostomella abyssorum** (Brady).

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Bathyal – abyssal.

Stratigraphic Range:

Miocene (Aquitanian?) – Recent.

Stilostomella alexanderi (Cushman), 1936
Figure 5.13.

1936 **Elliponodosaria alexanderi** Cushman: p. 52, pl. 9, figs 6-9.
1994 **Stilostomella alexanderi** (Cushman); Bolli et al**:** p. 145, fig. 38.27-28.

Original Designation:

Elliponodosaria alexanderi Cushman, 1936.

Type Specimen:

Holotype (CC 23254) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Upper Cretaceous. Taylor Marl.

Type Locality:

Road cut 14.4 miles south of Paris, 0.9 miles north of Lake City, Delta County, Texas, USA.

Description:

Test forms an elongate, uniserial series; rectilinear or slightly arcuate in overall shape and circular in cross-section. The subspherical, inflated chambers, that increase gradually in length and become ultimately twice as long as broad, are separated by constricted sutures. Chamber walls are calcareous, finely perforate, and ornamented with short, backward-pointing spines. Early stages of microspheric forms may only have a single ring of spines in the lower part of the chambers. Adult forms have numerous spines rather irregularly scattered over the surface. The primary aperture is arcuate or V-shaped terminal opening on a short, broad neck with a phialine lip and small tooth-like projection.

Biogeography:

Worldwide.

Bathymetry and Paleoecology:

Bathyal.

Stratigraphic Range:

Cretaceous (Santonian-Maastrichtian); rare (Bolli et al**.** 1994).

Stilostomella annulifera (Cushman and Bermúdez), 1936
Figure 5.14-15.

1936 **Ellipsonodosaria annulifera** Cushman and Bermúdez: p. 28, pl. 5, figs 8-9.
1990 **Stilostomella annulifera** (Cushman and Bermúdez); Thomas: p. 590, pl. 1, fig. 4.
1994 **Siphonodosaria annulifera** (Cushman and Bermúdez); Bolli et al**:** p. 358, figs 87.40, 40a.
1998 **Siphonodosaria annulifera** (Cushman and Bermúdez); Robertson: p. 178, pl. 66, figs 1-2.

Original Designation:

Ellipsonodosaria annulifera Cushman and Bermúdez, 1936.

Type Specimen:

Holotype (CC 23099) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Probably middle Eocene.

Type Locality:

Bermúdez Station 257, under library of Havana University, Havana, Cuba.

Description:

Test forms an elongate, large, slender, uniserial series; rectilinear or slightly arcuate in overall shape and circular in cross-section. The subspherical and moderately inflated chambers increase gradually in length and are separated by limbate sutures forming broad glassy bands between the chambers. Final chambers may be more elongated and separated by more distinct constrictions. Chamber walls are calcareous, finely perforate, and smooth with a single basal spine on the proloculus. The primary aperture is arcuate or V-shaped terminal opening on a short, broad neck with a phialine lip and small tooth-like projection.

Biogeography:

Worldwide. Common in Pacific sites (Thomas, personal commun., 1998). Weddell Sea, Antarctica (Thomas 1990).

Bathymetry and Paleoecology:

Lower bathyal (Thomas 1990).

Stratigraphic Range:

Eocene (Ypresian) to Miocene (Langhian); common from middle Eocene onwards (Thomas, personal commun., 1998).

Stilostomella paleocenica (Cushman and Todd), 1946
Figure 5.16.

1946 **Ellipsonodosaria paleocenica** Cushman and Todd: p. 61, pl. 10, fig. 26.
1994 **Stilostomella paleocenica** (Cushman and Todd); Bolli et al**:** p. 145, figs 38.29-30.

Original Designation:

Ellipsonodosaria paleocenica Cushman and Todd, 1946.

Type Specimen:

Holotype (CC 46415) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Paleocene.

Type Locality:

About 1000 ft south of Roosevelt Rd. viaduct, 200 ft east of railroad tracks, in small gully heading east, just upstream from small abandoned bridge, NE1/4, NW1/4, sec. 16, T. 1 N, R. 12 W., Little Rock, Pulaski County, Arkansas, USA.

Description:

Test forms an elongate, large, slender, uniserial series; rectilinear or slightly arcuate in overall shape, circular in cross-section, and slightly tapered in outline from the very narrow proloculus to the broadest final chamber. The inflated, subspherical, and numerous (up to 14) chambers increase very gradually in size and are separated by strongly depressed sutures forming narrow inter-chamber bands. Chamber walls are calcareous, finely perforate, and smooth or slightly hispid with a single basal spine on the proloculus. The last chamber is more elongated than previous chambers and is also more ornamented. The primary aperture is arcuate or V-shaped terminal opening on a short, broad neck with a phialine lip and small, tooth-like projection.

Remarks:

In Trinidad, specimens are somewhat smaller than the holotype (Bolli et al**.** 1994). Differs from **E. plummerae** Cushman in the shorter, more inflated chambers and smoother surface, (Cushman and Todd1946).

Biogeography:

Worldwide. Fairly common in the Paleocene of Arkansas, occurs also in the Paleocene of Alabama, (Cushman and Todd 1946), Trinidad (Bolli et al**.** 1994).

Bathymetry and Paleoecology:

Bathyal?

Stratigraphic Range:

Cretaceous (Santonian) – Eocene (Ypresian); fairly common (Bolli et al**.** 1994).

Stilostomella subspinosa (Cushman), 1943
Figure 5.17.

1943 **Ellipsonodosaria subspinosa** Cushman: p. 92, pl. 16, figs 6-7b.
1934 **Ellipsonodosaria** sp. Cushman and Jarvis: pl. 10, figs 4-5a.
1983 **Stilostomella subspinosa** (Cushman); Tjalsma and Lohmann: p. 36, pl. 14, figs 16-17.
1987 **Stilostomella subspinosa** (Cushman); Miller and Katz: p. 138, pl. 1, fig. 12.
1990 **Stilostomella subspinosa** (Cushman): Thomas: p. 590.
1994 **Stilostomella subspinosa** (Cushman); Bolli et al**:** p. 360, figs 63.30, 30a.
1998 **Siphonodosaria subspinosa** (Cushman); Robertson: p. 180, pl. 67, fig. 3.

Original Designation:

Ellipsonodosaria subspinosa Cushman, 1943.

Type Specimen:

Holotype (CC 21484) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Lower Middle Miocene; green clay.

Type Locality:

Cipero section, San Fernando, Trinidad, B.W.I.

Description:

Test forms an elongate, robust uniserial series; rectilinear or slightly arcuate in overall shape, subcylindrical and slightly tapered in outline, and circular in cross-section with the greatest breadth near the apertural end. The subspherical, strongly-inflated chambers increase gradually in size and are separated by strongly-depressed sutures (not forming narrow bands between chambers as in **Stilostomella paleocenica**). Chamber walls are calcareous, finely perforate, and ornamented by short, stout spines, either entirely covering the chambers or, in early stages, confined to the lower portion of the chamber wall. The primary aperture is arcuate or V-shaped terminal opening on a short, broad neck with a phialine lip and small, tooth-like projection.

Remarks:

Stilostomella subspinosa (Cushman) displays considerable variability in size and ornamentation. Spines may be more delicate than on the original type material and may tend to coalesce into fine costae in the lower part of the test (Tjalsma and Lohmann 1983).

Biogeography:

Worldwide.

Common in Pacific sites (Thomas, personal commun., 1998). Weddell Sea, Antarctic, (Thomas 1990). North Atlantic (Miller and Katz 1987)

Bathymetry and Paleoecology:

Lower bathyal (Thomas 1990). Abyssal, >3.5 km (Miller and Katz 1987).

Stratigraphic Range:

Eocene (Lutetian) – Miocene (Messinian?).

Common from middle Eocene onwards (Thomas 1990). Abundant in the Oligocene and Miocene (Miller and Katz 1987).

Genus Uvigerina

Uvigerina basicordata Cushman and Renz, 1941
Figure 5.18-20.

1941 **Uvigerina gallowayi** Cushman, var. **basicordata** Cushman and Renz: p. 21, pl. 3, fig. 18.
1986 **Uvigerina basicordata** Cushman and Renz; van Morkhoven et al**:** p. 193, pl. 65.
1993 **Uvigerina basicordata** Cushman and Renz; Katz and Miller: pl. 4, fig. 2.

Original Designation:

Uvigerina gallowayi Cushman, var. **basicordata** Cushman and Renz, 1941.

Type Specimen:

Holotype (CC 35924) deposited in the collections of the United States National Museum, Washington, D.C.

Type Level:

Lower Miocene, Lower Agua Salada Formation, Zone 2 (Zone of Siphogenerina multicostata and Gaudryina thalmanni). Given as upper Oligocene by Cushman and Renz (1941).

Type Locality:

Sample Su. A. 637, from Tocuyo, 18.7 km south (202°45') of San Juan de Los Cayos, District of Acosta, State of Falcón, Venezuela.

Description:

Test forms an almost rectangular triserial series; about twice as long as broad, but with greater breadth in the mid portion of the test, with a prominent basal spine, an almost rectangular outline, and a circular cross-section. The inflated chambers increase rapidly in size and are separated by depressed sutures. Chamber walls are calcareous, finely perforate, and ornamented with four to five continuous or discontinuous, longitudinal costae extending as spines at the base of the chambers. This ornamentation is reduced on the final chamber, which is often smooth. The primary aperture is a terminal opening at the end of an elongate, thin, cylindrical neck, bordered by a phialine lip and with an internal toothplate.

Remarks:

Uvigerina basicordata Cushman and Renz differs from **Uvigerina gallowayi** Cushman by its shorter, broader shape and the presence of discontinuous costae (van Morkhoven et al**.** 1986).

Biogeography:

Worldwide. Recorded from Trinidad, Puerto Rico, California, Venezuela, Ecuador, eastern Pacific, North Atlantic, and Gulf of Mexico (van Morkhoven et al**.** 1986).

Bathymetry and Paleoecology:

Bathyal.

Stratigraphic Range:

Miocene (Aquitanian) – Miocene (Langhian).

ACKNOWLEDGEMENTS

This work would not have been possible without the assistance of many people who generously provided taxonomic expertise, computing advice, access to collections, and technical support. We would like to thank most sincerely in particular**:** Haydon Bailey, Steve Culver, Adam Gasinski, Brian Huber, Bob Jones, Clive Jones, Michael Kaminski, Miriam Katz, Wolfgang Kuhnt, Norman MacLeod, Ewa Malata, Michel Moullade, Stefan Revets, Jane Swallow, Ellen Thomas, and John Whittaker. The project was funded by the Natural Environment Research Council (NERC).

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APPENDIX
Morphological descriptors used for taxonomic descriptions

Test Shape	Outline Shape (Plan View)	Cross-section (Apertural View)	Periphery Shape	Periphery Modifications	Chamber Arrangement	Chambe Shaper	Chamber Enlargement Series	Chamber Inflation
Lenticular	Subparallel	Suboval	Acute	Double keel	Trochospiral (Low/High)	Subspherical	Very gradual	High
Globular	Lobulate	Oval	Subacute	Imperforate band	Planispiral	Ovate	Gradual	Moderate
Flaring	Conical	Elliptical	Subrounded	Single keel	Biserial	Elongate	Rapid	Slight
Spherical	Tapered	Circular	Rounded	Spines	Triserial	Broad		
Elongate	Quadrate	Biconvex	Imperforate		Quadriserial	Crescentic		
Subrhombohedral	Globular	Subcircular	Truncate		Streptospiral	Globular		
Conical	Ovate/Ovoid	Plano-convex	Keeled		Unilocular	Narrow		
Cylindrical	Subcircular	Subquadrate			Triloculine	Chevron-shaped		
Rhomboid	Lanceolate	Concavo-convex				Trapeziform		
Discoidal		Triangular				Low		
Rectilinear						Subquadrate		
Fusiform						Subtriangular		
Tubular						Cylindrical		
						Broad and Low		
						Pyriform		
						Subtriangular-subquadrate		
						Tubular		
						Spherical		
						Triangular		
						Subcylindrical/fusiform		
						Cuneiform/reniform		
						Arched		
						Subglobular		
						Globular-cylindrical		
						Globular-irregular		
						Cylindrical - subspherical		
						Umbrella-shaped		
						Quadrate		

Appendix continued.

Suture Characteristics	Chamber Wall	Chamber Wall Ornament	Chamber Wall Composition	Aperture Position	Aperture Shape	Apertural Modifications	Supplementary Apertures
Flush	Perforate		Calcareous	Interiomarginal umbilical-extraumbilical	Arch	Toothplate	Sutural
Distinct	Finely perforate	Longitudinal Costae	Agglutinated	Interiomarginal umbilical	Slit	Imperforate lip	
Slightly depressed	Coarsely Perforate	Reticulation	Non calcareous	Equatorial	Round	Crista	
Moderately depressed	Imperforate	Longitudinal striae	Canaliculate	Terminal	High narrow arch	Sulcus	
Strongly depressed	Punctate	Smooth	Solid	Areal	Cribrate	Creases	
Indistinct		Crenulations	Alveolar	Subequatorial	Loop	Flap	
Limbate		Lobes	Porcelaneous	Interiomarginal	Radiate	Imbricate flap	
		Ponticuli		Lateromarginal	Oval	Folium	
		Pitted			Denticulate rim	Bifid tooth	
		Papillate			Radial	Phialine lip	
		Hispid			Elliptical	Neck	
		Pores			Subtriangular	Entosolenian tube	