STUDIES IN

FORAMINIFERA

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Preface .............................................................. v

Part 1: Planktonic Foraminifera ................................. 1
1. Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae ........................ (Text-figs. 1-9, pls. 1-11) 3
   By Hans M. Bolli, Alfred R. Loeblich, Jr., and Helen Tappan
2. The genera Praeglohotruncana, Rotalipora, Globotruncana, and Abathomphalus in the Upper Cretaceous of Trinidad, B. W. I. ........ (Text-fig. 10, pls. 12-14) 51
   By Hans M. Bolli
3. The genera Globigerina and Globorotalia in the Paleocene-lower Eocene Lizard Springs formation of Trinidad, B. W. I. .... (Text-figs. 11-13, pls. 15-20) 61
   By Hans M. Bolli
4. Chiloguembelina Loeblich and Tappan and related Foraminifera from the lower Tertiary of Trinidad, B. W. I. ............ (Text-figs. 14-16, pl. 21) 83
   By J. P. Beckmann
5. Planktonic Foraminifera from the Oligocene-Miocene Cipero and Lengua formations of Trinidad, B. W. I. .................. (Text-figs. 17-21, pls. 22-29) 97
   By Hans M. Bolli
6. Some planktonic Foraminifera of the type Danian and their stratigraphic importance. ........................ (Text-figs. 22-24, pl. 30) 125
   By J. C. Troelsen

Part 2: Benthonic Foraminifera ................................. 199
7. A revision of the foraminiferal family Heterohelicidae ...... (Pls. 31-34) 133
   By Eugenia Montanaro Gallitelli
8. Planktonic Foraminifera from the Eocene Navet and San Fernando formations of Trinidad, B. W. I. .............. (Text-figs. 25-26, pls. 35-39) 155
   By Hans M. Bolli
9. Planktonic Foraminifera of Paleocene and early Eocene age from the Gulf and Atlantic Coastal Plains .................. (Text-figs. 27-28, pls. 40-64) 173
   By Alfred R. Loeblich, Jr., and Helen Tappan

Part 2: Benthonic Foraminifera ................................. 199
10. New Cretaceous index Foraminifera from northern Alaska. (Text-fig. 29, pls. 65-71) 201
    By Helen Tappan
11. Eleven new genera of Foraminifera ............................ (Text-fig. 30, pls. 72-73) 223
    By Alfred R. Loeblich, Jr., and Helen Tappan
12. The foraminiferal genus Cruciloculina d'Orbighy, 1839 ........................ (Pl. 74) 233
    By Alfred R. Loeblich, Jr., and Helen Tappan

Plates ............................................................. 237
Index ............................................................. 313
Preface

MICROPALEONTOLOGISTS TODAY, as perhaps in every generation, are divided into two camps; those who complain bitterly about the increased taxonomic splitting of genera and species and those who are enthusiastically doing the splitting. The majority of micropaleontologists are relatively conservative in proposing new generic or specific names, probably more so than almost any other group of taxonomists.

This conservatism may, however, result in setting for the genera and species of Foraminifera boundaries that are too wide to be useful for correlation, or for ecological or distributional studies. A single species may be recorded from the Arctic to the tropics, from the beach or lagoon to a depth of over 2,000 fathoms, or from Jurassic to Recent. An examination of such specimens in any large collection will readily reveal many different geologically and ecologically restricted species and genera masquerading under a single name. For example, specimens recorded in the literature as *Spiroplectammina biforis* (Parker and Jones), or as "*Globigerina* cretacea*" d'Orbigny can be seen to be completely unlike the original types of those species, as can many species of Discorbis, Rotalia, or Textularia; they may even belong to quite different genera and even to different families.

With modern methods and the use of better optical equipment, better lighting, X-ray, and new techniques of sectioning or dissecting specimens to understand interior structures, it seems quite out of order to maintain that micropaleontology should remain stable and that only the genera known to Parker and Jones and d'Orbigny (or even those in the classifications of Cushman or Galloway) should be recognized. On the other hand, there are occasionally unavoidable conflicts, where workers unknowingly propose new names for forms already described elsewhere. Perhaps the original description was incomplete or inaccurate, and only later studies prove their co-identity; then the Rules of Zoological Nomenclature apply, and one of the names must be suppressed. Because of the present incomplete status of our knowledge, changes in the taxonomy must be expected. If progress is to be made in the classification and study of the Foraminifera, some genera and species previously recognized as valid must fall by the wayside as synonyms, and many new names must be proposed for the host of species masquerading under certain "wastebasket" names. Only in this way may we obtain a logical taxonomy, however difficult the adjustment might temporarily seem to the individual student.

Let no one assume, however, that the writer favor the immediate and indiscriminate erection of a multitude of new names. As mentioned above, many micropaleontologists believe that too many taxonomic units already exist. Certainly many examples could be cited where "splitting" has been carried to almost ridiculous extremes, with nearly every specimen a distinct species.

Part of the difficulty lies in the lack of sufficient experimental data on living populations to allow a determination of the truly important taxonomic characters. As a result, one specialist may place the greatest taxonomic emphasis on wall structure, another will consider the apertural position of prime importance, while others will use chamber arrangement, presence of particular internal characters, or even surface ornamentation as generic or family characters. Yet any of these proposed bases of classification might be considered useless by another equally sincere worker.

Each individual is entitled to his own opinion, provided it is based on facts and logical assumptions from these facts; but it is obvious that all workers, given the same set of facts, will not always arrive at identical conclusions; therefore, there is no insistence that all the papers here included use the same terminology or bases of taxonomic classification. We do feel it necessary, however, to ask that reasons be given for placing a genus or species in synonymy, or for subdividing a previously known genus or species, and to ask that means be presented for distinguishing the new form from other similar forms. In addition, it seems advisable that a general taxonomic philosophy be accepted—that certain characters be considered of higher taxonomic value than others and be used similarly throughout the classification. Where new taxonomic units are proposed in the included papers, this is done.

One other point must be mentioned because perhaps unfortunately, most micropaleontologists are primarily stratigraphers and only secondarily taxonomists or zoologists. Specimens placed in each species must be like the original type specimens, and if this necessitates a new name for a form widely but erroneously known by an old and classic name, sentiment cannot intervene. Likewise, if a "genus" is found to contain widely dissimilar species, the group like the type species must retain that name. This apparently obvious rule is repeatedly disregarded by some foraminiferal workers who in stating that a certain species does not belong to a genus, completely ignore the fact that it is the type species, and therefore the taxonomic basis, of the genus itself. In the generic studies which follow, particular emphasis is therefore placed on the type...
species although some of these may be less familiar to the average worker than other species previously there referred.

The present volume of studies in Foraminifera is divided into two sections: the first concerned with planktonic species, and the second with benthonic species. During the past decade the value of planktonic Foraminifera for purposes of interregional correlations and for detailed stratigraphic zonation has won increasing recognition. Their value is especially pronounced in zonation problems in beds nearly or completely devoid of macrofossils. Here, the planktonic Foraminifera have proved indispensable to a clear understanding of the stratigraphy. In the Tertiary strata, members of the planktonic families Orbulinidae, Hantkeninidae, Globorotaliidae, and certain of the Heterohelicidae are as useful for zonations as the ammonites were for the Mesozoic. In reality they are the “ammonites” of the Tertiary, having short stratigraphic ranges and wide geographic distribution.

In the Caribbean and in many areas of South America workable zonations in use by oil companies are almost entirely based on planktonic Foraminifera. American writers have tended to neglect the planktonic Foraminifera in stratigraphic and commercial micropaleontology, in part because of the chaotic condition of the literature and in part because benthonic species also work well in their areas of operation. However, as offshore drilling progresses and as thick sections of offshore beds are encountered, the planktonic Foraminifera will prove to be an added and welcome tool for correlation.

Many of my colleagues have decried the fact that planktonics are difficult to use because there is too much variation in the species themselves for clear delineation. Although this difficulty has been aggravated by the low caliber of illustrations in the literature, from which it is often impossible to identify the species, a detailed study of the planktonics based on actual specimens and good illustrations will show them to be no more variable or difficult to work with than the human species.

Part I has as its first objective the development of a logical classification of the families and genera of the planktonic Foraminifera. Its second objective is to describe various planktonic faunas, presenting adequate illustrations and clear descriptions with the hope of progressing toward a better understanding of interregional correlations and perhaps eventually to develop a uniform world-wide zonation. Its third objective is to present the results of studies that may be of use to the economic paleontologist in local well-to-well correlations or in exploration in unknown areas. The first two aims lead inevitably to the third, for science is valuable to man only insofar as it is his servant, and our artificial taxonomy, which is only man-made and not a product of nature itself, must be made useful if it is to be worthwhile.

Part II of the volume is concerned with the revision of some existing genera, and the description of certain new genera and species of benthonic Foraminifera; some of the papers being concerned with a taxonomic group, others with an ecologic or a stratigraphic assemblage. They are thus more varied in character than the papers included in the planktonic section, but it is hoped that all will contribute to a better understanding of one or more of the many aspects of our knowledge of the Foraminifera.

ALFRED R. LOEBLICH, JR.
Part I:

PLANKTONIC FORAMINIFERA
Planktonic Foraminiferal Families Hantkeninidae, Orbulinidae, Globorotaliidae and Globotruncanidae

By Hans M. Bolli, Alfred R. Loeblich, Jr., and Helen Tappan

Introduction

During the past 10 to 20 years there has been an enormous increase in the recognition of the value of the planktonic Foraminifera as stratigraphic index fossils. They form an excellent basis for precise regional and world-wide correlation. Their dispersal is world-wide, affected only by such environmental factors as temperature and salinity. After death their shells sink to the sea floor, regardless of whether the bottom facies is abyssal, neritic, lagoonal, or reefal. Furthermore, the advent and extinction of species and even genera, from the Cretaceous to the Recent, is so spaced that an excellent and exact zonation can be based on their stratigraphic distribution.

At the present time the value of the planktonic Foraminifera for stratigraphic correlation is masked by the incompleteness of our knowledge and especially by the divergent views of different workers on questions of taxonomic grouping. The basis for systematic separation of planktonic Foraminifera has varied greatly from author to author. Features used by one specialist as being of specific value only are used by others for generic and even family separations. The wide limits allowed for a genus in some instances have almost completely masked the true value of the planktonic Foraminifera for stratigraphic correlation. A critical examination of many species of widely varying geographic and stratigraphic occurrence makes it obvious that there are distinctive groups of species, within a “genus” as previously known, that are quite restricted in geologic range. Other species, attributed to different “genera” may have identical ranges and only minor distinctions for separation, and may even intergrade. For these reasons the classification of the planktonic Foraminifera definitely requires revision on the generic level.

Descriptions and illustrations in many publications, especially early ones, are often too generalized, inaccurate or incomplete for a precise species delineation. Lack of care in the collection of samples and failure to recognize reworking has in some instances given exaggerated geologic ranges. In many instances a disregard for the Rules of Nomenclature has caused confusion.

In order to revise the systematics of the planktonic Foraminifera and to determine their exact stratigraphic ranges and the factors important in their geographic distribution, a cooperative study of this group has been undertaken by a number of paleontologists in both hemispheres. The present article is the first of a series resulting from this project, and was undertaken largely as a basis for future publications. All known genera of the families Hantkeninidae, Orbulinidae, Globorotaliidae and Globotruncanidae have been re-described on the basis of their type species, and the best specimens obtainable of each of the type species have been figured here. In many instances, both the holotype of the type species and additional topotypes or hypotypes have been figured, and for certain genera additional species have also been included. Although we have placed many previously described generic names in synonymy, we have nevertheless figured the type species designated for those nominal genera, so that the record will be complete.

A general discussion of the planktonic Foraminifera is given here with remarks on their ecology, morphology and terminology, evolutionary trends, and geologic distribution. This is followed by the systematic portion of the paper.

In the present revision, a total of 56 generic names are considered, of which 32 genera are recognized as valid, including 5 proposed as new. Many of the previously described genera are emended somewhat, and recognized as valid on a basis distinct from that originally proposed. Some are used in a more restricted sense, thus becoming of greater stratigraphic value. Others are considered somewhat more inclusive than originally proposed, when neither valid structural distinctions nor differing geologic occurrence would uphold a closer separation.

Of the remaining generic names, 23 are here considered synonyms and suppressed. One name is a homonym and had been earlier replaced by a valid name, by the original author. Incidental to the generic studies, 7 new species are also described.

These 32 valid genera are placed in 4 families, with 7 subfamilies, of which 4 subfamilies are new. The

1 Arrangement of names alphabetical, no seniority implied. Hans M. Bolli, Trinidad Oil Company, Ltd. (formerly Trinidad Leaseholds, Ltd.), Pointe-a-Pierre, Trinidad, W. I.; Alfred R. Loeblich, Jr. (formerly associate curator of invertebrate paleontology, U. S. National Museum), California Research Corp., La Habra, Calif.; and Helen Tappan, Research Associate, Smithsonian Institution.
family placement of many of the genera is also modified. Family and subfamily definitions are given, with authors and dates cited, and with strict adherence to the zoological Rules of Nomenclature in these higher taxonomic categories as well as in generic and specific names.

Acknowledgments

This paper is the result of an exceptional amount of cooperation by paleontologists and organizations throughout the world. We have received aid and encouragement in its preparation from many sources, by the receipt of specimens and literature, the loan of types, aid in collecting material, and financial assistance for the preparation of illustrations.

In a study of this sort, it is imperative that the type species be obtained for each genus. Many primary types of these planktonic genera are present in the U. S. National Museum collections, due to the generosity of their authors, who have deposited primary types here. These include the late Dr. J. A. Cushman, the late W. J. Parr of Australia; and Drs. P. J. Bermudez, Josepin, Venezuela; W. H. Blow, London, England; P. Bronnimann, Havana, Cuba; A. F. M. Mohsenul, England; the State Museum of Czechoslovakia; H. H. Renz, Caracas, Venezuela; and R. M. Stainforth, Billings, Montana.

In addition, particular specimens and samples have been supplied by many others to whom we are exceedingly grateful. These include Drs. R. Wright Barker, Shell Development Company, Houston, Texas; F. Brozen, Geological Survey of Sweden, Stockholm; Noel Brown, Cuban Gulf Oil Company, Havana, Cuba; A. C. Collins, Geelong, Victoria, Australia; N. de B. Hornibrook, New Zealand Geological Survey, Wellington; V. Pokorny, Charles University, Prague, Czechoslovakia; M. Reichel, Basle, Switzerland; J. Sigal, Institut de Petrole, Reul-Malmaison, France; Hans Thalmann, Stanford University, California; David Ericson, Lamont Geological Observatory, Palisades, New York; Frances Parker, Scripps Institution of Oceanography, La Jolla, California; and W. Storrs Cole, Cornell University, Ithaca, New York.

Types were also loaned to us for study by other institutions and we should like to acknowledge our gratitude to Dr. Katherine Palmer and the Paleontological Research Institute, Ithaca, New York, for the loan of types from the Helen J. Plummer collection and Dr. John Imbrie and Columbia University for the loan of types from the Maynard White collection.

In order to study the original types of Brady, d’Orbigny, Parker and Jones, and others, and to obtain European topotype material, a visit to Europe was imperative. We are therefore grateful to the Smithsonian Institution for making available the Walcott funds to enable Alfred R. Loeblich, Jr., to spend 10 months studying and collecting in Europe, and to the Guggenheim Foundation who similarly financed 10 months of study in museums, re-illustration of types, and field collecting in Europe by Helen Tappan Loeblich. During their stay in Europe, great assistance was given to the Loeblichs by Dr. H. W. Parker, of the British Museum (Natural History), London, who allowed full access to the Brady and other collections there, and through whom they were able to obtain topotype material from the Challenger collections for study and illustration. In Paris, through the courtesy of Dr. Jean Roger, the original types of d’Orbigny deposited in the Museum National d’Histoire Naturelle were examined, studied, and compared with available topotype material.

Aid in the field, in collecting material used in the present study from classic European localities was given by Drs. H. Hiltermann and F. Schmid of the Amt für Bodenforschung, Hannover, Germany, and in England by Dr. Tom Barnard, Mr. Raymond Casey, and Mr. A. G. Davis. Acknowledgement is also made of the cooperation of Trinidad Leaseholds, Ltd., during the time spent by Alfred R. Loeblich, Jr., in collecting in Trinidad, B. W. I.

Illustrations are shaded camera lucida drawings prepared by Lawrence and Patricia Isham, scientific illustrators, with the assistance of a grant-in-aid from the Geological Society of America to re-illustrate type species of Foraminifera for use in the Treatise on Invertebrate Paleontology. The camera lucida illustrations of Brady’s types of Hastigerina murrayi Thomson were made at the British Museum by Helen Tappan Loeblich.

The authors are indebted to F. M. Bayer of the U. S. National Museum and J. B. Saunders, Trinidad Leaseholds, Ltd., for critical reading of sections of the manuscript.

The further progress of these planktonic studies at the specific level is assured by the receipt of grants-in-aid of research from certain petroleum companies for the hire of laboratory technicians and artists. We should, therefore, like to acknowledge this aid from the California Research Corporation, the Carter Oil Company, the Gulf Oil Corporation, the Humble Oil and Refining Company, and the Trinidad Oil Company, Ltd.

Ecology of the Planktonic Foraminifera

Pelagic animals are those which inhabit the free water of the ocean. They must be independent of any support except that of the water, and maintain themselves in the open water without sinking. A wide range of life is represented in the pelagic zone, including not only protozoans and microscopic plant life, but also ctenophores, cephalopods, copepod crustaceans, and fish. Ecologically speaking, the pelagic life may be subdivided into the nekton, which includes the animals that can swim freely and are independent of oceanic currents, and the plankton, which are only passively floating or suspended forms, and whose independent movement is insignificant in comparison with the movement of the ocean currents. Most of the plankton is
Small or microscopic and all pelagic microscopic animals are plankton (Hesse, Allee, and Schmidt, 1937, p. 233).

Special Characteristics of Planktonic Organisms

"Living matter is heavier than sea water; its specific gravity ranges from 1.02 to 1.06, averaging about 1.04. Special adaptations are consequently required to prevent animals from sinking. This distinguishes pelagic creatures from animals of the benthal and gives them certain features in common; these appear in various groups by convergent evolution". (Hesse, Allee, and Schmidt, 1937, p. 223).

The state of suspension may be brought about either by a reduction in specific gravity or by added resistance offered to the water by the animal.

Reduction in Specific Gravity: This may be accomplished by economy in use of skeletal material. According to Rhumbler (1911), *Orbulina universa* from surface waters has a thin shell with walls from 1.25μ to 18μ, whereas specimens from the bottom have walls up to 24μ in thickness. The planktonic *Globigerinae* of the surface waters are distinguished by thin-walled shells from the smaller cold-water species, such as *Globigerina pachyderma*, which may live at greater depths. The amount of calcium carbonate in the shells is also reduced in various genera and species by an increase in size of pores, by enlargement of the aperture, or by the development of supplementary apertures.

Specific gravity of planktonic organisms may also be reduced by taking up relatively large amounts of sea water, as is done by jellyfish. The absolute surplus of weight remains the same, but the relative difference is reduced by an increase in the volume of the organism. Invertebrate marine animals may take up water from their surroundings without injury since their body fluids are isotonic with sea water. Storage of lighter materials is an even more effective method of weight reduction used by some planktonic organisms. This would include internal storage of water of less salinity, of fat globules or even air bubbles. These various modifications of the protoplasm represent a possible field for research in the Foraminifera, for as yet no data are available as to possible differences in the composition of the protoplasm in planktonic and benthonic Foraminifera.

Added Resistance to Sinking: Increased friction with the water and resistance offered by the surface is obtained by increase in size in the horizontal plane of a sinking body. This method is most effective for small animals, such as Protozoans, which have a high value of surface-weight proportion. This may be accomplished by a flattening of the body itself, as in the development of a radial test, with elongate or clavate chambers, or by the development of lateral projections, such as the spines so characteristic of the Orbulinidae.

Emiliiani (1954, p. 153) stated:

The capacity of a certain foraminifer to live in a water of certain density depends obviously, upon its specific weight; this, in turn, depends upon (a) the specific weight of the protoplasm and its inclusions, (b) the specific weight of the test and (c) the ratio of the mass of the protoplasm and inclusions to the mass of the test. If the first two factors are assumed to be roughly constant for all species, the important factor appears to be the third one; i.e., the ratio of the mass of protoplasm and inclusions to the mass of the test. For a given locality, species in which this ratio is the largest will prefer shallower habitats, while species with a smaller ratio will occupy deeper habitats. . . .

If the specific weight surpasses a certain limit, which depends upon the density of the water, the foraminifer may not be able to live within a reasonable distance from the surface and may find itself in a zone too deep for efficient nutrition . . . mutations of pelagic species toward a decrease of the ratio mass of protoplasm to mass of test are more probably deadly, as are mutations of benthonic species in the opposite direction.

A foraminiferal species will change its depth habitat during its lifetime if growth processes modify the ratio above mentioned.

Samples of various species were checked by size groups, and only *Orbulina universa* showed an appreciable difference between the size groups. This is (p. 154) "explained by the fact that in this species, while the mass of protoplasm increased proportionally to the cube of the diameter of the test, the mass of the test increases proportionally to only the square of the diameter, the thickness of the wall remaining approximately constant. Therefore the animal grows progressively lighter and progressively migrates toward the surface"

Some theoretical assumptions could be made on this basis. It could be stated that there is a mechanical sifting, that is, a movement of the animals to the depths at which they can maintain themselves. It has been demonstrated that there is such a vertical sorting according to size in the radiolarians, with smaller species in the warmer surface waters, larger ones below. In part the reverse is true of the Foraminifera, due to the difference in development of the organism, for the larger the specimen the greater the mass ratio of protoplasm to test.

It will be noted that the species restricted to the surface waters are those in which the chambers increase rapidly in size as added, and which have consistently thin shells, large primary apertures and, in the case of *Globigerinoides*, numerous secondary openings as well. This shows a distinct correlation between the characters of these species and the adaptation necessary to maintain them in the surface waters they prefer. It would suggest that fossil species with similar appearance, probably inhabited similar levels in the ocean. The converse is true of *Orbulina* which apparently can live equally well in the higher layers which increase size, and therefore decreased specific gravity, causes it to occupy in its later growth. Emiliiani stated that the shell wall of the specimens he examined remained constant in thickness throughout development. However, in many samples one can find specimens of *Orbulina* with many concentric layers developed, suggesting that some specimens of this species had increased the specific gravity by an addition of shell material and thus regained the lower environmental zone. Rhumbler's comments cited above on the relative thickness of wall of surface specimens of *Orbulina universa* and those from the bottom tend to bear out this supposition.
In this connection, it may be noted that "weight-increasing" additions are not uncommon in the planktonic Foraminifera, a condition which would seem anomalous were it not for the fact that in nearly all instances they only occur in the later stages of development, after the increase in size of the test would otherwise have decreased the specific gravity and caused an involuntary upward migration of planktonic species adapted to greater depths. These "weight-increasing" additions include the development of flanges and thick walls, as in Sphaeroidinella dehiscens, a species Stubbings (1939, p. 174) stated to occur most often in samples from deeper water. He suggested this occurrence might be due to the survival of their massive tests as compared with those of more delicate species. It may equally well be due to the environmental choice of the species, and the development of the heavier test be related to the depth at which the organism lived, not an incidental character which merely allowed its preservation in the sediments.

Other examples of weight increasing additions may be the thickened walls of later chambers, found in Pulleniata obliqueloculata, and the marked decrease in the size of the wall pores with increase in the size of the test, also seen in Sphaeroidinella. The accessory shell structures or bullae, developed by the entire sub-family Catapsydracinae, may be only apertural protection, but they also would increase the shell weight. This would maintain a constant specific gravity in the specimen with increase in size; interestingly, these accessory features are not found in small or juvenile specimens.

Distribution of Planktonic Foraminifera

The free suspension of pelagic animals favors their wide distribution. In fact it has been stated (Chun, 1892, p. 120) that up to the present time no pelagic forms have been discovered in either the Atlantic or Pacific ocean which are not represented by parallel forms in the other.

Variations in environmental conditions are less frequent and less abrupt in the open sea than in the shore waters. Nevertheless conditions are not uniform and pelagic life is accordingly not completely uniformly distributed. These influencing factors are less complex than in littoral areas where depth, type of bottom, presence of fresh water, and high amounts of suspended sediments change rapidly with consequent influence on the fauna. In the open ocean the most important factors are food supply, temperature, depth, light, salinity, and quantity of suspended sediments. The order of their importance is not certain.

Food supply: The food supply of pelagic animals consists of the plankton itself, the basic supply being the plant portion of the plankton, or the single-celled algae and diatoms. As the Foraminifera are dependent upon the phytoplankton as a food source, which they capture by means of their radiating pseudopodia, they are most abundant where this food supply is at least periodically rich. In counts made in the Bay of Kiel, the planktonic plant cells outnumbered the protozoans by a ratio of 7 to 1 (text-fig. 1). The richest domain of the plankton is the upper 100 meters of the sea water, inasmuch as the plant element in it is dependent on light, and the impoverishment of the plankton begins below this level.

![Figure 1. Curves of volume of various groups of organisms in the total plankton at Laboe, in the Bay of Kiel, during the year. (From Hesse, Allee and Schmidt, 1937, after Lohmann.)](image)

Aggregations of plankton also appear in certain areas, especially meeting-places of currents rich in plankton. So-called "animal-streams" may appear in both open sea and near coasts, sometimes with considerable regularity. They form a veritable plankton soup and give a smooth oily appearance to the surface of the water. They may be dependent on wind and current; for example, they appear twice a day in the harbor of Messina (Haeckel, 1890, p. 85). Agassiz (1892, p. 31) reported these "winrows" of plankton, stating, "The most extraordinary winrows I have met were off the Tortugas, about 150 miles to the northward, where the surface of the Gulf of Mexico for a whole day's steaming swarmed with Globigerinae. It was a dead calm." He considered them to occur along the track of the oceanic currents.

The composition of the plankton varies with time as well as locality. For example the protozoans fluctuate from a low ebb in winter to a high in late summer in the Bay of Kiel, reflecting a similar seasonal fluctuation in the numbers of diatoms and other phytoplankton.

Temperature: The geographic distribution of the animal communities of the oceanic pelagial is determined primarily by temperature. There is a subdivision into oceanic communities typical of warm water and those typical of cold water, roughly corresponding to the tropical and subtropical areas on one hand and the cooler waters on the other. These can be further subdivided. Marine animals appear to recognize an equatorial belt of water with a temperature above 25° C. as distinct from cooler tropical waters lying on either side with temperatures from 20°–25° C. Similarly, there are different communities in the cold-water polar areas with temperatures below 10° C. and those of the less cold waters with temperatures between 10° and 15° C. The boundaries are not sharply defined, and they may shift with the seasons, but in general a distinction can be made.
A pelagic community in tropical seas may have 20 species of Foraminifera, whereas one in polar water will have only a few. However, species found in polar faunas may be exceedingly rich in number. The abundance of diatoms in polar seas is an ample supply of food in summer months. In fact, in actual numbers of organisms per liter of water it has been shown that cold water contains about three and a half times as abundant a fauna as the water warmer than 20°C. But this abundance is limited to the summer months, and there is a relative scarcity of life in winter, when the absence of sunlight causes the plant life to remain dormant; so that the total annual production may not be greater than that of tropical seas.

There is a great similarity in the faunas of the Arctic and Antarctic seas. This may partially be due to a connected distribution through the deeper and therefore colder waters between. For example, of 14 Antarctic Foraminifera, 12 also occur in the Arctic, they are partly generally distributed forms, but partly are found normally at great depths and only in the polar regions do they ascend to within 30–70 meters of the surface. (Fauré-Fremiet, 1913, p. 268.)

There are other cases where the identity of the polar forms has been referred to the convergent evolution of species. The thick shelled Globigerina pachyderma is found in both polar seas and was considered by Heron-Allen and Earland (1922, p. 190) to be a local subspecies of G. dutertrei, a species, found in the intermediate areas, which develops into pachyderma under the influence of low temperature.

Wiseman and Ovey (1950, p. 65) consider living planktonic species of Foraminifera to be useful as temperature indicators. They listed the species typical of the various zones as follows: Arctic and Antarctic species: Globigerina dutertrei d’Orbigny and Globigerina pachyderma (Ehrenberg). Temperate species: Globigerina bulloides d’Orbigny, G. inflata d’Orbigny, Globorotalia eburnea Cushman and Steward, G. canariensis (d’Orbigny), G. truncatulinoides (d’Orbigny), and G. hirsuta (d’Orbigny). Warm and tropical forms: Orbitolina universa d’Orbigny, Globigerina dubia Egger, Globigerinella aequilateralis (Brady), Globigerinoides rubra (d’Orbigny), G. sacculifera (Brady), G. conglobata (Brady), Globorotalia menardii (d’Orbigny), G. tumida (Brady), G. scitula (Brady), Sphaeroindinella dehiscens (Parker and Jones), and Pulleniatina obliquiloculata (Parker and Jones).

Phleger, Parker, and Pierson (1953, p. 17) give the distribution of species in the Atlantic as follows: Species characteristically abundant in low latitudes (less than lat. 20° N.) are Globorotalia menardii (d’Orbigny), G. tumida (Brady) and Pulleniatina obliquiloculata (Parker and Jones). They also occur in lesser numbers in middle latitudes. Abundant in low latitudes, but in lesser abundance in all other localities as well are Globigerina eggeri Rhumbler and Globigerinoides sacculifera (Brady). Only in high and middle latitudes is Globigerina pachyderma (Ehrenberg). Abundant in middle latitudes and rarer in low latitudes are Globigerina bulloides d’Orbigny, G. inflata d’Orbigny, Globorotalia hirsuta (d’Orbigny), G. scitula (Brady), and G. truncatulinoides (d’Orbigny). Uniformly distributed in uniform abundance over the entire area were Globigerinella aequilateralis (Brady), Globigerinoides glutinata (Egger), Globigerinoides conglobata (Brady), G. rubra (d’Orbigny), and Orbitolina universa d’Orbigny.

However, Phleger (1954, p. 8) did not believe that surface temperature was the most important ecological factor in this distribution. He considered that the different faunas were due to different “ecologic water masses,” with some mixing of faunas at the boundaries of these water masses. The Gulf Stream was cited as an example of a water mass transporting low-latitude species such as Globorotalia menardii (d’Orbigny) into middle latitudes, i.e., the southern Gulf of Maine. These “water masses” had been earlier discussed by Sverdrup, Johnson, and Fleming (1942) and by Thomsen (1933).

Oceanic currents may of course carry the plankton through varying temperature zones. For example, the closed currents of the South Atlantic carry water from the equator to the 45th parallel of south latitude. The plankton in such a current requires several months and even years to return to its origin, about one and one-fourth years in the North Atlantic current, and two and a fourth years in the South Atlantic. Among short-lived plankton, many generations are included in this period. A different condition results in the non-circulating currents, which may carry warm water into a cold region, as does the Gulf Stream, or cold water into warm, like the Labrador current. Here the plankton may be carried from a favorable environment to an unfavorable one in which they may suffer or die. Murray (1937, p. 23) showed that the deposits of pelagic Foraminifera on the sea bottom were greatest where currents of different temperature met. Possibly the water-masses cited by Phleger are themselves an influence because of differing temperatures.

Studies of planktonic Foraminifera in deep sea cores have been made by many workers in recent years. Faunas from sediments below the surface have been recognized as containing species typical of modern faunas of higher latitudes than that of the core being studied. These are generally considered to represent temporarily colder water during the various Pleistocene stages. These studies have been made by Cushman and Henbest (1940); Stubbings (1939); Phleger (1939, 1942, 1947, 1948), and Ericson, Ewing, and Heezen (1952) in various areas of the Atlantic, Pacific, Caribbean, Gulf of Mexico, Arabian Sea, and Tyrrhenian Sea. However, as noted by Phleger (1954, p. 16) this alternation of faunas in a core may not be entirely due to widespread climatic changes influencing surface water temperature variations. Smaller changes in boundaries of water-masses could cause similar fluctuations. Phleger stated: “The position of the Gulf Stream varies considerably, and... there are eddies,
counter-currents and numerous bodies of water which may have been detached from the main water-mass. Certain sequences of cold- and warm-water planktonic Foraminifera collected from this region may be suspected of reflecting such water movements."

For this reason, it would be necessary to show a similar sequence of fluctuation over an area sufficiently broad as to avoid control by minor current changes, in order to correlate these faunal changes with world-wide climatic changes.

The actual cause of these faunal fluctuations is still undetermined. As stated by Ovey (1950, p. 214), it is certain that there are oscillations in the equatorial Atlantic, and that "short-term fluctuations of temperature are unlikely to be traceable in deep-sea cores because sedimentation is slow and there is also the probability that the lag between temperature and faunal change is considerable."

Studies of ocean temperatures during the Tertiary by Emiliani and Edwards (1953, p. 889) by means of oxygen isotopes, showed "that greater mixing of the oceanic waters occurred in non-glacial times . . ." and "adds weight to the point repeatedly stressed by geologists that the climate of the earth was much more uniform in non-glacial times."

This would suggest that perhaps planktonic Foraminifera would be even more cosmopolitan in Cretaceous and Tertiary times than in the Recent seas, and as a result would be of even greater time value, where temperature control would be minimized.

**DETH AND ECOLOGIC STRATIFICATION:** Only a few studies of the distribution of living planktonic Foraminifera have been made on the basis of plankton tows. Early work established that there are approximately 20 or 30 living planktonic species, based on their presence in plankton tows. The largest populations are in the upper layers of water. Schott (1935) obtained several hundred specimens per tow from the upper 100 meters, and considerably less from greater depths. Phleger (1951) found an average population of 5 to 6 per cubic meter of water in the upper 50 meters in the northwestern Gulf of Mexico. However, some stations showed up to 73 living specimens per cubic meter.

Living specimens of planktonic species also were found in sediment samples, and were either bottom-dwelling or living in the 15 to 20 centimeters of water directly above the bottom. According to Phleger (1954, p. 3), "These data certainly suggest that while planktonic Foraminifera appear to be most abundant in the upper water layers they do live throughout the water column all the way to the bottom." Many plankton tows also contain empty tests of Foraminifera which did not sink to the bottom immediately upon death or reproduction of the animal.

Phleger summarized his findings by stating (1954, p. 3): "The fauna in a sediment may represent environmental conditions which existed throughout the entire water column from the surface to the bottom. There may be several populations living in different depth environments, or the same population may be variously affected by environments at various depths . . ." "Planktonic Foraminifera do not sink immediately, depending upon water turbulence conditions, and may be deposited at some distance from where they actually lived. The distance of such transport cannot be established at the present time and must be variable."

Studies of pelagic Foraminifera on the basis of oxygen isotope ratios by Emiliani (1954, p. 149) showed that different species from the same sample registered different temperatures for their development. They were, therefore, considered to occupy different habitats with respect to temperature and water density and therefore also with respect to depth. "The same species may vary considerably in its depth habitat in order to adjust itself to the proper temperature and water density." Correlating the temperatures at which these species lived with the variation in temperature with depth showed a well-defined stratification. He stated (p. 152) that, "The species Globigerinoides conglobata, rubra and sacculifera appear to occupy the shallower habitats, followed by Globigerina dubia, Pseudonatitina obliquiloculata and Globorotalia menardii, while Globorotalia tumida and truncatulinoides occupy the deeper habitats . . . The stratification with respect to temperature is, therefore, reproduced also with respect to depth; however, as already well known, the different species appear to be much less dependent upon pressure than upon temperature."

Further studies showed that species appear to be adapted to waters of the same densities in the different areas, even if this involves considerable differences in pressure. None of the pelagic specimens examined by Emiliani was found to live at a depth greater than about 220 meters.

Studies of specimens of different sizes of various species by Emiliani showed that the majority maintained the same depth habitat during at least most of their lives. The sole exception was Orbulina universa which showed the larger specimens to live at progressively shallower depths. This species was therefore considered to change its depth habitat during its development.

The depths at which the planktonic Foraminifera live and the modifications making this depth selection possible were discussed more fully, above, in the section on special characteristics of the planktonic Foraminifera. However, in determining climates, etc., on the basis of planktonic assemblages, the effect of this stratification of habitats should not be overlooked, as colder water forms may well inhabit deeper layers of the pelagic, whereas the surface layer may contain species typical of warmer latitudes, and thus cause an apparent mixing of faunas.

**Light:** The primary effect of light on the planktonic assemblage would be that on the phytoplankton, to which light is necessary for development. It would have a secondary effect on the Foraminifera, as a result of its effect on their source of food. There is also a
possibility of a direct effect of quantity of light on the Foraminifera. This has been demonstrated by Myers (1943, p. 453) on benthonic species, and was suggested as a possibility in the distribution of some planktonic species by Wiseman and Ovey (1950, p. 63). Their sample 8 from the south Atlantic contained a fauna typical of warmer water than did that of sample 2 from the north Atlantic, although the actual water temperature of sample 8 was lower than that of sample 2. "From the positions of these two samples (number 2 is farther from the equator than number 8) there is a much closer relationship with latitude than with temperature, which suggests the possibility that the distribution of the northern and southern cold species Globigerina pachyderma and G. dutertrei are at least partially governed by the low illumination in these latitudes . . . ." Thus the amount of light may also be a factor in the distribution of species.

Salinity and Suspended Sediments: According to Ovey (1948, p. 6), for the existence of pelagic Foraminifera deep water is not necessary, but "it appears only to be necessary to have water free from land-derived pollution by river sediments. Globigerinidae are often found in the Mediterranean, for example, in association with relatively shallow water benthic forms, but wherever found the water above has been clear."

This was substantiated by F. Parker (1954, p. 478) in work on sediments of the Gulf of Mexico. She found planktonic specimens to be much rarer in the region of the Mississippi River delta than elsewhere. They do not occur at all in sediments as shoal as in the rest of the area, and she stated, "Their absence in the delta region is probably due to the outflow of the Mississippi River which causes water to flow out over the surface for long distances." She considered (p. 472) that the salinity was not affected much thereby at the shoalest stations, and probably was not a controlling factor for the faunal changes at either side of the delta region. Quite possibly the large amount of sediment in the water in this area of delta formation is the factor controlling the planktonic population.

Similar evidence of a control by suspended sediments is found in fossil material. Although in general the Cretaceous has an abundant planktonic fauna, there are sediments which wholly lack them. An example is the Cretaceous sequence of northern Alaska which contains a fairly large total fauna of benthonic species (approximately 200 species). Planktonic species are absent, however, throughout the entire section ranging from Neocomian through Senonian, except for one thin horizon of Turonian age which contains two or three planktonic species. Tappan (1951, p. 4) stated: "The Alaskan Cretaceous is thus equivalent in age to a portion of the very fossiliferous Cretaceous sediments of the Gulf Coast, but the faunas have little in common other than age. The Gulf Coast fauna is extremely varied with many pelagic forms and a great abundance of calcareous and specialized types, but the Cretaceous of Alaska contains a dominantly arenaceous fauna and has almost no specialized forms." This difference was explained as environmental, as "the Alaskan section contains sands and clays but no limestones, and the clastic sediments are neither clean nor well-sorted, thus suggesting rapid sedimentation and muddy waters." This "graywacke" type of sediment is always very poor in pelagic species, although they may occur in contemporaneous sediments of differing lithologic type.

Morphology and Terminology

In order to avoid repetition, the morphology of the various planktonic genera is more fully discussed in the section on systematics. However, a general discussion is given here, with definitions of the terminology used.

In the past there has been little agreement in the descriptive terminology used in defining the genera of Foraminifera. Brozen (1942, p. 11) first used a more exact terminology in defining apertures and their position. He defined septal apertures and lateral apertures. The former could be interiomarginal, exiormarginal, or areal in position, or there could be composite apertures with one in each of two or more positions.

The lateral apertures could be either lateral, lateromarginal, or sutural, according to Brozen. This was a considerable advance over the earlier statements such as "at the base of the final chamber," but it did not take into consideration the origin of the apertures and their relative importance. Furthermore there are various types of openings in the planktonic Foraminifera which do not fit well into Brozen's classification.

The types of coiling have also been variously termed. That of Globorotalia for example has been termed trochoid by Cushman, rotaloid by Galloway, turbo-spiral by Brozen and trochospiral by Glaessner.

The two sides of the test in these asymmetrical forms have also been variously named. Cushman (1948, p. 16) referred to them as dorsal and ventral, the dorsal side being that on which the chambers of all the whorls are visible. Galloway defined ventral as "pertaining to the inferior side, particularly the apertural side in coiled forms; opposite the dorsal side." dorsal was stated (1933, p. 464) to be "pertaining to the back; opposite to the ventral side." But in some genera of planktonic Foraminifera the primary "ventral" aperture is closed; there are apertures only on the "dorsal" side, and none on the "ventral."

Glaessner (1948, p. 69) defined the dorsal side in high-spired forms as that with the apical surface of the spire, and the base he considered to be the ventral side. He added that in low-spired forms "the evolute side is usually referred to as dorsal and the involute side as ventral."

However, some benthonic genera are attached by the side showing all the whors, which in life was therefore "ventral" or inferior, and the aperture may also appear on this evolutely spiral side. Thus in these
genera the same side might be termed either dorsal or ventral, depending on whether the writer believes the position of the aperture, the position of the test in life, or the visibility of the early whorls to be the most important basis for defining dorsal and ventral. Brotzen (1942, p. 7) therefore, discarded the use of dorsal and ventral and instead used the terms spiral side and umbilical side.

Thus the terminology used by various authors in discussing the morphology is not always uniform, and in some cases the terms used are not sufficiently explicit. A lack of concise and explicit terminology requires lengthy and repetitious explanations with every description.

For these reasons certain terms previously used are here adapted, others are used in a more restricted sense, and some new terms are defined for structures which previously have required the repetitious use of long descriptive phrases for lack of a single concise and explicit term. As only planktonic Foraminifera are here discussed only the terminology used for these genera is given. Examples representative of each term are given, as well as appropriate sketches.

**Shape and Form of Test**

**Umbilicate**

Those tests with an open or closed umbilicus (the point on the axis of coiling where the septa of the final whorl join in an enrolled foraminifer) on one or both sides of the test (text-fig. 2).

**Planispiral umbilicate:** Tests symmetrically coiled, both sides umbilicate, e. g., *Hantkenina*. (This does not include low trochospiral forms although the term has been so used in the past.)

Evolute. All whorls partially or wholly visible on both sides, but equal on the two sides, e. g., *Hastigerina aequilateralis* (Brady).

Involute. Only the final whorl is visible on each side, e. g., *Hastigerina murrayi* Thomson.

**Trochospiral:** Asymmetrical tests with all chambers visible on one side (here termed spiral side, following Brotzen) and only those of the last formed whorl visible around the umbilicus on the opposite (umbilical) side.

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**Figure 2.—Test shapes in planktonic Foraminifera.**
Biconvex. Both spiral and umbilical sides convex, or more or less inflated, e. g., *Globorotalia tumida* (Brady).

Spireoconvex. Spiral side convex, umbilical side flattened to concave, e. g., *Globotruncana contusa* (Cushman).

Umbilico-convex. Umbilical side convex, spiral side flattened to concave, e. g., *Globorotalia truncatulinoides* (d'Orbigny).

**Enrolled Biserial:** This is a modification of the planispiral development in which biserially alternating chambers are enrolled. Characteristic of the nonplanktonic family Cassidulinidae, this type of coiling is also found in *Cassigerinella*, a genus of the family Hantkeninidae.

**Nonumbilicate**

Lacking an umbilicus (text-fig. 2).

**Streptospiral:** In the planktonic Foraminifera this may be a later modification of the trochospiral coiling, in which the plane of coiling continually changes, as in the coiling of a ball of string. As the plane of coiling changes, the axis of coiling changes, hence no umbilicus is formed at the terminus of the axis of coiling, e. g., *Pulleniatina*.

**Globular:** A globular test may be formed, by a completely enveloping final chamber as in *Orbulina*; or by the development of a many chambered test, with rapid increase in chamber size and commonly considerably embracing later chambers as in *Globigerinatheka* and *Globigerinatella*.

**Structures of Test**

**Primary Chambers**

The chambers whose pattern of development determine the test shape and form (text-fig. 3).

**Angular Conical:** Inflated chambers with angular margins and a conical form as in *Globorotalia truncatulinoides* (d'Orbigny).

**Angular Rhomboid:** Chambers with rhombic section and sharply angled as in *Rotalipora brotzeni* (Sigal).

**Angular Truncate:** Chambers inflated but with truncate margins, angular and commonly keeled, e. g., *Globotruncanana arca* (Cushman).

**Ovate:** Chambers moderately inflated and ovate in section, e. g., *Rotalipora roberti* (Gandolfi).

**Hemispherical:** Chambers inflated at one side, flattened on the opposite side, and thus hemispherical as in *Globotruncanana helvetica* Bolli.
Spherical: Individual chambers forming spheres as in *Globigerina bulloides* d’Orbigny.

Clavate: Chambers elongated and may be inflated terminally, having a club-shaped appearance as in *Clavigerinella akeri* Bolli, Loeblich, and Tappan.

Tubulospinate: Chambers produced radially into long hollow extensions, or tubulospines, as in *Schackoina*.

Radial elongate: Chambers produced radially as in *Rugoglobigerina hantkeninoides* Bronnimann.

Accessory Structures

These include the structures previously known variously as secondary chambers, chamberlets, umbilical plates, etc., but which are not true chambers as they do not follow the normal chamber arrangement. They are commonly related directly to the aperture and thus may be considered as apertural modifications (text-fig. 4).

A prominent feature of these accessory structures is that they become progressively more prominent with growth of the test and some are developed only in the adult, so that dissection of the tests fails to show any trace of such features as the bullae of the Catapsydracinae. This has been noted before, as F. Parker (1954, p. 477), in discussing a species found in the Gulf of Mexico, stated, "*Globigerina* sp. has a thin supplementary chamber extending from the dorsal side between the last-formed chamber and the first one in the last-formed whorl, to varying degrees over the umbilicus. There are supplementary apertures along the sides of this chamber which in many respects is similar to the supplementary chambers of *Globigerinita*. This chamber is apparently resorbed or destroyed when new regular chambers are added since there is no trace of a previous one."

It is probable that these additional structures serve to protect and reduce the size of primary or secondary apertures. They may also be a weight-increasing development necessary in the adult test to maintain the specific gravity of the animal after the increase to adult test size. The structures thus aid the animal in maintaining that depth level in the water where the temperature and water density afforded optimum conditions for the species. Thus, the absence of bullae in younger stages is not surprising. Its presence solely in the adult nevertheless does not lessen its taxonomic value, as many other important characters are developed only in the adult stages of Foraminifera.

Simple apertural lip: This is the simplest form of apertural modification or cover and may be narrow
and elongate, short and spatulate, or of various other shapes, e.g., Globorotalia.

Lateral aperture flanges: Similar to the apertural lip of trochospiral forms, but found on both sides of the commonly elevated peripheral aperture in Hantkeninina, Clavigerinella, and related genera.

Umbilical teeth: A triangular modification of the apertural lip, those of successive chambers in forms with an umbilical aperture giving a characteristic serrate border to the umbilicus as in Globoguadrina.

Chamber flanges: Broad folds developed along the basal margins of chambers which tend to obscure the sutures and thereby to cover the sutural and umbilical apertures as in Sphaeroidinella.

Tegilla (singular, tegillum; derivation: Latin diminutive of tegutum, roof, cover): This new term is proposed for the umbilical coverings of the Globotruncanidae (Globotruncana, Rugoglobigerina) which are extensions from the chambers, similar to a highly developed apertural lip, but which extend across the umbilicus, completely cover the primary aperture, and attach at their farther margin or at the tegilla of earlier chambers. Generally delicate and with thinner walls than the true chambers they may be broken out of the umbilical area and are commonly found only as ragged fragments. With great care in preparation of well-preserved material they may also be found in all species of these genera. They may have smaller openings along their margins, or be pierced centrally, these openings communicating beneath the tegilla with the primary umbilical apertures and the umbilical area.

Bulla (plural, bullae; derivation: Latin, blister): This term is here defined to include the accessory structures found in many planktonic Foraminifera of the family Orbulinidaceae, which in general are not closely related to the primary chambers, but are instead related only to the aperture. They may partially or completely cover the primary or secondary apertures, and may have one or more accessory apertures at their margins.

Umbilical bulla. A bulla covering the umbilicus and the apertures leading into it, as in Catapsydrax.

Sutural bulla. Bullae covering the secondary sutural apertures and only sutural in position, as in Globigerinatheka.

Umbilical-sutural bulla. A bulla covering both the umbilicus and the apertures leading into it and extending along the sutures as well, as in Integiligerinella.

Areal bulla. Bullae covering the multiple areal apertures as in Globigerinatella.

Apertural Openings in Test

These include the relatively large openings commonly termed apertures, which in general are characteristic for each genus, both in position and shape. The fine pores in the wall for the extrusion of pseudopodia are not considered here (text-fig. 5).

Primary Aperture

This is the main aperture opening from the final chamber of the test. In the families under consideration here, all primary apertures are interiomarginal, that is "at the base of the final chamber," but may vary in position as follows:

Umbilical: Opening from the final chamber directly into the umbilicus, on the umbilical side of trochospiral forms. Those of earlier chambers may also remain open, as in Globigerina.

Extraumbilical-umbilical: Extending from the umbilicus along the forward margin of the final chamber toward the periphery, and thus reaching a point outside the umbilicus, or extraumbilical as in Globorotalia.

Equatorial: This is characteristic of the planispiral forms, and is a symmetrical interiomarginal aperture in the final chamber, just above the peripheral margin of the previous whorl. It may be extremely high as in Clavigerinella, triradial as in Hantkenina, or a low arch as in Hastigerinoides.

Spiro-umbilical: An interiomarginal aperture extending from the umbilicus to the periphery and finally on to the spiral side; the most extensive aperture found in trochospiral forms, e.g., Hastigerinella.

Secondary Apertures

These include smaller openings which are developed in addition to the primary aperture, but in specialized forms may completely replace the primary aperture.

Relict apertures: In the Planomalalinaceae the umbilical portions of the equatorial aperture may not be covered by succeeding chambers, but remain open as short radial slits around the umbilicus. Even when they are secondarily closed, the elevated apertural lips or flanges remain visible around the umbilicus, as in Planomalina and Hastigerinoides.

Supplementary apertures: These may occur in addition to the primary aperture and thus are independent of it. In some cases they may completely replace the primary aperture.

Areal. Supplementary multiple areal apertures are developed in Cribrohantkenina. Specimens may be found in which both the primary equatorial aperture and the supplementary areal apertures occur, showing the latter to be of secondary rank.

Sutural. Sutural supplementary apertures are in general relatively small. They may be single, or one per suture, as in Rotalipora, or multiple,
with many openings along the sutures, as in *Candeina*. They may be restricted to the spiral side as in *Truncorotaloides*, restricted to the umbilical side as in *Rotalipora*, or present on both sides as in *Candeina*.

**Accessory Apertures:** The accessory apertures do not open directly into the primary chambers, but are openings in or under the accessory structures (i.e., bullae and tegilla) found in the planktonic Foraminifera.

**Infralaminal accessory apertures.** One or more openings along the margins of the accessory structures, e.g., *Catapsydrax*, *Globigerinita*.

**Infralaminal accessory apertures.** Openings, usually multiple, which pierce the accessory structures, e.g., *Rugoglobigerina*.

**Figure 5.—Apertural types in planktonic Foraminifera.**
Wall of Test

Composition

In the families under consideration, the wall is composed wholly of calcium carbonate (calcite).

Structure

All these planktonic genera have a perforate radial wall structure.

Bronnimann and Brown (1956) stated that the genera of the Globotruncanidae (including some genera here placed in the Globorotaliidae) have granular perforate walls, except for the surface ornamentation of keels, pustules, etc., which are imperforate. Wood (1949) had stated earlier that Globotruncana has a perforate radial wall structure, hence we have checked the wall of the various planktonic genera here described, and have found the wall of each to be perforate radial. As noted by Bronnimann and Brown, and earlier by Wood, the ornamentation of these genera, and that of many of the other genera and families of Foraminifera, may consist of apparently imperforate or very finely perforate shell material that is nevertheless quite distinct from the type of material of the imperforate or porcellaneous Foraminifera.

Because many workers have had difficulty in correctly determining the wall structure of various Foraminifera, and wrongly determine the shell of some to be granular, we are here giving the method used in these determinations. Wood (1949) gave an excellent summary of the wall characters of many genera and species, but his photographs of entire specimens of Foraminifera, to demonstrate the typical appearance of the different types, have apparently mislead some later workers. As was clearly stated by Wood in his text, however, the wall structure may be quite obscure if entire shells are examined in polarized light, especially if the walls are relatively thick. In this case, either fragmented specimens or thin sections must be used. The former method, being usually the quicker, is as follows: A clean specimen, free from extraneous filling if possible, is placed on a glass slide and gently crushed with pressure of another glass slide above. A drop of oil, of the index of refraction of calcite, is then added, the cover glass replaced above, and a fragment is sought which shows the wall in cross section. In this fragment the radial or granular structure can be easily determined in polarized light. Further details of the appearance of the fragments of various types of wall structure are given by Wood (1949).

Surface

The surface ornamentation is here considered to be of specific importance only. The following terms are in common use in specific descriptions.

Smooth: E. g., Candeina nitida d’Orbigny.
Cancellate: With a honeycomb-like surface, e. g., Globigerina reticulata Stache.
Spiral: With very fine solid spines, generally elongate, e. g., Hastigerinella rhumleri Galloway.

Hispid: Very fine, short, and hair-like “spines” as in Globorotalia truncatuloides (d’Orbigny).
Rugose: Rough irregular ornamentation, which may form ridges, e. g., Rugoglobigerina rugosa (Plummer).
Beaded: Small rounded elevations or “beads” which commonly occur along the sutures and keels, but may also occur on the chamber wall as in Globotruncanana area (Cushman).
Pitted: Small, generally rounded depressions in the surface of the wall, e. g., Sphaeroidinella dehiscens (Parker and Jones).

Evolutionary Trends

By a study of the geologic record in combination with the ontogeny of the species, several evolutionary trends may be noted. In general these trends are largely related to the pelagic nature of the organism, tending on the one hand to develop a lighter test (thus decreasing the specific gravity and so enabling it to float) or to develop a flattened or radial form (thus retarding its sinking by offering increased area of resistance to the water) and on the other hand a tendency to develop a heavier adult test by the addition of more shell material. These tendencies are undoubtedly the result of selective survival, but may be enumerated as follows:

1. Replacement of a single primary aperture by many smaller openings. This is accomplished in various ways: 1. By the development of lateral relict supplementary apertures, and in Biglobigerinella in developing paired apertures. 2. Development of multiple areal supplementary apertures as in Cribrohantkenina. 3. Development of sutural supplementary apertures on the spiral side as in Globigerinoides and Truncorotaloides, on the umbilical side as in Rotalipora, or on both spiral and umbilical sides as in Candeina. 4. Development of accessory intralaminal or infralaminal apertures as in Globotruncanana or Globigerinida.

Obscuring or covering of the aperture. The simpler forms have relatively uncomplicated and open apertures, but later developments such as the following may obscure the primary apertures: 1. Apertural lips (e. g., Globorotalia) or umbilical “teeth” (e. g., Globouadrina). 2. Chamber extensions, e. g., the flanges of Sphaeroidinella and tegilla of Globotruncanana. 3. Accessory structures or bullae, e. g., Globigerinida. 4. Enveloping final chambers, e. g., Orbulina. 5. Enfolding of chambers by development of streptospiral coiling, e. g., Pulleniata. 6. Tendency to develop a spherical test: 1. By means of enveloping chambers, e. g., Orbulina. 2. By becoming streptospiral in development, e. g., Pulleniata. 3. By much inflated chambers in planispiral genera, e. g., Hastigerina. 4. By becoming high spired in trochospiral genera, e. g., Globigerinoides.

Determination of test by development of radial elongate chambers as in Hastigerinella, Hantkenina aragonensis, and Rugoglobigerina Scotti.
2. By development of elongate true spines as in living *Globigerina*, *Hastigerina*, *Globigerinoides*, and *Hastigerinella*.

Coiling ratios. This is one apparent evolutionary trend which does not directly affect the pelagic nature of the organism.

As shown by Bolli (1950, p. 82 and 1951, p. 139) the trochospiral genera may develop a preference for sinistral or dextral coiling. Early representatives of a species or group of closely related species may show random coiling, with sinistral and dextral specimens in approximately equal numbers. The stratigraphically younger specimens studied prefer a single direction almost to the exclusion of the other, and this may be either sinistral or dextral, according to the species concerned. These results have been obtained with species of *Rotalipora*, *Globorotalia* and *Globotruncana*. Similar tendencies, though less distinct, have also been observed in several species of *Globigerina*, *Globigerinoides* and *Catapsydrax*. Once a preferred direction of coiling is established, it is generally persistent as in all species of *Globotruncana* and in the *Globorotalia foksi* group, or a rapid change to the opposite direction may take place, indicating possible ecological changes, as in *Globorotalia menardii* (Bolli, 1951) and *Globorotalia truncatulinoides* (Ericson, G. Wollin and J. Wollin, 1954). In rare cases a return to random coiling has been observed in late evolutionary stages, shortly before the extinction of the genus, as in certain related groups of species of *Rotalipora*. All known species of *Globotruncana* and *Rugoglobigerina* tend to develop an almost exclusive preference for dextral coiling. On the other hand, many species of *Globorotalia* develop predominantly sinistral coiling in their later stages, as do some mid-Tertiary species of *Globigerina*, *Globoguadrina* and *Globigerinoides*. However, the type species of *Catapsydrax*, originally named *Globigerina dissimilis*, prefers a dextral coiling (text-figs. 6, 7).

Bolli (1951, p. 142) further stated that “it appears unlikely that a species with random coiling in its early phylogenetic stage can be genetically related to a stratigraphically older species which shows a distinct preferential direction of coiling in its later stages”.

An interesting study in the coiling direction of living and subrecent *Globorotalia truncatulinoides* (d’Orbigny) was made by Ericson, G. Wollin, and J. Wollin (1954) from a study of specimens found in deep sea cores. They found three great provinces of the north Atlantic defined by populations with a dominance of one or the other coiling direction. The northeast quadrant of the north Atlantic shows a dominance of dextral coiling. A central zone of sinistral coiling extends from northwest Africa to North America. The third province is equatorial, extending through the Caribbean and Gulf of Mexico and around the Florida Straits, and contains again dominantly dextrally coiled specimens (text-fig. 8). Near the boundaries of these zones, coiling is almost random.

An examination of a number of cores showed that there was also a variation in coiling direction with time.

Two cores from the area with a present day dominant sinistral coiling, showed that sinistral coiling is exceptional in this region, for during deposition dextral coiling was dominant 80 percent of the time. Two swings to the left of short duration were noted in both cores, affording an excellent possibility for correlation.

Core evidence shows that the Recent province of sinistral coiling dominance has been in existence for at least 2,000 years and probably much longer. Equatorial cores show that the southern province of dextral coiling has existed continuously for at least some tens of thousands of years. There is no physical barrier between these provinces and the species distribution is continuous. Therefore, some unknown environmental factor or selective process must favor the coiling direction dominance in these provinces.

Vasícek (1953) also made a study of coiling ratios, based on the species *Globorotalia scitula*, both in time and regionally. He also concluded that the change in ratio was due to an unknown change in life environment, but that the coiling ratios were extremely useful in correlations within the Moravian Tortonian, where no species suitable for zoning had been found.

Other genera, namely *Spirillina* and *Discorbis*, were shown by Myers to have the direction of coiling related to the alternation of generations, one generation being dextral, the other sinistral. However, other species show a variation of coiling in the megalospheric forms.

It was suggested by Vasícek (p. 413) that the coiling might be related to the reproductive process of "plastogamy." Myers’ work on life cycles showed the
syzygy of megalospheric individuals before the production of the gametes of the sexual generation. This syzygy in the case of *Patinella* was thought to ensure completion of the reproductive processes, as the gametes were amoeboid and nonflagellate. However, other species also show syzygy which do develop flagellate gametes. The coiling direction might facilitate this process, as firm adherence of two tests by their umbilical sides is possible only between individuals of the same direction of coiling. According to Vašíček, the extremes in coiling ratios may thus be due to absolute dependence of the reproductive processes upon such syzygy, during relatively unfavorable conditions, and the fluctuations noted in cores may be due to mixing of populations from another province. In the Moravian region, the coiling ratio curves were somewhat different in the deeper portions of the basin, suggesting the possibility of an influence of temperature.

These theories can only be suggested on the basis of fossil material and to date very little experimental work has been done on life histories and processes of planktonic Foraminifera, due to the considerable difficulty encountered in propagating them under controlled laboratory conditions.

### Systematics

#### Historical Summary

In the classification of d’Orbigny, based solely upon chamber shape, the planktonic genera would fall into four of his seven orders. *Orbulina* would be placed in the Monostégues, or single chambered forms. *Globigerina* and other trochospiral forms would belong to the Helicostégues (or helically coiled forms), *Cassigerinella* (though then as yet unknown) would have been placed with *Cassidulina* in the Entomostégues and *Spaeroidinia* in the Agathistégues.

Carpenter (1862) included in the family Globigerinida all coarsely perforate forms, considering *Orbulina* to be the ancestral and simplest form. However, in the Globigerinida he also included with the Globigierinae the arenaceous Textulariinae, the *Bulimina* group (with complex internal tubes), and the Rotalinae (with complex canal systems); so that his “coarsely perforate” family included those with perforations of widely differing character, origin, and structure.

Brady (1884) restricted the Globigerinidae to include only *Globigerina*, *Orbulina*, *Hastigerina*, *Pullenia*, *Spaeroidina*, and *Candeina*. Other planktonic forms were referred to *Pulvinulina* [Globorotalia] in the Rotaliidae.

Cushman (1928) separated the then described genera which are included in the present study, into three families, the Globigerinidae, Globorotaliidae, and Hantkeninidae. He included in the family Globigerinidae the subfamilies Globigerininae, Orbulininae, Pulleniatininae, and Candeininae. The first of these subfamilies was quite inclusive, with genera of many varying characters, some of which are here placed in the family Hantkeninidae. Each of the last three subfamilies
were relatively exclusive, being either monotypic or including only two genera. The Globorotaliidae included both Globorotalia and Globotruncana, here separated in two families, as well as Cycloloculina and Sherbornina. The latter two bear no relation to these planktonic Foraminifera. In the Hantkeninidae he also originally included Mimosina and Trimosina which are completely unrelated to these planktonic families.

Cushman’s family and subfamily descriptions were extremely generalized. For example, the family diagnoses for the Globigerinidae and Rotaliidae could be interchanged without loss of meaning. In later editions of his text, Mimosina and Trimosina were removed from the Hantkeninidae, and Schackoina and Cribrohanthenina were added. The Globorotaliidae remained the same, with the addition of Rotalipora and two superficially similar but non-planktonic genera Globorotalites and Cribrogloborotalia (see summary of classifications, below).

Galloway (1933) placed Hantkenina in the Nonionidae, because of the planispiral coiling, and Globorotalia in the Rotaliidae. He recognized the family name Orbulinidae as having priority over the Globigerinidae, and included it in many of the forms placed in the latter by Cushman, as well as Globotruncana and Neocribrella and three “doubtful Foraminifera” Calpionella, Oligostegina and Disphoeridium.

In 1942, Brotzen subdivided the rotaiform Foraminifera into the Nonionidae (all planispira genera), Rotaliidae (with the conical turbospiral genera), Valvulineriidae (for the lenticular formed genera), and Epistominidae (also turbospiral lenticular, but with a sharply angled periphery, commonly with both an interiomarginal aperture and an areal exerimarginal aperture). He included within the Valvulineriidae the subfamilies Valvuleriinae, Cibicidinae, Globigerininae, and Globotruncininae. However, the name Anomaliniidae Cushman takes precedence over Cibicidinae, and the name Globorotaliidae has precedence over Globotruncininae. Furthermore, Orbulinidae has priority over Globigerininae, and all of these names—Anomaliniidae, Orbulinidae, and Globorotaliidae—take precedence over the name Valvulineriidae.

Glassner (1948) placed the Hantkeninidae as a subfamily within the Globigerinidae, and his Globorotaliidae was restricted to include only Globotruncana and Globorotalia, being separated from the Globigerinidae largely on the basis of the compressed trochospiral form and the carinate periphery.

In 1949 the important study of wall structures in the Foraminifera by Wood showed that the Globigerinidae, Hantkeninidae, and Globorotaliidae (including Globotruncana) all possessed a perforate radial wall structure. The Nonionidae were found to have a perforate granular wall structure. Thus the apparent similarity in planospiral coiling in the Hantkeninidae and Nonionidae is due to convergence and these groups are not closely related, as considered by Galloway.

Bermudez (1952) however, again placed the Hantkeninidae (reduced to a subfamily) in the Nonionidae. Globorotalia and Turborotalia (here included with Globorotalia) he placed with many other non-planktonic genera in the subfamily Valvulinieriinae, family Rotaliidae, apparently following Brotzen. However, if this group of genera were to be placed in the same subfamily, the name Globorotaliidae Cushman 1927 would necessarily have precedence, as noted above.

Globotruncana, Praeglobotruncana, Truncorotalia (here considered synonymous with Globorotalia), and Thalmaninella (here considered a synonym of Rotalipora) were separated by Bermudez into the subfamily Globotruncininae, although he did not include Globorotalia, as had Brotzen. Ticinella (here included in Rotalipora) and Rugoglobigerina were placed by Bermudez in the Globigerinidae. Rotalipora itself was placed in the Cymbaloporidae, following the suggested relationship of these genera referred to by Brotzen, although Bermudez had included Rotalipora and Cymbalopora in the Globotruncininae.

Bronnimann and Brown (1956) recently elevated the subfamily Globotruncininae to family rank, and included within it 12 genera. They stated (p. 526) that: “No single morphologic character yet known to us is sufficient to separate all of these twelve genera from some other families of Foraminifera, such as the Globorotaliidae or the Globigerinidae.” Within the family they included genera with either apertural cover plates [tegilla], supplementary apertures on the ventral side, a surface ornamentation of discontinuous costellae, or a single- or double-keeled periphery. These characters, however, are of variable taxonomic value, and a more restricted definition of the family seems advisable. The classification used in the present work considers the apertural characters to be of the greatest family significance, and excludes from the Globotruncinoidae all genera which do not have an umbilical aperture and umbilical tegilla. The surface ornamentation (such as keels, nodes, and costellae) are variable characters within a genus and are of specific value only. The genera with supplementary apertures on the umbilical side are here placed in the Globorotaliidae, as they all have a visible primary extrastomial-umbilical aperture like that of Globorotalia.

Within their family Globotruncinoidae Bronnimann and Brown have thus placed the genera Hedbergina (a probable synonym of Praeglobotruncana), Praeglobotruncana, Ticinella and Thalmaninella (two synonyms of Rotalipora), and Rotalipora, all of which, because of the extrastomial position of the primary aperture, we place in the family Globorotaliidae. Globotruncana and Rugoglobigerina are considered by both classifications to belong to the Globotruncininae. In addition, Bronnimann and Brown placed within their family Globotruncininae as distinct genera Plummerita, Trinella and Kuglerina (all synonyms of Rugoglobigerina) and Rugotruncana and Bucharina (synonyms of Globotruncana).

Hoffker (1956, p. 313) placed in the “family Marginolamellidae” (a family name which he had proposed, but which is invalid as it is not based on the name of
a type genus, and which is preoccupied by the Globo-
truncanidae of Brotzen, 1942), the “new” subfamily
Globotruncanidae (which was proposed by Brotzen,
1942, and is not new with Hofker), which is comprised
of four genera, Thalmanninella Sigal, 1948, Rotalipora
Brotzen, 1942, Globotruncanina Cushman, 1927, and a new
genus, Marginotruncanina Hofker. Thalmanninella is
here shown to be a synonym of Rotalipora, which be-
longs to the family Globorotaliidae, and Marginotrunc-
cana, as based on the type species selected by Hofker,
is a true Globotruncanina (see below under the descrip-
tion of that genus), although Hofker also included other
unrelated species in his proposed genus, including
species of typical Praeglobotruncanina, Rotalipora, and
Abathomphalus.

A summary of the principal classifications is given below:

Galloway 1933

Orbulinidae Schultze, 1854
Globigerina d'Orbigny
Neocribrella Cushman
Globotruncanina Cushman
Pulleniatina Cushman
Candeina d'Orbigny
Hastigerina Thomson
Orbulina d'Orbigny

Pegididae Heron-Allen and Earland, 1928
Sphaeroidinellina Cushman

Rotaliidae Reuss, 1860
Globorotalia Cushman

Nonionidae Reuss, 1860
Hantkenina Cushman

Cushman 1948

Globigerinidae
Globigerininae
Globigerina d'Orbigny
Globigerinoides Cushman
Globigerinatellina Cushman and Stainforth
Globigerinelloides Cushman and ten Dam
Globigerinellina Cushman
Hastigerina Thomson
Hastigerinellina Cushman
Orbulininae
Orbulina d'Orbigny

Pulleniatiniinae
Pulleniatina Cushman
Sphaeroidinellina Cushman
Candeininae
Candeina d'Orbigny
Candorbultina Jedlitschka

Hantkeninidae
Schackolina Thalmann
Hantkenina Cushman
Cribrohantkenina Thalmann

Globorotaliidae
Globotruncanina Cushman
Globorotalia Cushman
Globorotalites Brotzen
Rotalipora Brotzen
Cribrotruncorotalia Cushman and Bermudez
Cyclooculina Heron-Allen and Earland
Scherbornina Chapman

Bermudez 1952

Rotaliidae
Valvulineriinae
Globorotalia Cushman
Globorotalites Brotzen
Turborotalia Cushman and Bermudez
Globoquadrina Finlay
Cribrotruncorotalia Cushman and Bermudez

Globotruncaninae
Praeglobotruncanina Bermudez
Thalmanninella Sigal
Globotruncanina Cushman
Truncorotalia Cushman and Bermudez

Cymbaloporidae
Rotalipora Brotzen

Nonionidae
Hantkenininae
Schackolina Thalmann
Hantkenina Cushman

Sphaeroidinella Bermudez

Applinella Thalmann
Aragonella Thalmann

Globigerinidae
Globigerininae
Globigerina d'Orbigny
Globigerinoides Cushman
Hastigerina Cushman
Hastigerinoides Bronnimann
Globigerinellina Cushman
Biglobigerinellina Lalicker
Trinitella Bronnimann
Hastigerina Thomson
Globigerinatheca Bronnimann
Globigerinelloides Cushman and ten Dam
Globigerinita Bronnimann
Globigerinita Bronnimann
Rugoglobigerina Bronnimann
Plummerita Bronnimann
Tichella Reiche

Globigerinatellina Cushman and Stainforth

Orbulininae
Orbulina
Pulleniatiniinae
Pulleniatina Cushman
Sphaeroidinellina Cushman
Candeininae
Candeina d'Orbigny

Hantkeninidae
Schackolina Thalmann
Hantkenina Cushman
Cribrohantkenina Thalmann

Globorotaliidae
Globotruncanina Cushman
Globorotalia Cushman
Globorotalites Brotzen
Rotalipora Brotzen
Cribrotruncorotalia Cushman and Bermudez
Cyclooculina Heron-Allen and Earland
Scherbornina Chapman

Bolli, Loeblich, and Tappan 1957

Hantkeninidae Cushman, 1927
Planomaliniinae Bolli, Loeblich and Tappan, new sub-
family
Globigerinelloides Cushman and ten Dam
Planomalina Loeblich and Tappan
Hastigerinoides Bronnimann
Biglobigerinellina Lalicker
Hantkenininae Cushman, 1927
Schackolina Thalmann
Hantkenina Cushman
Cribrohantkenina Thalmann

Hastigerininae Bolli, Loeblich, and Tappan, new sub-
family
Hastigerina Thomson
Clavigerinellina Bolli, Loeblich, and Tappan
Cassigerinellina Bolli, Loeblich, and Tappan, new sub-
family
Cassigerinellina Pokorny
Globorotaliidae Cushman, 1927
Praeglobotruncanae Bermudez
Rotalipora Broten
Globorotalia Cushman
Truncorotaloides Bronnimann and Bermudez
Globotruncanidae Broten, 1942
Abathomphalus Bolli, Loeblich, and Tappan
Rugoglobigerina Bronnimann
Globotruncanida Cushman
Orbulinidae Schultze, 1854
Globigerininae Carpenter, 1862
Globigerina d’Orbigny
Globoquadridina Finlay
Hastigerinella Cushman
Globigerinoides Cushman
Sphaeroidinella Cushman
Pulvinita Cushman
Orbulina d’Orbigny
Catapsydraeinae Bolli, Loeblich, and Tappan, new subfamily
Catapsydra Broten, Loeblich, and Tappan
Globigerinita Bronnimann
Globigerinoides Bronnimann
Globigerinatella Bronnimann
Globigerinatella Cushman and Stainforth

The families of planktonic genera have been separated by earlier classifications variously on the external form of the test, type of coiling, or a combination of characters of varied importance, including surface ornamentation; and the families have been considered to properly include genera of differing wall structure, apertural characters, etc. These bases for separation have obviously not proved entirely successful, as certain genera have been placed in one family after another by successive workers, while the family and subfamily limits have varied widely in the different classifications.

Furthermore, little attention has been paid in the past to the priority status of family and subfamily names. Under the Rules of Nomenclature the family and subfamily names are treated as equal for purposes of priority. For this reason, the oldest name used for either a family or subfamily, based on a genus placed within the family, must be used as the valid family name, and if the family is divided into subfamilies, the subfamily containing the type genus of the family must also bear the name based on that genus.

Bases for Classification

MORPHOLOGIC EVIDENCE: In the present classification the morphology of the test is used as the primary basis. The families under consideration here are all alike in possessing a calcareous, perforate-radial wall, hence all genera with perforate granular walls are excluded. Similarly, these radial-walled genera cannot be placed within families characterized by granular walls.

The apertural position is considered second in importance only to the wall composition and structure. It is always a constant character in the adult, and one of the few characters which does not change with environmental changes. It may change in size and position in the ontogeny of the individual, but these changes are always the same in each individual of the species. Thus, they are also extremely valuable in showing relationships, for the aperture in the young stage is like that of the ancestral form, and there may be intermediate ancestral characters also shown in the gradual development of the adult characters.

The type of chamber development, primarily the type of coiling, is third in systematic importance within these groups. Thus, the Orbulinidae, Globorotaliidae, and Globotruncanidae, all have a basic trochospiral coiling. Specialized genera may develop modifications, but trochospiral coiling is nonetheless present in their early ontogenetic stages. Similarly the Hastigerinidae have a basically planispiral development.

The characteristic modifications of apertures, changes from simple to multiple apertures, from open to covered, or from an interiomarginal to an areal position, are fourth in importance.

Modifications of the chambers and the resultant test form are fifth in importance. In the planktonic groups this is generally expressed in one of two ways, a tendency to develop a radially expanding test or a tendency to develop a globular test.

Last are the more detailed characters of size and relative proportions of test, chambers, and apertures and ornamentation.

EVIDENCE FROM ONTOGENY: The well known biologic theory that “Ontogeny recapitulates phylogeny,” has also been a basis used in the present classification.

Dissections of many of the species have shown that they pass through early stages that resemble other genera. For example, specimens of the genus *Globigerinoides* pass through an early *Globigerina*-like stage, then a *Globigerinoides* stage, and finally develop the adult characters peculiar to their own genus. This ontogenetic development shows the family relationship between these genera, although the adult characters of *Globigerinoides*, in particular the development of the secondary bullae over the apertural openings, are considered of sufficient taxonomic value to place this genus in a separate subfamily. Similarly the early trochospiral development and *Globigerina*-like umbilical aperture of the young stage of *Hastigerinella* suggest that it should be placed with *Globigerina* rather than with *Hastigerinoides*, which it resembles only in the pelagic adaptation of developing radial-elongate chambers. This latter character is obviously due to convergence, as a similar flattening or spreading in a plane is developed merely as an aid to flotation in many other groups of pelagic animals.

STRATIGRAPHIC DISTRIBUTION: In order to devise a logical classification, the geologic occurrence should also be considered. The ancestral forms should of course be those found earliest in the geologic record, although in some proposed classifications certain “ancestral types” were found only in relatively young strata.
Unfortunately, published records are not always reliable. Foraminifera have been recorded at times from misdated horizons, or in other instances from beach sands or Recent deposits which also include reworked fossil material. In other instances the too-wide limits set for genera and species suggest a much wider geologic range than is actually the case. Thus, in order to use stratigraphic occurrence as a tool in classification, many of these records have had to be critically re-examined.

The tabulation in text-figure 9 shows the stratigraphic ranges of the genera of planktonic Foraminifera as here defined. As can be seen, many of the genera are more restricted in geologic range than has hitherto been suspected. The actual placement of the various species is not attempted in the present paper, but will appear in later publications of this series.

Summary

In the present revision the following characters have been used for classification:

Family characters: The wall composition and structure, general chamber arrangement (i.e., type of coiling), basic position of primary aperture (in adult of simpler forms, in ontogeny of specialized forms).

Subfamily characters: Presence or absence of apertural modifications, modifications in chamber arrangement (i.e., changes in type of coiling) and presence or absence of chamber modifications.

Generic characters: Position, shape and character of aperture in the adult, presence or absence of chamber modifications, and general form and development of the test.

Specific characters: Size; relative proportions of test, chambers and aperture, etc.; and surface ornamentation.

The resultant classification here presented is similar to that of Cushman in recognizing the families Hantkeninidae, Globorotaliidae and Orbulinidae (which has priority over the name Globigerinidae). The main differences lie in the separation of Globotruncanina from the Globorotaliidae and Rugoglobigerina from the Globigerinidae into a separate family—the Globotruncanidae (which has been done by Bronnimann and Brown, 1956, although they also included various genera here placed in the Globorotaliidae); the recognition of three new subfamilies in the Hantkeninidae—the Planomalinae, Hastigerininae and Cassigerinellinae—the family being enlarged to include all planispiral planktonic genera with equatorial apertures and thus including some forms placed by Cushman and others in the Globigerinidae; the suppression of two subfamilies of the Orbulinidae—the Candeininae and Pullenia-tininae—their type genera being placed in other previously described subfamilies; and the naming of the new subfamily Catapsydracinae for the orbulinids with apertural covers.

Systematic Descriptions

Family Hantkeninidae Cushman, 1927

Type genus: Hantkenina Cushman, 1924.
Coiling of test trochospiral or planispiral or enrolled biserial; chambers spherical, ovate, elongate, clavate or tubulospinato; wall calcareous, perforate, radial in structure; primary aperture symmetrical and equatorial, paired or multiple, may have relict or areal secondary apertures.

Planomalinae Bolli, Loeblich, and Tappan, new subfamily

Type genus: Planomalina Loeblich and Tappan, 1946.
Coiling planispiral; chambers spherical, ovate, clavate or angular rhomboid; primary aperture equatorial or symmetrically paired, with umbilical portions of successive apertures remaining as relict secondary apertures.
Range: Cretaceous.

Genus Globigerinelloides Cushman and ten Dam, 1948

Plate 1, Figures 1a, b


Type species: Globigerinelloides algeriana Cushman and ten Dam, 1948. Fixed by original designation and monotypy.
Test free, planispiral, evolute to nearly involute, biumbilicate; early chambers subglobular, later chambers ovate and flaring out in a more evolute coil, with a flange extending on each side back to the previous whorl, somewhat curved backward at the umbilical margin; sutures distinct, depressed, radial in the early coil, later sigmoid; wall calcareous, finely perforate, radial in structure, surface smooth or roughened; aperture interiomarginal, an equatorial arch.
Remarks: Globigerinelloides resembles Hastigerina Thomson in being planispiral with an equatorial aperture, but in Globigerinelloides the later chambers have
Figure 9.—Tentative stratigraphic ranges of planktonic foraminiferal genera.

an umbilical extension on each side, connecting the chambers to the previous whorl. In addition, there is a peculiar curvature, almost sinuate, of the later chambers and sutures near the umbilicus, and a tendency toward an uncoiled later stage.

In a new species of Biglobigerinella, described later in the present paper, an ontogenetic sequence is shown from a form much like Globigerinelloides algeriana, to a stage with two small lateral apertures, and finally to a bichambered end stage. A careful study of material from the type horizon of Globigerinelloides could determine whether or not a similar development is present in that form. If so, Biglobigerinella Lalicker would become a synonym of Globigerinelloides, for the present generic name was published three months prior to Biglobigerinella. Until definite evidence is available both genera are provisionally recognized.

Types and occurrence: Cushman and ten Dam (1948, p. 42) recorded this genus from the Upper Cretaceous of Djebel Menaouer in western Algeria.
Glintzboeckel and Magné (1955, p. 154) have shown that Globigerinelloides algeriana occurs about 200 meters below an Aptian (Upper Gargasian) ammonite assemblage and it is regarded by them as a "good guide fossil for the Aptian of North Africa."

Figured paratype (Cushman Coll. 56790) from greenish blue marls of Aptian age, Djebel Menouer, between Relizane and Uzes-le-Duc, western Algeria. Collected by A. ten Dam.

Range: Aptian.

Globigerinelloides ten and marls the Aptian paratype it Aptian Uzes-le-Duc, of which is regarded (Upper Magn6 (Cushman of algeriana age, Gargasian) by them Coll. 56790) as a "good have from 200 meters assem-

Planomalina

Globigerinelloides

IX

1956, (1949, 154)

alina

Planomalinae.

Types and occurrence: Planomalina apsidostroba Loeblich and Tappan (Cushman Coll. 45667) from the Main Street formation, in a road cut on the south side of the Godley-Cleburne road, just uphill from the bridge across Nolan's River, 4.8 miles southeast of Godley, locality HTT-102, sample 418,

Globigerinelloides

Globigerinella

Globigerinoides

Globorotalia

Globoflora

Planomalina

Planomalinae


\footnote{After the present paper had been sent to press, the genus Biticinella Stolz, 1950, was described, with Anomalina brepentina Gandolfi as type species. Biticinella, superficially very similar to Planomalina, was defined as a "morphologic genus" related to the Tiriella-Thalassodina-Rotalipora group in being slightly asimet-

tical, and in having accessory intraumbilical apertures, at the posterior border of the chambers. In Planomalina the umbilical slits are at the forward margins of the chambers and are relict apertures, i.e., the exposed umbilical remnants of the primary aperture. Biticinella thus may be related to Rotalipora of the family Globorotaliidae. If the supplementary aperture in Biticinella should prove to be relict apertures, however, the genus Biticinella would probably become a synonym of Planomalina.}

Type species: Planomalina apsidostroba Loeblich and Tappan, 1946. Fixed by original designation and monotypy.

Test free, planispiral, biumbilicate, involute to partially evolute, lobulate in outline; chambers spherical to ovate to angular rhomboid; sutures radial, straight or curved, elevated or depressed; wall calcareous, finely perforate, radial in structure, surface smooth or ornamented with nodes and keel; aperture interiomarginal, an equatorial arch, with lateral extensions reaching back at either side to the septum at the base of the chamber, the lateral umbilical portions of successive apertures remaining open as supplementary relict apertures after the equatorial portion is covered by the succeeding chambers, these small relict slits and prominent bordering lips giving a characteristic appearance to the umbilical region.

Remarks: Originally believed to be related to Anomalina because of the relatively coarsely perforate, planispiral test, Planomalina is now shown to possess lateral relict apertures in addition to the primary interiomarginal equatorial aperture, which with the planispiral plan of growth suggests a relationship to such planktonic genera as Hastigerinoides. Another excellently preserved species here described, which lacks the surface ornamentation of the type species, shows even more clearly the relationship to this group. As Planomalina is the most primitive of those with relict apertures it is here made the type genus for the subfamily Planomalinae.

Planomalina differs from Biglobigerinella Lalicker in having extremely prominent relict apertures, and in having only a single primary aperture, whereas Biglo-
bigerinella develops a paired primary aperture, and may have paired final chambers as well. If differs from Globigerinelloides Cushman and ten Dam in lacking the sinuately umbilical chamber extensions, and in possessing relict apertures.

Types and occurrence: Planomalina apsidostroba Loeblich and Tappan (Cushman Coll. 45667) from the Main Street formation, in a road cut on the south side of the Godley-Cleburne road, just uphill from the bridge across Nolan's River, 4.8 miles southeast of Godley, locality HTT-102, sample 418,

Globigerinelloides

Globigerinella

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\footnote{After the present paper had been sent to press, the genus Biticinella Stolz, 1950, was described, with Anomalina brepentina Gandolfi as type species. Biticinella, superficially very similar to Planomalina, was defined as a "morphologic genus" related to the Tiriella-Thalassodina-Rotalipora group in being slightly asimet-

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Johnson County, Texas. Collected 1940 by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5394) from a 1-foot sample of grayish clay in the upper Paw Paw formation, 7½ feet below the contact with the overlying Main Street formation, on the south side of the road at the western edge of the Federal Narcotic Farm, southeast of Fort Worth, locality HTL–55, Tarrant County, Texas. Collected 1939 by H. T. and A. R. Loeblich, Jr.

Range: Aptian to Maestrichtian.

Planomalina caseyi Bolli, Loeblich, and Tappan, new species

PLATE 1, FIGURES 4a–5b

Test free, planispiral, biumblicate, involute to partially evolute, lobulate in outline; chambers spherical to ovate, 7 to 9 in the final whorl, early ones closely coiled, later ones with a tendency to become evolute in some specimens, sutures radial, gently curved, moderately depressed; wall calcareous, finely perforate, surface smooth; aperture interiomarginal, a broad low equatorial arch, with lateral extensions reaching back on the umbilical margin of the chamber to the septum at the base of the chamber, the lateral slitlike extensions bordered above by a distinctly upturned lip, the umbilical portions of the apertures of successive chambers remaining open as relict supplementary apertures beneath the lips after later chambers have covered the primary apertures.

Greatest diameter of holotype 0.31 mm., thickness 0.13 mm. Paratypes range in diameter from 0.18 to 0.39 mm.

Remarks: Planomalina caseyi, new species, differs from Planomalina apsidostroba Loeblich and Tappan in having more globular and inflated chambers, a smooth rather than carinate periphery and depressed rather than limbate, elevated and beaded sutures. Planomalina caseyi is a more primitive form, occurring in somewhat older beds, in the Duck Creek formation of Texas and Oklahoma (mid-Albian) and in the Gault (Albian) of England, whereas the more ornate P. apsidostroba is found in the Weno, Paw Paw, and Main Street formations (upper Albian) of Texas.

It differs from Biglobigerinella barri, new species, in being about one-half as large, in having fewer and more inflated chambers, in lacking the rugose periphery, and in always having a single primary peripheral aperture, with no development of paired apertures or paired chambers.

The specific name is in honor of Mr. Raymond Casey, Geological Survey of Great Britain, in recognition of his outstanding work on the Lower Cretaceous ammonites and pelecypods and on the stratigraphy of Great Britain.


Unfigured paratypes (USNM P5396) from 5½ feet of section, alternating gray sand and marly limestone, 58 feet above the base of the Duck Creek formation, and 6½ feet below the fusoid-bearing basal limestone of the Fort Worth formation, Lower Cretaceous, Albian, on the west bank of the Red River, in the SW\½ Sec.22,T.S–S–R.2E., on the southwest side of Horseshoe Bend, locality HTL–13, Love County, Oklahoma. Collected August 1939 by H. T. and A. R. Loeblich, Jr.

Unfigured paratypes (USNM P5395) from the top 6 feet exposed in the excavation for the Denison Dam, alternating thin limes and yellow brown clays of the Duck Creek formation, 45 feet above the base, north of Denison, Grayson County, Texas. This excavation at the site of the dam for Lake Texhoma is now covered and grassed over. Locality HTL–104, collected July, 1940 by H. T. and A. R. Loeblich, Jr., sample 462–463.

Genus Hastigerinoides Bronnimann, 1952

PLATE 1, FIGURES 6a–10b


Type species: Hastigerinella alexanderi Cushman, 1931. Fixed by original designation.

Test free, stellate in appearance, planispiral, biumblicate, periphery rounded; early chambers globular, later chambers elongate-radial, much produced and tapering or clavate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth, pitted or finely hispid; primary aperture interiomarginal, equatorial, a simple arch bordered above by a protruding lip, with relict secondary apertures around the umbilical region, representing the umbilical portion of previous apertures, which may remain open or be closed.

Remarks: Bronnimann (1952b, p. 53) stated: “The difference in the shape of the adult chambers is considered to justify the splitting of the genus Hastigerinella Cushman into Hastigerinella s.s., with club-shaped adult chambers, and Hastigerinoides n. subgen. with pointed adult chambers.”

Topotype specimens of Hastigerinella alexanderi Cushman show occasional club-shaped as well as pointed chambers on a single specimen. Therefore, the chamber shape alone cannot be considered, in this case, a valid separation for genera or subgenera. However, a more important generic character is the type of coiling. The type species of Hastigerinella, and therefore of the genus, strictly considered, is trochospiral in development, whereas in Hastigerinoides the coiling is planispiral. The aperture of Hastigerinella is broad and extraulmibical-umbilical, in the later stages extending farther towards the periphery and even onto the spiral side, but is not a typical equatorial aperture as is the primary aperture of Hastigerinoides. The relict secondary apertures also are found only in the latter genus. These differences in coiling and apertural characters are considered a valid basis for elevating Hastigerinoides to generic rank.
TYPES AND OCCURRENCE: Holotype of Hastigerinella alexanderi Cushman (type of Hastigerinoides) (Cushman Coll. 15750), figured paratype (Cushman Coll. 15754), figured topotypes (USNM P3920a, b), unfigured topotypes (USNM P3933), and unfigured paratypes (Cushman Coll. 15754a), all from the Austin chalk, clay in road cut between two railroad underpasses (now removed) at the northern edge of Howe, Grayson County, Texas. Holotype and paratypes collected by C. I. Alexander; topotypes collected by A. R. Loeblich, Jr.

Figured topotype of Hastigerinoides watersi (Cushman) (USNM P3934) also from the Austin chalk at the same locality, collected by A. R. Loeblich, Jr.

Range: Aptian to Santonian.

Genus Biglobigerinella Lalicker, 1948

Plate 1, Figures 11–12b


Type Species: Biglobigerinella multispina Lalicker, 1948. Fixed by original designation and monotypy.

Test free, planispiral, nearly or completely involute, umbilicate, periphery rounded, peripheral margin lobulate; chambers globular, except for the final one or two which may become broadly ovate, flattened and finally replaced by two paired chambers, one on each side of the plane of coiling, in some species there is a tendency for the chambers of the final whorl to flare out in a less involute coil, with a flange extending back on each side toward the previous whorl, and curving backward at the umbilical margin, as in Globigerinelloides; sutures distinct, depressed, radial to curved or even sigmoid; wall calcareous, finely perforate, radial in structure, surface finely hispid to smooth or pitted; aperture an interiomarginal, equatorial, simple low arch in the early stages, in the later paired chambers there is one extrumbilical aperture in each chamber of the final pair.

Remarks: Biglobigerinella differs from Hastigerina Thomson in the presence of the final paired chambers and double aperture, although it is similar in being planispiral and more or less completely involute.

Types and Occurrence: Holotype of Biglobigerinella multispina Lalicker (Cushman Coll. 51898), figured paratypes (Cushman Coll. 51899 and 51900), unfigured paratypes (Cushman Coll. 51897) from the Marlbrook marl (Campanian), 8 feet above the base, 1½ mile north of Saratoga, Howard County, Ark.

Figured hypotype (USNM P3214a) and unfigured hypotypes (USNM P3214) from the upper Taylor marl (Campanian) on the right bank of Onion Creek, just downstream from the bridge at Moore and Berry's crossing, 8½ miles in a straight line southeast of the Capitol in Austin, Travis County, Texas. Collected by H. T. and A. R. Loeblich, Jr.

Unfigured hypotype (USNM P3215) from the Navarro (Corsicana marl), Maestrichtian, exposed in a steep 80-foot slope on the right bank of Onion Creek just east of the bridge (known as Jones' Crossing) on the Austin-Bastrop highway, Travis County, Texas. Collected by A. R. Loeblich, Jr.

Range: Aptian to Maestrichtian.

Biglobigerinella barri Bolli, Loeblich, and Tappan, new species

Plate 1, Figures 13–18b

Test free, planispiral, umbilicate, nearly involute to evolute; peripheral margin somewhat lobulate; chambers ovate to nearly spherical, 8 to 10 in the final planispiral whorl, in some specimens a smaller low but broad final chamber may cover a double apertured penultimate chamber or there may be a small chamber at each side of the periphery, each covering one of the lateral apertures of the penultimate chamber; sutures distinct, depressed, radial in the early portion, becoming sigmoid in the later stages; wall calcareous, finely perforate, surface distinctly rugose in the early portion, later chambers nearly smooth or pitted; aperture interio-marginal, in the early stage equatorial, a low arch bordered above with a narrow lip, in the later stage there is a double aperture consisting of a small extrumbilical arch at each side of the last chamber, or one to each of the final paired chambers which may extend almost into the umbilicus, each aperture bordered by a lip.

Greatest diameter of holotype 0.49 mm., thickness across paired chambers 0.36 mm. Paratypes range from 0.39 to 0.62 mm. in diameter.

Remarks: Biglobigerinella barri, new species, differs from B. multispina Lalicker in being larger and more compressed and in having 8 to 10 chambers per whorl instead of only 5 to 6. The chambers are also more nearly globular in B. multispina.

The shape and number of the chambers is also similar to Globigerinelloides algeriana Cushman and ten Dam, from which the present species differs only in developing a double aperture and finally the double-chambered end stage. This species strongly suggests that Biglobigerinella may have arisen from the Aptian genus Globigerinelloides.

The specific name is given in honor of Dr. K. W. Barr, in recognition of his work on the geology of Trinidad.

Types and Occurrence: Holotype (USNM P4543), figured paratypes (USNM P4544a–e) and unfigured paratypes (USNM P4545) from the Lower Cretaceous (Aptian) Maridale formation, Maridale Estate, east Central Range, Trinidad, B. W. I. Collected by H. H. Renz.

Subfamily Hantkenininae Cushman, 1927

Type Genus: Hantkenina Cushman, 1924.

Coiling of test trochisporal to planispiral; chambers globular, elongate to tubulospinate; aperture equatorial or areal multiple.

Range: Cretaceous to Eocene.
Genus Schackoina Thalmann, 1932

**Plate 2, Figures 1a–2**


**Type species**: _Siderolina cenomana_ Schacko, 1896. Fixed by original designation.

Test free, early portion may be more or less trochospiral, later becoming nearly planispiral; chambers radially elongate with one or more elongate, tapering hollow tubulospines extending outward from the midline of each chamber on the periphery; sutures straight, radial, depressed; wall calcareous, finely perforate, surface smooth or very finely hispid; primary aperture an interiomarginal arch, extramarginal and tending to become equatorial, may be bordered above by a narrow lip.

**Remarks**: _Schackoina_ differs from _Hantkenina_ Cushman in being trochospiral and in having a simple interiomarginal arched aperture, whereas _Hantkenina_ has a triradiate aperture with a high slit extending up the face of the final chamber.

It differs from _Hastigerinoides_ Bronnmann in being trochospiral and in having the tubulospines distinctly separated from the main chamber cavity.

**Types and occurrence**: Figured hypotypes (USNM P4644a, b) and unfigured hypotypes (USNM P4563) of _Schackoina cenomana_ (Schacko) from the Cenomanian _Sclerobachia varians_ zone; unfigured hypotypes (USNM P4562) from the Cenomanian _Inoceramus crippsei_ zone; all from Ziegzelei Zeltberg, at Luneburg, southeast of Hamburg, Province Niedersachsen, Germany. Collected by H. T. and A. R. Loeblich, Jr.

**Range**: Aptian to Maestrichtian.

Genus Hantkenina Cushman, 1924

**Plate 2, Figures 3a–8b**


_Hantkenellina_ Bronnmann, Journ. Paleontol., vol. 24, No. 4, p. 399, 1950. (Type species: _Hantkenella abalabemis_ Cushman var. _principalis_ Cushman and Jarvis, 1929. Fixed by original designation and monotypy.)

**Type species**: _Hantkenella abalabemis_ Cushman, 1924. Fixed by original designation.

Test free, planispiral, involute, biconvex, biumbilicate; chambers rounded, ovate or radial elongate, generally with a single relatively long and heavy spine at the forward margin of each chamber on the periphery, although they may rarely be lacking on one or more chambers, spines in the plane of coiling; sutures depressed, radial; wall calcareous, finely perforate, radial in structure, surface finely hispid, especially in the area just beneath the aperture on the previous whorl; primary aperture interiomarginal, equatorial, triradiate, two of the “rays” forming a slit across the base of the final chamber face, the third ray arising from the center of this slit and extending up the face toward the peripheral spine, flaring slightly to become rounded at its upper end, the vertical slit bordered laterally by apertural flanges which join above as a narrow lip.

**Remarks**: In the original description of _Hantkenina_, Cushman stated (1924, p. 1) that it included _Siderolina_ of Hantken (not Defrance), and “while they should probably be referred to the Rotaliidae are very different from _Siderolites_ or _Calcarina_.” In his classification (1927, p. 64) Cushman placed it in a separate family, the Hantkeninidae; he included with it _Mimosina_ Millett and _Trimosina_ Cushman, and stated (p. 65), “the family is related to the Heterohelicidae.”

In later publications (1933, p. 267) _Mimosina_ and _Trimosina_ were placed by Cushman in the Buliminidae and _Schackoina_ Thalmann was placed with _Hantkenina_. Galloway (1933, p. 266) placed _Hantkenina_ in the Nonionidae, stating (p. 264) that it “evolved from _Nonion_ by developing a long spine on each chamber.”

Bermudez defined _Sporohantkenina_ in 1937, but the type species selected is congeneric with _Hantkenina_. Thalmann (1942) defined three new subgenera of _Hantkenina_: _Cribrohantkenina_, which included Bermudez’s forms (but not the _Hantkenina brevispina_ of Cushman), _Aragonella_, and _Applinella_.

Cushman’s test (1948) did not mention the latter two subgenera, although he raised _Cribrohantkenina_ to generic status and stated (p. 328), “Further studies of these forms seem to show that they were derived from the Globigerinidae and were probably pelagic, at least during part of their life history.”

Glaessner (1948, p. 149) placed the subfamily _Hantkenininae_ in the family _Globigerinidae_, and Sigal (1952, p. 235) recognized it as a separate family. Bermudez (1952, p. 108) placed _Hantkenina_ and the three subgenera mentioned above in the _Hantkeninidae_, family _Nonionidae_, apparently following Galloway’s earlier suggestion.

Wood (1949, p. 250) showed that _Hantkenina_ is perforate radial in wall structure (like the _Globigerinidae_ and _Heterohelicidae_), whereas the _Nonionidae_ were perforate granular (exclusive of the _Elphidiidae_, which Cushman placed in the _Nonionidae_). Therefore, _Hantkenina_ and its allies cannot be related to the _Nonionidae_, and the planispiral development of the two families is merely convergence. It is more probable that this group arose from the _Planomalintiidae_ or the early _Globorotaliidae_, for _Schackoina_, developing in the Cretaceous, was trochospiral. The entire family _Hantkeninidae_ may have been derived from an ancestor such as _Pragoglobotruncana_ of the _Globorotaliidae_, since many lines of evolution point to a development of planispiral forms from the trochospiral, rather than the converse.
Barnard (1954, p. 384) made a study of the apertural characters of specimens of Hantkenina from the Jackson Eocene of Cocoa Post Office, Alabama, showing the ontogenetic development of the multiple aperture of the subgenus Cribrohankeiina. He concluded (p. 389): "The sub-genera are arbitrary divisions, and in the opinion of the author the use of them should be discouraged."

We have examined large suites of specimens of many species of Hantkenina from many areas and have found none that show a gradation from the simple triradial aperture of Hantkenina to the multiple aperture of Cribrohankeiina. Furthermore, in our suite of specimens from the area of the Cocoa Post Office the typical H. alabamensis is much flatter; the sutures are moderately depressed, straight, and radial; and the periphery is entire. The associated "Cribrohankeiina bermudensi" always has more inflated chambers and a lobulate periphery, very deeply constricted sutures; and the rounded openings of the multiple aperture are found even on quite small specimens. We believe, therefore, that Barnard was dealing with more than one species but that all the specimens he used to show a developmental series of apertures belong to Cribrohankeiina and do not show a gradation between this genus and Hantkenina.

There are other species of the Hantkenininae also present at this locality, and Hantkenina brevispina Cushman resembles Cribrohankeiina bermudensi in possessing much inflated chambers, but does not develop a multiple aperture. Possibly specimens of this species of true Hantkenina may have been considered as transitional forms by Barnard.

Typical Hantkenina is found from the middle to upper Eocene, but Cribrohankeiina occurs only in the upper Eocene. We therefore consider these two as distinct genera on the basis of different apertural characters and different geologic ranges, although Cribrohankeiina undoubtedly developed from Hantkenina.

However, the subgenera Aragonella Thalmann, Applinella Thalmann, and Hantkeninella Bronnimann are much less distinctive, for a single species may show considerable variation in the chamber shape, and in the length of the spines and their apparent relative position. Applinella was defined as differing from typical Hantkenina in having the spines at the anterior portion of the chambers, whereas those of Hantkenina were nearly sutured in position. A glance at the final chamber of each species shows that the spines are in almost exactly similar positions, at the dorsal angle of the chamber. The different appearance in earlier chambers depends entirely on the amount of overlap by the following chamber. When the wall of the final chamber is attached just at the spine base of the previous chamber, the spine appears sutured in position. When the wall of the final chamber is more restricted, the preceding spine appears to be on the anterior portion of the penultimate chamber. Also, the wall of the final chamber may partially or wholly envelop the spine of the preceding chamber, so that it may appear spineless, or the spine may even seem to be protruding from the posterior portion of the final chamber. This character varies considerably in a species and may show some variation even on a single specimen. On the specimens we have of H. alabamensis (topotype), H. alabamensis primitiva (holotype), and H. (Applinella) dumblei (lectotype), the early chambers show the spines on the anterior portion of the chambers and not touching the following sutures, whereas the later chambers show a stronger overlap and the spines "appear" sutural. The final chamber is broken from the lectotype of H. dumblei, but the remnants of this final chamber show an attachment partially enveloping the base of the spine of the penultimate chamber. Therefore, the basis for separation of Applinella seems to be too variable in all these "subgenera" to be of value, and we consider Applinella a synonym of Hantkenina.

Hantkeninella was separated, as including only H. alabamensis var. primitiva, whose early chambers lack spines. Bronnimann (1950a, p. 417), in describing the subgenus, stated, "At present it is the only known Hantkenina with a spineless early stage and, therefore, it cannot be referred to any of the existing subgenera."

The development of spines is not an invariable character in this group, however. We have large suites of H. alabamensis including many specimens with non-spinose early chambers. We also have some with early chambers bearing spines and an occasional adult chamber lacking any spine. Rare specimens also occur with two or even three spines on a single chamber, both in H. alabamensis and in other species. Some specimens which are typical H. brevispina in all other characters lack spines on early chambers. In general, the young forms of all species show shorter and less well developed spines and, because of the amount of variation in this feature, we do not consider their absence on early chambers to be a diagnostic generic character. Therefore, Hantkeninella is considered synonymous with Hantkenina.

Hantkenina differs from Schackoina Thalmann in being planispiral, and in having a tripartite aperture, with an elongate slit extending up the apertural face, whereas Schackoina has a very low arched aperture.

Cribrohankeiina Thalmann differs in having multiple areal apertures instead of a triradial, interiomarginal equatorial aperture bordered by lateral flanges.

Types and Occurrence: Figured hypotype of Hantkenina alabamensis Cushman (USNM P4791) from the Pachuta formation, Jackson Eocene, Cushman's "Cocoa sand," 1 mile southwest of the old Cocoa Post Office, Choctaw County, Alabama. Collected by C. G. Lalicker. Figured hypotype of H. alabamensis Cushman (USNM P4786) from the Pachuta formation, 2.2 miles south of Melvin, Choctaw County, Alabama.

Holotype of Hantkenina alabamensis primitiva Cushman and Jarvis (Cushman Coll. 10067) from the Eocene Mount Moriah beds, from bed of yellow sandy clay directly underlying orbitoidal limestone of Vistabella quarry, Trinidad, B. W. I. Collected by P. W. Jarvis.
Lectotype of *Hantkenina dumbeii* Weinzierl and Applin (Cushman Coll. No. 12204) and figured paratype (USNM P4790) from the Eocene Yegua formation, Rio Bravo Oil Co., Deussen B 1, 4010 feet, South Liberty Dome, Liberty County, Texas.

Lectotype of *Hantkenina mexicana* var. *aragonesis* Nuttall (Cushman Coll. No. 59476) from the Eocene Aragon formation, 2600 meters N. 73° E. of El Tule, México, and figured paratype (Cushman Coll. No. 59477) from the Aragon formation, 1200 meters N. 48° W. of La Antigua Crossing, México.

**Range:** Eocene.

**Genus** Cribrohantkenina Thalmann, 1942

**Plate 2, Figures** 9a–11b


**Type species:** *Hantkenina* (Cribrohantkenina) *bermudezi* Thalmann, 1942. Fixed by original designation.

Test free, planispiral, biumbilicate; chambers subglobular, with the prominent peripheral spine at the foreward margin of each chamber, succeeding chambers are attached near the base of the spines and may partially or completely envelop the spine of the preceding chamber; sutures distinct, depressed, radial; wall calcareous, perforate, surface smooth, finely punctate, or finely spinose; primary aperture interiomarginal, equatorial, secondary multiple areal aperture consisting of small rounded or elongate openings above the primary interiomarginal aperture, in well developed specimens the terminal portion of the chamber may form a protruding "pore-plate," which lacks fine perforations in the area between the apertural pores, and may cover the primary interiomarginal aperture and attach to the peripheral margin of the previous whorl, the primary interiomarginal aperture and secondary areal apertures commonly bordered by distinct and protruding lips, and the multiple secondary openings may rarely be filled with a later-formed shell growth.

**Remarks:** Cribrohantkenina differs from Hantkenina Cushman in having the secondary multiple areal aperture in the region between the final spine and the primary interiomarginal aperture.

*Sporohantkenina* was defined by Bermudez (1937, p. 151) as a subgenus of *Hantkenina*, with *Hantkenina brevispina* Cushman, 1925, cited as type species. Thalmann in 1942 stated that the type species was a true *Hantkenina*, making *Sporohantkenina* a synonym of *Hantkenina*, s. s. He therefore proposed the name Cribrohantkenina for the species with a multiple aperture, and cited as type species Cribrohantkenina bermudezi Thalmann, new name for *Hantkenina brevispina* Bermudez, 1937, not *Hantkenina brevispina* Cushman, 1925. Later authors followed Thalmann (Cushman, 1948, p. 329; Glaessner, 1948, p. 149; Sigal, 1952a, p. 236, although he incorrectly indicated the illustrated species as Cribrohantkenina brevispina (Cushman); Le Calvez, 1953, p. 251; and Barnard 1954, p. 384) in recognizing the validity of Cribrohantkenina. However, Bermudez (1952, p. 109) again used the name Sporohantkenina, this time citing as type species "*Hantkenina* (Sporohantkenina) brevispina Cushman," Bermudez (not *Hantkenina brevispina* Cushman 1925, 1937," and added that the species was renamed by Thalmann as *Hantkenina* (Cribrohantkenina) bermudezi Thalmann, but probably was conspecific with *Hantkenina danvillei* Howe and Wallace, 1934.

Bermudez cited certain Rules of Nomenclature to substantiate the validity of his generic name, namely Art. 30, I, and Opinion 65. These state in part (Art. 30, Ia): "When in the original publication of a genus, one of the species is definitely designated as type, this species shall be accepted as type regardless of any other consideration"; and (Art. 30, Ic) "A genus proposed with a single original species takes that species as its type." Opinion 65 states: "If an author designates a certain species as genotype, it is to be assumed that his determination of the species is correct; if a case presents itself in which it appears that an author has based his genus upon certain definite specimens, rather than upon a species, it would be well to submit the case, with full details, to the Commission."

Bermudez then quoted a personal communication from Doctor de Rivero, of Venezuela, who stated that she believed the original publication to indicate the Cuban specimens as the type, and therefore would uphold *Sporohantkenina*. However, in the original publication Bermudez stated that he had been given specimens of *H. brevispina* by Cushman, from the Mexican Eocene, and that he had a "good collection of specimens of *Hantkenina brevispina* Cushman" from Mexico, from the R. Wright Barker collection, given to him by Mrs. Dorothy K. Palmer. He then stated that in a collection of Cuban Eocene material, also obtained from Mrs. Palmer, were "abundantes ejemplares de *Hantkenina brevispina* Cushman." His description was therefore not based solely on the Cuban specimens. His discussion of the aperture was followed by the statement (translation), "The apertural character described above is very constant and of use in determining the species, as it has been observed only in *Hantkenina brevispina* . . ."; he therefore proposed the new subgenus. Bermudez thus definitely cited *Hantkenina brevispina* Cushman as type in the original publication with no question as to the identification of the Cuban specimens, and according to Art. 30, Ic, that was not only original designation, but also designation by monotypy.

The Copenhagen decisions on Zoological Nomenclature clarify some of the earlier rules, and a pertinent quotation is here given concerning Art. 30(c). In these decisions (1953, p. 70) it was stated that a genus would be considered as published "with only one included species . . . where more than one nominal species is so cited by the author of the generic name, but only one of these nominal species possesses a specific name validly published with an indication . . ." Thus, *Hantkenina brevispina* Cushman would be considered as designated by monotypy as it was the only valid
specific name cited, even if two species were erroneously included, as no other named species was available.

The only possibility of a new type being later designated would arise in a case where the type species had been definitely cited in the original publication as not conspecific with Cushman's species. This possible recourse was stated in the above-cited Copenhagen decisions (p. 68) to be limited to cases "... where an author ... designates as the type species a nominal species previously established by some author, and in doing so, makes it clear that he is applying that specific name, not to the species to which that name was applied by its original author, but to some species to which that name had been applied by some later author." This was the case in the erection of the name Cribro-
hantkenina by Thalmann, who definitely stated that Bermudez's specimens were the type for the proposed new generic and specific names, and that these were not conspecific with Cushman's original types. It was not the case in the original publication of Bermudez, as there was no question, stated or implied, as to the belief of the author in the validity of the specific determination. On the contrary, the references to the many specimens of true H. brevispina available to him substantiate the assumption that he considered the Cuban specimens correctly identified, and the type species to be Cushman's species. Thus, Hankenina brevispina Cushman is the type species of Sporohant-
kenina by original designation and monotypy, and Thalmann was correct in suppressing the generic name as a synonym of Hankenina, s.s.

Although originally described as a subgenus of Hankenina, Cribrohan
tkenina was later elevated to generic rank (Cushman, 1948, p. 328). Barnard (1954, p. 384) showed the ontogenetic development of the aperture in Cribrohan
tkenina, although he considered it gradational with Hankenina. It seems probable that he was dealing with more than one species, how-
ever, as in the many large suites of specimens we have studied, there seems to be a sharp boundary between the two. We consider both as distinct genera.

Types and occurrence: Figured hypotypes (USNM P4784a-c) and unfigured hypotypes (USNM P4785) of Cribrohan
tkenina bermudezi Thalmann from the Jackson Eocene, Pachuta formation, Cushman's "Cocoa sand," 2.2 miles south of Melvin, Choctaw County, Aabam.

Range: Upper Eocene.

Genus Hastigerina Thomson, 1876

Plate 3, Figures 1-4b


Type species: Hastigerina murrayi Thomson, 1876. Fixed by monotypy.

Test free, early stage may be slightly trochospiral, the adult planispiral, ranging from involute to loosely coiled, biumbilicate, periphery broadly rounded; chambers spherical to ovate; sutures deeply depressed, radial; wall finely to coarsely perforate, radial in structure, surface smooth, hispid, or spinose; aperture interiorimal-
ginal, a broad equatorial arch.

Remarks: Brady described the type species of the genus as Hastigerina pelagica (d'Orbigny) [=Nonionina pelagica d'Orbigny, 1839], placing Hastigerina murrayi Thomson in synonymy. D'Orbigny's original illustrations are similar, but no mention is made of an aperture, nor is one shown on the drawing. Furthermore, d'Orbigny's figures are of a specimen about one-third the size of H. murrayi. As the aperture is so large and characteristic in H. murrayi, we consider the two to be distinct and the valid name for the type species to be Hastigerina murrayi Thomson, 1876.

The great similarity of Hastigerina and Globigerinella Cushman is evident, and was in fact noted by Brady (1884, p. 614), who stated that the only species with which Hastigerina pelagica (=H. murrayi) "is likely to be confused is Globigerina aequilateralis," and it later became the type species of Globigerinella. He added that the latter was evolute. In the original de-
scription of Globigerinella, no comparisons were given by Cushman as to how the two genera could be differentiated. In later texts a discussion was given of the relative coarseness of spines but no statement as to how the two genera could otherwise be separated. The type of ornamentation is variable in planktonic genera, and the type species of both Hastigerina and Globigerinella range from nearly involute to somewhat evolute. This is therefore not regarded as a sufficient basis for generic separation and Globigerinella is considered a junior synonym of Hastigerina.

Mesozoic species referred to Globigerinella upon close examination will be seen to belong either to Plano
talina Loeblich and Tappan, Biglobigerinella Lalicker, or to Globigerinelloides Cushman and ten Dam.

Types and occurrence: Figured hypotypes of Hastigerina murrayi Thomson are the specimens figured and described by Brady as Hastigerina pelagica (d’Orbigny). The dead shell here figured (BMNH ZF 1563) from dredging at 1,990 fathoms, Challenger Station 338, in the South Atlantic, lat. 21° 15’ S., long. 14° 02’ W. Hypotypes (BMNH ZF 1562) mounted in balsam, were living specimens taken by tow net of the Challenger, but the exact locality is not given. The side view of
the balsam-mounted specimen is of the same figured by Brady, but the apertural view in balsam is of a different specimen on the same slide and not that figured by Brady in this orientation.

Original types of Globigerinella aequivalateralis (Brady) in the British Museum (Natural History), London. Figured topotype (USNM P3918) and unfigured topotypes (USNM P3211) from the Recent at Challenger Station 224, lat. 7° 45' N., long. 144° 20' E., at 1,850 fathoms. Collected March 21, 1875.

Range: Middle Eocene to Recent.

Clavigerinella Bolli, Loeblich, and Tappan, new genus

Type species: Clavigerinella akersi, new species. (Derivation: Claviger, L., club-bearing + ina + ella, L. diminutives; gender, feminine.)

Test free, planispiral, biumbilicate, involute, radially lobulate in outline; chambers spherical in the early stages, later becoming radially elongate or clavate; sutures radial, depressed; wall calcareous, finely perforate, radial in structure, surface finely pitted; aperture interiomarginal, equatorial, an elongate slit extending up the apertural face, bordered laterally by wide flanges which narrow toward the upper extremity of the aperture, where they join to form a small lip.

Remarks: Clavigerinella, new genus, resembles Hastigerinella Cushman in having early globular chambers followed by later radial elongate and clavate chambers. It differs in being planispiral instead of trochispiral, and in having the distinctive equatorial aperture elongated in the plane of coiling and bordered laterally by flanges. The aperture is reminiscent of that in Hanthkenina aragonensis Nuttall, but the present genus does not have tubulospines, and Hanthkenina may only have radially elongate chambers which never become clavate.

Clavigerinella, new genus, differs from Hastigerinoides Bronnimann in having the distinctly elongate slitlike equatorial aperture and wide bordering flanges and in lacking, around the umbilical region, the secondary relict apertures which are the persistent lateral margins of the earlier equatorial primary apertures. As a rule, the chambers of Hastigerinoides are tapering and those of Clavigerinella are club-shaped.

Range: Middle to Upper Eocene.

Clavigerinella akersi Bolli, Loeblich, and Tappan, new species

Plate 3, Figures 6a-c

Test free, planispiral, biumbilicate, involute, lobulate in outline; early chambers spherical, later chambers radial elongate and typically much inflated at the extremity, with four chambers in the final whorl; sutures radial, distinct and depressed; wall calcareous, distinctly perforate, surface finely pitted; aperture interiomarginal, equatorial, an elongate slit extending up the apertural face for about half the length of the final chamber, aperture bordered laterally by wide flanges which are flared at the base and become progressively narrower toward the upper extremity of the aperture, joining at the top to form a narrow lip, a short distance below the bulbous or clavate extreme of the chamber.

Greatest diameter of holotype 0.86 mm., greatest thickness 0.23 mm. Paratypes range from 0.49 to 0.73 mm. in greatest diameter.

Remarks: This species differs from Hastigerinella eocanica Nuttall var. aragonensis Nuttall from the Eocene of Mexico, in having the terminally clavate chambers, with their nearly spherical inflations, and in having only four chambers per whorl. The Mexican species has narrower, more elongate cylindrical chambers and may have four or five chambers per whorl, but also belongs to the present genus.

The species is named in honor of W. H. Akers, paleontologist with The California Company, in recognition of his work on the planktonic Foraminifera of the Gulf Coast.

Types and occurrence: Holotype (USNM P4550) and unfigured paratypes (USNM P4551) from the Eocene Navet formation, equivalent in age to the Friendship Quarry marl and Dunmore Hill marl (middle Eocene) in Spring Branch of the Navet River, 1,100 feet south of the 12.5 milepost of the Brasso-Tamana Road, Central Range, Trinidad, B. W. I. Collected by Dr. Hans Kugler, sample K.8820.

Cassigerinellinae Bolli, Loeblich, and Tappan, new subfamily

Type genus: Cassigerinella Pokorný, 1955.

Coiling of test planispiral in the early stage, becoming enrolled biserial in the later stage; chambers spherical to ovate; primary aperture equatorial in neanic stage, extrabulbical and alternating in the adult.

Range: Oligocene to Miocene.

Genus Cassigerinella Pokorný, 1955

Plate 3, Figures 6a-c


Type species: Cassigerinella boudecensis Pokorný, 1955. Fixed by original designation.

Test free, robust, early portion planispiral and similar to Hastigerina, later with biserially arranged chambers continuing to spiral in the same plane, biumbilicate, periphery broadly rounded; chambers globular to ovate and only a few pairs arranged as in Cassidulina to each whorl of the test; sutures distinct, depressed, radial to curved; wall calcareous, perforate, radial in structure, surface smooth to pitted; aperture interiomarginal, an extrabulbical arch alternating in position from one side to the next in successive chambers.

Remarks: Cassigerinella differs from Hastigerina Thomson in having the adult spire composed of biserially arranged chambers. Biglobigerinella Lalicker
is similar in early planispiral development but has only a single pair of "biserial" chambers, which are opposing, however, rather than alternating, and each of which has a distinct aperture. It differs from Cassidulina d'Orbigny in having a perforate radial wall structure rather than granular and in having an early planispiral stage.

**Types and occurrence:** Figured topotype (USNM P3389) and unfigured topotypes (USNM P3056) from the Middle Oligocene, Boudky near Velké Němčice, Moravia, Czechoslovakia. Collected by Dr. Vladimír Pokorný.

**Range:** Oligocene to Miocene.

**Family Orbulinidae Schultze, 1854**

**Type genus:** Orbula d'Orbigny, 1839.

Test trochospirally or streptospirally coiled or globular; chambers spherical, ovate or clavate; wall calcareous, perforate, radial in structure; primary aperture umbilical or spiroumbilical, may have secondary sutural or areal apertures and may have bullae and accessory infralaminar apertures.

Subfamily Globigerininae Carpenter, 1862

**Type genus:** Globigerina d'Orbigny, 1826.

Coiling of test trochospiral to streptospiral; chambers spherical, ovate or clavate; primary aperture umbilical or spiroumbilical, may have secondary sutural apertures.

**Range:** Cretaceous to Recent.

Genus Globigerina d'Orbigny, 1826

**Plate 4, Figures 1a-c**


**Type species:** Globigerina bulloides d'Orbigny, 1826. Fixed by subsequent designation of Parker, Jones and Brady (1865, p. 36).

Test free, trochospiral, chambers spherical to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface may be smooth, pitted, cancellated, hispid or spinose; aperture interiomarginal, umbilical, with a tendency in some species to extend to a slightly extrumbilical position, and previous apertures remaining open into the umbilicus.

**Remarks:** Formerly considered a more inclusive genus, Globigerina is now restricted to include only those trochospiral species with a single large open umbilical aperture.

In Globigerina the aperture is interiomarginal and primarily umbilical, leading from each chamber into the open umbilicus, and the chambers are always globular to subglobular. Globorotalia has an interiomarginal, extrumbilical-umbilical aperture, and the chambers vary from ovate or subhemispherical to strongly compressed or angular, commonly have a peripheral keel but rarely are truly spherical. Praeglobotruncana has an extrumbilical-umbilical aperture like that of Globorotalia, but commonly with spherical or only slightly compressed chambers.

All classifications are somewhat artificial and there are some species with globular chambers whose apertural position is transitional, so that in some instances it may be somewhat difficult to decide whether such a species should be placed in Globigerina or Globorotalia.

**Types and occurrence:** This genus, like the majority of planktonic forms, has a wide geographic occurrence. The hypotype of *G. bulloides* d'Orbigny here figured (USNM P3917) is from Recent beach sand at Marina di Ravenna (Porto Corsini), Italy. Collected by H. T. and A. R. Loeblich, Jr., March 15, 1954. The original type locality of d'Orbigny was at Rimini, approximately 60 kilometers farther south on the Italian coast.

**Range:** Cretaceous to Recent.

There is a continuous geologic record of Globigerina from the Paleocene to Recent and, in addition, species are found from the Hauterivian to Coniacian in the Lower and Middle Cretaceous which appear to be morphologically identical. The gap in the geologic record from the Coniacian to Paleocene strongly suggests that this genus as here recognized is polyphyletic, and the Tertiary species are not direct descendants from those of the Lower Cretaceous. The absence of any distinguishing morphologic characters prevents their separation, with the material and methods thus far available, into two nominal genera.

Genus Globocassidulina Finlay, 1947

**Plate 5, Figures 4a-6**


**Type species:** Globorotalia dehiscens Chapman, Parr and Collins, 1934. Fixed by original designation.

Test free, trochospiral, umbilicate, periphery rounded to truncate; chambers spherical to subangular truncate; wall calcareous, perforate, radial in structure, surface pitted to hispid; aperture interiomarginal, umbilical, covered above by an apertural flap which may vary from a narrow rim to an elongate toothlike projection, and in openly umbilicate forms earlier apertures remain open into the umbilicus.

**Remarks:** Globocassidulina differs from Globigerina d'Orbigny in having apertural flaps covering each aperture. It differs from Globorotalia in the aperture being umbilical instead of extrumbilical-umbilical in position.

**Types and occurrence:** Figured hypotype (USNM P3926) and unfigured hypotype (USNM P3927) of Globocassidulina dehiscens (Chapman, Parr, and Collins) from the Miocene (Balcombian) at Balcombe Bay, Victoria, Australia. Collected by A. C. Collins.

Unfigured hypotypes (Cushman Coll. 14240) from the Balcombian at Grices Creek, Victoria, Australia; (Cushman Coll. 24844) from the Miocene at Western Beach, Geelong, Victoria, Australia; and (Cushman Coll. 24837) from the Lower Miocene, lower beds,
Muddy Creek, Victoria, Australia. All from W. J. Parr.

Holotype of *Globoquadrina altispira* (Cushman and Jarvis) (Cushman Coll. 22482) from the Miocene Bowden marl at milestone 71 east of Port Antonio, Jamaica, B. W. I.

Figured specimen of *Globoquadrina* sp. (USNM P4575) from the *Globorotalia mayeri* zone of the Miocene Lengua formation, on Cunjal road, between Barakpoire and Princes Town, Trinidad, B. W. I.

**Range:** Upper Eocene to Miocene.

**Genus Hastigerinella Cushman, 1927**

*Plate 5, Figures 1–3b*


**Type species:** *Hastigerina digitata* Rhumber, 1911 [=*Hastigerinella rhumbleri* Galloway, 1933]. Fixed by original designation and monotypy.

Test free, trochospiral, early portion with globular chambers, later chambers radially elongate, clavate or cylindrical; sutures distinct, depressed, radial; wall calcareous, perforate, radial in structure, with elongate spines which may be concentrated at the outer ends of the chambers, but are normally broken away in fossil or dead shells; aperture interiomarginal, extraumbilical-umbilical, a broad arch which becomes more extensive with age, extending to the periphery or even becoming spiroumbilical.

**Remarks:** *Hastigerinella* differs from *Hastigerina* in being trochospiral instead of planispiral, and in having elongate chambers. It differs from *Hastigerinoides* Bronnimann in being distinctly trochospiral rather than planispiral.

Cushman, in describing *Hastigerinella* (1927, p. 87), cited as type species "*Hastigerina digitata* Rhumber, Foram. Plankton Exped., Part 1, 1911, pl. 37, fig. 9a,b," The *digitata* of Rhumber, 1911, is not conspecific with *Globoquadrina digitata* Brady, 1879, which is another species of *Hastigerinella*. This led Galloway (1933, p. 333) to cite as type *Hastigerinella rhumbleri* n. sp. This confusion primarily results from Rhumber's failure to give any descriptions for his plates in the "Plankton-Expedition" volume cited above. However, Ellis and Messina (1949, p. 40) published the plate explanations of Rhumber's "Plankton-Expedition" that they had obtained as a manuscript from Dr. Otto Wetzel. The copy furnished by Dr. Wetzel was from the manuscript preserved in the library of the University of Göttingen, Germany. On the plate explanation for plate 37, figs. 9a,b were stated to be *Hastigerina digitata* (Brady) variante *digitifera*. This "variante" is thus the use of a new name, but it is invalid, according to the Rules of Nomenclature (Art. 25c), as no description was given. It must be assumed that Cushman considered the combination *Hastigerina digitata* as used by Rhumber (1911, pp. 202, 220) as being a new combination and not referring to *Globoquadrina digitata* Brady, 1879, for nowhere did Rhumber (1911) use the name Brady in combination with *Globoquadrina digitata*. The type thus should be cited as *Hastigerina digitata* Rhumber, 1911, but this is a homonym of *H. digitata* (Brady), 1879. Galloway in reality only renamed this homonym and did not describe a new species as he stated, hence the name *Hastigerinella rhumbleri* Galloway, 1933, is the valid name for the species.

**Types and occurrence:** The original specimens figured by Rhumber were from the Atlantic Ocean in 2,000 meters. Figured hypotype of *Hastigerinella digitata* (Brady) (USNM P3037) is from Challenger Station 120, lat. 8° 37' S., long. 34° 28' W., at 675 fathoms.

**Range:** Miocene to Recent.

**Genus Globigerinoides Cushman, 1927**

*Plate 4, Figures 2a–c*


**Type species:** *Globigerina rubra* d’Orbigny, 1839. Fixed by original designation and monotypy.

Test free, trochospiral; chambers globular to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth, hispid or spinose; primary aperture interiomarginal, umbilical, with previous apertures remaining open into the umbilicus, smaller secondary sutural apertures on the spiral side, one or more per chamber, often confined to the last few chambers.

**Remarks:** The type species has a distinctive coloration, being rose-colored in the early portion, later chambers progressively lighter, and final chamber nearly white. d’Orbigny originally described the species as having two supplementary apertures on the final chamber and one on the preceding, but added that the number was variable in other specimens. In the specimens here figured there are two secondary apertures on the spiral side of each chamber of the final whorl, although the specimen must be rotated to see all of them.

*Globigerinoides* differs from *Globigerina* d’Orbigny in possessing the secondary sutural apertures on the spiral side.

**Types and occurrence:** The original types of *Globigerina rubra* d’Orbigny are in the Muséum National d’Histoire Naturelle, Paris. Figured hypotype of *Globigerinoides rubra* (d’Orbigny) (USNM P3916) from the Recent, Albatross Station H 47, lat. 17° 46' 30" N., long. 65° 10' 25" W., at 1,482 fathoms.

**Range:** Paleocene to Recent.

**Genus Sphaeroidinella Cushman, 1927**

*Plate 6, Figures 1–5*


**Type species:** *Sphaeroidina dehiscens* Parker and Jones, 1865. Fixed by original designation and monotypy.
Test free, elongate ovate, early portion trochospiral, the two or three much-embracing chambers of the final whorl enveloping the early whorl, each with marginal flanges extending out toward the opposing chambers and partially obscuring the arched apertures; sutures depressed, radial or curved; wall calcareous, perforate, radial in structure, in the young stage the pores are extremely large and closely arranged, giving an almost latticelike appearance, the area between pores raised and cancelled, in the later chambers a somewhat irregularly fimbriate or scolophaged, of clear shell material and relatively poreless, is formed around the chamber near its base and tends to coalesce laterally and become much produced, the exterior surface of the final chambers is smoother and glassy in appearance, rather than hispid, and appears to be due to an external secondary deposit; primary aperture in the young stage as in Globigerina, interiomarginal umbilical, in the adult this is covered by the embracing final chamber, and there may be one or more sutural secondary apertures on opposite sides of the final chamber, but these may be partially obscured by the overhanging chamber flanges which parallel the sutures, the chambers may be distinctly separated with a wide open area between the flanges of opposing chambers, and there may be small arched bullae crossing the sutural slit, and partially covering the apertural regions, the walls of the bullae more smoothly finished than that of the chamber, with finer pores although of similar spacing.

Remarks: Sphaeroidinella differs from Globigerina d'Orbigny in having embracing later chambers which cover the primary umbilical aperture, the chambers developing flanges paralleling the sutures and partially obscuring the secondary apertures. There may also be more than one secondary sutural aperture in the final stage, and occasional specimens develop small bullae over the sutural apertures. It resembles Globigerina atheka Bronnimann in the enveloping final chamber, sutural secondary apertures and bullae, but differs in having the typical chamber flanges in the adult and the final involute coiling obscuring the early coil. The bullae, when present, are relatively small arches and do not completely cover the secondary apertures.

Types and occurrence: Lectotype of Sphaeroidina dehiscens Parker and Jones, 1865 (here designated) British Museum (Natural History) ZF 3580 and paratypes ZF 3579 from 1,080 fathoms, lat. 2° 20' N., long. 25° 44' W. Figured paratypes (from the type locality) (USNM P4224).

Figured hypotypes (USNM P4225) and unfigured hypotypes (USNM P4226) from Challenger Station 224, lat. 7° 45' N., long. 144° 20' E., at 1,850 fathoms.

Range: Miocene to Recent.

Genus Pulleniatina Cushman, 1927

Plate 4, Figures 3a-5


Type species: Pullenia obliqueloculata Parker and Jones, 1865. Fixed by original designation and monotypy.

Test free, globose, trochospiral to streptospiral, early portion as in Globigerina, with open umbilicus, later chambers completely enveloping the entire umbilical side of the previous trochospiral coil, including the previous open umbilicus, and thus may even appear involutely coiled; wall calcareous, perforate, radial in structure, later part comparatively thickened, surface distinctly hispid in the Globigerina stage, as can be seen in dissected tests, the surface in the adult smooth, although the portion of the earlier whorl just below the aperture may show the hispid surface; aperture interiomarginal, in the young broad umbilical arch, as in Globigerina, in the adult a broad low extrumbilical arch at the base of the final enveloping chamber, bordered above by a thickened lip, but not directly opening into the earlier umbilicus, because of the streptospiral plan of growth.

Remarks: Pulleniatina resembles Globigerina d'Orbigny in the early development, but differs in the later streptospiral coiling and embracing final chamber and in the characteristic extrumbilical peripheral aperture. Pulleniatina resembles Globigeropsis, new genus, in having the Globigerina stage followed by a more embracing final chamber, and in the change in coiling from trochospiral to streptospiral, but Pulleniatina has a single aperture, whereas Globigeropsis has in the final chamber multiple apertures which are against the sutures of the early coil.

Types and occurrence: Lectotype (here designated) of Pulleniatina obliqueloculata Parker and Jones, 1865 (the type species of Pulleniatina), British Museum (Natural History) No. ZF 3583, and figured paratype (USNM P4228) from Abrolhos Bank, at 200 fathoms, lat. 22° 54' S., long. 40° 37' W., in the South Atlantic.

Figured hypotypes (USNM P4229a, b) from Challenger Station 224, at 1,850 fathoms, lat. 7° 45' N., long. 144° 20' E., collected March 21, 1875.

Range: Pliocene to Recent.

Subfamily Orbulininae Schultze, 1854

Type genus: Orbulina d'Orbigny, 1839.

Coiling trochospiral to streptospiral, later stages enveloping or globular; chambers spherical to ovate; primary aperture not visible in adult, secondary apertures multiple and sutured or areal.

Range: Middle Eocene to Recent.

Globigerapsis Bolli, Loeblich, and Tappan, new genus

Plate 6, Figures 7a-c

Type species: Globigerapsis kugleri Bolli, Loeblich, and Tappan, new species. (Derivation: Globus, L., a globe or ball + gero, L., to bear or carry + apsis, L., arch; gender, feminine.)

Test free, subglobular; early portion trochospiral with subglobular chambers, final chamber embracing and covering the umbilical region of the early coil; sutures depressed, radial to curved; wall calcareous, perforate,
radial in structure, surface smooth to hispid or spinose, the spines broken from the later chambers during preservation, but remaining visible on the earlier chambers when unfilled specimens are dissected; primary aperture interiomarginal, umbilical in the young stage, covered in the adult by an enveloping final chamber, with two or more arched secondary apertures at the lower margin of the final chamber, at the contact with the sutures of the earlier whorl.

**Remarks:** *Globigerapsis*, new genus, differs from *Globigerinattheka* Bronnimann in lacking the small angular bullae covering the secondary apertures. It differs from *Globigerinoides* Cushman in the absence of an umbilical primary aperture in the adult. *Globigerapsis* does not show the multiple apertures on earlier chambers as does *Globigerinoides* and *Porticulasphaera*, new genus.

Bonnimann (1952a, p. 27, text-fig. 3d-f) included a single specimen of *Globigerapsis kugleri* with his *Globigerinattheka barri*, considering it to represent a stage prior to the development of the sutured bullae. Although the two genera may be closely related, they have different geologic ranges, the present genus beginning earlier.

*Globigerinoides semiinvoluta* Keijzer also belongs to the present genus and a hypotype (USNM P3937) from the Eocene Navet formation, Hospital Hill marl, *Globigerapsis semiinvoluta* zone type locality, San Fernando, Trinidad, B. W. I., is here figured for comparison.

Bermudez (1949), p. 279, pl. 21, fig. 44) described as *Globigerina mexicana* Cushman a specimen which actually belongs to the present genus, and seems closer to the species *Globigerapsis semiinvoluta* (Keijzer), although it is perhaps a distinct species.

**Range:** Middle to upper Eocene.

*Globigerapsis kugleri* Bolli, Loeblich, and Tappan, new species

**Plate 6, Figures 6a-c**

Test free, subglobular, early portion trochospraial with globular chambers increasing rapidly in size as added, about four to each whorl, final chamber considerably larger and somewhat embracing, covering the umbilical region of the early coil; sutures deeply depressed, commonly almost incised, radial to curved; wall calcareous, coarsely perforate, surface originally finely spinose, but surface spines broken in fossilization, although those of earlier chambers remain visible in dissected specimens, or may be seen through the apertural openings of the final chamber; aperture in the early stage interiomarginal, umbilical, but this is covered in the adult by the final embracing chamber, which has two to four arched sutural secondary apertures, each bordered by a slight lip, at the basal margin of the final chamber.

Greatest diameter of holotype 0.44 mm., greatest thickness 0.47 mm. Paratypes range from 0.36 to 0.47 mm. in greatest diameter.

**Remarks:** *Globigerapsis kugleri*, new species, differs from *Globigerapsis semiinvoluta* (Keijzer) in having more inflated and nearly globular chambers, more deeply incised sutures, a somewhat less embracing final chamber and lower and less arched secondary apertural openings. It is also similar in appearance to *Globigerinattheka barri* Bronnimann but may have a less embracing final chamber, and always lacks the small bullae which cover the secondary sutural apertures of *Globigerinattheka*.

The specific name is in honor of Dr. H. G. Kugler, in recognition of his work on the geology of Trinidad, B. W. I.

**Types and occurrence:** Holotype (USNM No. P4220), unfigured paratypes (USNM P4221, 4222, and 4827) from the Eocene Navet formation, Penitence Hill marl, *Globigerinattheka barri* zone, from a block in the Oligocene Nariva formation, Pointe-a-Pierre, Trinidad, B. W. I.

*Porticulasphaera* Bolli, Loeblich, and Tappan, new genus

**Type species:** *Globigerina mexicana* Cushman, 1925. (Derivation: *Porticula*, L., diminutive of *porticus*, an arcade, series of arches—*sphaera*, L., ball; gender, feminine.)

Test free, subglobular, early portion trochospiral, final chamber much inflated to almost spherical, and strongly enveloping, covering the umbilical region of the early coil; sutures depressed, radial to curved; wall calcareous, comparatively thick, coarsely perforate, radial in structure, surface with numerous fine elongate spines, broken from the exterior, but those of the early portion may be preserved in the interior and visible in dissected specimens; primary aperture in the early portion interiomarginal, umbilical, with secondary sutural openings on the spiral side, as in *Globigerinoides*, the umbilical aperture covered by the final enveloping chamber of the adult, which has smaller sutural secondary apertures around its lower margin; these, together with the secondary sutural apertures on the spiral side, remain uncovered.

**Remarks:** *Porticulasphaera*, new genus, resembles *Orbulina* d'Orbigny in having a strongly embracing final chamber, although less inflated. In *Porticulasphaera* the early coil always remains visible, and there are no areal secondary apertures as in *Orbulina*.

It resembles *Globigerinoides* Cushman in having the multiple sutural secondary apertures in addition to the large interiomarginal umbilical primary aperture in the early portion, but differs in having the embracing final chamber obscuring the primary umbilical aperture, the adult possessing only the small sutural secondary openings.

*Porticulasphaera*, new genus, differs from *Globigerapsis*, new genus, in having the *Globigerinoides*-type of secondary apertures on the spiral side in the early coil.

**Range:** Middle Eocene.
Portulasphaera mexicana (Cushman), emended

Plate 6, Figures 8–9b


Test free, subglobular, of medium size, early portion in a low trochospiral coil with five inflated chambers per whorl, final chamber hemispherical, much inflated and strongly embracing and enveloping the umbilical region of the early coil, larger in size than the entire previous portion of the test; sutures generally distinct and depressed; wall calcareous, coarsely perforate, radial in structure, thin and delicate in the early portion, but wall of final embracing chamber very thick, with a secondary layer of comparable thickness covering the remaining exposed portion of the earlier whorls and somewhat obscuring the chamber contacts but leaving open the sutural apertures, surface finely spinose, the elongate delicate spines visible on earlier chambers in the interior of dissected specimens, but broken from the exterior of the fossil shells; primary aperture in the early portion interiomarginal, umbilical, an extremely large opening, with smaller arched secondary sutural openings on the spiral side as in Globigerinoides, the primary aperture of the early portion covered by the final embracing chamber, which has only the numerous small arched, sutural secondary apertures (as many as 25) completely encircling its basal margin.

Greatest diameter of figured hypotype 0.65 mm. Other specimens range from 0.42 to 0.83 mm. in greatest diameter.

Remarks: Portulasphaera mexicana was originally described from the upper Eocene Tantoyuca formation, Vera Cruz, Mexico. It was recorded as Globigerinoides mexicana (Cushman) by Beckmann (1953, p. 393, pl. 25, figs. 15–19) from the Oceanic formation of Barbados.

Types and occurrence: Holotype (Cushman Coll. 4334) from the upper Eocene Tantoyuca formation, Palacho Hacienda, south of Panuco-Tampico railroad, State of Vera Cruz, Mexico. Figured hypotype (USNM P3901), figured dissected hypotype (USNM P3902), and unfigured hypotypes (USNM P3903 and P3906) from the Eocene Navet formation, Penitence Hill marl, Globigerinatheka barri zone, in a block in the Oligocene Nariva formation, Pointe-a-Pierre, Trinidad, B.W.I.

Unfigured hypotypes (USNM P4855) from the Globigerina facies of the Middle Eocene Guayabal formation (“Lower Chappapot”) in Tierra Amarilla Well No. 25, at 1,200 feet, Vera Cruz, Mexico. From R. Wright Barker.

Unfigured hypotypes (USNM P3904) from the Navet formation (Penitence Hill marl), Town Hall site, San Fernando, Trinidad, B.W.I.

Unfigured hypotypes (USNM P3905) from the Oceanic formation (Lower Mount Hillaby member), Mount Hillaby section, Barbados, B.W.I. Collected by J. P. Beckmann.

Genus Candea d'Orbigny, 1839

Plate 6, Figures 10a–11

Candea d'Orbigny, Foraminifères, in de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, p. 107, 1839.

Type species: Candea nitida d'Orbigny, 1839. Fixed by monotypy.

Test free, trochospiral, relatively high spired; chambers globular to hemispherical; sutures depressed, radial to curved; wall calcareous, finely perforate, radial in structure, surface smooth; primary aperture in the very early stage interiomarginal, umbilical, later in development smaller secondary sutural apertures occur on each side of the primary aperture; in adult tests there is no primary opening and the small rounded sutural secondary apertures almost completely surround the later chambers.

Remarks: Candea differs from Globigerina d'Orbigny in lacking the umbilical primary aperture in the adult, and in having the numerous rounded sutural secondary apertures. It differs from Globigerinoides Cushman in lacking the umbilical primary aperture and in having numerous small sutural secondary openings on both spiral and umbilical sides of the test, instead of having a relatively few larger secondary sutural apertures on the spiral side only.

Candea passes through a Globigerina stage and a Globigerinoides stage in its ontogenetic development, as can be seen by a dissection of the test.

Hofker (1954, p. 151) stated that Candea has a reduced toothplate, but the specimens we dissected show nothing that could be so construed. The upper border of the aperture is merely slightly thickened, as is often true of Globigerina.

Types and occurrence: Figured hypotype (USNM P3924) of Candea nitida d'Orbigny from Albatross Station 2660, lat. 28°40'00" N., long. 78°46'00" W., depth 504 fathoms. Figured hypotype of dissected specimen (USNM P3923) of C. nitida from Albatross Station D.2754, lat. 11°40'00" N., long. 58°33'00" W., at a depth of 880 fathoms.

Range: Miocene to Recent.

Genus Orbula d'Orbigny, 1839

Plate 7, Figures 1–5


Biorgulina Blow, Mieropaleontologie, vol. 2, No. 1, p. 69, 1956. (Type species: Globigerina bilobata d'Orbigny, 1846. Fixed by original designation and monotypy.)

Type species: Orbula universa d'Orbigny, 1839. Fixed by monotypy.

Test free, generally spherical and composed of a single chamber, rarely 2- or 3-chambered, or specimens
may occur with early chambers arranged trochospirally, in the adult the globigerine coil may remain visible at one side, or may be completely enveloped by the final spherical chamber, or the test may consist of a number of completely enveloping and concentric globular chambers; wall calcareous, perforate, radial in structure; primary aperture interiomarginal, umbilical, in the early globigerine stage, where this is present, but areal in the adult, with numerous small openings which may be scattered over one side or over much of the test, small sutural secondary openings commonly found around the early globigerine chambers of specimens where these are visible at the surface.

Remarks: As shown by Bronnimann (1951a, p. 133) there is a variation from the completely spherical single chamber to the more rare 2- or even 3-chambered forms, and to those forms with a globigerine coil either completely or partially enclosed by the globular end chamber. Biorbulina and Candorbulina are therefore synonyms of Orbutilina. Unilocular, bilocular and trilocular forms are here illustrated, as well as those of "Candorbulina" type with globigerine coil visible at one side.

Types and Occurrence: Figured hypotype of Orbutilina universa d’Orbigny (USNM P3910) from Albatross Station D.2377, lat. 29°07’30” N., long. 78°46’00” W., in gray mud at 210 fathoms; 3-chambered hypotype (USNM P3911) from Albatross Station D.2042, lat. 39°33’00” N., long. 68°26’45” W., depth 1,555 fathoms; 2-chambered hypotype (USNM P3909) such as was named Biorbulina, from Albatross Station D.2660, lat. 28°40’00” N., long. 78°46’00” W., depth 504 fathoms; hypotype of Orbutilina universa d’Orbigny (USNM P3908) showing "Candorbulina" development of test from the Miocene Choctawhatchee formation (lower Area zone) near head of Vaughan Creek, Sec. 27, T.2 N., R.19 W., Walton County, Florida; and figured hypotype (USNM P3907) showing "Candorbulina" stage of development from the Miocene, Baden near Vienna, Austria.

Range: Miocene to Recent.

Catapsydracinae Bolli, Loeblich, and Tappan, new subfamily

Type genus: Catapsydrax, new genus.
Test trochospirally coiled to enveloping; chambers spherical to ovate; primary aperture umbilical, may have secondary sutural or areal apertures, apertures in the test covered by bullae and with infralaminal accessory apertures.

Range: Middle Eocene to Recent.

Catapsydrax Bolli, Loeblich, and Tappan, new genus

Plate 7, Figures 6s-8s

Type species: Globigerina dissimilis Cushman and Bermudez, 1937. (Derivation: Kata, Gr., down, below + psydrax, Gr., blister; gender, masculine.)
Test free, trochospiral; chambers spherical to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth or pitted; primary aperture interiomarginal, umbilical, in the final stage covered by a single umbilical bulla, with one or more accessory infralaminal apertures.

Remarks: Catapsydrax, new genus, differs from Globigerina d’Orbigny in the presence of the umbilical bulla covering the primary aperture, and in having the accessory infralaminal apertures.

It differs from Globigerina d’Orbigny in having a small umbilical bulla with relatively few infralaminal accessory apertures which are sutural in position. In Globigerina the bulla spreads along the sutures and the accessory apertures occur all along its margins.

Catapsydrax resembles Globigerinatheka Bronnimann in having the bulla but differs in having a single umbilical one, rather than more than one, situated in sutural positions.

Types and Occurrence: In addition to the type species, C. dissimilis, three new Tertiary species of this genus are here described.

Catapsydrax dissimilis was originally described as Globigerina dissimilis Cushman and Bermudez. The holotype (Cushman Coll. 23430) and paratypes (Cushman Coll. 23429) are from the Eocene, I kilometer north of Arroyo Arenas, on road to Jaimanitas (water well), Havana Province, Cuba. Collected by P. J. Bermudez.

Figured hypotypes (USNM P4218a, b) are from the Oligocene Cipero formation, Globigerina ciperoensis zone, Cipero Coast section, Trinidad, B. W. I. Collected by H. M. Bolli.

Range: Upper Eocene to Miocene.

Catapsydrax parvulus Bolli, Loeblich, and Tappan, new species

Plate 7, Figures 10s-3

Test free, tiny, subglobular, low trochospiral, periphery broadly rounded; chambers ovate, increasing rapidly in size as added, four to five per whorl, mostly with four in the final whorl; sutures distinct, slightly depressed, oblique, somewhat curved on the spiral side; wall calcareous, finely perforate, surface smooth; primary aperture interiomarginal, umbilical and covered over by an arched blisterlike bulla, with a single very low arched or slitlike infralaminal accessory aperture opening at one side.

Greatest diameter of holotype 0.16 mm., thickness 0.13 mm. Paratypes range from 0.13 to 0.18 mm. in diameter.

Remarks: This species differs from Catapsydrax dissimilis (Cushman and Bermudez) in its much smaller size, being about one-fourth the diameter; in the less globular and less inflated chambers and more even periphery; and in having only a single infralaminal accessory aperture rather than two to four.

Types and Occurrence: Holotype (USNM P4219) and unfigured paratypes (USNM P4822) from the Miocene Lenga formation (Globorotalia mayeri zone), in a ditch on the north side of Cunjal Road, southern Trinidad, B. W. I.
Catapsydrax stainforthi Bolli, Loeblich, and Tappan, new species

Plate 7, Figures 11a–e

Test free, small, trochospiral, chambers subglobular to ovate, forming about two whorls, with four or rarely five chambers in the final whorl; sutures distinct, radial, straight to curved, depressed; wall calcareous, perforate, surface pitted; primary aperture interiomarginal, umbilical, and covered by a single umbilical bulla with a small infralaminal accessory aperture opening over each suture of the final whorl.

Greatest diameter of holotype 0.36 mm., thickness 0.26 mm. Paratypes range from 0.26 to 0.42 mm. in diameter.

Remarks: Catapsydrax stainforthi, new species, differs from C. dissimilis (Cushman and Bermudez) in being about one-half as large, and in having a more closely appressed bulla which may extend a short way along the sutures and which has much smaller arched accessory openings that are restricted to the area over the sutures, instead of the relatively large arches of C. dissimilis which may open over much of the umbilical area of a chamber. It differs from C. parvulus, new species, and C. unicaucus, new species, in having the four or more smaller accessory openings beneath the umbilical bulla, rather than a single larger opening at one side only.

The specific name is given in honor of R. M. Stainforth, in recognition of his work on the planktonic Foraminifera.

Types and occurrence: Holotype (USNM P4840) and unfigured paratype (USNM P4841) from the Cipero formation, Catapsydrax stainforthi zone (Miocene), Cipero Coast section, Trinidad, B. W. I.

Unfigured paratypes (USNM P4842) from the Ste. Croix member of the Brasso formation (basal Globigerinatella inesueta zone, Miocene), Ste. Croix quarry, near Broomage trigonometric station, south of Princes Town, Naparima region, Trinidad, B. W. I.

Catapsydrax unicaucus Bolli, Loeblich, and Tappan, new species

[Plate 7, Figures 9b–c]

Test free, small, trochospiral, low-spired, periphery rounded; chambers subglobular, arranged in two whorls, only a few chambers per whorl, ranging from six in the first whorl to only four in the final whorl; sutures distinct, depressed, slightly curved; wall calcareous, perforate, surface punctate or cancellate in appearance, primary aperture interiomarginal, umbilical, and covered by a small subquadrate bulla which is attached at three sides, with an arched infralaminal accessory opening at the fourth side.

Greatest diameter of holotype 0.31 mm., thickness 0.21 mm. Paratypes range from 0.26 to 0.36 mm. in greatest diameter.

Remarks: Catapsydrax unicaucus, new species, differs from C. dissimilis (Cushman and Bermudez) in being somewhat smaller, with less inflated chambers and less depressed sutures, and the umbilical bulla has a single accessory opening rather than two to four as in C. dissimilis. Catapsydrax parvulus, new species, also has a single accessory opening, but differs in being much smaller, with a nearly smooth surface, less globular chambers and nearly flush sutures.

Types and occurrence: Holotype (USNM P4216) and unfigured paratype (USNM P4217) from the Cipero formation, Globigerina ciperoensis zone, exposure on San Fernando By-pass road, Trinidad, B. W. I. Collected by H. M. Bolli.

Unfigured paratypes (USNM P4837) from the Cipero formation, Globigerinatella inesueta zone (Miocene) Cipero Coast section, Trinidad, B. W. I. Collected by H. G. Kugler.

Genus Globigerinita Bronnimann, 1951

Plate 8, Figures 1a–2c


Type species: Globigerinita naparimaensis Bronnimann, 1951. Fixed by original designation and monotypy.

Test free, trochosiral; chambers spherical to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface generally smooth, pitted or hispid; primary aperture interiomarginal, umbilical, in the final stage this aperture is completely covered by an irregular bulla covering the umbilicus and expanding along the earlier sutures, with numerous infralaminal accessory apertures along the margins, both at the junction with the sutures of earlier chambers and along the contact with the primary chambers.

Remarks: Globigerinita differs from Globigerina d’Orbigny in the presence of the umbilical bulla with multiple infralaminal accessory apertures. It differs from Globigerinoides Bronnimann in having a single globigerine primary aperture and a single umbilical-sutural bulla.

Catapsydrax, new genus, differs in having a more restricted bulla, covering only the umbilical region, and in the accessory apertures being only sutural in position, rather than along the entire bulla margin.

The specimen selected as holotype of the type species, Globigerinita naparimaensis, is a rather atypical specimen. The transparent “supplementary chamber” of this specimen is not typical in that it is more globular, resembling a normal chamber which has expanded somewhat on the umbilical side. It has only two small accessory apertures instead of the typical numerous openings along the margins of the bulla. However, although it does not show the generic characters well, this specimen is apparently conspecific with Bronnimann’s paratypes.

Originally described from the Miocene of Trinidad, the genus has recently been recorded by Conato (1954) from the Italian Pliocene. It has also been recorded in Recent sediments.

Types and occurrence: Holotype of Globigerinita naparimaensis (Cushman Coll. 64182), paratypes
Genus Globigerinoita Bronnimann, 1952

PLATE 8, FIGURES 3a-d


Type species: Globigerinoita morugaensis Bronnimann, 1952. Fixed by original designation and monotypy.

Test free, trochospiral; chambers spherical to ovate; sutures depressed, radial to curved; wall calcareous, perforate, radial in structure, surface spinose; primary aperture umbilical in position, with one or more secondary sutural apertures as in Globigerinoides on the spiral side, in the adult stage the primary aperture is covered by an umbilical bulla and the secondary apertures of the spiral side may also be covered by sutural bullae, with commonly two to three accessory infralaminar apertures at the margins of each of the bullae.

Remarks: Globigerinoita differs from Globigerinita Bronnimann in having the secondary spiral Globigerinoides apertures and in having two or more bullae, one over the primary umbilical aperture and others covering the secondary sutural apertures of the spiral side. Globigerinoita differs from Globigerinatækha Bronnimann in having a Globigerinoides stage, followed by the development of one or more bullae covering the primary and secondary apertures. In Globigerinatækha the primary aperture is covered by an enveloping final chamber as in Orbitulina, and the bullæ cover only the secondary apertures.

Types and occurrence: Holotype (USNM P3919) and figured and unfigured paratypes (USNM P3213) from the Miocene Lengua formation, Globorotalia menardii zone, Moruga area, Trinidad, B. W. I.

Range: Miocene.

Genus Globigerinatækha Bronnimann, 1952

PLATE 7, FIGURES 12a-c


Type species: Globigerinatækha barri Bronnimann, 1952. Fixed by original designation and monotypy.

Test free, globular, early chambers trochospiral as in Globigerina, later with a large enveloping final chamber covering the previous umbilical side as in Orbitulina; sutures depressed, radial; wall calcareous, perforate, radial in structure; primary aperture of the early Globigerina stage interiomarginal, umbilical, but this is covered in the adult by the final enveloping chamber, the secondary sutural apertures multiple on the spiral side and covered by small bullae, each of which have one or more small arched infralaminar accessory apertures.

Remarks: Globigerinatækha has a stage like Globigerina, new genus, preceding the development of bullæ, whereas Globigerinatækha Bronnimann has a Globigerina stage followed by the development of a very irregular umbilical-sutural bulla.

Globigerinoita Bronnimann has an early Globigerinoides stage with one or more sutural secondary apertures on the spiral side, with bullæ covering both the primary and secondary apertures.

Types and occurrence: Holotype of Globigerinatækha barri (USNM P3919) and paratypes (USNM P3213) from the Eocene Mount Moriah formation, Vermilion Bank, Louisiana, 10°17'37" N., 127°39'12" W., at a depth of 1820 fathoms.

Range: Middle to upper Eocene.

Genus Globigerinatækha Cushman and Stainforth, 1945

PLATE 8, FIGURES 4-7c


Type species: Globigerinatækha insueta Cushman and Stainforth, 1945. Fixed by original designation and monotypy.

Test free, subglobular, early portion trochospiral with the final chamber usually embracing; wall calcareous, perforate, radial in structure, surface smooth or pitted; aperture in the early stage interiomarginal, umbilical, in the later chambers with secondary sutural and areal apertures, surrounded by distinct lips, with small knobby pustulellike bullae covering the areal secondary apertures, or more irregular spreading sutural bullae covering the secondary sutural apertures, all bullae may have infralaminar accessory apertures.

Remarks: Bronnimann (1950, p. 80) discussed and illustrated in considerable detail the ontogenetic development of Globigerinatækha, leaving little to be added, other than a mention of the wall structure. He did include, with question, one “aberrant” form which he later referred to the genus Globigerinatæ (1951b, p. 16). The latter genus does not have a stage with multiple areal apertures, and does not have an enveloping final chamber.

Hofker (1954, p. 151) stated of Globigerinatæ: “Walls in polarized light granular, not radiate as in Globigerina.” He also stated that specimens from Ecuador showed “reduced toothplates very similar to those found in Candeina nitida d’Orbigny.”

The wall structure was rechecked for this study and
found to be distinctly radial, as in *Globigerina*. Furthermore, *Candeina* also has a radial wall structure. No suggestion of “toothplates” was seen in either genus, unless Hofker referred to the typical lip as a toothplate.

Hofker considered *Globigerinatella* to be related to “Quadrimorpha, Pullenoides, Candeina and possibly also with *Chilostomella*.” As has been shown earlier (Loeblich and Tappan, 1953, p. 93), *Chilostomella* has a granular wall structure, and a planispiral coil of lining, and thus is quite distinct from these trochospiral forms with radially built walls.

*Globigerinatella* is considered to belong unquestionably to the Orbulinidae. It is related to *Globigerina*, as shown by the early trochospiral stages with a single umbilical aperture, and to *Orbulina* in having the strongly embracing final chamber with areal and sutured secondary apertures. It differs from *Globigerina* in the presence of the bullae and accessory apertures, and from *Orbulina* in having the early stage also with areal apertures.

**Types and occurrence:** Holotype of *Globigerinatella insueta* Cushman and Stainforth (Cushman Coll. 44040), paratypes here figured (Cushman Coll. 44043a, b) and unfigured (Cushman Coll. 44041, 44042, and 44043); figured topotypes (USNM P3932a, b) and unfigured topotypes (USNM P3931 and P3936) from the Cipero formation, *Globigerinatella insueta* zone (Miocene), Cipero Coast section, Trinidad, B. W. I. Topotypes collected by H. M. Bolli.

**Range:** Miocene.

**Family Globorotaliidae Cushman, 1927**

**Type genus:** *Globorotalia* Cushman, 1927.

Coiling of test trochospiral; chambers angular to ovate or spherical; wall calcareous, perforate, radial in structure; primary aperture extrumbilical-umbilical, may have secondary sutured apertures on spiral or umbilical side.

**Range:** Cretaceous to Recent.

**Genus Praeglobotruncana Bermudez, 1952**

**Plate 9, Figures 1a–4c**


**Type species:** *Globorotalia delrioensis* Plummer, 1931. Fixed by original designation.

Test free, trochospiral, biconvex to spiroconvex, umbilicate, periphery rounded to subangular, or with a moderate keel in the early stages, commonly progressively less prominent in the later development; chambers globular, ovate or subangular; sutures on the spiral side depressed to elevated and thickened or even beaded, radial or curved, on the umbilical side depressed and radial; wall calcareous, finely perforate, radial in structure, surface smooth to hispid; aperture interiomarginal, a relatively high and open extrumbilical-umbilical arch bordered above by a narrow lip or spatulate flap commonly directed toward the umbilicus, and in forms with a broad open umbilicus successive apertural flaps may remain visible to present a serrate or scalloped border around the umbilicus.

**Remarks:** Although the type species of *Praeglobotruncana* had been originally described as belonging to *Globorotalia*, Bermudez did not give any comparisons of his proposed new genus to *Globorotalia*, but considered it ancestral to *Globotruncana*, because of its having a more open umbilicus. Bermudez did not describe the apertural characters completely, stating only that the aperture was a simple groove in the base of the septal face of the final chamber (i.e., interiomarginal). In the type species selected, the aperture, like that of a typical *Globorotalia*, consists of an extrumbilical-umbilical arch bordered by a lip. It is perhaps somewhat more open and directed more in an umbilical direction.

*Rotundina* Subbotina, 1953, (with *Globotruncana stephani* Gandolfi as type species) was said by the describer to be characterized by an open umbilicus and aperture situated near the umbilical ends of the chambers, extending for some distance along the peripheral suture. Near the umbilicus an outgrowth of the wall was said to be present that, taken together, produced a wide rim or border surrounding the umbilicus. Reichel (1949) had provisionally placed *Globotruncana stephani* Gandolfi in *Globotruncana*, s. s., although stating that it could equally well be placed in *Globorotalia*. He figured a specimen that shows an umbilicus bordered by such a scalloped lamellar expansion. On topotypes obtained from Reichel, this feature is not evident and sutures are radial into the open umbilicus. However, a suite of specimens of *Praeglobotruncana delrioensis* (Plummer) included a few possessing large and well-developed apertural lips. These projected somewhat above the normal curvature of the chamber, so that the final lip, together with the earlier ones, presented an irregular umbilical margin. This represents the feature mentioned by Subbotina and Reichel and may also be observed in occasional specimens of many of the other species of *Praeglobotruncana*. A specimen of *P. planispira* (Tappan) is here figured which excellently demonstrates this feature. Thus, *Rotundina stephani* and *Praeglobotruncana delrioensis* possess identical apertural characteristics, and as they are congeneric, *Rotundina* Subbotina is suppressed as a junior synonym.

Bermudez also included *Globotruncana appenninica* Renz in *Praeglobotruncana*, but this species is a true *Rotalipora* as has been noted by Reichel (1949, p. 604), Sigal (1952b, p. 24), Hagn and Zeil (1954, p. 22) and Küpper (1955, p. 114). A specimen figured here also shows the well developed secondary sutural apertures typical of *Rotalipora*.

*Hedbergina* was described by Bronnimann and Brown
as a globigerine form in the family Globotruncanidae, with a small umbilicus and apertural flaps but no cover plate and no peripheral keel. It was considered to be ancestral to Ticinella [= Rotalipora], although lacking secondary apertures. The type species, Globigerina seminolensis Harlton, is a Cretaceous species, represented only by the holotype, which was found as contamination or a possible outlier in the Pennsylvania from the Ardmore basin of Oklahoma. As the type lacks the most important character of the Globotruncanidae (the tegulla) it cannot be placed in this family, and the absence of secondary apertures shows that it is not a Ticinella. This type species was an unfortunate selection, as the central portion of the holotype is completely obscured by matrix. As its true stratigraphic position is unknown it cannot be conclusively checked on other material. This poorly preserved specimen (here refigured) could easily be fit into a number of the various species of "Globigerina," Praeglobotruncana, etc., described from the Lower and Upper Cretaceous within a relatively short distance from the Pennsylvania outcrop. Bronnimann and Brown state that the type species, G. seminolensis, is "rather rough-walled, coarsely granular", with "markedly elongated" chambers, and an interiomarginal aperture, bordered by a short apertural flap, opening into the umbilicus. The holotype of the species is smooth-walled, and has a finely perforate test, and the aperture and umbilicus are both completely obscured by extraneous material. Bronnimann and Brown figured a specimen from Cuba, which they referred to G. seminolensis, but they did not give any exact stratigraphic data for the Cuban specimen either. The figures of this form also show a filled umbilicus, with no indication of the umbilical and apertural characters they mentioned. Furthermore, the chambers of both specimens that have been figured are nearly spherical, and show no indication of the elongation mentioned by Bronnimann and Brown. The only character they indicated which could separate this species from Praeglobotruncana, is the absence of a keel, and this is not considered here to be of generic significance. There are many gradations from rounded to slightly compressed to keeled species in most celled genera of calcareous Foraminifera. Hence, Hedbergina is tentatively considered to be a synonym of Praeglobotruncana, although, because the position of the aperture cannot be definitely determined on the basis of the material available, it might possibly be a species of Globigerina.

Praeglobotruncana is regarded as one of the more primitive planktonic genera, and possibly gave rise not only to other genera of the Globorotaliidae but also to the Globotruncanidae and Orbulinidae, and possibly even to the Hantkeninidae. Various early species show tendencies in these various directions. Perhaps the closest relationship is to Globorotalia, which differs in having a more extrumbilical aperture, in being more prominently keeled, and in having ovate to angular chambers. Praeglobotruncana has a resemblance to Globigerina d'Orbigny in having spherical or ovate chambers and a more umbilically directed aperture, but differs in the somewhat extrumbilical extension of the aperture and the faint keel which may be developed in the early stages of some species. The broad apertural lips are also not characteristic of Globigerina. Both of these genera could thus have arisen from Praeglobotruncana by slight modifications in apertural position and chamber shape.

Fusion of the apertural lips at their umbilical margins could leave sutural openings and give rise to the Rotalipora group. A continued increase in the development of the apertural flaps until they completely covered the umbilicus and attached at their opposite margin, coupled with a gradual restriction in the position of the aperture from extrumbilical-umbilical to only umbilical, would give rise to Rugoglobigerina and Globotruncana.

Other species, such as P. suberetacea (Tappan) [=Hastigerinella suberetacea Tappan], show a tendency to develop radially elongate chambers, and may show a relationship to the Hantkeninidae. Schackoinea does show a trochospiral coiling, differing only in the restriction of the aperture to a completely extrumbilical position and in the development of tubulospines.

Praeglobotruncana is restricted to the Cretaceous, these globular chambered forms not being found in the same strata as true Globorotalia. Many Cretaceous species originally placed in various other planktonic genera also belong to Praeglobotruncana (i.e., some "Globigerina," "Hastigerinella," "Globorotalia," "Globotruncana," etc.), as they possess these apertural and test characters in common, but do not have the specialized features of the genera to which they had previously been referred.

Types and Occurrence: Holotype of Globorotalia delrioensis Plummer (type species of Praeglobotruncana) in the Paleontological Research Institute, Ithaca, New York, from the Cenomanian, Del Rio clay, on right bank of Shoal Creek in a steep slope just south of the Thirty-fourth Street bridge in Austin, Travis County, Texas. Figured topotype (USNM P4481) from the same locality, collected by H. T. and A. R. Loeblich, Jr., July 1940.

Figured topotype of Globotruncanina stephani Gandolfi (USNM P4849), the type species of Rotundina Subbotina, and unfigured topotype (USNM P4532) from the Cenomanian, Breggia number 56, Canton Ticino, Switzerland. Received from Professor M. Reichel.


Figured holotype of Globigerina seminolensis Harlton (USNM 71380), a Cretaceous specimen erroneously reported to be from the Pennsylvania (upper Glenn formation) from the SW\(^{\circ}\), SE\(^{\circ}\), NW\(^{\circ}\) sec. 20, T. 5S., R. 1E., Carter County, Oklahoma.

Range: Aptian to Maestrichtian.
Genus *Rotalipora* Brotzen, 1942

PLATE 9, FIGURES 5a–7c AND PLATE 10, FIGURES 1a–c


**Type species:** *Rotalipora turonica* Brotzen, 1942. Fixed by original designation and monotypy.

Test free, trochospiral, biconvex to planoconvex, umbilicate, periphery rounded or with a single keel; chambers ovate to angular-rhomboid; sutures on spiral side curved, depressed to elevated, may be beaded, on umbilical side flush to depressed, radial or slightly curved; wall calcareous, perforate, radial in structure, surface in general smooth; primary aperture interiomarginal, extrumbilical-umbilical, and may be bordered above by a lip, secondary apertures sulcral on the umbilical side, one per suture or rarely two or more, and each may be bordered by a narrow lip.

**Remarks:** *Rotalipora* differs from *Globotruncanana* Cushman in possessing an interiomarginal, extrumbilical-umbilical primary aperture, in having secondary sulcral apertures and an open umbilicus, and in lacking the umbilical tegilla.

*Thalmanninella* Sigal is here considered a synonym of *Rotalipora*, as an examination of specimens identified by the authors of both type species shows no fundamental differences. The secondary sulcral apertures may be situated in various positions along the sutures, from the midregion of the suture to the inner margin of the umbilical rim, and may then be aligned at an angle. In every case these sulcral apertures open into the chambers themselves and not into the umbilicus. The toptype of *Thalmanninella brotzeni* Sigal, here figured, shows some of these secondary apertures which are as definitely sulcral in position as those of the figured specimen of *Rotalipora turonica* Brotzen. The remaining differences are only of specific importance.

*Ticinella* was defined by Reichel as having apertural characters identical with those of *Thalmanninella* Sigal. He separated *Ticinella* on the basis of the globular chambers and absence of a keel other than a slight indication of one in the early chambers. *Thalmanninella* was characterized by a simple marginal keel, but this was also stated to be common absent in the last chambers. Both have been recorded from the Cenomanian, although *Ticinella* has been recorded as lower in the Cenomanian and ?Albian. Nevertheless, as their sole distinction is a matter of degree (*Ticinella* is without a keel except in the early chambers and *Thalmanninella* may be without one in the later chambers), we consider *Ticinella* Reichel also a junior synonym of both *Thalmanninella* Sigal and *Rotalipora* Brotzen.

**Types and occurrence:** Figured hypotype of *Rotalipora turonica* Brotzen (USNM P50) and unfigured hypotypes (USNM P4237) from the lower Turonian, Gristow, Sweden.

Figured toptype of *Thalmanninella brotzeni* Sigal (USNM P3930) from the middle Cenomanian, Sidi-Aissa, Algeria.

Figured hypotype of *Ticinella roberti* (Gandolfi) (USNM P4829) from Breggia Number 27, lower Cenomanian, Canton Ticino, Switzerland.

Figured specimen of *Rotalipora* cf. *appenninica* (Renzi) (USNM P4873) from the Cenomanian Del Rio formation on right bank of Shoal Creek just south of the 34th Street bridge, in Austin, Travis County, Texas. Collected by H. T. and A. R. Loeblich, Jr.

**Range:** Albion to Turonian.

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Genus *Globorotalia* Cushman, 1927

PLATE 10, FIGURES 2a–4c


*Pseudogloborotalia* Haque, Ibid., vol. 1, p. 184, 1956. (Type species: *Pseudogloborotalia ranikotensis* Haque, 1956. Fixed by original designation.)

**Type species:** *Pulvinulina menardii* (d’Orbigny) var. *tumida* Brady, 1877. Fixed by original designation and monotypy.

Test free, trochospiral, biconvex to umbilicoconvex, umbilicate, periphery with or without a single keel; chambers ovate to angular rhomboid or angular conical; sutures on the spiral side depressed to elevated, curved or radial, may be thickened on the umbilical side, depressed and radial; wall calcareous, finely perforate, radial in structure, surface smooth to hispid; aperture interiomarginal, an extrumbilical-umbilical arch bordered by a lip, varying from a narrow rim to a broad spatulate to triangular flaps.

**Remarks:** *Globorotalia* differs from *Globotruncanana* Cushman in having an interiomarginal, extrumbilical-umbilical aperture and a simple umbilicus, and in lacking the umbilical tegilla and accessory intralaminal
and infralaminal apertures. It differs from *Truncorotaloides* Bronnimann and Bermudez in lacking the secondary sutural apertures on the spiral side.

Other generic names have been proposed for various species of *Globorotalia*, largely based on chamber shape. However, in considering all species there are gradations from each extreme of chamber shape or size of umbilicus to the typical form of *Globorotalia*. Thus although certain extreme forms may appear to represent distinctive types, the other species are intermediate in character, so that no sharp boundaries appear.

*Truncorotalia* Cushman and Bermudez included species with an umbilico-convex form, sharply angular-rhomboid chambers and an elongate and slitlike aperture. However, these features are regarded as only of specific importance, and intermediate species between this form and that represented by *Globorotalia tumida* are impossible to separate.

*Turborotalia* Cushman and Bermudez included species with a globose form, with a small or indistinct umbilicus, and with a narrower apertural lip. There are also many intermediate forms, and the distinctions are again regarded only as of specific value.

Acarinina Subbotina was proposed for the same group of species as *Turborotalia*, and even included its type species. Hence it also becomes a junior synonym.

Haque (1956, p. 147) described *Glabanomalina*, separating it from *Globigerina* d'Orbigny, because of the very smooth test as compared to the spinose test of *Globigerina bulloides* d'Orbigny, and because of the peripheral rather than umbilical aperture. However, the majority of the described species of *Globigerina*, including *G. bulloides*, may also have a smooth surface, and the trochospiral test and the extralaminal-umbilical position of the aperture of *Glabanomalina* prove it to be a synonym of *Globorotalia*. The type species, *Glabanomalina ovalis*, is apparently close to the early Paleocene group of *Globorotalia* with rounded, keelless chambers, e.g., *Globorotalia compressa* (Plummer) and *Globorotalia pseudobulloides* (Plummer).

Haque (1956, p. 185) also described *Pseudoglaborotalia*, separating it from *Globorotalia* mainly on the basis of the smooth and shiny test, whereas he stated that Cushman characterized *Globorotalia* as having a thick cancelled surface. Cushman (1927, p. 91) stated that *Globorotalia* has a “wall frequently roughened throughout,” but did not state it to be cancelled, and the type species, *G. tumida*, has a smooth surface. Thus this basis for separation is invalid. *Pseudoglaborotalia* is here questionably placed as a synonym of *Globorotalia*, and is also questionably considered a planktonic species. Specimens deposited in the U. S. National Museum by Haque closely resemble the genus *Globorotalites* Broten, which is not a planktonic form, but a study of additional and better preserved material will be necessary to definitely place *Pseudoglaborotalia*.

**Types and occurrence**: Syntypes of *Pulexina menardii tumida* Brady (USNM P3143), the type species of *Globorotalia* Cushman, from the Post Tertiary of New Ireland.

Figured topotype (USNM P4542) of *Rotalina truncatulinoides* d'Orbigny (the type species of *Truncorotalia*) and unfigured topotypes (USNM P4231) from d'Orbigny's original sample, Recent, Ile de Teneriffe, Canaries.

Holotype of *Globorotalia centralis* Cushman and Bermudez (Cushman Coll. 23426) the type species of *Turborotalia*, and paratypes (Cushman Coll. 23425) from the Eocene, under railroad bridge on Central Highway, located in Jicotea, Santa Clara Province, Cuba. Collected by P. J. Bermudez.

Hypotypes of *Pseudoglaborotalia ranikotensis* Haque (USNM P3398) from the Paleocene (Ranikot formation), Nammal Gorge, Salt Range, Pakistan. Sent by A. F. M. Mohsenul Haque.

Hypotypes of *Glabanomalina ovalis* Haque (USNM P3399) from the lower Eocene, upper part of the lower Laki formation, Nammal Gorge, Salt Range, Pakistan. Sent by A. F. M. Mohsenul Haque.

**Range**: Paleocene to Recent.

**Genus Truncorotaloides** Bronnimann and Bermudez, 1953

**Plate 10, Figures 5a-c**


**Type species**: *Truncorotaloides rokri* Bronnimann and Bermudez, 1953. Fixed by original designation.

Test free, trochospiral, biconvex to umbilicoconvex, umbilicate, with or without a single keel; chambers ovate to angular-rhomboid; sutures depressed, radial to oblique on the spiral side, radial and depressed on the umbilical side; wall calcareous, perforate, radial in structure, surface prominently hispid throughout; primary aperture interiomarginal, extraumbilical-umbilical, with single secondary sutural apertures on the spiral side at the inner margin of the later chambers where they lie against the previous whorl.

**Remarks**: *Truncorotaloides* resembles *Globigerinoides* Cushman in having the small secondary apertures on the spiral side, but differs in having the primary aperture interiomarginal, extraumbilical-umbilical, rather than completely umbilical.

*Truncorotaloides* differs from *Globorotalia* Cushman in the presence of the secondary sutural apertures on the spiral side.

**Types and occurrence**: Holotype of *Truncorotaloides rokri* Bronnimann and Bermudez (USNM P4233) from the Eocene Navet formation, marl pebble bed, Duff road area, near Kelly junction, about 7 miles east of Pointe-a-Pierre, Central Trinidad, B. W. I.

**Range**: Eocene.

**Family Globotruncanidae** Brotzen, 1942

**Type genus**: *Globotruncanidae* Cushman, 1927.

Coiling of test trochospiral; chambers spherical to angular, commonly truncate or keeled; wall calcareous, perforate, radial in structure; primary aperture umbil-
cal in position but covered by a spiral system of tegilla, accessory intraluminal and infraluminal apertures present.

**Range:** Upper Cretaceous.

*Abathomphalus* Bolli, Loeblich, and Tappan, new genus

**Plate 11, Figures 1a-c**

**Type species:** *Globotruncana mayaroensis* Bolli, 1951. Derivation: Abathes, Gr., shallow + omphalos, Gr., umbilicus; gender, masculine.

Test free, trochospiral, biconvex to conoconvex, almost nonumbilicate, periphery with a single or double keel; sutures depressed, curved and sometimes beaded on the spiral side, depressed and radial on the umbilical side; wall calcareous, perforate, radial in structure, commonly ornamented with fine nodes, and the peripheral keels and sutures may also be beaded; primary aperture interiomarginal, extraumbilical, as a rule covered by a continuous umbilical tegillum of irregular outline, with accessory infraluminal apertures situated at the suture contacts with the tegillum.

**Remarks:** *Abathomphalus*, new genus, differs from *Globotruncana* Cushman in lacking a wide and deep umbilicus with a sharply angled rim and delicate tegilla extending from each chamber and in the interiomarginal, extraumbilical position of the primary aperture.

In *Abathomphalus*, new genus, the umbilical area is not open, the final whorl of chambers all meeting ventrally, although their junction may be obscured by the single umbilical tegillum, which appears to be an extension from the final chamber. The accessory apertures are always infraluminal, not both infraluminal and intraluminal as in *Globotruncana*.

*Abathomphalus*, new genus, differs from *Globorotalia* Cushman in the presence of the tegillum and accessory infraluminal apertures. It differs from *Rotalipora* Broten in lacking the secondary sutural apertures on the umbilical side, in having a tegillum and accessory infraluminal apertures.

**Types and occurrence:** Holotype (Cushman Coll. 59685) and paratypes (Cushman Coll. 59686) of *Abathomphalus mayaroensis* (Bolli) from the Maestrichtian (*Abathomphalus mayaroensis* zone), Guayaguayare formation, subsurface section in the Guayaguayare area, Trinidad, B. W. I.

Figured hypotype (USNM P4833) and unfigured hypotypes (USNM P4833, P4861, P4862 and P4863) from the Maestrichtian Guayaguayare formation (*Abathomphalus mayaroensis* zone), from a subsurface core, Guayaguayare area, southeastern Trinidad, B. W. I.

**Range:** Maestrichtian.

Genus *Rugoglobigerina* Bronnimann, 1952

**Plate 11, Figures 2a–5c**


**Type species:** *Globigerina rugosa* Plummer, 1926. Fixed by original designation.

Test free, trochospiral, biconvex, umbilicate, periphery rounded to slightly angular; chambers spherical, hemispherical, radial elongate or rarely angular in the later portion; sutures radial to slightly curved on the spiral side, radial on the umbilical side, depressed throughout; wall calcareous, perforate, radially in structure, surface typically rugose with numerous large pustules which may coalesce into distinct ridges, radiating from the midpoint of each chamber on the periphery, or much produced peripherally into spine-like extensions, more rarely smooth; primary apertures interiomarginal, umbilical, in well preserved specimens covered by tegilla perforated by the accessory infraluminal and intraluminal apertures; these are the only openings to the exterior. The tegilla, however, as a rule are partially or wholly broken out in preservation.

**Remarks:** *Rugoglobigerina* resembles *Globotruncana* Cushman in the apertural characters and the presence of the umbilical tegilla, but differs in the prominent surface ornamentation and less angular chambers.

*Rugoglobigerina* may be regarded as the form ancestral to *Globotruncana*, and various species of the latter genus seem to have branched off from the main *Rugoglobigerina*-stem at different geologic times.

*Rugoglobigerina* differs from *Globigerina d'Orbigny* in having the umbilical tegilla covering the primary aperture, in having the infraluminal and intraluminal accessory apertures, and often in the characteristic rugose and highly ornamented surface.

In her original description of the type species, Plummer (1926, p. 39) compared it with *Globigerina rosetta [=Globotruncana] stating that the umbilical features were precisely the same. No orbulinids show these umbilical tegilla, but they are characteristic of *Globotruncana*.

Bonnimann originally defined *Rugoglobigerina* with three subgenera: *Rugoglobigerina*, s. s., *Plummerella* (later *Plummerella*, new name, as *Plummerella* was a homonym), and *Trinitella*.

*Plummerella* was separated from *Rugoglobigerina*, s. s., because of its peripheral spinelike chamber extensions and more flattened spire, but specimens figured by Bronnimann as *Rugoglobigerina* reicheli reicheli (1952b, p. 19, text fig. 4a, b) show two definitely radial-elongate chambers, and others placed in *Plummerella hantkenioides inflato* show chambers as well rounded as those of typical *Rugoglobigerina* (Bonnimann, 1952b, pl. 41, text fig. 19a, b).
Trinitella was considered to have slightly flattened later chambers, tending toward Globotruncana, but this is present only on the last one or two chambers. No true keel as in Globotruncana is found in this group.

As all three of these subgenera were from the same horizon and all have the same type of surface ornamentation and apertural characters, it seems probable that these gradations are not accidental, and that only a single genus is present, the differences found being only sufficient to warrant specific separation.

Later, Bronnimann and Brown (1956) described the monotypic genus Kuglerina, the type species being one originally considered by Bronnimann as a subspecies of the type species of Rugoglobigerina, with which it is associated. The original types were deposited in the U. S. National Museum, and show the general chamber shape and ornamentation characteristic of R. rugosa. Bronnimann and Brown state that Kuglerina differs from Rugoglobigerina in being higher spired and in having a smaller and deeper umbilicus, and in completely lacking umbilical cover plates. The height of the spire and size and depth of the umbilicus are characters of only specific or subspecific rank. Although the apertural character is of greater importance, the apertural region of the type specimen is completely obscured by matrix, and the actual presence or absence of tegula cannot be determined. Because the species has never been recorded from other localities, the characters can only be those visible on the type specimens, and the tegulae are so fragile that they are only preserved in very fine specimens. Therefore, the basis for separation of this genus is extremely doubtful and we consider it a synonym of Rugoglobigerina, the questionable assignment being due only to the poor preservation of the type specimens.

Types and occurrence: Holotype of Rugoglobigerina rugosa (Plummer) in the Paleontological Research Institute, Ithaca, New York. Unfigured topotypes (USNM P3928, P3921) from the Navarro (Kemp Clay), Maestrichtian, 10 feet below the contact with the Midway (Paleocene), in the bank of Walker Creek, 6 miles N. 15° E. of Cameron, about 1 mile upstream from the intersection of Walker Creek and the Cameron-Clarkson road, Milan County, Texas. Figured hypotype (USNM P3929) from the Navarro (Corsicana marl), branch of Mustang Creek, 1 mile WSW of Noack, 900 feet downstream from the road and 0.2 mile southwest of Christ Evangelical Lutheran Church, Williamson County, Texas. Collected by A. R. Loeblich, Jr., 1955.

Holotype of Plummerella hantkeninoides hantkeninoides Bronnimann (=Plummerita, new name) (USNM P4847) from the Maestrichtian, Guayaguayare beds, Abathomphalus mayaroensis zone, Trinidad, B. W. I.

Holotype (USNM P4856) of Trinitella scotti Bronnimann from the Maestrichtian, Guayaguayare beds, Abathomphalus mayaroensis zone, Trinidad, B. W. I.

Figured hypotype (USNM P4833) and unfigured hypotypes (USNM P4823) of Trinitella scotti Bronnimann from the Maestrichtian, Navarro (Kemp clay), 10 feet below the Midway (Paleocene) contact, in bank of Walker Creek, 6 miles N. 15° E. of Cameron, about 1 mile upstream from intersection of Walker Creek and the Cameron-Clarkson road, Milan County, Texas.

Holotype of Rugoglobigerina rugosa rotundata Bronnimann, the type species of Kuglerina Bronnimann and Brown (USNM P5401) from the Maestrichtian Guayaguayare beds, Abathomphalus mayaroensis zone, Trinidad, B. W. I.

Range: Turonian to Maestrichtian.

Genus Globotruncana Cushman, 1927

Plate 11, Figures 6-11c

Rugotruncana Bronnimann and Brown, Ibid., p. 546, 1956. (Type species: Rugotruncana tinei Bronnimann and Brown, 1956. Fixed by original designation.)

Type species: Pulvinulina arca Cushman, 1926.

Fixed by original designation and monotypy.

Test free, trochospiral, biconvex, sphericonvex or umbilicoconvex, broadly umbilicate, periphery rounded, with a single keel or truncate with a double keel; chambers ovate, hemispherical, angular rhomboid or angular truncate; sutures on the spiral side curved or radial, depressed to elevated, may be limbate and beaded, on the umbilical side sutures curved or radial, depressed or more rarely elevated; wall calcareous, perforate, radial in structure, surface smooth, rugose or beaded; primary apertures interiomarginal, umbilical, in well preserved specimens covered by tegilla, which are perforated by accessory infralaminial and intralaminial apertures, which are then the only openings to the exterior, the tegilla commonly are partially or wholly broken out in the process of fossilization, or may be preserved only as scalloped fragments.

Remarks: D’Orbigny described the first species of Globotruncana in 1839 under the name Rosalina linneiana. The genus Rosalina had been proposed by d’Orbigny in 1826, with Rosalina globularis as type species. In later years several species of Globotruncana were described as Rosalina (e. g., Rosalina canaliculata, R. marginata, R. stuarti), or Pulvinulina (e. g., Pulvinulina tricarinata, P. arca).

Cushman, in 1927, without referring to Rosalina, named the genus Globotruncana with Pulvinulina arca as type species. In 1933 Thalmann stated that Rosalina d’Orbigny, 1826, was a junior synonym of Discorbis Lamarr, 1804, and thus not related to the group of species under discussion here. Globotruncana is there-
fore the first valid name for the species originally described as *Pulvinulina area*.

The true apertural characters of this genus were not given in the original description (Cushman, 1927, p. 91) which stated only “aperture on the ventral side.” In his textbook (1928, p. 311) Cushman separated *Globorotalia* and *Globotruncana* solely on the basis of the periphery, the former “periphery acute or rounded, with a single keel,” the latter “periphery truncate, usually with a double keel.” In the generic description of *Globotruncana* he added, “aperture on the ventral side, often in well-preserved specimens with a thin plate-like structure over the umbilical area.”

Galloway (1933, p. 332) described *Globotruncana* as having the “aperture a slit at the base of the last chamber opening into the large umbilicus,” and placed it in the Orbulinidae, while placing *Globorotalia* (p. 278) in the Rotaliidae, subfamily Rotaliinae. Galloway’s key separated *Globotruncana* from *Globigerina d’Orbigny* only by its having limbate sutures.

Glaessner (1948, p. 150) included *Globotruncana* and *Globorotalia* in the Globorotaliidae, and stated of *Globotruncana* “aperture large, basal, leading from each chamber into the wide umbilicus which is often concealed by a thin perforate plate.”

Some of the French workers, evidently on the basis of Cushman and Galloway’s earlier descriptions, considered *Globotruncana* to have a single aperture, as that of *Globorotalia*, separating the two only on the peripheral characters. Marie (1941, p. 237) commented on the separation of *Globorotalia* and *Globotruncana* according to the number of keels, and considered this basis for subdivision invalid. His key considered *Globorotalia* as having a single terminal aperture, on the last chamber face. He then described the new genus *Rosalinella*, with apertures, particularly in the chambers of the last whorl, opening into the umbilicus. He placed *Globotruncana* Cushman, 1927, in the synonymy of his new genus, *Rosalinina* de Lapparent (not d’Orbigny), etc., selecting as type species *Rosalinina linneiana* d’Orbigny. As *Globotruncana* is a valid name and antedates *Rosalinella*, the latter becomes a junior synonym. The type species, *Rosalinina linneiana* d’Orbigny, was described from Recent sands of Cuba, where it is undoubtedly reworked from the outcropping Cuban Cretaceous strata.

Reichel (1949, p. 600) considered *Globotruncana* to have four subgenera: *Globotruncana*, s. s., *Rotalipora* Brotzen, *Thalmaninella* Sigal and *Ticinella* Reichel. The latter three subgenera of Reichel are here considered unrelated to *Globotruncana*, and are fully discussed under *Rotalipora*.

Sigal (1952, p. 236) stated that *Globotruncana* and *Globorotalia* had been differentiated by the number of keels, but that in reality the position of the aperture was a more certain criterion, and he thus recognized as genera (not subgenera) *Ticinella* Reichel (with barely delineated keel), *Thalmaninella* Sigal (with one keel), both with secondary umbilical apertures; *Rotalipora* Brotzen with one keel and secondary apertures in sutural slits, and *Globotruncana*, s. s., with one or two keels without secondary apertures.

However, in *Globotruncana*, s. s., only the accessory apertures of the tegilla are visible in perfect specimens, the primary apertures being visible only when the tegilla are broken out in preservation or in the preparation of the fossil material for study. These tegilla and accessory apertures are present on fully preserved specimens of every species.

*Rugotruncana* was separated from *Globotruncana* by Bronnimann and Brown (1956) because of a surface ornamentation of discontinuous ridges. The genera are otherwise identical, and Bronnimann and Brown admitted (p. 546) that “the morphologic differences between the two genera are slight.” We do not regard surface ornamentation as a character of generic value, hence *Rugotruncana* is here considered a synonym of *Globotruncana*. In addition to the type species, Bronnimann and Brown listed other ornamented *Globotruncana* which they considered to belong to *Rugotruncana*, among which were *G. intermedius* Bolli and *G. mayaroensis* Bolli. These two species differ from *Globotruncana* in lacking an open umbilicus, in having only a single tegillum which extends from the final chamber, and has only infralaminal accessory apertures, and the primary aperture is extramatrical-umbilical in position, instead of truly umbilical. These two species we place in the new genus *Abathomphalus*, and *G. mayaroensis* is the type species.

*Bucherina* was described by Bronnimann and Brown as a monotypic genus from the Maestrichtian of Cuba, which resembles *Globotruncana* and *Rugotruncana* in having a keel and small apertural flaps, but was said to differ in that these flaps do not extend across the umbilicus to form a true cover plate (tegilla). In nearly all species of *Globotruncana* these fragile tegilla are only partially preserved, and only very rare specimens show them as well preserved as in the specimens here figured. Tegilla were not recognized even in the type species of *Globotruncana* until many years after its original description, and they have not been mentioned in the original descriptions of the majority of species. It is probable that better preserved specimens of *Bucherina sandulgei* will also show the complete umbilical tegilla, and we regard *Bucherina* as a synonym of *Globotruncana*.

Hofker (1956, p. 319) proposed the generic name *Marginotruncana*, with *Rosalinina marginata* Reuss as type species. He considered *Globotruncana* to have a strongly reduced protoformen (primary aperture), which is no longer an open slit, and *Marginotruncana* was said to have lost the protoformen or to have it fused with a deuteroformen (secondary aperture). The diagrammatic figures in his text-fig. 1 are highly misleading, as there are not two openings in the final chamber of true *Globotruncana*, and there is no extramatrical opening into the chamber. If such openings exist in specimens studied by Hofker, they are totally unlike those of the type species of the genus, and his specimens undoubtedly are of a form referable to the...
family Globorotaliidae, probably Rotalipora. The minor differences in proportions of these two openings shown in various “genera” in his text-fig. 1 are certainly of not more than specific value.

As shown in the present paper, and recognized by most authorities on the planktonic genera, true Globo- truncana has an umbilical primary aperture. In well preserved specimens this is always covered by the um- bilical tegilla, the only connection to the outside being through the infralaminal accessory apertures, which open beneath the tegilla, not directly into the chambers themselves.

Hofker selected Rosalina marginata Reuss as type species for his genus. In the original description of the species (a true Globotruncana), Reuss (1845) mentioned the perpendicularly truncate outer margin (typical of double-keeled forms) and broad umbilicus. The original figures are small and somewhat generalized. However, that of Reuss’ fig. 68, pl. 13, from the Plänermergel (Turonian) is here designated as lectotype, as it shows the open umbilicus and other characters mentioned in the original description. Better figures are given by Cushman (1936, pl. 62, fig. 1), of a specimen in the Reuss collection at Cambridge, which is from the original locality. Hagn and Zeil (1954, pl. 2, fig. 4) showed very similar specimens from the Turonian of the Bavarian Alps.

In addition to the lectotype, Reuss also figured as Rosalina marginata a specimen (pl. 8, fig. 74) from the lower Planer (Cenomanian) which differed from the written description in lacking an open umbilicus. Because of this character and the apparently extra- umbilical aperture, this specimen is probably a species of Praeglobotruncana or Rotalipora. The geologic occurrence supports this assumption, as true Globo- truncana does not occur in the Cenomanian, whereas both Praeglobotruncana and Rotalipora do appear there.

Completely disregarding Reuss’ original description of the species (only the later publication of Reuss, 1854, was cited by Hofker) as well as the later descriptions and figures of the species, Hofker figured as Marginotruncana marginata (Reuss) a single-keeled form with an extraumbilical aperture. Hofker commented with regard to his text-fig. 6 that itsome what resembled Rotalipora, and also stated (p. 323) that no typical M. marginata occurs in the Cenomanian-Turonian of southern Germany, although it was originally described from Bohemia and has since been recorded from Bavaria by Hagn and Zeil (1954). Hofker stated (p. 324) that Hagn’s form was not true marginata (he credited the 1954 publication solely to Hagn, although it was under the joint authorship of Hagn and Zeil), yet Hagn and Zeil’s specimens of a double-keeled Globotruncana more closely resemble the original figures and description of Reuss, and are geographically closer to the type area, than those of Hofker.

From the illustrations given, it is probable that Hof- ker identified as the species marginata, specimens which are actually Praeglobotruncana, although his citation of Rosalina marginata as type species, places the genus Marginotruncana as a junior synonym of Globotruncana.

In addition to the type species, Hofker also included in Marginotruncana the following species of typical Globotruncana: Rosalina stuarti Lapparent, Globotruncana globigerinoides Brotzen, Marginotruncana para- ventricosa Hofker (which included G. ventricosa of Brotzen, not White) and Marginotruncana papaerata Hofker (including G. marginata of Visser, not Reuss). He also included other totally unrelated species, such as G. intermedia Bolli (an Abathomphalus), G. citae Bolli (a Praeglobotruncana), G. stephani var. turbinata Reichel (a variety of the type species of Rotundina, a junior synonym of Praeglobotruncana), G. ticeinensis Gandolfi (a Rotalipora previously placed in Thalmaninella, junior synonym of Rotalipora), and G. appenninica Renz (also a Rotalipora). He thus included in his Marginotruncana, species with the distinctive characters of the genera Praeglobotruncana Bermudez, 1952 (and its synonym Rotundina Subbotina, 1953), Rotalipora Brotzen, 1942 (and its synonym Thalmaninella Sigal, 1948), which belong to the family Globorotaliidae, and the genera Globotruncana Cushman, 1927 (and its synonym Rosalinella Marie, 1941) and Abathomphalus Bolli, Loeblich and Tappan, which belong to the family Globotruncanaeidae. All but the last of these generic names preoccupy that of Hofker, if all were congeneric.

**Types and Occurrence:** Holotype of Puleinulina area Cushman (type species of Globotruncana) (Cushman Coll. 5078) from the Mendez shale, near Huiches, Hacienda El Limón, San Luis Potosí, Mexico.

Figured hypotypes of Globotruncana area Cushman (USNM P4242 a-e) from Navarro (Corsicana marl), branch of Mustang Creek, 1.0 miles WSW of Noack, 900 feet downstream (south) from road and 0.2 mile southwest of Christ Evangelical Lutheran Church, Williamson County, Texas. Collected by Noel Brown.

**Range:** Turonian to Maestrichtian.
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OVET, C. D.

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The Genera Praeglobotruncana, Rotalipora, Globotruncana, and Abathomphalus in the Upper Cretaceous of Trinidad, B. W. I.

By Hans M. Bolli

Introduction

Since the publication of the author's papers on the genus Globotruncana and on the Upper Cretaceous stratigraphy of Trinidad (Bolli, 1951, 1952), much new paleontologic and stratigraphic information has been gained. It is the purpose of the present paper to describe those species of the genera Praeglobotruncana, Rotalipora, Globotruncana and Abathomphalus that were not known before, to discuss some changes in the previous results, and to show the stratigraphic distribution in Trinidad of all recorded species of these genera.

The highly complex geology of central and southern Trinidad, with its strongly distorted and incomplete surface sections, is not an inviting ground for detailed biostratigraphic studies. This applies in particular to the Upper Cretaceous sediments. The few, widely scattered outcrops are small, isolated slipmasses that do not offer continuous stratigraphic sections. It is only in recent years, during exploration activities in search of Cretaceous oil, that valuable paleontologic and stratigraphic information has come to light. Wells drilled into and through the Upper Cretaceous have made available a number of sections which, combined, represent a fairly continuous succession of sediments. Although this combined sequence is not regarded as truly comprehensive—several stratigraphic gaps apparently still exist—it may now be said that its completeness is at least equal to many of the best known Upper Cretaceous sections in Central and South America.

The faunistic content of Trinidad's Upper Cretaceous sediments is variable, but more often than not the sediments contain rich fossil assemblages. Foraminifers are predominant in all formations. Only occasionally are they out-numbered by Radiolaria (in parts of the Naparima Hill formation). Mollusks may be numerous in the lower part of the Naparima Hill formation where they become valuable markers. The stratigraphic usefulness of certain species of Didymoceras and some ammonites in these beds has been noted recently (Imlay, 1955).

About 450 different species and subspecies of Foraminifera are recognized today in Trinidad's Upper Cretaceous. Of these, about 380 belong to calcareous and arenaceous bentonic genera and the remaining 70 odd to planktonic genera. Of the latter, about 15 are classified under the various genera of the family Hantkeninidae and the genus Rugoglobigerina; another 20 under the genera Guembelina, Pseudotextularia, and Ventilabrella; and the remaining 35 under Praeglobotruncana, Rotalipora, Globotruncana, and Abathomphalus. Bentonic and planktonic Foraminifers are often present in equal numbers, though in the Guayaguayare and Gautier formations the latter predominate. The abundance and short range of many of the planktonic species make them ideally suited as markers for stratigraphic work in the Upper Cretaceous of Trinidad.

The generic position of several species discussed in this paper had to be changed according to the classification of planktonic Foraminifera proposed recently by Bolli, Loeblich, and Tappan (1957). Globorotalia delrioensis Plummer and Globotruncana citae Bolli are now included in Praeglobotruncana. Globotruncana intermedia Bolli and G. mayaroensis Bolli belong to Abathomphalus. Several Upper Cretaceous species published as Globigerina (e. g., Globigerina gautieriensis Bronnimann) have been removed to the genus Praeglobotruncana since completion of this paper and are therefore omitted.

Stratigraphy

The Upper Cretaceous sediments of Trinidad are at present grouped into the Gautier, Naparima Hill, and Guayaguayare formations. Because of non-deposition or subsequent erosion these formations show a very irregular pattern of distribution in central and south Trinidad. Strong tectonic movements in which they were involved have further complicated the study of the original sequence of the sediments. Most outcrops are small isolated masses, each representing not more than one zone. The only exception is found in the Gautier River of the eastern Central Range (for detailed locality description, see p. 52). There, the black Gautier shales (Rotalipora appenninica appenninica zone) are seen in contact with strongly silicified beds of the Naparima Hill formation. Higher

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1 Trinidad Oil Company, Ltd., Pointe-a-Pierre, Trinidad, B. W. I.
2 Credit for this goes in the first place to Trinidad Oil Company, Ltd. (formerly Trinidad Leasehold, Ltd.), and to Trinidad Petroleum Development, Ltd., the two Companies most active in exploring the Upper Cretaceous oil prospects.
in the same section we find two small outcrops of the highly calcareous Guayaguayare formation (transition Globotruncana ganesi—Abathomphalus mayaroensis zone). The contact with the Naparima Hill formation is, however, not exposed.

Because of the virtual absence of surface sections it is fortunate that a number of subsurface profiles are available, thus permitting the study of a fairly continuous sequence of Upper Cretaceous foraminiferan faunas.

For reasons already mentioned, and because of the possibility of correlation with established type sections in Europe and North Africa, where the same forms are found, species of Praeglobotruncana, Rotalipora, Globotruncana and Abathomphalus have been chosen for the zoning. Several species that prove to be important markers in Europe and North Africa have not yet been recorded in Trinidad. Rotalipora cushmani (Morrow), R. reicheli Mornod, R. turonica Brotzen, and Praeglobotruncana stephani (Gandolfi) constitute one group of species absent so far from known Trinidad sections. They are restricted to the upper part of the Cenomanian. A widespread hiatus between the Gautier and Naparima Hill formations, with the Upper Cenomanian and probably the lower Turonian missing, may thus be assumed. Globotruncana calcarea Cushman, which is probably restricted to the upper part of the Campanian, is another form not yet recorded in Trinidad, suggesting that a minor stratigraphic gap is likely to exist between Naparima Hill formation and Guayaguayare formation. This is further supported by an abrupt change in lithology between the two formations.

Because the distribution of the various zones in Trinidad is so irregular, it is quite possible that the missing intervals are present but have not yet been found.

The Gautier formation consists of dark grey to black, noncalcareous or calcareous shales. Strongly indurated shales, sandstones and conglomerates may be interbedded. Based on faunistic evidence, the age is considered to be Alban to lower part of the Cenomanian. The formation is divided into the following zones (from top to bottom):

Rotalipora appenninica appenninica zone
Globigerina washitsensis zone
Rotalipora ticenensis ticenensis zone

The Rotalipora ticenensis ticenensis and Globigerina washitsensis zones have both been established in the subsurface section of Trinidad Leaseholds well Marac 1 (coordinates N:152141 links, E:424447 links). The type locality for the youngest zone is located in the Gautier River (right side branch of Cunapo River at junction of waterfall branch, north of Chert Hill, 1½ miles southeast of Mamon Guaico-Tamana Road, eastern Central Range, coordinates N:331460 links, E:526400 links). Some of the samples collected there consist of up to 9 percent by weight of Foraminifera, predominantly Globorotaliidae and Planomalinae.

The maximum recorded thickness of the Gautier formation is about 2,000 feet.

The Naparima Hill formation consists in its upper part of argillite, a whitish to grey-brown siliceous indurated claystone with an average CaCO₃ content of 10 to 20 percent. Towards its base, the formation becomes increasingly well-bedded and shaly, with occasional interbedded sands; the colour then changes to dark grey or black. Based on megafossil and microfossil evidence, the Naparima Hill formation ranges from Turonian to Campanian. The following zones are distinguished (from top to bottom):

Globotruncana stuarti zone
Globotruncana fornicata zone
Globotruncana concavata zone
Globotruncana renzi zone
Globotruncana inornata zone

The bottom four zones had to be established in subsurface sections. In the Globotruncana inornata zone (Trinidad Petroleum Development well Moruga 15, coordinates N:149878 links, E:497002 links) are found the single-keeled Globotruncana inornata, new species, G. schneegansi Sigal, and G. helvetica Bolli, with no double-keeled species. The Globotruncana renzi zone (Trinidad Petroleum Development well Moruga 15, coordinates N:149878 links, E:497002 links) is defined by the first occurrence of double-keeled Globotruncana (Globotruncana renzi Gandolfi and G. cf. lapparenti coronata Bolli) and the absence of Globotruncana concavata (Brotzen), G. wilsoni, new species, and G. fornicata Plummer. Restricted to the Globotruncana concavata zone (Trinidad Leaseholds well Marac 1, coordinates N:151141 links, E:424447 links) are the zonal marker and Globotruncana wilsoni, new species. The Globotruncana fornicata zone (Trinidad Petroleum Development well Moruga 15, coordinates N:149878 links, E:497002 links) is characterized by the absence of Globotruncana concavata (Brotzen) and G. stuarti (de Lapparent) in an assemblage that contains Globotruncana fornicata Plummer.

As in the case of the Gautier formation, only the highest zone is known from the surface. Its type locality is the Naparima Hill in San Fernando (Usine Ste. Madeleine Quarry at the SE end of the hill; coordinates N:235800 links, E:364000 links). The zonal marker Globotruncana stuarti (de Lapparent) appears first in the upper part of the Naparima Hill formation, and continues into the Guayaguayare formation. The relatively scarce Globotruncana ventricosa White and Praeglobotruncana coarctata, new species, are confined to the Globotruncana stuarti zone. The maximum recorded thickness of the Naparima Hill formation is about 2,000 feet.

The Guayaguayare formation, consisting of blotchy, grey, highly calcareous shale, overlies the Naparima Hill formation. The major part of the formation is regarded as Maestrichtian, though its lower portion is of possible late Campanian age. Outcropping isolated slipmasses of the Guayaguayare formation have been discussed and described previously (Bolli, 1950,
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**Figure 10**—Species distribution of *Praeglabratulina, Rotalipora, Globigerina*, and *Elphidium* in Trinidad, B. W. I.
The formation is divided into the zones (all established in the subsurface section of Trinidad Leaseholds well Guayaguayare 163, coordinates N:157646 links, E:572808 links):

- Abathomphalus mayaroensis zone
- Globotruncanana gansseri zone
- Globotruncanana lapparenti tricarinata zone

The lowest zone of the Guayaguayare formation still lacks Globotruncanana gansseri Bolli and Abathomphalus mayaroensis (Bolli), but abounds in several subspecies of Globotruncanana lapparenti Broten, predominant among which is the zonal marker Globotruncanana lapparenti tricarinata (Quereau). A few specimens of Globotruncanana andori de Klasz were found in this zone. The following species do not range into the younger zones: Globotruncanana lapparenti lapparenti Bolli, G. lapparenti bulloides Vogler, G. lapparenti tricarinata (Quereau), G. globigerinoides Broten, G. fornicata Plummer, and G. repanda, new species.

The marker for the Globotruncanana gansseri zone has also been recorded from Turkey (under the synonym of Globotruncanana lugeoni Tiley) and from mid-Pacific sea mounts (Hamilton, 1953). The author has seen it in material from Cuba and in the Navarro formation. Globotruncanana calciformis (de Lapparent), G. contusa (Cushman), G. gagnepini Tiley and Abathomphalus intermedia (Bolli) are other species occurring for the first time in the Globotruncanana gansseri zone; they continue into the Abathomphalus mayaroensis zone.

The zonal marker of the Abathomphalus mayaroensis zone is a typical and apparently short-lived species which so far has not been recorded in publications from outside Trinidad. However, the author has seen specimens in material from the type locality of the Mendez shale (300 meters east of Mendez Station, kilometer 629.3 on the San Luis Potosi-Tampico railway, Mexico) and from Bavaria. An outcrop containing a fauna transitional between the Globotruncanana gansseri and Abathomphalus mayaroensis zones is known from the Gautier River section (see p. 52).

The maximum recorded thickness of the Guayaguayare formation is about 500 feet.

**Evolutionary Trends**

In recent years much has been written on the evolutionary trends of the genera under discussion. Hagn and Zeil (1954, pp. 51–56) gave a condensed review of the various interpretations. Although there might be a relatively simple general pattern in the phylogeny of Praeglobotruncanana, Rotalipora, Globotruncanana, and Abathomphalus, the details are complex and little studied.

The evolutionary trend in Rotalipora, from a single inflated earlyform to several compressed later species, seems to be fairly well established. Of special interest is the pattern of coiling during the evolution of Rotalipora. As may be expected, the early species, Rotalipora roberti (Gandolfi) and R. ticinensis (Gandolfi), coil at random, later becoming predominantly dextral in the Rotalipora appenninica (Renz)-R. reicheli Mornod group. Before the extinction of the genus, its latest representatives, Rotalipora turonica Broten and R. cushmani (Morrow), unexpectedly revert to random coiling. This might represent a gerontic stage. Whereas abrupt changes in coiling from one preferred direction to the opposite one are known to take place in later evolutionary stages of certain Globorotalia species (Bolli, 1950), such a return to random coiling had not, to the author's knowledge, been observed before.

Transitional stages exist between certain Rugoglobigerina and Globotruncanana species. This suggests a close generic relationship of at least a number of Globotruncanana species with Rugoglobigerina species. It may be assumed that species of Globotruncanana branched off independently from rugoglobigerinid forms on more than one occasion between Turonian and Maestrichtian time. One of the first attempts by Rugoglobigerina to produce forms with one or more peripheral keels and compressed chambers took place in the Turonian and led to the short lived Globotruncanana helvetica Bolli which has no apparent direct descendants. The single-keeled Globotruncanana schneegansii Sigal developed independently at approximately the same time from similar forms, possibly via Globotruncanana inornata, new species. This seems to have been a more successful mutation, as it appears that the single-keeled Globotruncanana schneegansii gave rise to the double-keeled Globotruncanana renzi Gandolfi-G. angusticarinata Gandolfi-G. concavata (Broten)G. ventricosa White suite. However, the possibility that the single-keeled Globotruncanana schneegansii might have developed from late representatives of Praeglobotruncanana stephani (Gandolfi) should not be overlooked. A tendency is observed in late representatives of Praeglobotruncanana stephani for the aperture to move from an interiomarginal, extrabulbilical-umbilical position to an umbilical one.

Globotruncanana wilsoni, new species, appears to have developed independently from Rugoglobigerina ancestors in early Senonian time. This species may have given rise subsequently to the Globotruncanana fornicata Plummer-G. contusa (Cushman) suite.

Globotruncanana globigerinoides Broten whose relation to rugoglobigerine forms is obvious, is a comparative latecomer, appearing in Trinidad only after many other typical Globotruncanana species have already become extinct. It initiates another attempt by the Rugoglobigerine to change their shape. Globotruncanana lapparenti bulloides Vogler and G. lapparenti tricarinata (Quereau) are connected by transition to G. globigerinoides; they are to a large degree contemporaneous.

The Campanian Globotruncanana repanda, new species, is short lived and likely to have sprung directly from a Rugoglobigerina ancestor.

Globotruncanana gansseri Bolli, which is morphologically similar to the Turonian Globotruncanana helvetica Bolli, appears in the Maestrichtian, again with transitional
rugoglobigerinid forms. Like *Globotruncana helvetica*, it is a short-lived offshoot from a *Rugoglobigerina* species. The Maestrichtian *Trinitella scotti* Bronnimann (=*Rugoglobigerina*) with its compressed end chambers is further proof of the repeated and seemingly independent attempts of the Turonian-Maestrichtian *Rugoglobigerinae* to develop one or two peripheral keels. This brief outline of the probable phylogenetic pattern demonstrates the close relationship between the genera *Rugoglobigerina* and *Globotruncana* and at the same time throws light on the artificial division into two genera of planktonic Foraminifera that are genetically closely related. The identical pattern of coiling is further proof of such relationship. All species of both groups maintain a strong preference for dextral coiling from the Turonian to their contemporaneous extinction in the Maestrichtian. An earlier evolutionary stage with random coiling such as is found in certain Oligo-Miocene *Globorotalia* species (Bolli, 1951) or in *Rotaliopora* may be expected in Cenomanian ancestors.

**Systematic Descriptions**

**Family Globorotaliidae Cushman, 1927**

**Genus Praeglobotruncana Bermudez, 1952**

*Praeglobotruncana cf. delrioensis* (Plummer)

**Plate 12, figures 4a–c**

*Globorotalia delrioensis* Plummer, Univ. Texas Bull. 3101, p. 199, pl. 13, figs. 2a–c, 1931.

Shape of test: low trochospiral, biconvex; equatorial periphery slightly lobate, no distinct keel. Wall: calcareous, perforate, surface smooth. Chambers: moderately compressed; about 12, arranged in 2½ to 3 whorls; the 5 chambers of the last whorl increase rapidly in size; early whorls small by comparison. Sutures: spiral side curved, depressed; umbilical side nearly radial, depressed. Umbilicus: details obscure; part appears to be covered by extensions of chambers. Aperture: An interiomarginal, extraumbilical-umbilical slit. Coiling: Random; of the 8 specimens counted, 5 coiled dextrally.

Dimensions of figured hypotype: Diameter 0.32 mm.; thickness 0.15 mm.

**Range:** *Globotruncana stuarti* zone, Naparima Hill formation.

**Types and occurrence:** Usine Ste. Madeleine Quarry, southeast end of Naparima Hill, San Fernando, Trinidad (coordinates N:235800 links, E:364000 links). Holotype (USNM P4794) from sample Bt. 37 (TLL 151935); figured paratype (USNM P4795) from sample Bt. 46 (TLL 151943).

**Remarks:** *Praeglobotruncana coarctata*, new species, differs from *Praeglobotruncana citae* (Bolli) in having an almost flat spiral side instead of a convex one and in having usually five chambers in the last whorl instead of four.

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Genus Rotalipora Brotzen, 1942

Rotalipora ticinensis ticinensis (Gandolfi)

PLATE 12, FIGURES 1a–c


Thalmanninella ticinensis ticinensis (Gandolfi), Rhiechi, Ecol. Geol. Helvetiae, vol. 42, pt. 2, p. 603, pl. 16, fig. 6, and pl. 17, fig. 6, 1949.

Shape of test: low trochospiral, biconvex, with spiral side slightly more convex; equatorial periphery nearly circular, with single keel. Wall: calcareous, perforate, surface smooth. Chambers: compressed; 18–20, arranged in 2½–3 whorls; the 7–8 chambers of the last whorl increase slowly in size. Sutures: spiral side curved, depressed, occasionally slightly raised; umbilical side radial, depressed. Umbilicus: details obscure; part appears to be covered by extensions of chambers. Apertures: primary aperture an interiomarginal, umbilical-extraumbilical silt; no secondary sutural apertures have been observed in the rather poorly preserved Trinidad specimens. Coiling: random; of the 25 specimens counted, 15 coiled sinistrally.

Dimensions of figured hypotype: diameter 0.31 mm.; thickness 0.11 mm.

Range: Rotalipora ticinensis ticinensis zone, Gautier formation.

Type and occurrence: Figured hypotype (USNM P4792) from Trinidad Leaseholds well Maraca 1, Trinidad (coordinates N:152141 links, E:424447 links), sample at 11,979 feet (TLL 178532).

Family Globotruncanidae Brotzen, 1942

Genus Globotruncana Cushman, 1927

Globotruncana helvetica Bolli

PLATE 13, FIGURE 1 a–c


Shape of test: very low trochospiral; spiral side almost flat, inner whorls often slightly raised, umbilical side strongly inflated; equatorial periphery lobate, in well developed specimens a distinct keel is present though it is often weakened in the last chamber; specimens with faint or missing keels, transitional to rugoglobigerine forms, were observed in material from Tunisia. Wall: calcareous, perforate, surface rugose especially on umbilical side. Chambers: hemispherical; 15–18, arranged in 2–3 whorls; the 5 chambers of the last whorl increase rapidly in size, early whorl is small by comparison. Sutures: spiral side curved, depressed; umbilical side almost radial, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegula with accessory apertures not preserved in examined specimens. Coiling: the few specimens recorded so far in Trinidad coil dextrally; of 100 specimens counted in a sample from Tunisia, 98 coiled dextrally.

Dimensions of figured hypotype: diameter 0.44 mm.; thickness 0.24 mm.

Range: Globotruncana inornata zone, Naparima Hill formation.

Type and occurrence: Figured hypotype (USNM P4797) from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links), sample from core 6980–7005 feet (TLL 228918).

Globotruncana repanda Bolli, new species

PLATE 13, FIGURES 2 a–c

Shape of test: very low trochospiral, spiral side concave, umbilical side strongly inflated; equatorial periphery lobate, early chambers of last whorl with double keel, which may be absent in the ultimate and penultimate chambers. Wall: calcareous, perforate; surface in well preserved specimens slightly rugose, especially on the umbilical side. Chambers: globular to hemispherical; 12–15, arranged in 2–3 whorls; the 4 chambers of the last whorl increase rapidly in size, earlier whorls small by comparison. Sutures: spiral side almost radial, depressed; umbilical side radial, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegula with accessory apertures not preserved in Trinidad material, but present in specimens of this species from the Gulf Coast. Coiling: the 25 specimens counted all coiled dextrally.

Dimensions of holotype: diameter 0.4 mm.; thickness 0.24 mm.

Range: Globotruncana fornicata zone to Globotruncana lapparenti triacarinata zone, Naparima Hill formation. Holotype from Globotruncana stuarti zone, Naparima Hill formation.

Type and occurrence: Holotype (USNM P4797) from Usine Ste. Madeleine Quarry, southeast end of Naparima Hill, San Fernando, Trinidad (coordinates N:235800 links, E:364000 links), sample Bt. 37 (TLL 151935).

Remarks: In its planoconvex shape, Globotruncana repanda, new species, shows similarities to G. helvetica Bolli, G. ganssleri Bolli, G. concavata (Brotzen), and G. ventricosa White. It differs from the last two by having in the last whorl fewer and more inflated chambers, which are bent upwards on the spiral side. It is usually slightly smaller in size. From Globotruncana helvetica and G. ganssleri the new species differs in having two peripheral keels, a more concave spiral side, and a less rugose surface. The stratigraphic range of Globotruncana repanda is similar to that of G. ventricosa but differs considerably from that of the other three species.
Globotruncana concavata (Brotzen)

Plate 13, Figures 3a–c


Shape of test: very low trochospiral, spiral side often slightly concave, umbilical side strongly convex; equatorial periphery distinctly lobate with closely spaced double keel. Wall: calcareous, perforate, surface smooth. Chambers: hemispherical; 15–20, arranged in 3–3 3/8 whors; the 5–6 chambers of the last whorl increase rapidly in size, early whors small by comparison. Sutures: spiral side distinctly curved, depressed; umbilical side radial, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegill with accessory apertures not preserved in examined specimens. Coiling: predominantly dextral; of 50 specimens counted, only 3 coiled sinistrally.

Dimensions of figured hypotype: diameter 0.69 mm.; thickness 0.4 mm.

Range: Globotruncana concavata zone, Naparima Hill formation.

Type and occurrence: Figured hypotype (USNM P4798) from Trinidad Leaseholds well Marac 1, Trinidad (coordinates N:152141 links, E:424447 links), sample from core 8,180–8,237 feet (TLL 175917).

Remarks: The characteristic features of Globotruncana concavata (Brotzen) are similar to those of Globotruncana ventricosa White. Through the courtesy of Dr. B. F. Ellis, some specimens of Globotruncana ventricosa from White's original collection at Columbia University, N. Y., were obtained for comparison with specimens of Globotruncana concavata from Israel (original locality), Tunisia, and Trinidad. It was found that the two species differ as follows:

Globotruncana ventricosa as a rule has 6–7 chambers in the last whorl with slightly more oblique sutures on the spiral side, as against usually 5 chambers with slightly curved sutures in Globotruncana concavata. The spiral side of Globotruncana concavata is often slightly concave, that of Globotruncana ventricosa is flat or slightly raised. Compared with Globotruncana concavata, the 2 peripheral keels in Globotruncana ventricosa are a little further apart and more strongly developed, and the sutures are often beaded. Finally, the stratigraphic range of the two species is different: Globotruncana concavata appears to be restricted to the upper part of the Coniacian and the Lower Santonian, Globotruncana ventricosa to the Upper Santonian and the Campanian. Because of their similarity, the two species may easily be mistaken. The specimen figured by Dalbiez (1955) as Globotruncana ventricosa ventricosa is, in the author's opinion, a Globotruncana concavata. Globotruncana ventricosa carinata Dalbiez is probably identical to Globotruncana ventricosa White, while Globotruncana ventricosa primitiva Dalbiez could be close to Globotruncana renzi Gandolfi, judging from the single peripheral view given by Dalbiez and the stratigraphic range quoted by him. According to Dalbiez's range chart, the three species (Globotruncana ventricosa primitiva (=G. renzi), G. ventricosa ventricosa (=G. concavata) and G. ventricosa carinata (=?G. ventricosa White) follow each other in time. Transitional specimens suggest that they probably represent an evolutionary sequence.

Globotruncana ventricosa White

Plate 13, Figures 4a–c

Globotruncana canaliculata var. ventricosa White, Journ. Palaeontol., vol. 2, No. 4, p. 284, pl. 38, figs. 5a–c, 1928.

Shape of test: very low trochospiral, nearly flat or slightly convex on spiral side, strongly convex on the umbilical side; equatorial periphery lobate, with distinct, robust double keel, often weakened in last chambers. Wall: calcareous, perforate, surface smooth. Chambers: angular, inflated; 15–20, arranged in 2 3/8 whors; the 6–7 chambers of the last whorl increase moderately in size. Sutures: spiral side: curved, strongly raised, beaded in early portion; umbilical side: slightly curved, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegill with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens seen coiled dextrally.

Dimensions of figured hypotype: diameter 0.63 mm.; thickness 0.34 mm.

Range: Globotruncana stuarti zone, Naparima Hill formation.

Type and occurrence: Figured hypotype (USNM P4799) from Usine Ste. Madeleine Quarry, southeast end of Naparima Hill, San Fernando, Trinidad (coordinates N:235800 links, E:364000 links), sample Bt. 37 (TLL 151935).

Remarks: See remarks under the description of Globotruncana concavata (Brotzen).

Globotruncana inornata Bolli, new species

Plate 13, Figures 5a–6c

Shape of test: low trochospiral, biconvex; equatorial periphery strongly lobate, early chambers of last whorl rounded at periphery, last and occasionally penultimate chambers compressed with sharp peripheral edge or faint keel. Wall: calcareous, perforate, surface of early chambers in well preserved specimens showing some rugosity. Chambers: subangular, compressed; 14–16, arranged in 3 whors; the 4 chambers of the last whorl increase rapidly in size, early whors small by comparison. Sutures: spiral side slightly curved, depressed; umbilical side: straight, depressed. Umbilicus: shallow, wide. Apertures: primary apertures interiomarginal, umbilical; tegill with accessory apertures poorly preserved in examined specimens. Coiling: predominantly dextral; of 50 specimens counted, only 4 coiled sinistrally.
Dimensions of holotype: diameter 0.44 mm.; thickness 0.2 mm.

Range: Globotruncana inornata zone to Globotruncana concavata zone, Naparima Hill formation. Holotype from Globotruncana renzi zone, Naparima Hill formation. Similar forms seem to extend into the Globotruncana fornicata and G. stuartii zones of the Naparima Hill formation.

Types and occurrence: Figured types from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links). Holotype (USNM P4800) from core 6,802–6,827 feet (TLL 223498), paratype (USNM P4801) from core 6,980–7,005 feet (TLL 223504).

Remarks: Globotruncana inornata, new species, differs from Globotruncana wilsoni, new species, in having the early chambers of the last whorl rounded at the periphery rather than with a double keel. It also has a longer stratigraphic range than Globotruncana wilsoni, new species.

Globotruncana schneegansi Sigal

Plate 14, Figures 1a–c


Shape of test: low trochosحوال, biconvex; equatorial periphery lobate, with distinct single keel on all chambers of last whorl. Wall: calcareous, perforate, surface smooth. Chambers: angular, strongly compressed; about 14, arranged in 2½–3 whors; the 5 chambers of the last whorl increase rapidly in size, early whors small by comparison. Sutures: spiral side curved, slightly raised in last whorl, occasionally beaded, in early part depressed; umbilical side depressed, radial or slightly curved. Umbilicus: shallow, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens seen coiled dextrally.

Dimensions of figured hypotype: diameter 0.6 mm.; thickness 0.2 mm.

Range: Globotruncana inornata zone to Globotruncana renzi zone, Naparima Hill formation.

Type and occurrence: Figured hypotype (USNM P4802) from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links), sample from core 6,980–7,005 feet (TLL 223504).

Globotruncana renzi Gandolfi

Plate 14, Figures 3a–c


Shape of test: low trochosحوال, biconvex; equatorial periphery slightly lobate, with closely spaced double keel in early chambers of last whorl; last and occasionially penultimate chambers with a single keel only. Wall: calcareous, perforate, surface smooth. Chambers: angular, strongly compressed; about 14, arranged in 2½–3 whors; the 5 chambers of the last whorl increase rapidly in size, early whors small by comparison. Sutures: spiral side curved, slightly raised in last whorl, occasionally beaded, in early part depressed; umbilical side depressed, radial or slightly curved. Umbilicus: shallow, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens seen coiled dextrally.

Dimensions of figured hypotype: diameter 0.6 mm.; thickness 0.23 mm.

Range: Globotruncana renzi to Globotruncana concavata zone, Naparima Hill formation.

Type and occurrence: Figured hypotype (USNM P4803) from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links), sample from core 6,802–6,827 feet (TLL 223498).

Globotruncana cf. lapparenti coronata Bolli

Plate 14, Figures 2a–c

Globotruncana lapparenti coronata Bolli, Eclog. Geol. Helvetiae, vol. 37, No. 2, p. 233, pl. 9, figs. 14, 15, and figs. 21 and 22 of text fig. 1, 1944.


Shape of test: low trochosحوال, biconvex; equatorial periphery lobate, with closely spaced double keel. Wall: calcareous, perforate, surface smooth. Chambers: angular, strongly compressed; about 14, arranged in 2½–3 whors; the 5 chambers of the last whorl increase rapidly in size; early whors small by comparison. Sutures: spiral side curved, slightly raised in last whorl, depressed in early portion; umbilical side slightly curved, depressed. Umbilicus: shallow, wide. Apertures: primary apertures interiomarginal, umbilical. Tegilla with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens seen coiled dextrally.

Dimensions of figured hypotype: diameter 0.56 mm.; thickness 0.2 mm.

Range: Globotruncana renzi to Globotruncana concavata zone, Naparima Hill formation.

Type and occurrence: Figured specimen (USNM P4804) from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links), sample from core 6,519–6,544 feet (TLL 223495).

Remarks: The Trinidad specimens are slightly smaller than the typical forms from the Alpine-Mediterranean region.

Globotruncana wilsoni Bolli, new species

Plate 14, Figures 4a–c

Shape of test: low trochosperial, biconvex; equatorial periphery slightly lobate, early chambers of last whorl with a
faint double keel, which is reduced to a single keel in the last and penultimate chamber. Wall: calcareous, perforate, surface smooth. Chambers: moderately compressed; 12–15, arranged in 3 whorls; the 4 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side slightly curved, depressed; umbilical side nearly radial, depressed. Umbilicus: wide. Apertures: primary aperture interiomarginal, umbilical; tegula with accessory apertures not preserved in examined specimens. Coiling: the 50 specimens counted coiled dextrally.

Dimensions of holotype: diameter 0.49 mm.; thickness 0.24 mm.

Range: Globotruncana concavata zone, Naparima Hill formation.

Type and occurrence: Holotype (USNM P4905) from Trinidad Leasholds well Marac 1, Trinidad (coordinates N:152141 links, E:424447 links), sample from core 8,332–8,362 feet (TLL 176080).

Remarks: Globotruncana wilsoni, new species, differs from Globotruncana lapparenti bulloides Vogler in having only 4 chambers in the last whorl. The general outline of the equatorial periphery is more oval compared with the more circular form of bulloides, and the 2 keels are more closely spaced and often reduce to one in the last chamber. Globotruncana wilsoni, new species, occurs in the Globotruncana concavata zone, before the advent of typical Globotruncana lapparenti bulloides. Transitional forms between Globotruncana wilsoni, new species, and Globotruncana fornicata Plummer have been observed.

The species is named in honor of Mr. C. C. Wilson, Chief Geologist of Trinidad Petroleum Development, Ltd.

Globotruncana gagnebini Tiley

Plate 14, Figures 5a–c


Shape of test: very low trochospiral, dorsal side flat, umbilical side strongly convex; equatorial periphery distinctly lobate with 2 closely spaced keels, occasionally reduced to one in last chamber. Wall: calcareous, perforate, surface smooth. Chambers: angular, inflated; about 14, arranged in 2½ whorls; the 4–5 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side curved, raised, beaded in early whorls; umbilical side radial, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegula with accessory apertures missing or only poorly preserved in examined specimens. Coiling: predominantly dextral; of 50 specimens counted, only 2 coiled sinistrally.

Dimensions of figured hypotype: diameter 0.48 mm.; thickness 0.23 mm.

Range: Globotruncana gansseri zone to Abathomphalus mayaroensis zone, Guayaguayare formation.

Type and occurrence: Figured hypotype (USNM P4806) from outcrop on right bank of Gautier River (right side branch of Cunapo River) about 1,100 feet southwest, above junction of waterfall branch (Chert Hill), ½ miles southeast of Mamon-Guaco-Tamana Road, eastern Central Range. Sample G. 3644A (TLL 226184).

Remarks: In its general shape, Globotruncana gagnebini Tiley shows similarities to Globotruncana ventricosa White but differs in the following: 4–5 chambers in last whorl, rapidly increasing in size, against 6–7 in Globotruncana ventricosa, where the increase in size is slower. The peripheral double keel is less pronounced in gagnebini and the stratigraphic range is different (Maestrichtian for Globotruncana gagnebini, Campanian for Globotruncana ventricosa). Furthermore, Globotruncana gagnebini is somewhat smaller in size and less robust. The Globotruncana ventricosa of Maestrichtian age mentioned by the author in his earlier paper (1951) on Trinidad Globotruncana are now regarded as Globotruncana gagnebini. Typical Globotruncana ventricosa have been recorded in Trinidad from the upper part of the Naparima Hill formation.

Globotruncana andori de Klass

Plate 14, Figures 6a–c

Globotruncana andori De Klass, Geol. Bavaria, No. 17, p. 233, pl. 6, figs. 1a–c, 1953.

Shape of test: very low trochospiral, spiral side almost flat, umbilical side strongly convex; equatorial periphery nearly circular, with distinct single keel. Wall: calcareous, perforate, surface smooth. Chambers: subangular, inflated; about 15, arranged in 2–3 whorls, 6 chambers in last whorl. Sutures: spiral side curved, raised, slightly beaded; umbilical side slightly curved, slightly depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegula with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens counted coiled dextrally.

Dimensions of figured hypotype: diameter 0.67 mm.; thickness 0.47 mm.

Range: Globotruncana lapparenti tricarinata zone, Guayaguayare formation.

Type and occurrence: Figured hypotype (USNM P4807) from Trinidad Leasholds well Guayaguayare 163, Trinidad (coordinates N:157646 links, E:572808 links), sample from 5,061½ feet (TLL 153681).

Remarks: Note that the species Globotruncana cretacea Cushman and G. cf. calcarata Cushman, which were mentioned as occurring in Trinidad (Bolli, 1951), are left out of the present distribution chart. Forms originally referred to as Globotruncana cretacea are now regarded as being closer to Globotruncana gagnebini Tiley. The specimens of Globotruncana cf. calcarata (Bolli, 1951, pl. 35, figs. 16–18) differ in size and shape from the typical form. They have only been found so far reworked in the Upper Eocene. Though it is likely that they come from the Guayaguayare formation, the exact stratigraphic position remains uncertain.
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The Genera Globigerina and Globorotalia in the Paleocene-Lower Eocene Lizard Springs Formation of Trinidad, B.W.I.

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Introduction

Although the planktonic Foraminifera are strongly predominant in many samples of the Lizard Springs formation, not much attention was paid to them until Bronnimann's paper on the Globigerinidae appeared in 1952. The usefulness of planktonic Foraminifera for zonation has already been proved in older and younger sediments (Upper Cretaceous, Eocene-Miocene). The present study of Globigerina and Globorotalia shows that a similar pattern of comparatively short ranges for most species also prevails in the Paleocene-lower Eocene Lizard Springs formation of Trinidad.

On the basis of benthonic Foraminifera, the Lizard Springs formation was previously subdivided into a lower and an upper zone. The stratigraphic distribution of the planktonic Foraminifera in the more complete sections now available allows eight well-defined zones to be distinguished, five of which are regarded as of Paleocene age (lower Lizard Springs) and three as of lower Eocene age (Upper Lizard Springs). As a rule the fauna of the basal part of the Lizard Springs formation is entirely arenaceous. The arenaceous Lizard Springs facies, which is given zonule mark, may however also occur in higher parts of the Paleocene portion of the Lizard Springs formation. Beds almost indistinguishable from this facies may possibly also replace part of the calcareous Upper Cretaceous Guayaguayare formation. Furthermore it is a time and facies equivalent of the Chaudiere formation of the Central Range.

Preliminary examination of Paleocene and lower Eocene samples from widely separated regions such as Venezuela, the United States Gulf Coast area, Peru, North Africa, and Europe suggests that a zonation of the Paleocene-lower Eocene on the basis of planktonic Foraminifera can be a useful tool for interregional correlation.

Stratigraphy

For the history and earlier zonation of the Lizard Springs formation, reference is made to Cushman and Renz (1946). On the basis of benthonic smaller Foraminifera, these authors subdivided the formation into a lower and upper zone and a probable late Maestrichtian to Danian age was suggested for both. A short account of a subsequent controversy on the Cretaceous age of the Lizard Springs formation was given by Bolli (1952), who regarded the age as Paleocene. Bronnimann (1952) maintained the subdivision of the formation into a lower and upper zone, both of Paleocene age.

These authors restricted their observations on the Lizard Springs formation to the type locality as described by Cushman and Renz, and to a few other surface samples. The type locality represents a slipmass within a synorogenic clay-boulder bed of Miocene age. It was already stressed by Cushman and Renz that this section, measuring about 250 feet, is strongly disturbed and incomplete. Other Lizard Springs outcrops in central and south Trinidad have the same shortcomings and often consist of only a single zone. Similar conditions were previously mentioned for Upper Cretaceous sediments (Bolli, 1956). It is therefore fortunate that there is available a number of carefully recorded favorable subsurface profiles which allow the study of fairly continuous sections of Paleocene and lower Eocene sediments.

The most complete of these profiles was found in the subsurface section of Trinidad Leaseholds, Ltd., well Guayaguayare 150. This well is situated in southeast Trinidad, in the same general area as the original Lizard Springs type locality. Here, six of the nine established subdivisions are represented by cores in

1 Trinidad Oil Company, Ltd. (formerly Trinidad Leaseholds, Ltd.), Pointe-à-Pierre, Trinidad, B. W. I.
normal stratigraphic succession in the 1,200 feet of Lizard Springs penetrated in the well. The thickness of the zones varies in this well from approximately 100 feet to 500 feet.

The distribution chart (text-fig. 11) of the species of *Globigerina* and *Globorotalia* clearly shows the short ranges of most species within this age period. This short range pattern led to the present subdivision of the Lizard Springs formation into eight zones based on the stratigraphic distribution of characteristic single species or groups of species. The arenaceous facies is placed in a separate zonule. Five lower zones and the zonule are included in the lower Lizard Springs and regarded as Paleocene; the remaining three zones comprise the upper Lizard Springs, and are placed in the lower Eocene.

The lower Lizard Springs-upper Lizard Springs boundary is marked by a distinct change in both planktonic and benthonic Foraminifera. Two planktonic species become extinct in the top zone of the lower Lizard Springs and eight appear new in the bottom zone of the upper Lizard Springs. Only one *Globorotalia* species (*G. aequa* Cushman and Renz) ranges from the lower into the upper Lizard Springs. In addition, numerous benthonic forms such as the Upper Cretaceous-Paleocene *Rzehakina epigona* (Rzehak), *Clavulina aspera* var. whitei (Cushman and Jarvis), *Gaudryina pyramidata* Cushman, *Trocchammina ruthven-murrayi* Cushman and Renz and *Bolivinoides trinitatensis* Cushman and Jarvis are not known from the upper Lizard Springs formation.

The complete change of the planktonic foraminiferan fauna between the Upper Cretaceous Guayaguayare formation and the Paleocene-lower Eocene Lizard Springs formation is not followed by the benthonic Foraminifera. According to recent investigations by J. P. Beckmann (private communication) as many as about two-thirds of the benthonic species known in the Upper Cretaceous continue into the Paleocene-lower Eocene. In cases where only benthonic Foraminifera are present, it may become difficult, therefore, to determine whether a fauna is of Upper Cretaceous or Paleocene age. Some of the earlier students on foraminiferan faunas of the Lizard Springs formation restricted their observations mainly to the benthonic part. Their preference for attributing an Upper Cretaceous age to the Lizard Springs formation is thus well understandable.

The distribution of the zones and zonule in surface and well sections of central and south Trinidad is very irregular. In the Central Range area the arenaceous facies is known as Chaudiere formation, and is strongly predominant as such. Towards the south, calcareous benthonic and planktonic Foraminifera become predominant and the arenaceous facies often remains restricted to the basal part of the formation.

The zones of the Lizard Springs formation as specified in this paper may not yet represent a continuous stratigraphic sequence. There are indications of at least two stratigraphic breaks; these will be considered in the discussion on coiling. It is still possible that such missing intervals are present in certain areas but have not yet been found.

The Lizard Springs formation consists of grey or green-grey, calcareous or noncalcareous shales. The greenish color appears to be restricted to the lower Lizard Springs. The calcium carbonate content in the calcareous facies varies from 5 to 30 percent. The percentage by weight of Foraminifera at the type localities varies from 1 to 6 percent.

**Lower Lizard Springs Formation**

The lower Lizard Springs formation is divided into the following zones and zonule (from bottom to top):

**Rzehakina epigona Zonule**

**Type Locality:** Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links; E:497002 links), core 4,617–37 feet.

**Remarks:** The zonule consists entirely of an arenaceous fauna and is found restricted to the basal part of the formation in many subsurface sections of south Trinidad. It may, in addition, represent a facies equivalent to any of the lower Lizard Springs zones. *Rzehakina epigona* (Rzehak) becomes extinct at the top of the *Globorotalia velasecoensis* zone. It is a typical form throughout the Chaudiere formation of the Central Range. Thus it may be assumed that this formation is an age equivalent of the whole, or part, of the lower Lizard Springs. The *Rzehakina epigona* zonule is known to rest unconformably on the Upper Cretaceous in several places. The contact is often marked by the St. Joseph boulder bed (Bolli, 1952). In some parts of south Trinidad however, sedimentation appears to be uninterrupted between the Upper Cretaceous Guayaguayare formation and the Paleocene Lizard Springs formation. There, the *Rzehakina epigona* zonule can possibly replace parts of the Guayaguayare formation and thus represent also an Upper Cretaceous age.

**Globorotalia trinidadensis Zone**

**Type Locality:** Trinidad Petroleum Development well Moruga 3, Trinidad (coordinates N:143522 links; E:504382 links), core 10,259–61 feet.

**Remarks:** The *Globorotalia trinidadensis* zone is characterized by the first appearance of calcareous benthonic and planktonic Foraminifera. The planktonic fauna with *Globorotalia compresa* (Plummer), *G. pseudobulloides* (Plummer), *G. trinidadensis* Bolli, new species, *Globigerina trifolumoides* Plummer and *G. daubjergensis* Bronnimann shows strong affinities to that described from Danian localities of Denmark (Bonnimann, 1952), to the basal part of the Esna shale (Buffer zone) of Egypt (Nakkady, 1951) and to parts of the Midway (e.g., Plummer, 1926).

The species of *Globigerina* and *Globorotalia* of the *Globorotalia trinidadensis* zone originate either in this zone or in a favorable facies environment contemporaneous with the underlying *Rzehakina epigona* zonule.
Figure II.—Species distribution of Globigerina and Globorotalia in the Paleocene-lower Eocene Lizard Springs formation of Trinidad, B. W. I.
Globorotalia uncinita Zone

**Type Locality:** On the west side of the railway track, south of the Pointe-a-Pierre Railway Station, about 500 feet from the level crossing of Station Road, Pointe-a-Pierre, Trinidad (coordinates N:259200 links; E:362900 links).

**Remarks:** The type locality is a small slipmass in the Oligocene-Miocene Nariva formation. The zone is characterized by *Globorotalia uncinita* Bolli, new species, and *Globigerina spiralis* Bolli, new species, in addition to the planktonic fauna of the *Globorotalia trinidadensis* zone (with the exception of *Globigerina daubjergensis* Bronnimann).

Globorotalia pusilla pusilla Zone

**Type Locality:** Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), cores 4,524-36 feet and 4,778-90 feet.

**Remarks:** *Globorotalia pusilla pusilla* Bolli, new species, with subspecies, extends into the basal part of the overlying *Globorotalia pseudomenardii* zone. *Globorotalia angulata* (White), *G. ehrenbergii* Bolli, new species, and *G. angulata hexaceramata* Bolli, new subspecies, are other typical forms of the zone.

Globorotalia pseudomenardii Zone

**Type Locality:** On the northeast bank of the Tank Farm at the old Club Site, Pointe-a-Pierre, Trinidad (coordinates N:256950 links; E:380000 links).

**Remarks:** The type locality is a small slipmass in the Oligocene-Miocene Nariva formation. A marked change in the planktonic fauna occurs at the base of this zone. Four species become extinct here and eight appear for the first time.

Globorotalia velascoensis Zone

**Type Locality:** The original Lizard Springs locality is maintained for this zone: Ravine Ampelu, Lizard Springs area, about 1 ½ miles southeast of the road junction of the Rio Claro-Guayaguayare Road (8 ½ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), samples Rz. 281, 293, 296 (TLL 50314, 50512, 50515).

**Remarks:** *Globorotalia formosa formosa* Bolli, new species, new subspecies, *G. aragonensis* Nuttall, *Globigerina solidadoensis angulosa* Bolli, new subspecies, and *G. prolata* Bolli, new species, occur for the first time in this zone.

Globorotalia aragonensis Zone

**Type Locality:** Outcrop on the east side of the Pointe-a-Pierre Road behind a dwelling house some 60 feet from the north end of the bridge across the Vista Bella River, San Fernando, Trinidad (coordinates N:238700 links; E:263090 links).

**Remarks:** The *Globorotalia aragonensis* zone which is the uppermost zone of the Lizard Springs formation is also known as Ramdat marl. In earlier publications (Cushman and Renz, 1948; Bronnimann, 1952) it was attributed to the Navet formation. Because of its close faunistic and lithologic affinities with the *Globorotalia formosa formosa* zone the Ramdat marl is now included in the upper Lizard Springs. From a point of view of lithology and fauna it is more justified to place the Lizard Springs-Navet boundary at the top of the *Globorotalia aragonensis* zone. The calcium carbonate content rises sharply from 10 to 25 percent in the Ramdat marl and other Lizard Springs zones to 50 to 70 percent in the overlying beds of the Navet formation. Many new planktonic species, e. g., *Globorotalia palmerae* Cushman and Bernydez, *G. crassa* (Cushman), and the first *Hantkenina* species appear in the Navet formation in rapid succession.
The *Globorotalia* species from the type sample (K. 2950) of “Bed 3” from Soldado Rock of Trinidad (Kugler, 1938; Cushman and Renz, 1942) have been re-investigated and determined as follows: *G. velascoensis* (Cushman), (determined as *G. wilcozensis* var. *acuta* Toulin by Cushman and Renz, 1942, and Bolli, 1950), *G. aequa* Cushman and Renz, *G. whitei* Weiss and *G. elongata* Glassner. These species correspond with those characterizing the *Globorotalia velascoensis* zone which is the highest zone of the lower Lizard Springs. Cushman and Renz compare the “Bed 3” Foraminifera with Midwayan faunas from Alabama, but also point to a relationship with the Salt Mountain and the Wilcox of Ozark, Alabama. A stratigraphic position of “Bed 3” of Soldado Rock comparable with that of the uppermost lower Lizard Springs agrees also with the views of Bronnimann (1952).

Stratigraphic Correlation with Areas outside Trinidad

A limited number of samples was available to the author from areas outside Trinidad. The study of their planktonic Foraminifera allows a correlation of the Trinidad zones of the Lizard Springs formation with the widespread localities represented. Although this correlation is rather sketchy it appears to be sufficiently accurate to indicate the value of the fauna discussed for interregional correlation of the Paleocene and lower Eocene.

Samples from the Rio Querecuál type section of Eastern Venezuela (Hedberg, 1937; Hedberg and Pyre, 1944) show that the Upper Cretaceous part of the Vidoño shale of the Santa Anita formation=the *Globotruncana gansseri* to Abathomphalus mayaroensis zones of Trinidad’s Guayaguayare formation and probably corresponding to Hedberg and Pyre’s “Gemmellina-Siphogenerinoides Zone”) is overlain by shales which may be correlated with the *Globorotalia pseudomenardii* and *Globorotalia velascoensis* zones of the lower Lizard Springs (probably Hedberg and Pyre’s “Rzehakina-Spiroplectammina Zone”). A gap of about 450 feet exists between the uppermost Cretaceous examined and the first Paleocene sample. It is left to additional sampling of this gap to establish the presence or absence of the *Rzehakina epigona* zone and the *Globorotalia trinidadensis*, *Globorotalia uncinita* and *Globorotalia pusilla pusilla* zones of the lower Lizard Springs. Hedberg and Pyre’s “*Gyroidina-Bulimina Zone*” possibly falls into this interval.

The facies of the higher parts of the Santa Anita formation does not appear to be favorable for the study of planktonic Foraminifera, with the exception of some layers towards the top of the formation where planktonic Foraminifera indicate a middle Eocene age.

Planktonic Foraminifera seen in a number of samples of the Midway group from the Gulf Coast area correlate well with those found in the lower Lizard Springs, especially in the *Globorotalia trinidadensis* zone. This observation is supported by publications such as that of Plummer (1926).

Available samples and published information (Cushman and Ponton, 1932; Toulin, 1941) from the Wilcox group indicate that the planktonic Foraminifera correlate with the *Globorotalia rex* zone of the upper Lizard Springs and also with the uppermost part of the lower Lizard Springs.

Planktonic Foraminifera typical for the *Globorotalia uncinita* and *Globorotalia pusilla pusilla* zones of the lower Lizard Springs, as well as for the *Globorotalia formosa formosa* and *Globorotalia aragonensis* zones of the upper Lizard Springs have seemingly not been recorded from the Paleocene and lower Eocene of the Gulf Coast area according to the information available to the author.

The planktonic Foraminifera of a sample from the type locality of the Velasco formation of Mexico correspond with those of the *Globorotalia pseudomenardii* zone of the lower Lizard Springs. A sample from the type locality of the Aragon formation contains *Globorotalia aragonensis* but the associated fauna suggests an age slightly younger than the *Globorotalia aragonensis* zone of the upper Lizard Springs formation.

The planktonic and benthonic Foraminifera described from the Pale Greda formation of Peru indicate basal upper Lizard Springs which would place the formation into the lower Eocene, rather than Paleocene as suggested by Weiss (1955).

Two faunas have been examined from the Esna shales of Egypt. One, from the Bufter zone of Nakkady, 1951, correlates well with the *Globorotalia trinidadensis* zone of the lower Lizard Springs. The other, from Nakkady’s *Globorotalia* zone, can be placed in the *Globorotalia velascoensis* zone of the lower Lizard Springs.

Planktonic forms representative of the *Globorotalia trinidadensis* and *Globorotalia pusilla pusilla* zones of the lower Lizard Springs have been seen in samples from the Paleocene of Tunisia.

Brotzen (1948) describes *Globigerina triluculinoidea* Plummer, *G. pseudobulloides* Plummer, and *Globorotalia compressa* (Plummer) from the Swedish Paleocene. This would indicate an age comparable to the lower part of the lower Lizard Springs.

The planktonic Foraminifera from Danish localities of Jutland, Denmark (Brommann, 1952) are considered to be not younger than those from the *Globorotalia trinidadensis* zone of the lower Lizard Springs.

Finally, a Paleocene sample seen from Bavaria, Germany, contains *Globorotalia pusilla pusilla* Bolli, new species, new subspecies, *G. angulata* (White) and *G. quadrata* (White). This fauna is characteristic for the *Globorotalia pusilla pusilla* zone of the lower Lizard Springs.

Evolutionary Trends

A rapid tempo of evolution in the planktonic Foraminifera during Paleocene-Lower Eocene time is indicated by the short life ranges of many of the *Globigerina* and *Globorotalia* species described in this paper. Nine
species are restricted to a single zone, fifteen to two zones, ten to three zones. Only four species have a longer range. Several groups of genetically closely related species and subspecies can be distinguished. The assumption of such genetic relationships is based on occurrences of morphologically transitional forms. Together with the evolutionary trends it is also of interest to follow the ratios of the direction of coiling. It will be shown in the following section that such ratios may be an indication of the stratigraphic position of a fauna and help to verify the genetic relation between some species and subspecies.

The dominant suite of related species begins in the Globorotalia trinidadensis zone with Globorotalia trinidadensis Bolli, new species (text-fig. 12). Based on intermediate forms it may be assumed that Globorotalia pseudobulloides (Plummer) which also appears in this zone, is closely related to G. trinidadensis. Common ancestors might be found in beds equivalent in age to those of the underlying Rzehakina epigona zone. In the Globorotalia uncinata zone we find the zonal marker developing from G. pseudobulloides (for a transitional form, see pl. 17, figs. 16–18). G. uncinata Bolli, new species, is regarded as the ancestor of G. angulata (White). G. quadrata (White) is considered a separate branch developing from G. trinidadensis. At the base of the G. pusilla pusilla zone, G. angulata apparently leads through transitional forms to the long ranging G. aequa Cushman and Renz. Before the extinction of G. aequa at the end of the G. rex zone the two closely related G. rex Martin and G. formosa gracilis Bolli, new species, new subspecies, branch off. These two forms lead in the following zone to G. aragonensis [Nuttall and G. formosa formosa Bolli, new species, new subspecies,

Figure 12.—Tentative evolution of Globigerina and Globorotalia species in the Paleocene—lower Eocene, Lizard Springs formation of Trinidad, B.W.I.
respectively. The last two are the end forms of the evolutionary sequence that began with *G. trinidadensis* in the lower Lizard Springs. *G. formosa formosa* becomes extinct at the close of the *G. aragonensis* zone whereas *G. aragonensis* continues without noticeable morphological changes for a considerable time into the middle Eocene Navet formation.

Another suite of *Globorotalia* species closely related morphologically is *G. compressa* (Plummer)—*G. ehrenbergii* Bolli, new species—*G. pseudomenardii* Bolli, new species, and probably *G. elongata* Glassner. *G. compressa* appears in the Globorotalia trinidadensis zone and might originate from the same stock as *G. trinidadensis*. It ranges from the Globorotalia trinidadensis zone into the Globorotalia pusilla pusilla zone where it develops into *G. ehrenbergii* by increasing its size and becoming more compressed. *G. pseudomenardii*, the descendant of *G. ehrenbergii*, becomes still more compressed and acquires a peripheral keel. Towards the end of its range this species can become of considerable size and may depart from its usual shape (see pl. 20, fig. 17). *G. elongata* which probably developed from *G. ehrenbergii-G. pseudomenardii* at the base of the Globorotalia pseudomenardii zone continues into the Globorotalia velascoensis zone where the suite becomes extinct.

*Globigerina davibergensis* Bronniman which is restricted to the Globorotalia trinidadensis zone shows no apparent morphologic relationship to other species of that zone. It may possibly be regarded as the ancestor of *Globigerina spiralis* Bolli, new species, which is confined to the Globorotalia uncina zone. Both forms are distinctly trochospiral, however no intermediate forms were observed in the limited number of samples available from these zones.

No ancestral forms were found in the investigated sections for *Globorotalia pusilla pusilla* Bolli, new species, new subspecies. This species develops by transitions into *G. pusilla laevigata* Bolli, new species, new subspecies, of the *G. pseudomenardii* zone.

*Globorotalia velascoensis* (Cushman) is a distinct form characterizing the *Globorotalia pseudomenardii* and *Globorotalia velascoensis* zones. The species appears first in the Globorotalia pusilla pusilla zone, where it might have branched off from the *Globorotalia angulata* (White) group. Transitional forms between these species could not be clearly established in the studied sections.

*Globigerina triloculinoides* Plummer which first occurs in the *Globorotalia trinidadensis* zone, might have a common ancestor with *Globorotalia trinidadensis*. Specimens of *Globigerina triloculinoides* which show *Globorotalia*-like apertural characters are common throughout its range (see pl. 17, figs. 25–26). The triangular shaped *Globigerina triloculinoides* seemingly develops into the long-ranging and little-changing *G. linaperta* Finlay. Before that change, the more triangular shaped *G. triangularis* White branches off from *G. triloculinoides* at the base of the *Globorotalia pusilla pusilla* zone. *Globigerina velascoensis* Cushman, a form with a slight lateral compression of the chambers, may be regarded as a further evolutionary step from *G. triangularis*.

The laterally strongly compressed *Globorotalia tortiva* Bolli, new name, appears almost contemporaneously with *Globigerina velascoensis* at the base of the *Globorotalia pseudomenardii* zone. This short-lived species is likely to have developed from *Globigerina triangularis*. It is possible that *Globorotalia tortiva* Bolli, new name, is the ancestral form of the equally short-lived *Globorotalia mckannai* (White) which is found higher in the same zone.

*Globorotalia whitei* Weiss which appears in the *Globorotalia pseudomenardii* zone and might develop into the *Globigerina tricalcarata*-*G. velascoensis* group. It is regarded as the ancestral form of *Globorotalia velascoensis* Cushman and Ponton and *G. quetra* Bolli, new species.

Towards the close of the *Globorotalia pseudomenardii* zone and during the *Globorotalia velascoensis* zone the first specimens of the closely related *Globigerina primitiva* Finlay and *G. soldadoensis* Bronniman appear. Similar morphology strongly suggests that *G. primitiva* developed from *G. velascoensis*. Several species and subspecies develop in the upper Lizard Springs from *G. soldadoensis* Bronniman, which is regarded as related to *G. primitiva*; in order of first occurrence they are *G. gravalli* Bronniman, *G. soldadoensis* angulosa Bolli, new subspecies, and *G. turgida* Finlay. *G. tarubensis* Bronniman might also be related to this group, probably most closely to *G. turgida*.

*Globigerina collactea* (Finlay) appears first in the *Globorotalia rex* zone with no apparent ancestral forms in the underlying *Globorotalia velascoensis* zone. Such forms might however be expected in beds presumed missing between these two zones. *Globigerina yrolata* Bolli, new species, is likely to have developed from *G. collactea* at the base of the *Globorotalia formosa formosa* zone.

*Globorotalia brodermannii* Cushman and Bermudez is another form that occurs first in the *Globorotalia rex* zone. Some intermediate specimens in the *Globorotalia rex* zone indicate a possible relationship to *Globigerina collactea*.

### Direction of Coiling

Earlier observations on the direction of coiling of a number of planktonic species led to the conclusion that distinct changes in ratios occur during the evolution of many species (Bolli, 1950, 1951). During the early evolutionary stage, such species or group of related species normally coils at random. Later, up to 90 to 100 percent of the specimens have a preference for either sinistral or dextral coiling. Once such a preference has arisen the species does not revert to random coiling any more, except in some possible gerontic stages (Bolli, 1957, p. 54). Very rapid or almost instant changes from one preferred direction of coiling to the opposite can, however, be observed in the later stages of some species, e. g., *Globorotalia menardii*. 

The coiling of a few Lizard Springs *Globorotalia* species has already been discussed in an earlier paper (Bolli, 1950). Coiling ratios for several *Globigerina* and *Globorotalia* species and groups of related species have again been followed through the now better known sections of the Lizard Springs formation. The basic picture has changed little. The coiling ratios for a hypothetical lowermost Lizard Springs given in the earlier paper have now been observed. The probable relation between *Globorotalia aequa* Cushman and Renz and *G. aragonensis* Nuttall (via *G. rex* Martin) was not realized at the time and *G. wilcoxensis* var. *acuta* Toulmin is now regarded as a synonym of *G. velascoensis* (Cushman).

Some of the more significant results are briefly discussed in the following paragraphs and shown on text-figure 13.

A genetic relationship between *Globorotalia trinidaddensis* Bolli, new species, *G. pseudobulloides* (Plummer), *G. uncinita* Bolli, new species, *G. angulata* (White), *G. aequa* Cushman and Renz, *G. rex* Martin, *G. aragonensis* Nuttall, *G. formosa gracilis* Bolli, new species, new subspecies and, *G. formosa formosa* Bolli, new species, new subspecies and, *G. formosa formosa* Bolli, new species, new subspecies has been discussed in the previous section. When following the coiling ratios of these species we find that the stratigraphically older forms (*G. trinidaddensis* to *G. angulata*) coil at random, thus representing the early evolutionary stage. With the transition of *G. angulata* to *G. aequa*, a very rapid change to an almost exclusively dextral coiling takes place. This preference is maintained to the point of extinction of the species at the top of the *Globorotalia rex* zone. *G. rex* and *G. formosa gracilis* which apparently branch off from the *G. aequa* group at the base of *Globorotalia rex* zone maintain the same trend. *G. aragonensis* and *G. formosa formosa* which are assumed to develop from *G. rex* and *G. formosa gracilis*, respectively, higher in the same zone, rapidly switch to sinistral coiling. The change is more rapid in *G. aragonensis* which becomes about 90 percent sinistral in the *Globorotalia aragonensis* zone. The same trend is maintained by this species until its extinction in the Navet formation. Of *G. formosa formosa*, 64 percent were found to coil sinistrally before the extinction of the species towards the top of the *Globorotalia aragonensis* zone. A sample from the probable upper part of the *Globorotalia formosa formosa* zone showed 10 percent of *G. formosa formosa* and 44 percent of *G. aragonensis* coiling sinistrally. Counts of another sample presumably from lower in the *G. formosa formosa* zone showed an almost exclusive dextral coiling for both *G. formosa formosa* and *G. aragonensis*.

*Globorotalia compressa* (Plummer), *G. ehrenbergii* Bolli, new species, *G. pseudomenardii* Bolli, new species, and *G. elongata* Claessner represent another evolutionary sequence. All investigated samples showed the species coiling at random, with the exception of the topmost sample in the *Globorotalia pseudomenardii* zone.

There, apparently shortly before its extinction, 80 to 85 percent of the specimens of the zonal marker were found to coil sinistrally. *G. elongata* maintains random coiling throughout its range.

*Globorotalia velascoensis* (Cushman) has a strong preference for sinistral coiling throughout most of its range. Only in its very early stages does the species coil at random. The very rapid change from random to sinistral coiling in *G. velascoensis* occurs concurrently with that of the *G. angulata-G. aequa* group to dextral coiling. These changes take place within a short interval in the section studied, probably within less than 100 feet. From this it may be assumed that either the change to a strongly preferred direction of coiling took place within a short time interval or the abrupt change might indicate a hiatus.

Throughout the upper Lizard Springs *Globorotalia broedermanni* Cushman and Bermudez is found to coil almost exclusively sinistrally. No random-coiling ancestral forms indicating an earlier evolutionary stage of this species were seen in the lower Lizard Springs. This suggests the presence of a hiatus between lower and upper Lizard Springs. The ancestral forms of *G. broedermanni* and *G. wilcoxensis-G. queta* would be expected to occur in the missing beds.

*Globorotalia wilcoxensis* Cushman and Ponton and *G. queta* Bolli, new species, which probably developed from *G. whitei* Weiss were found to have a strong preference for dextral coiling throughout their distribution in the upper Lizard Springs.

The above results on coiling ratios are based on approximately 25 samples, the majority of them coming from one section (Trinidad Leascholds, Ltd., Guay-nayare well 150). For this type of investigation it would be desirable to have a greater number of samples available from well established stratigraphic sequences. The results obtained from the rather limited sources are however regarded as conclusive to warrant the presentation of the tentative picture that is discussed above and shown on text-figure 13.

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Illustrations are camera lucida drawings prepared by Patricia and Lawrence Isham of the U. S. National Museum.
### Systematic Descriptions

Fourteen species of *Globigerina* and twenty-four species of *Globorotalia* are described or listed. Most of the Lizard Springs *Globigerina* have already been accurately described by Bronnimann (1952); for these, reference is made to that publication. Although some of the *Globorotalia* species had already been described, all species, whether new or previously established, are here described in full, to present a uniform picture.

The principal difference between the genera *Globigerina* and *Globorotalia* lies in the position of the aperture. In *Globigerina* it is interiomarginal, umbilical (leading from each chamber into the open umbilicus). In *Globorotalia* it is interiomarginal, extraumbilical (on the umbilical side of the last chamber along the suture with the first chamber of the last whorl, and leading from near the equatorial periphery into the umbilicus). Chambers in *Globigerina* are always globular or only slightly compressed; in *Globorotalia*...
**Globigerina** have a peripheral keel. In a number of species with globular chambers, described in this paper, it becomes difficult to decide whether the position of the last aperture was truly umbilical or was to some degree extrumbilical—umbilical. Such transitional positions make it difficult to decide whether a species belongs to *Globigerina* or *Globorotalia* and the decision remains rather arbitrary.

The determination of the majority of the previously established *Globigerina* and *Globorotalia* species is based on a direct comparison of the Lizard Springs fauna with type material. The holotypes of the species erected by Bronnimann, Cushman and coauthors, Nuttall, Weiss and White were available to the author. Copies of most of the remaining species have been seen.

*Globigerina finlayi*, *G. hornibrooki* and *G. stainforthi*, which were erected by Bronnimann (1952) from the Lizard Springs formation, are omitted from the following species descriptions. They were found to be either exceedingly scarce, or, in the present author's opinion, not sufficiently differentiated from existing species to warrant separation. *G. finlayi* is placed in synonymy with *G. linaperta* Finlay, and *G. hornibrooki* with *G. triangularis* White, while *G. stainforthi* is regarded as close to *G. triloculinoides* Plummer.

**Family Orbulinidae Schultze, 1854**

**Subfamily Globigerininae Carpenter, 1862**

**Genus Globigerina d’Orbigny, 1826**

**Globigerina daubjergensis** Bronnimann

*Plate 16, Figures 12-15*


**Coiling random. Largest diameter of figured hypotype 0.16 mm.**

**Stratigraphic range:** *Globorotalia trinidadensis* zone, Lizard Springs formation.

**Locality:** Figured hypotype (USNM P5029) from Trinidad Leaseholds, Ltd., Premier Consolidated Oilfields, Ltd., well Rochard 1, Trinidad (coordinates N:143189 links; E:392552 links), sample from core 8,556-65 feet (TLL 228753).

**Remarks:** *Globigerina daubjergensis* Bronnimann differs from all other known early Paleocene *Globigerina* species in its small size and in the distinctly trochospiral arrangement of the chambers. *G. spiralis* Bolli, new species, displays a similar trochospiral coiling but is larger in size and possesses more chambers.

**Globigerina spiralis** Bolli, new species

*Plate 16, Figures 16-18*

Shape of test medium to high trochospiral, biconvex, spiral side distinctly convex, umbilical side less so; equatorial periphery lobate; axial periphery rounded.

Wall calcareous, perforate, surface smooth. Chambers inflated, globular or slightly compressed laterally; about 15, arranged in 3 whorls; the 5-6 chambers of the last whorl increase moderately in size. Sutures on spiral side radial or slightly curved, depressed; on umbilical side radial, depressed. Umbilicus narrow, open. Apertures distinct arches with faint lips, interiomarginal, umbilical; that of last chamber in some specimens tends to an extraumbilical—umbilical position. Coiling random. Largest diameter of holotype 0.28 mm.

**Stratigraphic range:** *Globorotalia uncinita* zone, Lizard Springs formation.

**Locality:** Holotype (USNM P5030) from west side of railway track, south of the Pointe-a-Pierre railway station, about 500 feet from the level crossing of Station Road, Pointe-a-Pierre, Trinidad (coordinates N:253200 links; E:362900 links), sample KR 23575 (TLL 178894).

**Remarks:** See remarks under *Globigerina daubjergensis* Bronnimann.

**Globigerina triloculinoides** Plummer

*Plate 15, Figures 18-20; and Plate 17, Figures 25-26*


*Globigerina pseudotritoba* WHITE, Journ. Paleontol., vol. 2, No. 3, pp. 194-195, pl. 27, figs. 17a-b, 1925.

Coiling random in the *Globorotalia trinidadensis* and *Globorotalia uncinita* zones, but developing a preference for dextral coiling (up to 85 percent) in the *Globorotalia pusilla* pusilla* zone. Largest diameter of figured hypotype 0.30 mm.

**Stratigraphic range:** *Globorotalia trinidadensis* zone to *Globorotalia pusilla* pusilla* zone, Lizard Springs formation.

**Locality:** Figured hypotype (USNM P5031) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,778-90 feet (TLL 23276).

*Globigerina linaperta* Finlay

*Plate 15, Figures 15-17*


Coiling random from the *Globorotalia pseudomenardii* zone to *Globorotalia formosa formosa* zone; a slight preference for dextral coiling was noted in the *Globorotalia aragonensis* zone. Largest diameter of figured hypotype 0.42 mm.

**Stratigraphic range:** *Globorotalia ehrenbergi* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, continuing into the Navet formation.

**Locality:** Figured hypotype (USNM P5032) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,212-24 feet (TLL 233002).
Remarks: *Globorotalia tinaperta* Finlay is probably a descendant of *G. triloculinoideas* Plummer from which it is distinguished by its larger size and less distinct flaring lip protecting the aperture.

*Globorotalia triangularis* White

**Plate 15, Figures 12-14**


*Globorotalia hornibrooki* Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, p. 15, pl. 2, figs. 4-6, 1952.

Coiling random. Largest diameter of figured hypotype 0.46 mm.

**Stratigraphic range:** *Globorotalia pusilla pusilla* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, possibly continuing into the Navet formation.

**Locality:** Figured hypotype (USNM P5033) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,434-46 feet (TLL 233005).

**Remarks:** *Globorotalia triangularis* White apparently developed from *G. triloculinoideas* Plummer, from which it is distinguished by the more trochospiral arrangement of its chambers and by the smaller relative size of the final chamber.

*Globorotalia velascoensis* Cushman

**Plate 15, Figures 9-11**


Shape of test low trochospiral, spiral side often slightly concave, umbilical side strongly inflated; equatorial periphery strongly lobate; axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers inflated, subglobular, slightly compressed laterally, about 10, arranged in 2½ whorls, the 4 chambers of the last whorl increasing rapidly in size. Sutures on spiral side oblique, depressed; on umbilical side radial, depressed. Umbilicus narrow, partly covered by the lip of the last chamber. Apertures low arches, with distinct lips; interiomarginal, umbilical; the aperture of the ultimate chamber often tends to an extrumbilical-umbilical position. Coiling random. Largest diameter of figured hypotype 0.33 mm.

**Stratigraphic range:** *Globorotalia pseudomenardii* zone to *Globorotalia velascoensis* zone, Lizard Springs formation.

**Locality:** Figured hypotype (USNM P5034) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,324-30 feet (TLL 233004).

**Remarks:** *Globorotalia velascoensis* Cushman apparently developed from *G. tri angularis* White, from which it is distinguished by having the chambers of the last whorl slightly compressed laterally. Cushman's holotype of *G. velascoensis* is a poorly preserved and somewhat deformed specimen. The Lizard Springs types compare well with those of White (1928).

*Globorotalia primitiva* Finlay

**Plate 15, Figures 6-8**


Coiling random. Largest diameter of figured hypotype 0.37 mm.

**Stratigraphic range:** *Globorotalia pseudomenardii* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, continuing into the Navet formation.

**Locality:** Figured hypotype (USNM P5035) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,707-13 feet (TLL 232994).

**Remarks:** *Globorotalia primitiva* Finlay probably developed from *G. velascoensis* Cushman, from which it is distinguished mainly by its spinose surface.

*Globorotalia soldadoensis* Bronnimann

**Plate 16, Figures 7-12**


Coiling random. Largest diameter of figured hypotype 0.55 mm.

**Stratigraphic range:** *Globorotalia velascoensis* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, continuing into the Navet formation.

**Locality:** Figured hypotype (USNM P5036) from Ravine Ampelu, Lizard Springs area, about 1½ miles southeast of the road junction of the Río Claro-Guayaguayare Road (8¾ M. P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 293 (TLL 50512).

**Remarks:** *Globorotalia soldadoensis* Bronnimann is closely related to *G. primitiva* Finlay, from which it is distinguished mainly by its larger size and greater number of chambers in the final whorl.

*Globorotalia soldadoensis* angulosa Bolli, new subspecies

**Plate 16, Figures 4-6**

Shape of test low trochospiral, spiral side slightly convex to flat, umbilical side strongly inflated; equatorial periphery distinctly lobate; axial periphery subangular. Wall calcareous, perforate, distinctly spinose. Chambers subangular, inflated; about 12, arranged in 2½ whorls, the 5 chambers of the last whorl increasing fairly rapidly in size. Sutures on spiral side oblique, depressed; on umbilical side radial, depressed. Umbilicus medium sized, open. Apertures low arches; interiomarginal-umbilical. Coiling random. Largest diameter of holotype 0.57 mm.

**Stratigraphic range:** *Globorotalia formosa formosa* zone to *Globorotalia aragonensis* zone.

**Locality:** Holotype (USNM P5037) from Ravine Ampelu, Lizard Springs area, about 1½ mile southeast...
of the road junction of the Río Claro–Guayaguayare Road (8% M. P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 293 (TLL 50512).

Remarks: Globigerina soldadoensis angulosa Bolli, new subspecies, differs from G. soldadoensis Bronnimann in the more angular shape of the chambers. It also has a more restricted stratigraphic range.

Globigerina gravelli Bronnimann

Plate 16, Figures 1–3


Coiling random. Largest diameter of figured hypotype 0.47 mm.

Stratigraphic range: Globorotalia rex zone to Globorotalia aragonensis zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5038) from Ravine Ampelu, Lizard Springs area, about 1½ miles southeast of the road junction of the Río Claro–Guayaguayare Road (8% M. P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links E:556755 links), sample Rz. 293 (TLL 50512).

Remarks: Globigerina gravelli Bronnimann is closely related to the spinose G. primitiva Finlay–G. soldadoensis Bronnimann group, from which it is distinguished by its larger size and greater number of chambers in the final whorl.

Globigerina collactea (Finlay)

Plate 15, Figures 21–23


Coiling random. Largest diameter of figured hypotype 0.35 mm.

Stratigraphic range: Globorotalia rex zone to Globorotalia aragonensis zone, Lizard Springs formation, continuing into the Navet formation.

Locality: Figured hypotype (USNM P5039) from Trinidad Lesseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core, 3,707–13 feet (TLL 323994).

Remarks: Some doubt exists as to the generic position of this species. Finlay (1939) originally described it as a Globorotalia. Because of the umbilical position of the apertures, Bronnimann (1952) removed it to Globigerina. The apertures of the specimens examined are usually umbilical, though a slight shifting of the aperture of the ultimate chamber towards an extra-umbilical-umbilical position is often noted.

Globigerina prolata Bolli, new species

Plate 15, Figures 24–26


Shape of test low trochospiral, biconvex. Equatorial periphery elongate, distinctly lobate. Axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers inflated globular to slightly compressed; about 12, arranged in 2½ whorls, the 4–5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side radial or slightly oblique, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, open. Apertures distinct arches, interiomarginal, umbilical; in some specimens the aperture of the last chamber tends to become extraumbilical-umbilical in position. Coiling in two-thirds of the specimens counted in the Globorotalia aragonensis zone, sinistral. Largest diameter of holotype 0.40 mm.

Stratigraphic range: Globorotalia formosa formosa and Globorotalia aragonensis zones, Lizard Springs formation; continuing into the Navet formation.

Locality: Holotype (USNM P5040) from Ravine Ampelu, Lizard Springs area, about 1½ mile southeast of the road junction of the Río Claro—Guayaguayare Road (8% M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 281 (TLL 50314).

Remarks: Globigerina prolata Bolli, new species, probably branched off from G. collactea Finlay in the Globorotalia rex zone. It became fairly common in the Globorotalia formosa formosa and Globorotalia aragonensis zones. Bronnimann (1952) figured and described this species as Globigerina pseudobulloides Plummer. Because of the interiomarginal, extraumbilical-umbilical position of its apertures, pseudobulloides is now placed in Globorotalia. Globigerina prolata differs from Globorotalia pseudobulloides in the umbilical position of the apertures, absence of a flaring lip in the last chamber, and more trochospiral arrangement of the chambers. Also it has a distinctly different stratigraphic range. Globorotalia pseudobulloides is restricted to the Paleocene (Globorotalia trinidadensis to the Globorotalia pusilla pusilla zones) and Globigerina prolata to the lower Eocene (Globorotalia rex to the Globorotalia aragonensis zones).

Globigerina taroubaensis Bronnimann

Plate 15, Figures 1–2


Largest diameter of figured hypotype 0.27 mm.

Stratigraphic range: Globorotalia aragonensis zone, Lizard Springs formation, continuing into the Navet formation.
**STUDIES IN FORAMINIFERA**

Locality: Figured hypotype (USNM P5041) from outcrop on the east side of the Pointe-a-Pierre Road behind a dwelling some 60 feet from the north end of the bridge across the Vista Bella River, San Fernando, Trinidad (coordinates N:238700 links; E:363090 links), sample Bo. 112 (TLL 137688).

Globigerina turgida Finlay

Plate 15, Figures 3-5


Largest diameter of figured hypotype 0.43 mm.

**Stratigraphic range:** Globorotalia aragonensis zone, Lizard Springs formation, continuing into the Navet formation.

Locality: Figured hypotype (USNM P5042) from outcrop on the east side of the Pointe-a-Pierre Road behind a dwelling some 60 feet from the north end of the bridge across the Vista Bella River, San Fernando, Trinidad (coordinates N:238700 links; E:363090 links), sample Bo. 112 (TLL 137688).

Family Globorotaliidae Cushman, 1927

Genus Globorotalia Cushman, 1927

Globorotalia pseudobulloides (Plummer)

Plate 17, Figures 19–21

Globorotalia pseudobulloides PLUMMER, Univ. Texas Bull. 2644, pp. 133–134, pl. 8, figs. 9a-c, 1926.


Shape of test very low trochospiral, biconvex, moderately compressed. Equatorial periphery lobate. Axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers moderately compressed; 12–15, arranged in 2–2½ whorls. The 5 chambers of the last whorl increase fairly rapidly in size. Sutures on spiral side curved, less so in the last chambers, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, open. Aperture a low arch with a lip; interiomarginal, extrumbilical—umbilical. Coiling random in the Globorotalia trinidadensis and Globorotalia uncinata zones. A preference for dextral coiling (up to 75 percent) develops in the Globorotalia pusilla pusilla zone. Largest diameter of figured hypotype 0.35 mm.

**Stratigraphic range:** Globorotalia trinidadensis zone to Globorotalia uncinata zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5043) from Trinidad Leasoholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 232705).

Remarks: Because of the interiomarginal, extraumbilical—umbilical position of the aperture, pseudobulloides is removed from Globigerina to Globorotalia. The Globigerina pseudobulloides described and figured by Bronnimann (1952) from the upper Lizard Springs is not identical with Plummer’s form, but belongs to Globigerina prolata Bolli, new species.

Globorotalia trinidadensis Bolli, new species

Plate 16, Figures 19–23

Shape of test very low trochospiral, inflated; equatorial periphery lobate; axial periphery rounded. Wall calcareous, perforate, surface smooth, in early chambers often slightly rugose. Chambers globular; 14–18, arranged in 2–2½ whorls, the 5–7 chambers of the last whorl increasing slowly in size. Sutures on spiral side radial, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, open. Aperture a low arch, with a thin, lip-like flap in well-preserved specimens; interiomarginal, extrumbilical—umbilical. Coiling random. Largest diameters of figured types 0.40–0.43 mm.

**Stratigraphic range:** Globorotalia trinidadensis zone to Globorotalia uncinata zone, Lizard Springs formation.

Locality: Holotype (USNM P5044) and paratypes (USNM P5045 and P5046) from Trinidad Petroleum Development well Moruga 3, Trinidad (coordinates N:143522 links; E:504532 links), sample from core 10,259–10,261 feet (TLL 192632).

Remarks: Globorotalia trinidadensis Bolli, new species, differs from G. pseudobulloides (Plummer) in its larger size and in having more chambers in the final whorl. Early chambers often show a rugose surface.

Globorotalia quadrata (White)

Plate 17, Figures 22–24


Shape of test very low trochospiral, spiral side commonly slightly concave, umbilical side inflated; equatorial periphery lobate, quadrangular; axial periphery rounded. Wall calcareous, perforate, surface smooth, early chambers finely cancellate. Chambers inflated, globular to slightly compressed laterally; about 10–12, arranged in 2½ whorls, the 4–5 chambers of last whorl increasing rapidly in size; ultimate chamber commonly slightly smaller than penultimate. Sutures on spiral side radial, depressed; on umbilical side: radial, depressed. Umbilicus fairly wide, open. Aperture a low arch; interiomarginal, extrumbilical—umbilical. Coiling random. Largest diameter of figured hypotype 0.42 mm.

**Stratigraphic range:** Globorotalia uncinata zone to Globorotalia pseudomentardii zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5047) from Trinidad Leasoholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 232705).

Remarks: Because of the interiomarginal, extrumbilical—umbilical position of the aperture, quadrata is removed from Globigerina to Globorotalia. The

...
species is morphologically closely related to *Globorotalia trinidadensis* Bolli, new species, from which it differs in having fewer chambers in the final whorl.

**Globorotalia uncinata** Bolli, new species

**PLATE 17, FIGURES 13–15**

Shape of test low trochospiral, spiral side almost flat or slightly convex, umbilical side distinctly convex; equatorial periphery distinctly lobate; axial periphery rounded to subangular. Wall calcareous, perforate, surface finely spinose. Chambers subangular, inflated, laterally compressed; 12–15, arranged in about 2¼ whors, the 5–6 chambers of the last whorl increasing moderately in size. Sutures on spiral side strongly curved, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling random. Largest diameter of holotype 0.35 mm.

**Stratigraphic-range:** *Globorotalia uncinata* zone to *Globorotalia pusilla pusilla* zone, Lizard Springs formation.

**Locality:** Holotype (USNM P5048) from west side of railway track, south of the Pointe-a-Pierre Railway Station, about 500 feet from the level crossing of Station Road, Pointe-a-Pierre, Trinidad (coordinates N:259200 links; E:362800 links), sample K.R. 23575 (TLL 178894).

**Remarks:** *Globorotalia uncinata* Bolli, new species, differs from the related *G. pseudobulbooides* (Plummer) in having subangular, laterally distinctly truncated chambers and more strongly curved sutures on the spiral side. An intermediate specimen is shown on plate 17, figures 16–18 (USNM P5075). *Globorotalia uncinata* is regarded as the anecstor of *Globorotalia angulata* (White). A transitional form between these two species is shown on plate 17, figures 10–12 (USNM P5074).

**Globorotalia angulata** (White)

**PLATE 17, FIGURES 7–9**


Shape of test very low trochospiral, spiral side almost flat, umbilical side distinctly convex; equatorial periphery distinctly lobate; axial periphery acute, ornamented with minute spines in well preserved specimens. Wall calcareous, perforate, finely spinose, especially the umbilical side. Chambers angular, inflated; 12–15, arranged in 2¾–3 whors, the 5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side strongly curved, slightly depressed; on umbilical side radial, strongly depressed. Umbilicus narrow, deep, open. Aperture a narrow slit; interiomarginal, extraumbilical—umbilical. Coiling random. Largest diameter of figured hypotype 0.41 mm.

**Stratigraphic range:** Upper part of *Globorotalia uncinata* zone to *Globorotalia pusilla pusilla* zone.

**Locality:** Figured hypotype (USNM P5049) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 223705).

**Remarks:** *Globorotalia angulata* (White) differs from the ancestral *G. uncinata* Bolli, new species, in having subangular chambers and an acute periphery. *G. angulata* is regarded as the ancestor of *G. aequa* Cushman and Renz. It is further closely related to *G. angulata abundocamerata* Bolli, new subspecies.

**Globorotalia angulata abundocamerata** Bolli, new subspecies

**PLATE 17, FIGURES 4–6**

Shape of test very low trochospiral, spiral side almost flat, inner whorl occasionally slightly raised; umbilical side strongly convex; equatorial periphery slightly lobate, almost circular; axial periphery subacute to acute without distinct keel. Wall calcareous, perforate, surface finely spinose. Chambers subangular, inflated; 14–18, arranged in 2–2¼ whors, the 6–7 chambers of the last whorl increasing slowly in size. Sutures on spiral side curved, slightly depressed; on umbilical side radial, depressed. Umbilicus narrow, deep, open. Aperture a narrow slit; interiomarginal, extraumbilical—umbilical. Coiling random. Largest diameter of holotype 0.4 mm.

**Stratigraphic range:** *Globorotalia pusilla pusilla* zone to lower part of *Globorotalia pseudomenardii* zone, Lizard Springs formation.

**Locality:** Holotype (USNM P5050) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 223705).

**Remarks:** *G. angulata abundocamerata* Bolli, new subspecies, is a multichambered form of *G. angulata* (White) with a slightly different stratigraphic range.

**Globorotalia aequa** Cushman and Renz

**PLATE 17, FIGURES 1–3; PLATE 18, FIGURES 13–15**


Shape of test. Very low trochospiral, spiral side flat to slightly convex, umbilical side strongly convex; equatorial periphery lobate; axial periphery acute, faint keel ornamented with spines occasionally observed. Wall calcareous, perforate, surface covered with fine spines in well preserved specimens. Chambers angular, inflated; about 10–12, arranged in 2½ whors; the 3–4 chambers of the last whorl increase rapidly in size. The last chamber may represent almost 50 percent of the surface of the test. Sutures on spiral side strongly curved, slightly depressed; on umbilical side radial, distinctly depressed. Umbilicus narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling over 90 percent dextral. Largest diameter of figured hypotypes 0.40 mm.

**Stratigraphic range:** *Globorotalia pseudomenardii* zone to *Globorotalia rex* zone, Lizard Springs formation.
Locality: Figured hypotypes (USNM P5051 and P5052) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,813–25 feet (TLL 232995).

Remarks: No close morphologic or stratigraphic connection is evident between *Globorotalia aequa* Cushman and Renz and the coarsely spinose *G. crassata* (Cushman) from the middle to upper Eocene. Specific rank is therefore given to *G. aequa*. It is distinguished from the related *G. angulata* (White) by having a more spinose surface, a relatively large ultimate chamber and in a distinct preference for dextral coiling. A comparison of the holotypes of *G. aequa* and *G. lacertii* Cushman and Renz clearly indicates that the latter is a junior synonym. *G. aequa* is regarded as the ancestor of *G. rex* Martin and *G. formosa gracilis* Bolli, new species, new subspecies.

**Globorotalia rex Martin**

**Plate 18, Figures 10–12**


*Globorotalia simulatilis* (Schwager), Le Roy (not Schwager, 1893), Geol. Soc. Amer., Mem. 54, pp. 32–33, pl. 9, figs. 1–3, 1933.

Shape of test, very low trochospiral, spiral side flat or slightly convex, umbilical side strongly convex; equatorial periphery lobate; axial periphery angular with distinct peripheral keel, often ornamented with spines. Wall calcareous, perforate, surface coarsely spinose. Chambers angular, inflated; about 12, arranged in 2–2½ whorls, the 4–5 chambers of the last whorl increasing rapidly in size. Sutures on dorsal side strongly curved; on umbilical side radial, depressed. Umbilicus narrow, deep, open. Aperture a low arch; interiomarginal, extrumbilical-umbilical. Coiling between 90 and 100 percent dextral. Largest diameter of figured hypotype 0.56 mm.

**Stratigraphic range:** *Globorotalia rex* zone to *Globorotalia aragonensis* zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5054) from Ravyne Ampelu, Lizard Springs area, about 1¼ mile southeast of the road junction of the Rio Claro—Guayaguayare Road (8½ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample KWB 6972 (TLL 102301).

Remarks: *Globorotalia aragonensis* Nuttall differs from the ancestor *G. rex* Martin in having a more compact test, less lobate periphery, stronger peripheral keel, a greater number of chambers, and a strong preference for sinistral coiling in the younger specimens.

**Globorotalia formosa gracilis** Bolli, new species, new subspecies

**Plate 18, Figures 4–6**

Shape of test very low trochospiral, spiral side almost flat or slightly convex, umbilical side distinctly convex; equatorial periphery lobate; axial periphery angular with a faint keel ornamented with spines. Wall calcareous, perforate, surface distinctly spinose. Chambers angular, inflated; about 12, arranged in 2½–3 whorls, the 5–6 chambers of the last whorl increasing rapidly in size. Sutures on dorsal side slightly curved to oblique, slightly depressed; on umbilical side radial, distinctly depressed. Umbilicus fairly narrow, deep, open. Aperture a low arch; interiomarginal, extra-umbilical-umbilical. Coiling between 90 and 100 percent dextral. Largest diameter of holotype 0.50 mm.

**Stratigraphic range:** *Globorotalia rex* zone to *Globorotalia formosa formosa* zone, Lizard Springs formation.

Locality: Holotype (USNM P5055) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,707–13 feet (TLL 232994).

Remarks: *Globorotalia formosa gracilis* Bolli, new species, new subspecies, differs from the related *G. aequa*
Globorotalia formosa formosa Bolli, new species, new subspecies

PLATE 18, FIGURES 1–3


Shape of test very low trochospiral, spiral side almost flat, inner whorls occasionally slightly raised, umbilical side strongly convex; equatorial periphery slightly lobate, nearly circular; axial periphery angular with pronounced keel which is ornamented with spines in well preserved specimens. Wall calcareous, perforate, surface finely to distinctly spinose, especially on the umbilical side. Chambers angular, inflated; 15–18, arranged in about 3 whorls; the 6–8 chambers of the last whorl increasing slowly in size. Sutures on spiral side curved, on umbilical side radial, depressed. Umbilicus fairly wide, deep, open. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling about 90 percent dextral in the Globorotalia formosa formosa zone, becoming predominantly sinistrally in the Globorotalia aragonensis zone (up to 64 percent). Largest diameter of holotype 0.65 mm.

STRATIGRAPHIC RANGE: Globorotalia formosa formosa zone and Globorotalia aragonensis zone, Lizard Springs formation.

LOCALITY: Holotype (USNM P5056) from Ravine Ampelu, Lizard Springs area, about 1¼ mile southeast of the road junction of the Rio Claro—Guayaguayare Road (8¾ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample KWB 6972 (TLL 102301).

REMARKS: Globorotalia formosa formosa Bolli, new species, new subspecies, differs from the related G. formosa gracilis Bolli, new species, new subspecies, in its more robust test, larger size, and greater number of chambers in the last whorl. G. formosa formosa differs from G. aragonensis Nuttall in its slightly larger size, more lobate periphery, greater number of chambers in the last whorl, and wider umbilicus. Also, it has a much more restricted stratigraphic range.

Globorotalia velascoensis (Cushman)

PLATE 20, FIGURES 1–4

Pulvinulina velascoensis CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, p. 19, pl. 3, figs. 5a–c, 1925. Globorotalia velascoensis Cushman and Ponton var. acuta TOLLON, Journ. Paleontol., vol. 15, No. 6, p. 608, pl. 82, figs. 6–8, 1941. For additional references see Cushman and Bermudez (1949, pp. 39, 41).

Shape of test very low trochospiral, spiral side flat; umbilical side strongly convex; in large specimens the outer wall of the chambers of the last whorl may be somewhat concave; equatorial periphery nearly circular; axial periphery angular with distinct keel which may be spinose. Wall calcareous, perforate, surface smooth, around umbilical area often rugose. Chambers angular, inflated; 12–18, arranged in 2½–3 whorls, the five chambers of the last whorl increasing moderately in size. Sutures on spiral side curved, may be slightly raised; on umbilical side radial, depressed. Umbilicus narrow and deep in small specimens, becoming wider in large specimens. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling random in the upper part of the Globorotalia pusilla pusilla zone; becoming sinistrally in the Globorotalia pseudomenardii and Globorotalia velascoensis zones (about 95 percent). Largest diameter of figured hypotypes 0.49 mm. (pl. 20, figs. 1–3), and 0.27 mm. (pl. 20, fig. 4).

STRATIGRAPHIC RANGE: Globorotalia pusilla pusilla zone to Globorotalia velascoensis zone, Lizard Springs formation.

LOCALITY: Figured hypotypes (USNM P5057 and P5058) from Trinidad Leaseholds, Ltd., Guayaguayare well 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,324–30 feet (TLL 233004).

REMARKS: Globorotalia velascoensis (Cushman) shows considerable variety in size and shape (especially of the umbilical area). Material studied from a Velasco shale sample of Mexico shows every intermediate stage between very small forms with a narrow umbilicus (G. velascoensis var. acuta Toulmin group) and large specimens with a wide umbilicus (G. velascoensis, s. s., group). The same has been observed throughout the life range of the species in Trinidad sections. Forms belonging to both these groups are therefore regarded as G. velascoensis, of which G. velascoensis var. acuta is a synonym. This confirms Grimsdale (1951) who regards G. velascoensis var. acuta as a variety of G. velascoensis.

Globorotalia velascoensis appears in the upper part of the G. pusilla pusilla zone where it may have branched off from the G. angulata (White) group though no clearly intermediate forms have been observed. At the end of the G. velascoensis zone, the species becomes extinct in Trinidad together with numerous other planktonic and benthonic forms. The author's previous assumption (Bolli, 1952) that G. velascoensis occurs in the upper Lizard Springs and may be regarded as the ancestor of G. aragonensis Nuttall is no longer maintained. G. velascoensis is in fact restricted to the lower Lizard Springs; the forms previously described under this name from the upper Lizard Springs are now regarded as a new species (G. formosa gracilis Bolli, new species, new subspecies, and G. formosa formosa Bolli, new species, new subspecies) probably developing from the G. acuta Cushman and Renz group. This is supported by the coiling ratios of the species under discussion. G. velascoensis cools almost exclusively sinistrally before its extinction at the end of the Globorotalia velascoensis
zone. *G. aqua* and *G. formosa* both coil predominantly dextrally in the *Globorotalia* rex and *Globorotalia formosa formosa* zones of the upper Lizard Springs.

*Globorotalia compressa* (Plummer)

**Plate 20, Figures 21-23**

*Globigerina compressa* Plummer, Univ. Texas Bull. 2644, p. 135, pl. 8, fig. 8, 1926.


Shape of test very low trochospiral, inflated; equatorial periphery distinctly lobate, slightly elongate; axial periphery subacute to acute. Wall calcareous, perforate, surface smooth. Chambers slightly compressed; 12–15, arranged in about 2½ whorls, the 4–5 chambers of the last whorl increasing fairly rapidly in size. Sutures on spiral side radial to slightly curved in early chambers, radial in last chambers, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, open. Aperture a distinct arch, may have a slight lip; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of figured holotype 0.23 mm.

**Stratigraphic range**: *Globorotalia trinidadensis* zone to *Globorotalia pusilla pusilla* zone, Lizard Springs formation.

**Locality**: Figured holotype (USNM P5059) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 232705).

**Remarks**: *Globorotalia compressa* (Plummer) is the ancestor of *G. ehrenbergi* Bolli, new species, from which it is distinguished by its smaller size, less compressed chambers and absence of a peripheral keel.

*Globorotalia ehrenbergi* Bolli, new species

**Plate 20, Figures 18-20**


Shape of test low trochospiral, compressed; equatorial periphery strongly lobate; axial periphery acute, last chamber often with a faint keel. Wall calcareous, perforate, surface smooth. Chambers compressed; about 12–15, arranged in 2–3 whorls, the 5 chambers of the last whorl increasing fairly rapidly in size. Sutures on spiral side slightly curved, distinctly depressed; on umbilical side radial, depressed. Umbilicus shallow, open. Aperture a low arch with a lip; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of holotype 0.28 mm.

**Stratigraphic range**: *Globorotalia pusilla pusilla* zone to *Globorotalia pseudomenardii* zone, Lizard Springs formation.

**Locality**: Holotype (USNM P5061), paratype (USNM P5062) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample (holotype) from core 4,324–30 feet (TLL 233004); sample (paratype) from core 3,992–4,000 feet (TLL 233006).

**Remarks**: *Globorotalia pseudomenardii* Bolli, new species, is closely related to *G. ehrenbergi* Bolli, new species, from which it apparently developed and from which it is distinguished by its less lobate periphery and less depressed spiral sutures. The name has been chosen for the resemblance to small specimens of *G. menardii* (d'Orbigny), to which it has no genetic relationship however. *G. pseudomenardii* becomes extinct at the close of the Paleocene whereas *G. menardii* appears first in the middle to upper Miocene.

*Globorotalia elongata* Glaessner

**Plate 20, Figures 11-13**


Shape of test very low trochospiral, compressed, spiral
Globorotalia pusilla Bolli, new species, new subspecies

**Plate 20, Figures 8-10**

Shape of test low trochospiral, biconvex, compressed; equatorial periphery nearly circular, slightly lobate; axial periphery acute to subacute. Wall calcareous, perforate, surface smooth. Chambers moderately to strongly compressed; about 12, arranged in 2–2½ whors, the 6 chambers of the last whorl increasing rapidly in size. Sutures on spiral side slightly curved, distinctly depressed; on umbilical side radial, distinctly depressed. Umbilicus fairly wide, open. Aperture a low arch, interiomarginal, extrumbilical-umbilical. Coiling random. Largest diameter of figured hypotype 0.33 mm.

**Stratigraphic range:** Globorotalia pseudomenardii zone to Globorotalia velascoensis zone, Lizard Springs formation.

**Locality:** Figured hypotype (USNM P5063) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,212–24 feet (TLL 233002).

**Remarks:** *Globorotalia elongata* Gaessner is probably closely related to the *G. ehrenbergi* Bolli, new species—*G. pseudomenardii* Bolli, new species, group. *G. ehrenbergi*, it is distinguished by the more elongate equatorial periphery caused by the rapid increase in size of the ultimate and often also the penultimate chamber. From *G. pseudomenardii* it is distinguished by the more depressed sutures on the spiral side. The final whorl consists of 6 chambers, instead of 5 as in the other two species and the early portion is depressed in relation to the chambers of the last whorl on the spiral side.

Globorotalia pusilla Bolli, new species, new subspecies

**Plate 20, Figures 5–7**

Shape of test low trochospiral, biconvex, compressed; equatorial periphery circular, slightly lobate; axial periphery acute, last chambers often with a faint keel. Wall calcareous, perforate, surface smooth. Chambers strongly compressed; 12–16, arranged in about 3 whors; the 5–6 chambers of the last chamber increasing moderately in size. Sutures on spiral side strongly curved; on umbilical side radial. Umbilicus narrow, open. Aperture a low arch; interiomarginal, extrumbilical-umbilical. Largest diameter of holotype 0.28 mm.

**Stratigraphic range:** Globorotalia pseudomenardii zone, Lizard Springs formation.

**Locality:** Holotype (USNM P5065) from northeast bank of Tank Farm at the old Club Site, Pointe-a-Pierre, Trinidad (coordinates N:256960 links; E:380000 links), sample K. 10832 (TLL 228674).

**Remarks:** *Globorotalia pusilla laevigata* Bolli, new species, new subspecies, is closely related to *G. pusilla pusilla* Bolli, new species, new subspecies, from which it develops. The subspecies *laevigata* is distinguished from the subspecies *pusilla* by its more circular outline and acute axial periphery and by its spiral sutures not being depressed.

Globorotalia tortiva Bolli, new name

**Plate 19, Figures 10–21**

Globigerina velascoensis var. compressa White, Journ. Paleontol., vol. 2, No. 3, p. 196, pl. 25, figs. 3a–b, 1928.

Shape of test very low trochospiral, spiral side almost flat, umbilical side strongly convex; equatorial periphery lobate, chambers give a quadrangular to pentagonal outline; axial periphery rounded to subangular. Wall calcareous, perforate, surface finely spinose. Chambers laterally strongly compressed; 10–12, arranged in 2–2½ whors, the 4–4½ chambers of the last whorl increasing rapidly in size. Sutures on spiral side curved in early chambers, often straight, oblique between penultimate and ultimate chambers, depressed; on umbilical side radial or slightly curved, depressed. Umbilicus narrow, open. Aperture a high arch; interiomarginal, extrumbilical-umbilical. Coiling 85 percent dextral in the only sample investigated. Largest diameter of holotype 0.33 mm.

**Stratigraphic range:** Lower part of *Globorotalia pseudomenardii* zone, Lizard Springs formation.

**Locality:** Hypotype (USNM P5066) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,434–46 feet (TLL 233005).

**Remarks:** White (1928) described an identical form from Mexico under the name *Globigerina velascoensis* var. *compressa*. The interiomarginal, extrumbilical-umbilical position of the aperture places it within the genus *Globorotalia* where it becomes a homonym of *G. compressa* (Plummer). For this reason the new name *G. tortiva* is proposed. *G. tortiva* possibly branched...
off from *Globigerina velascoensis* which has less compressed chambers and an umbilical position of the apertures.

**Globorotalia mekannai** (White)

**Plate 19, Figures 16–18**


Shape of test low trochospiral, umbilical side strongly inflated; equatorial periphery nearly circular, slightly lobate; axial periphery rounded. Wall calcareous, perforate, finely spinose. Chambers inflated, slightly compressed laterally; 12–16, arranged in 2–3 whorls, the 5–7 chambers of the last whorl increasing moderately in size. Sutures on spiral side oblique, depressed; on umbilical side, radial, depressed. Umbilicus narrow, open. Aperture a low arch; interiomarginal, extra-umbilical-umbilical. Coiling random. Largest diameter of figured hypotype 0.35 mm.

**Stratigraphic range:** Upper part of *Globorotalia pseudomenardii* zone, Lizard Springs formation.

**Locality:** Figured hypotype (USNM P5067) from northeast bank of Tank Farm at the old Club Site, Pointe-a-Pierre, Trinidad (coordinates N:256950 links; E:380000 links), sample K. 10832 (TLL 228674).

**Remarks:** The species is moved to the genus *Globorotalia* because of the interiomarginal, extra-umbilical-umbilical position of the aperture. *G. mekannai* (White) is possibly related to *G. tortiva* Bolli, new name, from which it is distinguished by having more chambers in the last whorl.

**Globorotalia whitei** Weiss

**Plate 19, Figures 10–12**


Shape of test very low trochospiral, umbilical side inflated; equatorial periphery lobate; axial periphery rounded to subacute. Wall calcareous, perforate, finely spinose. Chambers inflated, slightly compressed laterally; about 12, arranged in 2–2½ whorls, the 4–5 chambers of the last whorl increasing moderately in size. Sutures on spiral side oblique, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, open. Aperture a low arch; interiomarginal, extra-umbilical-umbilical. Coiling random. Largest diameter of figured hypotype 0.33 mm.

**Stratigraphic range:** *Globorotalia pseudomenardii* to *Globorotalia velascoensis* zone, Lizard Springs formation.

**Locality:** Figured hypotype (USNM P5068) from Trinidad Leaseholds, Ltd., Guayaguayare well 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,212–24 feet (TLL 233002).

**Remarks:** *Globorotalia whitei* Weiss appears to be the ancestor of *G. velascoensis* Cushman and Ponton. From that species it is distinguished mainly by its smaller size and less acute axial periphery.

**Globorotalia wilcoxensis** Cushman and Ponton

**Plate 19, Figures 7–9**


Shape of test very low trochospiral, spiral side flat, occasionally slightly concave; umbilical side strongly convex and inflated; equatorial periphery lobate; axial periphery rounded, in last chambers often becoming acute. Wall calcareous, perforate, distinctly spinose. Chambers inflated, slightly compressed laterally; about 10, arranged in 2–2½ whorls, the 4 chambers of the last whorl increasing rapidly in size, the last chamber often slightly reduced again. Sutures on spiral side oblique, depressed; on umbilical side radial, strongly depressed. Umbilicus narrow, deep, open. Aperture a low arch; interiomarginal, extra-umbilical-umbilical. Coiling about 85 percent dextral. Largest diameter of hypotype 0.48 mm.

**Stratigraphic range:** *Globorotalia rex* zone, Lizard Springs formation.

**Locality:** Figured hypotype (USNM P5069) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,707–13 feet (TLL 232994).

**Remarks:** *Globorotalia wilcoxensis* Cushman and Ponton is regarded as the ancestor of *G. quetra* Bolli, new species.

**Globorotalia quetra** Bolli, new species

**Plate 19, Figures 1–6**

Shape of test very low trochospiral, spiral side flat or slightly concave, umbilical side strongly convex, angular; equatorial periphery strongly lobate; axial periphery subacute to acute, a spiny peripheral keel is often present in the early chambers of the last whorl; ultimate and penultimate chambers acute or rounded. Wall calcareous, perforate, distinctly spinose. Chambers angular to subangular, inflated; about 12, arranged in 2½ whorls, the 4–5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side oblique or curved, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, deep, open. Aperture a low arch; interiomarginal, extra-umbilical-umbilical. Coiling over 90 percent dextral in the *Globorotalia formosa formosa* and *Globorotalia aragonensis* zones. Largest diameter of holotype 0.64 mm. Largest diameter of figured paratype 0.50 mm.

**Stratigraphic range:** *Globorotalia rex* zone to *Globorotalia aragonensis* zone, Lizard Springs formation.

**Locality:** Holotype (USNM P5070) and figured paratype (USNM P5071) from Ravine Ampelu, Lizard Springs area, about 1½ mile southeast of the road junction of the Rio Claro—Guayaguayare Road (5½ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 293 (TLL 50512).

**Remarks:** *Globorotalia quetra* Bolli, new species, is a very characteristic form in the upper Lizard Springs,
where it is especially abundant in the Globorotalia formosa formosa zone. By its shape it might readily be mistaken for the middle Eocene Truncorotaloides rohir var. mayoensis Bronnimann and Bermudez or for G. topilensis Cushman (which probably is a Truncorotaloides). However, G. quetra lacks the sutured apertures on the spiral side which are characteristic for Truncorotaloides while its stratigraphic range is restricted to the lower Eocene. G. quetra appears to be closely related to G. wilcozeensis Cushman and Ponton, from which it is distinguished by the distinct angular shape of its test. Intermediate forms were found in the Globorotalia rex zone.

Globorotalia broedermanni Cushman and Bermudez

Plate 19, Figures 13-15


Shape of test biconvex, low trochospiral, moderately compressed; equatorial periphery nearly circular; axial periphery rounded to subangular. Wall calcareous, perforate, surface covered with short spines. Chambers subangular, inflated; about 12–15, arranged in 2 1/2–3 whorls, the 5–6 chambers of the last whorl increasing slowly in size. Sutures on spiral side curved, slightly depressed between last chambers of final whorl; on umbilical side radial, slightly depressed. Umbilicus narrow, open. Aperture a low arch; interiomarginal, extrumbilical—umbilical. Coiling over 90 percent dextral. Largest diameter of hypotype 0.33 mm.

Stratigraphic range: Globorotalia rex zone to Globorotalia aragonensis zone, Lizard Springs formation; continuing into the Navet formation.

Locality: Figured hypotype (USNM P5072) from Ravine Ampelu, Lizard Springs area, about 1 1/2 mile southeast of the road junction of the Rio Claro—Guayaguayare Road (8% M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 293 (TLL 50512).

Remarks: The origin of Globorotalia broedermanni Cushman and Bermudez cannot be traced in the Trinidad sections. The species appears at the base of the Globorotalia rex zone apparently fully developed and with a strong preference for dextral coiling (indicating an advanced evolutionary stage). A marked faunistic change between the Globorotalia rex zone and the older Globorotalia velascozeensis zone indicates a hiatus in the studied sections. It is in this missing interval that possible ancestral forms of Globorotalia broedermanni have to be sought.

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Chiloguembelina Loeblich and Tappan and Related Foraminifera from the Lower Tertiary of Trinidad, B. W. I.

By J. P. Beckmann

Introduction

Recent studies by Montanaro Gallitelli (1955) indicate that Guembelina Egger, 1899, is a junior synonym of Heterohelix Ehrenberg, 1843, and therefore invalid. Loeblich and Tappan (1956) have erected the genus Chiloguembelina, to include some Tertiary species previously referred to Guembelina. Chiloguembelina is distinguished from the Cretaceous genus Heterohelix by the absence of an early coiled stage, the presence of necklike apertural extensions, and the tendency to develop a twisted test and asymmetrical aperture.

In Trinidad, Chiloguembelina is present in a great number of planktonic faunas of Paleocene, Eocene, and Oligocene age. The specimens are usually well preserved and the morphological details are easily seen, except in some middle Eocene samples, where the number of good specimens is sometimes insufficient.

It is the purpose of this paper to describe the species of Chiloguembelina from the lower Tertiary of Trinidad, to establish their stratigraphic ranges, and to discuss their relationships to the Heterohelicidae and Buliminidae.

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Stratigraphy

The species of Chiloguembelina, Guembelitria and Zeaowigerina described in this paper were obtained from samples from the following formations:

- Cipero formation, lower part (Oligocene)
- San Fernando formation (uppermost Eocene)
- Navet formation (middle Eocene to lower part of upper Eocene)
- Lizard Springs formation (Paleocene to lower Eocene).

Details of the further subdivision of these formations are given in the range chart (text-fig. 16). The complete data, with descriptions of the planktonic Foraminifera, have been published by Bolli (1957a, 1957b, 1957c).

The generic names of the zonal markers used in this paper are in accordance with the recent classification of planktonic Foraminifera by Bolli, Loeblich, and Tappan (1957).

General Morphology

The chamber arrangement of the Tertiary species of Chiloguembelina is biserial throughout. None of the species investigated by the author show the early coil described from the Cretaceous Heterohelicidae (Loeblich, 1951; Montanaro Gallitelli, 1955). The presence of a triserial stage in Guembelina venezuelana Nuttall, recorded by Hofker (1954), could not be confirmed. The diameter of the proloculum is from 0.005 to 0.02 mm. Its size varies from species to species, as well as within one species. In the latter case, this seems to indicate the existence of megalospheric and microspheric generations.

The characteristics fairly constant within one species, and therefore most useful for systematic purposes, are: The aperture—its shape and position (eccentric or in the center of the apertural face), and the presence or absence of transparent collars or
Numbers 1–4. *Chiloguembelina crinita* (Glaessner), (USNM P5754) from sample 228674.
Numbers 5–8. *Chiloguembelina cubensis* (Palmer), (USNM P5757), from sample 215702.
Numbers 9–11, 14–18, 20–23. *Chiloguembelina martini* (Pijpers): 9–11 (USNM P5760a–c), from sample 177760, Hantkenina aragonensis zone. 14–18 (USNM P5761a–e) from sample 221009, Porticulasphaera mexicana zone. 20–23 (USNM P5762a–d), from sample 238622, Globigeropsis semiinvoluta zone.
Numbers 12, 13, 19. *Chiloguembelina cf. mauriciana* Howe and Roberts:
12, 13 (USNM P5765a, b), from sample 177760, Hantkenina aragonensis zone. 19 (USNM P5766), from sample 221009, Porticulasphaera mexicana zone.
Numbers 24–27. *Chiloguembelina midwayensis midwayensis* (Cushman) (USNM P5769a–d), from sample 232705.
Numbers 32–35. *Chiloguembelina midwayensis subcylindrica* Beckmann, new subspecies (USNM P5776a–d), from sample 228484.

**Figure 14.**—Variability of species of *Chiloguembelina* (all figures approximately × 120; a list of the sample localities is given on p. 88).
Numbers 36-38. *Chiloguembelina parallela* Beckmann, new species (USNM P5781a-c), from sample 232994. Small end chamber visible in Nos. 36 and 38 (partly broken).

Numbers 39-42. *Chiloguembelina subtirangularis* Beckmann, new species (USNM P5784a-d), from sample 232706.

Numbers 43-45. *Chiloguembelina trinitatensis* (Cushman and Renz) (USNM P5787a-c), from sample 50315.


flanges; the general shape of the chambers (compressed or globular); and the surface of the wall (smooth or spinose). Other features, such as the number and the rate of increase in size of the chambers or the nature of the sutures (oblique or horizontal, straight or curved) are more variable, but can in certain cases be used for the distinction of subspecies.

Whereas the aperture is usually characteristic for each species, there is a considerable diversity within the whole Chiloguemhelina group. Extremely asymmetrical apertures with a transparent flange occur in Chiloguemhelina midwayensis (Cushman) and Chiloguemhelina martini (Pipers) (pl. 21, figs. 1–3, 6, 14). The asymmetrical shape and position of the aperture is not due to lateral compression or distortion of the test, but is a character which alternates regularly within one specimen as a result of the biserial arrangement of the chambers. On the other hand, Chiloguemhelina wilcozensis (Cushman and Ponton) and Chiloguemhelina trinitatisensis (Cushman and Renz) have a symmetrical, semicircular to crescentic aperture, similar to that of many Cretaceous species of Heterohelix (pl. 21, figs. 7, 10, 12). Another variant is Chiloguemhelina parallela, new species, where the aperture is high and narrow, symmetrical in shape and situated in the center of the apertural face (pl. 21, fig. 8).

In Chiloguemhelina midwayensis subcylindrica, new subspecies, C. parallella, new species, and C. wilcozensis (Cushman and Ponton), the aperture of the last regular chamber is occasionally covered by a small chamber of irregular shape (pl. 21, figs. 3, 13; text-fig. 15, Nos. 36, 38, 56). The wall surface of this small chamber is usually smoother than that of the previous chambers. This feature resembles the terminal chamber of Zeauvigera and suggests a close relationship between this genus and Chiloguemhelina. The tubular neck characteristic of Zeauvigera is, however, absent in Chiloguemhelina.

It is interesting to note that Chiloguemhelina midwayensis subcylindrica, new subspecies, C. parallella, new species, and C. wilcozensis (Cushman and Ponton), the only three species which have this end chamber, seem to be the last stages of three different evolutionary lines, as follows:

This suggests that the end chamber in Chiloguemhelina is a generon stage, which is developed shortly before the extinction of an evolutionary line.

Evolutionary Trends and Relationships to Other Genera

It is easy to recognize evolutionary trends in the Paleocene-lower Eocene Chiloguemhelina species from the Lizard Springs formation. The faunas are well preserved and contain intermediate forms which indicate the origin of the various species. On the other hand, it has not been possible to trace definite evolutionary trends in Chiloguemhelina within the Navet and Cipero formations.

The preceding discussion of morphological details indicates that the genus Chiloguemhelina includes species showing various apertural characteristics. Distinctive features, however, such as a symmetrical aperture or a small terminal chamber, occur independently in different evolutionary lines. Species showing various types of apertures and shapes of the test are apparently closely related and it seems therefore reasonable to include them in one single genus.

The main features distinguishing Chiloguemhelina from Heterohelix, are the absence of a coiled early stage, the tendency to develop a twisted test, and the presence of necklike extensions or flaps around the aperture. The chamber arrangement is biserial as in Bolivina, and some species of Chiloguemhelina and Bolivina are similar in appearance. However, Chiloguemhelina has inflated chambers, no ornamentation, but often a hispid wall surface. The aperture is rare in high and narrow as in typical Bolivina. Further characteristics of Chiloguemhelina are the twisted test and the absence of an internal structure connecting the apertures of successive chambers. There is also a difference in the habitat of the two genera. The frequency of Chiloguemhelina in Globigerina marls suggests a planktonic mode of life for this genus, whereas Bolivina is generally regarded as bottom-living.

The relationship between Chiloguemhelina and Zeauvigera has been mentioned above.

Stratigraphic Occurrence

The stratigraphic range (see text-fig. 16) of Chiloguemhelina in Trinidad is from Paleocene to Oligocene. This is in agreement with the observations of most previous authors. None of the Chiloguemhelina species described in this paper occur in the Upper Cretaceous of Trinidad. The author has not systematically checked upper Oligocene, Miocene, or Recent faunas for the presence of Chiloguemhelina, and it is possible that additional species will be found in these faunas.

The variety of species of Chiloguemhelina reaches a first climax around the Paleocene-lower Eocene bound-
Figure 16.—Species distribution of *Chiloguembelina*, *Guembelitria*, and *Zeauvigerina* in the Tertiary of Trinidad, B. W. I.

<table>
<thead>
<tr>
<th>AGE</th>
<th>FORMATION</th>
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<tr>
<td>Oligocene</td>
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<td></td>
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<td></td>
<td>GLOBIGERINA AMPLI-APERTURA</td>
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<td>San Fernando</td>
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<td>GLOBIGERAPSID SEMI-INVOLUTA</td>
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<td></td>
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<td>TRUNCOROTALIDOS ROHRI</td>
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<tr>
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<td>PORTICULASPHAERA MEXICANA</td>
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<td></td>
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<td>GLOBOROTALIA LEHNERI</td>
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<td></td>
<td></td>
<td>GLOBIGERAPSID KUGLERI</td>
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<td></td>
<td></td>
<td>HANTKENINA ARAGONENSIS</td>
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<td>Upper Lizard Springs</td>
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<td>GLOBOROTALIA PALMERAEN</td>
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<td>GLOBOROTALIA REX</td>
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<td>GLOBOROTALIA UNCINATA</td>
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<td>GLOBOROTALIA TRINIDADENSIS</td>
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</table>

Specimens of *Chiloguembelina* occur in great numbers and the poor preservation of the specimens from the *Globiagerapside kugleri* and *Globorotalia Lehneri* zones.

*Chiloguembelina martini* disappears at the Eocene-Oligocene boundary and is therefore a good Eocene marker. The only survivors in the Oligocene are *Chiloguembelina cubensis* (Palmer) and *Chiloguembelina victoriana*, new species. The latter species died out suddenly in the middle of the *Globiagerina ampliapertura* zone, and the last occurrence of *Chiloguembelina cubensis* is in the *Globorotalia opima opima* zone.

Specimens of *Chiloguembelina* occur in great numbers...
in most of the Paleocene, Eocene, and lower Oligocene Globigerina marls of Trinidad. They can be easily recognized in a fauna consisting of fossils of Globigerina and Globorotalia and are therefore useful for a first quick estimation of the age of a sample. Chiloguembelina is also found in samples containing mainly a benthonic fauna. This type of fauna is well known from the Gulf Coast of the United States. Chiloguembelina is then often the most accurate means of correlating these faunas with planktonic assemblages from other localities.

**Previous Records of Chiloguembelina from the Tertiary of Trinidad**

Cushman and Jarvis (in Cushman, 1938) describe Guembelina goodwini from the Hospital Hill marl of Trinidad (upper Eocene, Globigeropsis seminovoluta zone). Cushman and Renz (1948, p. 23) report Guembelina goodwini from all units of the Navet formation except the Ramdat marl. Guembelina goodwini is now regarded as a junior synonym of Textularia martini Pijpers (1933).

**Guembelina trinitatensis** was described from the Paleocene of Soldado Rock (off the southwest coast of Trinidad) by Cushman and Renz (1942).

**Guembelina ultimaturnida** White is reported by Cushman and Renz (1946, p. 36, pl. 6, figs. 1, 2) from the Lizard Springs formation. This identification has to be revised, as it was probably influenced by the belief that the Lizard Springs formation was of Upper Cretaceous age. A re-examination of the type assemblages of the Lizard Springs formation, prepared by H. H. Renz, shows that they include Guembelina representing several Tertiary species (Chiloguembelina crinita-midwayensis group, Chiloguembelina wilcoxensis and Chiloguembelina trinitatensis), but do not contain any Cretaceous species. It is not possible to identify with certainty the figures given by Cushman and Renz (1946). Figure 1 on plate 6 of their paper is probably a Chiloguembelina crinita or midwayensis strombiformis; figure 2 seems to be a different genus.

**Systematic Descriptions**

Fourteen species and subspecies of *Chiloguembelina*, one species of *Guembelitria* and one species of *Zeusigerina* are here recorded. The following new species and subspecies are described:

- **Chiloguembelina midwayensis** strombiformis, new subspecies
- **Chiloguembelina midwayensis subhybrida**, new subspecies
- **Chiloguembelina paralela**, new species
- **Chiloguembelina subriangularis**, new species
- **Chiloguembelina victoriana**, new species

The figured types are deposited in the U. S. National Museum in Washington. A duplicate set of the species described in this paper is deposited in the Natural History Museum, Basel, Switzerland.

**Localities**

The following list gives the localities for the samples from which the figured holotype, paratypes and hypotypes were obtained. The sample numbers given here and in the explanations of the plates and text-figures are the catalogue numbers of the paleontological collection of The Trinidad Oil Company.

50315: About 1½ mile southeast of the junction between the Rio Claro-Guayaguayare Road and the road to the abandoned Lizard Springs oilfield, southeast Trinidad (locality described in detail by Cushman and Renz, 1946), in eastern tributary of Ampelu River, 150 feet from its junction with Ampelu River, collected by H. H. Renz (282).

102301: 120 feet north of sample 50315, collected by K. W. Barr (6972).

177760: In ravine between Brasso-Tamana Road and Navet River, central Trinidad, 1,450 feet south of milepost 5½ of Brasso-Tamana Road (see Bolli, 1937b, text-fig. 25), collected by W. H. Kugler (8820).

178162: 4,570 feet south of milepost 9½ of Brasso-Tamana Road, central Trinidad; in small northern tributary of Nariva River, 100 feet from its junction with the Nariva River (coordinates N:313850 links; E:478580 links), collected by H. G. Kugler (6073).

193785: Cipero Coast, San Fernando, Trinidad, 475 feet southwest of fixed point at northern end of coast section (Bolli, 1957c, text-fig. 19), collected by J. B. Saunders (19).

215702: Cipero Coast, San Fernando, Trinidad, 276 feet southwest of fixed point at northern end of coast section, collected by H. M. Bolli (3138).

217095: 550 feet west of road junction between The Avenue and Bon Accord Road, Pointe-a-Pierre, Trinidad, in cutting west of tank 127, 200 feet north of The Avenue, collected by L. W. Hawkins (408).

221009: Same locality as 221995, collected by H. G. Kugler (10781).

232470-73: Trinidad Petroleum Development Co. well Moruga No. 15, south Trinidad (coordinates N:149878 links; E:497062 links); 223470 from core at 3,593-3,615 feet (upper part), 223472 from core at 3,720-3,740 feet, 223473 from core at 3,796-3,816 feet.

232484: Left bank tributary of Casares River, 180 feet from its junction with the Casares River, Moruga, south Trinidad (coordinates N:138700 links; E:35000 links), collected by L. W. Hawkins (1831).
Family Heterohelicidae Cushman, 1927

Genus Chiloguembelina Loeblich and Tappan, 1956

Chiloguembelina crinita (Glaessner)

Plate 21, Figure 4; Text-figure 14 (1-4)

Gumbelina crinita Glaessner, 1937, p. 383, pl. 4, fig. 34 (Paleocene or lower Eocene, Caucasus, U.S.S.R.).

The general shape of the test, the spinose surface of the wall and the semicircular aperture agree well with the type description. Chiloguembelina crinita is closely related to C. midwayensis (Cushman), but differs in the more globular shape of its chambers and the more rapid increase in chamber size. The wall of C. crinita is more spinose and resembles that of C. midwayensis strombiformis, new subspecies. This subspecies, however, has less inflated chambers and in general a lower and more elongate aperture. LENGTH: 0.2–0.3 mm.

Occurrence: Lower Lizard Springs formation (Paleocene), Globorotalia pseudomenardii zone (common) and Globorotalia velascoensis zone (lower part; rare).

Types: Figured hypotypes (USNM P5753, P5754) and unfigured hypotypes (USNM P5755).

Chiloguembelina cubensis (Palmer)

Plate 21, Figure 21; Text-figure 14 (5-8)

Gumbelina cubensis Palmer, 1934, p. 74, text-figs. 1–6 (upper Eocene and lower Oligocene, Cuba).—Palmer and Bermudez, 1936, p. 284 (lower Oligocene, Cuba).—Bermudez, 1938, p. 11 (Eocene, Cuba).—Cushman, 1939, p. 63, pl. 10, fig. 54 (Eocene, North Atlantic Ocean).—Palmer, 1940, p. 292 (Oligocene, Cuba).—Cushman, 1946, p. 22, pl. 4, fig. 28 (Eocene, Alabama, U. S. A.).—Cushman and Todd, 1946b, p. 90 (Oligocene, Mississippi, U. S. A.).—Renz, 1948, p. 138, pl. 6, fig. 9 (Oligo-Miocene, Venezuela).—Bandy, 1949, p. 124, pl. 24, fig. 3 (upper Eocene, Alabama, U. S. A.).—Bermudez, 1949, p. 175, pl. 11, fig. 40 (middle Oligocene, Cuba).—Beckmann, 1953, p. 364, pl. 21, fig. 2 (Oligocene, Barbados, W. I.).

Gumbelina cubensis Palmer var. heterostoma Bermudez, 1937, p. 143, pl. 17, figs. 5–7 (upper Eocene, Cuba).—Cushman and Stone, 1947, p. 11, pl. 1, fig. 29 (Eocene, Peru).—Bandy, 1949, p. 124, pl. 24, fig. 7 (upper Eocene, Alabama, U. S. A.).

Most well-preserved specimens from Trinidad have the slightly asymmetrical aperture described in Gumbelina cubensis var. heterostoma Bermudez. Forms with a symmetrical aperture, as shown in D. K. Palmer’s type figures of G. cubensis, are rare and seem only to be extreme variants of the group. By courtesy of Dr. Bermudez, the author obtained typical hypotypes of Chiloguembelina cubensis and the variety heterostoma. Specimens with asymmetrical apertures occur at both localities. The author is therefore inclined to consider the variety heterostoma as a synonym of C. cubensis. H. M. Bolli (personal communication) came to the same conclusion after a comparison of the types deposited in the U. S. National Museum.

Length: 0.12–0.25 mm.

Occurrence: Eocene and lower Oligocene, Portuila-sphaera mexicana zone to Globorotalia opima opima zone.

Single, badly preserved specimens, which may be closely related to Chiloguembelina cubensis, are found in the lower part of the Navet formation (Hantkenina aragonensis and Globigerina kugleri zones).

References to Chiloguembelina cubensis from Cuba (Palmer, 1940), Venezuela (Renz, 1948) and the Dominican Republic (Bermudez, 1949) seem to be from younger strata than the highest occurrence of the species in Trinidad. A re-examination of these localities will be necessary to check the possibility of reworking.

Types: Figured hypotypes (USNM P5756, P5757) and unfigured hypotypes (USNM P5758).

Chiloguembelina maritima (Pijpers)

Plate 21, Figure 14; Text-figure 14 (9–11, 14–18, 20–23)

Textularia maritima Pijpers, 1933, p. 57, figs. 6–10 (upper Eocene, Bonaire, D. W. I.).

Gumbelina martini (Pijpers), Drooger, 1953, p. 100, pl. 1, fig. 2; text-fig. 4 (upper Eocene, Curacao and Bonaire).

Gumbelina goodwinii Cushman and Jarvis, in Cushman, 1933, p. 69, pl. 7, figs. 15, 16 (upper Eocene, Trinidad, B. W. I.).—Bermudez, 1938, p. 11 (Eocene, Cuba).—Cushman and Renz, 1948, p. 23 (Eocene, Trinidad, B. W. I.).

Gumbelina venezuelana Nuttal, 1935, p. 126, pl. 15, figs. 2–4 (upper Eocene, Venezuela).—Cushman, 1939, p. 62, pl. 10, figs. 50–53 (Eocene, North Atlantic Ocean).—Cushman and Todd, 1945b, p. 94, pl. 15, fig. 9 (upper Eocene, Mississippi, U. S. A.).—Cushman, 1946, p. 22, pl. 4, fig. 29 (upper Eocene, Alabama, U. S. A.).—Cushman and Stone, 1947, p. 10, pl. 1, fig. 28 (Eocene, Peru).—Cushman and Stainforth, 1951, p. 149, pl. 26, fig. 23 (upper Eocene, Peru).

The long list of references and synonyms indicates that Chiloguembelina maritima is widespread in the American Eocene and shows considerable variability. The synonymy is, in principle, that proposed by Drooger (1953). The range of variation at various stratigraphic levels is illustrated by a series of text-figures. The younger specimens (text-fig. 14, Nos. 20–23) are usually slightly larger than those from the lower part of the Navet formation (text-fig. 14, Nos. 9–11) and their chambers are often more inflated and show a greater increase in size. Yet these minor differences are overshadowed by the individual variability within one sample.

Length: 0.2–0.32 mm.

Occurrence: Upper Lizard Springs (Globorotalia aragonensis zone), Navet and San Fernando formations (Eocene).

Types: Figured hypotypes (USNM P5759, 5760a–c, 5761a–e, 5762a–d) and unfigured hypotypes (USNM P5763).

Chiloguembelina cf. mauriciana (Howe and Roberts)

Plate 21, Figure 15; Text-figure 14 (12, 13, 19)


Gumbelina mauriciana Cushman and Todd, 1945a, p. 16, pl. 4, fig. 2 (Eocene, Alabama, U. S. A.).

The Trinidad specimens are mostly shorter and thicker than the holotype of Chiloguembelina mauriciana,
but some resemble very closely the specimen figured by Cushman and Todd (1945a). Unfortunately the type description does not give any detail as to the variability of the species. It is therefore not possible to decide whether the Trinidad specimens can definitely be included in Chiloguembelina mauriciana.

The specimens here referred to Chiloguembelina cf. mauriciana (Howe and Roberts) are shorter and thicker than C. martini (Pijpers). The aperture is lower and often more symmetrical in shape and position. Many transitional forms exist, however, between the two groups, but they are here separated as they have different stratigraphic ranges.

**Length:** 0.14–0.22 mm.

**Occurrence:** Navet formation (Eocene), Hantkenina aragonensis zone to Porticulaphera mexicana zone.

**Types:** Figured hypotypes (USNM P5764, 5765a, b, 5768) and unfigured hypotypes (USNM P5767).

Chiloguembelina midwayensis midwayensis (Cushman)

**Plate 21, Figure 1; Text-figure 14 (24–27)**

Gambelina midwayensis Cushman, 1940, p. 65, pl. 11, fig. 15 (Paleocene, Alabama, U. S. A.)—Cushman and Todd, 1946a, p. 58, pl. 10, fig. 15 (Paleocene, Arkansas, U. S. A.)—Cushman, 1951, p. 37, pl. 11, figs. 7, 8 (Paleocene, Alabama, Arkansas, and Texas, U. S. A.).

The greatest number of typical specimens occurs in the Globorotalia pusilla pusilla zone. In the overlying G. pseudomenardii zone the variability of the species becomes greater, and at the same time closely related forms appear, i.e., Chiloguembelina crinita (Glassner) and C. midwayensis strombiformis, new subspecies.

A characteristic not mentioned by Cushman in his original description is the asymmetrical shape of the aperture, an important feature of the Chiloguembelina midwayensis group and other species of Chiloguembelina.

**Length:** 0.2–0.3 mm.

**Occurrence:** Lower Lizard Springs formation (Paleocene).

**Types:** Figured hypotypes (USNM P5768, P5769a–d) and unfigured hypotypes (USNM P5770).

Chiloguembelina midwayensis strombiformis Beckmann, new subspecies

**Plate 21, Figure 6; Text-figure 14 (28–31)**

Test rapidly increasing in breadth, slightly compressed laterally. Periphery rounded. Chambers slightly inflated, biseriately arranged, with their apertural faces not at right angles to the plane of greatest breadth of the test, thus giving the test a twisted appearance. Sutures depressed, slanting. Wall finely spinose. Aperture large, broader than high, surrounded by a transparent collar. One side of the aperture projects more than the other; its position is therefore oblique with regard to the general shape of the test.

Holotype from the Paleocene, lower Lizard Springs formation, Globorotalia pseudomenardii zone; Trinidad Petroleum Development Co. well Moruga No. 15, south Trinidad (coordinates N: 149878 links, E: 497002 link), core 3720–40 feet (TTOC 223472).

The variability of Chiloguembelina midwayensis strombiformis is illustrated by the text-figures 14, numbers 25–31. It increases more rapidly in size than Chiloguembelina midwayensis midwayensis and has a more spinose wall, more oblique sutures and a broader aperture. It is separated from Chiloguembelina crinita (Glassner) by the lower, less globular chambers, the slightly coarser spinosity of the wall and the broader aperture.

**Length:** 0.23–0.3 mm.; holotype, 0.25 mm.

**Occurrence:** Lower Lizard Springs formation (Paleocene), Globorotalia pseudomenardii zone (common) and Globorotalia velascoensis zone (rare).

**Types:** Figured holotype (USNM P5771) and paratypes (USNM P5772 a–d), unfigured paratypes (USNM P5773).

Chiloguembelina midwayensis subcylindrica Beckmann, new subspecies

**Plate 21, Figures 2, 3; Text-figure 14 (32–35)**

Test large for the genus, rapidly increasing in size in the early stages, only slightly increasing in the later portion, which may become almost cylindrical. Chambers biseriately arranged, moderately inflated. Sutures depressed, slightly slanting. Wall very finely spinose. Aperture fairly large, about as broad as high, oblique to the plane of greatest breadth of the test, usually with a narrow transparent collar. The aperture is sometimes covered by a small end chamber (pl. 21, fig. 3).

Holotype from the lower Eocene, upper Lizard Springs formation, Globorotalia formosa formosa zone, about 1¼ miles southeast of the junction between the Rio Claro-Guayaguayare Road and the road to the abandoned Lizard Springs oilfield, southeast Trinidad, 120 feet north of small Ampelu River tributary described as type section of the Lizard Springs formation by Cushman and Renz (1946), and 130 feet east of Ampelu River (coordinates N:187610 links, E:556600 links), collected by K. W. Barr (No. 6972) (TTOC 102301).

There is some variation in the length to breadth ratio of the test and in the degree of inflation of the chambers as shown in the text-figure. Chiloguembelina midwayensis subcylindrica, new subspecies, differs from C. midwayensis midwayensis (Cushman) in the larger size of the test, the greater increase in size of the early chambers, and in the shape of the later part of the test, which is much thicker and often almost cylindrical. It is separated from C. midwayensis strombiformis, new subspecies, by its larger size, more cylindrical test, higher chambers and less oblique sutures. The little end chamber which covers the aperture of some specimens of C. midwayensis subcylindrica is absent in other subspecies of C. midwayensis.

**Length:** 0.25–0.42 mm.; holotype, 0.4 mm.

**Occurrence:** Upper Lizard Springs formation (lower Eocene), Globorotalia rex and Globorotalia formosa formosa zones.
Types: Figured holotype (USNM P5774) and paratypes (USNM P5775, 5776a-d), unfigured paratypes (USNM P5777).

Chiloguembelina cf. multicellaris (Hussey)

Plate 21, Figure 17

?Gambilina multicellaris Hussey, 1949, p. 130, pl. 27, fig. 10 (Eocene, Louisiana, U. S. A.).

The specimens from Trinidad are rare and badly preserved. They are similar to Hussey's species, but the chambers increase more regularly in size. The Trinidad specimens differ from Chiloguembelina cubensis (Palmer) in having a larger, arched aperture, but the shape of the test is the same as in many slender specimens of Chiloguembelina cubensis.

Length: 0.15–0.2 mm.

Occurrence: Navet formation (Eocene), Hantkenina aragonensis zone to Globorotalia lehneri zone.

Types: Figured hypotype (USNM P5778) and unfigured hypotypes (USNM P5779).

Chiloguembelina parallela Beckmann, new species

Plate 21, Figure 8; Text-figure 15 (36–38)

Test short, thick, rapidly tapering towards the base, slightly compressed. Chambers subglobular, usually 8 to 12 in number, biserially arranged, rapidly increasing in size. Sutures oblique, depressed. Wall smooth or slightly spinose. Aperture high and narrow, symmetrically bordered by two parallel lateral flanges, occasionally by a small end chamber of irregular shape (text-fig. 15, Nos. 36, 38).

Holotype from the lower Eocene, upper Lizard Springs formation, Globorotalia rex zone, left bank tributary of Casca River, 180 feet from its junction with the Casca River, Moruga, south Trinidad (coordinates N:138700 links, E:435000 links), collected by L. W. Hawkins (No. 1831) (TTOC 228484).

This species is easily separated from other species of Chiloguembelina by its symmetrical, high and narrow aperture. Its restricted range makes it a good index fossil. The holotype is a large specimen, hence a few smaller paratypes are illustrated in the text-figure in order to give the full size range of the species.

Length: 0.22–0.42 mm.; holotype 0.4 mm.

Occurrence: Upper Lizard Springs formation (lower Eocene), Globorotalia rex zone.

Types: Figured holotype (USNM P5780) and paratypes (USNM P5781a–c), unfigured paratypes (USNM P5782).

Chiloguembelina subtrianlularis Beckmann, new species

Plate 21, Figure 5; Text-figure 15 (39–42)

Test small, subtriangular, pointed at the base, compressed, with a subangular periphery. Chambers biserial, very slightly inflated. Sutures nearly horizontal, slightly depressed, at least in the later stages. Wall smooth. Aperture commonly slightly eccentric, semicircular to subquadrangular, may have a slight collar.

Holotype from the Paleocene, lower Lizard Springs formation, Globorotalia pusilla pusilla zone. Locality: TTOC well Guayaguare No. 159, southeast Trinidad (coordinates N:151361 links, E:554095 links), core 4778–90 feet (TTOC 232706).

The compressed, subtriangular test makes it easy to distinguish Chiloguembelina subtriangularis, new species, from other Chiloguembelina species. The variability is shown in the text-figure but the extreme forms (Nos. 39 and 42) are rare. C. subtriangularis occurs in all zones of the lower Lizard Springs formation, but is most common in the Globorotalia pusilla pusilla zone. The specimens from the Globorotalia trinitatensis zone have a more rounded periphery, slightly curved sutures and resemble compressed specimens of C. midwayensis.

Length: 0.14–0.22 mm.; holotype, 0.21 mm.

Occurrence: Lower Lizard Springs formation (Paleocene).

Types: Figured holotype (USNM P5783) and paratypes (USNM P5784a–d), unfigured paratypes (USNM P5785).

Chiloguembelina trinitatensis (Cushman and Renz)

Plate 21, Figure 7; Text-figure 15 (43–45)

Gambilina trinitatensis Cushman and Renz, 1942, p. 8, pl. 2, fig. 8 (Paleocene, Soldado Rock, Trinidad, B.W.I.); Cushman, 1951, p. 38, pl. 11, fig. 9 (same locality).

The specimens from Trinidad, especially those from the Lizard Springs type area, are commonly slightly larger than the types from Soldado Rock, but the other morphological characters are the same.

Length: 0.26–0.38 mm.

Occurrence: Lower Lizard Springs formation (Paleocene), Globorotalia velascoensis zone.

Types: Figured hypotypes (USNM P5786, P5787a–c) and unfigured hypotypes (USNM P5788).

Chiloguembelina victoriana Beckmann, new species

Plate 21, Figures 19, 20; Text-figure 15 (46–48)

Test elongate, slender, somewhat compressed. Periphery rounded, slightly lobate. Chambers biserial, broader than high, slightly inflated. Sutures straight, depressed, oblique in the early portion of the test, later more or less horizontal. Wall smooth. Aperture semicircular, sometimes with a faint lip, in an oblique position, i. e., with one side projecting more than the other.

Holotype from the upper Eocene, San Fernando formation, Globorotalia cocoaensis zone, Branch of Pointe-a-Pierre Road, between Joga Grant Street and Jarvis Street, San Fernando, Trinidad, 90 feet east of southern end of Joga Grant Street (coordinates N:239020 links, E:363330 links), collected by H. G. Kugler (No. 9613) (TTOC 240966).

The variability of the species is shown by the text-figure. The specimens from the upper Eocene (pl. 21, fig. 19) are, on an average, slightly more elongated than the specimens from the Oligocene (pl. 21, fig. 20). Some specimens are moderately twisted at the base,
but the biserial chamber arrangement is maintained throughout the test.

*Chiloguembelina victoriana*, new species, differs from *Chiloguembelina cubensis* (Palmer) in its higher and narrower aperture, smooth wall surface, and somewhat less inflated chambers.

The name *Chiloguembelina victoriana* is derived from the county of Victoria, Trinidad, where the species is found in various surface localities (San Fernando area, Cipero Coast section).

**Length**: 0.15–0.22 mm; holotype, 0.2 mm.

**Occurrence**: San Fernando formation (upper Eocene), *Globorotalia cocaensis* zone. Cipero formation (Oligocene), *Globigerina ampliapertura* zone (lower part).

**Types**: Figured holotype (USNM P5789) and paratypes (USNM P5790, P5791a–c), unfigured paratypes (USNM P5792).

*Chiloguembelina wilcoensis* (Cushman and Ponton)

**PLATE 21, FIGURES 10, 12, 13; TEXT-Figure 15 (49–58)**

*Gambelina wilcoensis* Cushman and Ponton, 1932, p. 66, pl. 8, figs. 16, 17 (lower Eocene, Alabama, U. S. A.).—TOUMLIN, 1941, p. 597, pl. 80, fig. 24 (lower Eocene, Alabama, U. S. A.).

With its globular chambers and its symmetrical, semicircular aperture, *Chiloguembelina wilcoensis* is easily distinguished from other *Chiloguembelina* species, but is similar to some Cretaceous species of *Heterohelix* (formerly *Guembelina*).

Loeblich and Tappan (1956) do not mention this species among those to be included in *Chiloguembelina*. However, like *C. trinitatis* Cushman and Renz, which has no twisted test or asymmetrical apertural flap either, it seems to develop from *C. crinida*, which is a typical *Chiloguembelina* (see p. 59). Therefore *C. trinitatis* and *C. wilcoensis* are probably not directly related to the Cretaceous *Heterohelix*. The genus description of *Chiloguembelina* does not exclude species with symmetrical test. The necklike extension of the aperture mentioned by Loeblich and Tappan is present in many specimens of *C. wilcoensis*, especially the earlier ones.

There is a distinct increase in size from the lowest to the highest occurrence of the species. A few specimens show a small end chamber covering the aperture of the last regular chamber, as in plate 21, figure 13, and text-figure 15 (No. 56).

**Length**: 0.2–0.58 mm.

**Occurrence**: Lizard Springs formation (Paleocene and lower Eocene), *Globorotalia pseudomenardii* zone to *Globorotalia formosa* zone.

**Types**: Figured hypotypes (USNM P5793, P5794, P5795, P5796a–d, P5797a–c, P5798a–c) and unfigured hypotypes (USNM P5799).

*Chiloguembelina sp.*

**PLATE 21, FIGURE 18**

Rather slender, elongate, more or less compressed specimens with a low, arched, asymmetrical aperture are fairly common in the lower and middle part of the Navet formation. They are rather badly preserved and several important characters, e. g., wall surface and exact shape of the aperture, are difficult to determine. Specimens similar to the figured type are particularly frequent, others resemble *Chiloguembelina garretti* (Howe) and *Chiloguembelina victoriana* n. sp.

**Length**: 0.15–0.24 mm.

**Occurrence**: Navet formation (Eocene), *Hantkenina aragonensis* zone to *Globorotalia lehneri* zone. Searc and not typical specimens occur in the *Porticucaphaera mexicana* zone.

**Types**: Figured specimen (USNM P5800).

Genus *Guembelitria* Cushman, 1933

*Guembelitria cOLUMBIANA* HOWE

**PLATE 21, FIGURE 16**

*Guembelitria columbia* HOWE, 1939, p. 62, pl. 8, figs. 12–13 (Eocene, Louisiana, U. S. A.).—CUSHMAN and TAPPAN, 1945a, p. 16, pl. 4, fig. 3 (Eocene, Alabama, U. S. A.).—

**HUSSET, 1949, p. 131 (Eocene, Louisiana, U. S. A.).**

**Typical representatives** of this species are common in the lower and middle part of the Navet formation.

**Length**: 0.12–0.18 mm.

**Occurrence**: Navet formation (Eocene), *Hantkenina aragonensis* zone to *Porticucaphaera mexicana* zone.

**Types**: Figured hypotype (USNM P5801) and unfigured hypotypes (USNM P5802).

Genus *Zeauvigerina* Finlay, 1939

*Zeauvigerina aegyptiaca* SAID and KENAWY

**PLATE 21, FIGURES 11, TEXT-Figure 15 (39–62)**

*Zeauvigerina aegyptiaca* SAID and KENAWY, 1956, p. 141, pl. 4, fig. 1 (Maastrichtian and Paleocene, Egypt).

The specimens from Trinidad agree in shape and size with the type description. The stratigraphic range of the species seems to be shorter than in Egypt. In Trinidad, this is restricted to the upper part of the Paleocene. This is about the same level as that of the type sample (No. 8, Nekhl section, see Said and Kenawy, 1956, p. 107, text-fig. 1).

There is considerable variation in length and breadth of the test. The size and shape of the last chamber is very irregular, and the terminal neck with the aperture can be short and wide or long and narrow. The wall of the last chamber is thinner and more fragile than that of the previous chambers.

There is some controversy about the relationship between *Zeauvigerina* Finlay, 1939, and *Eowigerina* Cushman, 1926 (Loeblich, 1951, p. 110; Said and Kenawy, 1956, p. 141). The arrangement of chambers is biserial in both genera. The main difference lies in the last chambers. In *Zeauvigerina* the long apertural neck is present in the terminal end chamber only. If this chamber is missing or broken off, the test looks like a *Chiloguembelina*. The aperture is then at the base of the last chamber, semicircular and often slightly eccentric in position (see pl. 21, fig. 9).
This was also noted by Finlay in his description of *Zeauvigerina teuria* (Finlay, 1947, p. 276). *In Eovigerina*, on the other hand, tubular projections are present in a number of earlier chambers as well and are usually connected by a thin, band-like structure. For this reason, the author is inclined to retain the name *Zeauvigerina* for the present. A definite solution of the problem will depend on a detailed examination of additional species of both genera, and on the possible discovery of intermediate forms.

**Length:** 0.25–0.38 mm.

**Occurrence:** Lower Lizard Springs formation (Paleocene), *Globorotalia pseudomenardii* zone and *Globorotalia velascoensis* zone (lower part).

**Types:** Figured hypotypes (USNM P5803, P5804, P5805a–d) and unfigured hypotypes (USNM P5806).

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Planktonic Foraminifera from the Oligocene-Miocene Cipero and Lengua Formations of Trinidad, B.W.I.

By Hans M. Bolli

Introduction

This paper discusses the planktonic Foraminifera of the Oligocene-Miocene Cipero and Lengua formations and their stratigraphic distribution. Planktonic Foraminifera have been chosen as a basis for the subdivision of the Cipero and Lengua formations because of their abundance and the short time ranges of many species. By their nature, they are independent of bottom conditions and therefore have a wider lateral distribution than many benthonic Foraminifera, making them very valuable for both local and interregional correlation.

Cushman and Stainforth (1945) were the first to realize the stratigraphic importance of the strongly dominant planktonic Foraminifera in the Cipero formation. They described 16 planktonic species and subdivided the formation into three zones with Globigerina concinna (now known as Globigerina ciperoensis) diagnostic for Zone I, Globigerinatella insueta for Zone II and Globochonatidella fohsi for Zone III.

The need for a closer zonation of the Cipero formation, in particular its upper part where the oil-bearing Herrera sands occur, later led to the subdivision of the Globochonatidella fohsi zone into four additional zones. This subdivision was based on evolutionary changes of Globochonatidella fohsi (Bolli, 1951). In addition, the Globigerina dissipilis zone (now Catapsydrax dissipilis zone) lying between Cushman and Stainforth’s Zones I and II and the Globigerina apertura zone (now Globigerina ampliapertura zone) were introduced (Cushman and Renz, 1947; Suter, 1951). The last mentioned zone represents the basal Cipero.

Detailed surface and subsurface exploration during recent years made it necessary to further subdivide the lower part of the Cipero formation. It is now possible to separate a Globochonatidella opima opima zone from the Globigerina ciperoensis ciperoensis zone, a Globochonatidella kugleri zone from the Catapsydrax dissimilis zone, and a Catapsydrax staiforthi zone from the Globigerinatella insueta zone. Thus, the Cipero formation can be clearly divided into 11 biozones, based on the distribution of planktonic Foraminifera.

The Lengua formation is divided into two zones, a lower Globochonatidella mayeri and an upper Globochonatidella menardii zone (Bronnimann, 1951a).

1 Trinidad Oil Company, Ltd. (formerly Trinidad Leaseholds, Ltd.), Pointe-a-Pierre, Trinidad, B.W.I.

The detailed zonation of the Cipero and Lengua formations finds its practical application in the geological surface and subsurface exploration for oil in the Oligocene and Miocene of south Trinidad. Foraminifera provide the safest means of subdividing and correlating the marl and calcareous clay sequences of these formations.

Several papers on individual genera and species of planktonic Foraminifera from the Cipero and Lengua formations have been published recently. Bronnimann (1950) gave a detailed account of the genus Globigerinatella from the Cipero formation. The same author (1951a, 1952) described the genera Globigerinata, and Globigerinatella from the Lengua formation. Bronnimann (1951b) and Blow (1956) discussed the genus Orbilina and its evolutionary trends in the Cipero and Lengua formations. The present author followed his earlier investigations on coiling ratios of some Cipero-Lengua Globochonatidellas (1950) with a study on a number of species of other planktonic genera (1951).

Herein are figured and described, or discussed, 60 planktonic species and subspecies, belonging to 15 genera; of these, 1 genus and 21 species or subspecies are new. The age of the Cipero and Lengua formations is discussed, and a correlation with other formations in Trinidad and the Caribbean and the Gulf Coast region is presented. A re-interpretation of the Cipero type section is also presented.

For details on the lithostratigraphy, earlier stratigraphic subdivisions, and environmental conditions of the Cipero formation, reference is made to Stainforth (1948b).

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Mr. R. A. Pallant, Senior Draftsman of The Trinidad Oil Company, supervised the preparation of the tables. The plate illustrations are camera lucida drawings by Patricia and Lawrence Isham, scientific illustrators, U. S. National Museum. The plates were arranged and mounted by Drs. Alfred and Helen Loeblich.

**Stratigraphy**

Unlike the Upper Cretaceous and lower Tertiary formations, the Cipero and Lengua formations are well exposed over wide areas of south Trinidad. The best exposed section of the Cipero formation, the type section along the Cipero coast south of San Fernando, has previously been described in detail by Stainforth (1948b). Although none of the known surface sections presents a complete and tectonically undisturbed sequence, it would nevertheless be possible to compile the present-day stratigraphic subdivision of the Cipero formation from these sources alone. However, the subdivision of the Cipero and Lengua formations, as herein presented, has been developed almost entirely from subsurface information. Over one hundred wells, mainly situated in the oilfields of the Barrackpore-Penal area, have penetrated the Lengua and upper part of the Cipero formation, and numerous exploration wells have penetrated the lower part of the Cipero formation. Many of these subsurface sections, often closely cored, are stratigraphically more complete and tectonically less disturbed than any of the known surface sections.

Text-figure 17 shows the calcium carbonate content and the percentages by weight of Foraminifera in samples taken at the type localities of the Cipero and Lengua zones. In addition, the number of planktonic species and subspecies occurring in each zone is shown. These figures show a marked increase in species from the Globorotalia kugleri zone to the Catapsydrax dissimilis zone. It is here that the Oligocene-Miocene boundary is tentatively placed. The stratigraphic ranges of all species and subspecies discussed are given in text-figure 18.

**The Cipero Formation**

The Cipero formation of south Trinidad consists predominantly of marls and highly calcareous clays which, in the upper and middle part, may be replaced by turbidity flow conglomerates and sands of the Herrera and Retrench members. Part of the uppermost Cipero formation (Globorotalia fohsi robusta zone) and the lower Lengua formation (Globorotalia mayeri zone) may be replaced by the widespread Karat formation in which planktonic Foraminifera are virtually absent. Along the southern edge of the Central Range, a part of the Cipero formation (Globorotalia kugleri to Catapsydrax stainforthi zones) is replaced toward the north by the Nariva formation in which planktonic Foraminifera are also absent. The part of the Cipero formation which is above the Catapsydrax stainforthi zone changes northward into the neritic facies of the Brasso formation.

Small reefal limestone developments with orbitoidal faunas are occasionally found in the Cipero formation (e., Morne Diablo limestone, Mejias limestone; vide Kugler, 1953). The coralliferous limestone of the Ste. Croix member seemingly belongs to the base of the Brasso formation.

The basal part of the Cipero formation (Globigerina ampliapertura zone) often appears as a dark silt. Lithologically it then becomes almost indistinguishable
from the similar facies of the Mount Moriah silt member of the upper Eocene San Fernando formation. Those beds which have a Mount Moriah silt aspect but do not contain any Eocene foraminiferal markers are here placed in the Oligocene part of the Cipero formation. The Globigerina ampliapertura zone commonly also occurs in a calcareous clay that weathers to a light creamy-brown color and as such is different from the Mount Moriah silt.

The thickness of a single Cipero zone may vary considerably, even within such a small area as the Barrackpore oilfield (Higgins, 1955). In a normal sequence of beds one expects a zone to measure several hundred feet, but thicknesses of over 1,000 feet have been recorded, especially for the Globorotalia fohsi robusta zone. The Globorotalia fohsi lobata zone, on the other hand, is usually rather reduced in thickness, seldom exceeding 200 feet. Often one or several zones are found to be completely absent, either due to non-deposition or to subsequent submarine erosion. Because of these irregularities it is difficult to give even an average thickness for any zone.

There is a very strong predominance of planktonic Foraminifera in the Cipero formation which according to Stainforth (1948b, p. 1321) fulfills the requirement for a fossil Globigerina ooze. Stainforth (1948b, p. 1320) counted several thousand Foraminifera in random samples of Cipero marl, which gave the following results:

Zone I (= Globigerina ciperoensis ciperoensis zone): several hundred planktonic to each benthonic specimen.

Zone II (= Globigerinatella insueta zone): 2197 planktonic to 37 benthonic specimens (59:1).

Zone III (= Globorotalia fohsi lobata zone): 2984 planktonic to 119 benthonic specimens (25:1).

The Cipero formation is here divided into the following zones (from top to bottom):

Globigerina ampliapertura Zone

**Type Locality:** Cipero type section, between 20 and 240 feet southeast from fixed point (see p. 103). Type sample JS 20 (TTOC 193265). Rx 90 (TTOC 21721), the type sample for Cushman and Stainforth's zone I (Globigerina concinna zone), comes from the same section.

**Lithology:** Bluish grey marl with dark grey blotches, gypsumiferous; brown and yellow limonitic patches.

**Remarks:** The zonal marker Globorotalia opima opima Bolli, new species, new subspecies, is restricted to the zone. Globigerina ciperoensis ciperoensis Bolli and Globigerina venezuelana Hedberg are usually abundant. Globigerina ampliapertura Bolli, new species and Globigerina parva Bolli, new species, present in the underlying zone, became extinct before the appearance of Globorotalia opima opima.

Globigerina ciperoensis ciperoensis Zone

**Type Locality:** Cipero type section, between 60 feet northeast and 20 feet southeast of fixed point (see p. 103). Type sample Bo 291A (TTOC 215656).

**Lithology:** Green-brown marl with reddish iron streaks.

**Remarks:** The Globigerina ciperoensis ciperoensis zone differs faunally from the Globorotalia opima opima zone only in the absence of Globorotalia opima opima Bolli, new species, new subspecies. The zonal marker disappears at the upper limit of this zone.

Globorotalia kugleri Zone

**Type Locality:** South bank of San Fernando Bypass Road, approximately 240 feet northeast from the north end of road bridge across the Siparia railway line. Coordinates N:225700 links; E:357940 links.

**Lithology:** Grey and yellow brown, mottled, calcareous clay, gypsumiferous and limonitic.

**Remarks:** The zonal marker Globorotalia kugleri
Bolli, new species, is restricted to the zone. The genus *Globigerinoides* makes its appearance in the upper part of the zone. *Globoherina juventilis* Bolli, new species, and *Globoherina bradyi* Wiesner are other species which are recorded for the first time in the *Globorotalia kugleri* zone.

**Catapsydrax dissimilis Zone**

**Type Locality:** South bank of San Fernando Bypass Road, approximately 1,050 feet northeast from north end of road bridge across the Siparia railway line. Coordinates N:226600 links; E:352200 links. Type sample Bo 267 (TTOC 201216).

**Lithology:** Cream to light grey marl, with yellow limonite patches, gypsiferous; black iron stains.

**Remarks:** The *Catapsydrax dissimilis* zone, as compared with the *Globorotalia kugleri* zone, shows a marked increase of planktonic *Foraminifera* from 16 to 25 species or subspecies. Various species of *Globoherina* are at a large degree responsible for the increase.

**Catapsydrax stainforthi Zone**

**Type Locality:** Cipero type section, between 2,150 and 3,200 feet southwest from fixed point (see p. 103) at the southern end of the exposed section. Coordinates N:227300 links; E:352900 links. Type sample K. 9397 (TTOC 193790).

**Lithology:** Cream to grey brown marl, occasionally blotchy.

**Remarks:** *Globigerinatella insueta* Cushman and Stainforth first appears in the *Catapsydrax stainforthi* zone, where it occurs with the zonal marker and *Catapsydrax dissimilis* (Cushman and Bermudez), *Globoradina dehiscens* (Chapman, Parr, and Collins) and *Globoradina altispira alitispira* (Cushman and Jarvis) also make their first appearance in this zone. Otherwise the planktonic fauna is very much the same as that of the underlying *Catapsydrax dissimilis* zone.

**Globigerinatella insueta Zone**

**Type Locality:** Cipero type section, small promontory generally known as “Cipero Nose,” approximately 820 feet southwest from fixed point (see p. 103). Coordinates N:229450 links; E:354250 links. Rz 108 (TTOC 21743), the type sample for Cushman and Stainforth’s Zone II (*Globigerinatella insueta* zone), comes from the same section. A co-locality, representing the Radiolaria rich facies of the zone, has been established near the Retrench trigonometrical station, Golconda Estate. Coordinates N:217290 links; E:371482 links.

**Lithology:** Massive, cream to yellow grey marl, fairly resistant to weathering, hence forming topographic highs.

**Remarks:** The *Globigerinatella insueta* zone is characterized by the zonal marker and by the absence of *Catapsydrax dissimilis* (Cushman and Bermudez). *Globoherina* *diminuta* Bolli, new species, is a characteristic form restricted to the zone or part of it. Blow (1956), in his study on the origin and evolution of the genus *Orbulina*, described the first occurrence of *Globoherina* *bisphera* Todd in the upper half of the *Globigerinatella insueta* zone. Within the short time interval of the uppermost part of the zone he then showed the development of *Orbulina* from this species (op. cit., p. 69, text-fig. 4). Based on these evolutionary trends, a further subdivision of the upper part of the *Globigerinatella insueta* zone could readily be established.

**Globorotalia fohsi barisanensis Zone**

**Type Locality:** Hermitage Quarry, on the west side of the road leading from Hermitage Village to Ally’s Creek about 1,200 feet northwest from the road junction in the village, south Trinidad. Coordinates N:208100 links; E:351800 links. Type sample Bo 202 (TTOC 193125).

**Lithology:** Cream to white marl with yellow limonitic patches.

**Remarks:** *Globigerinatella insueta* Cushman and Stainforth and *Catapsydrax stainforthi* Bolli, Loeblich, and Tappan have become extinct before the *Globorotalia fohsi barisanensis* zone. The transitional forms leading from *Globoherina* *bisphera* Todd to *Orbulina* disappear in the lower part of the zone. The characteristic *Hastigerinella bermedez* Bolli, new species, has thus far been recorded only from this zone.

**Globorotalia fohsi fohsi Zone**

**Type Locality:** On east bank of cricket ground southwest of Golconda Estate house which is about one-sixth mile south of Golconda Village, south Trinidad. Coordinates N:208100 links; E:357800 links. Type sample Bo 185A (TTOC 193121).

**Lithology:** Cream to light yellow marl, with grey patches; slightly limonitic and gypsiferous.

**Remarks:** *Globorotalia fohsi fohsi* Cushman and Ellisor, the zonal marker, developed from *Globorotalia fohsi barisanensis* Le Roy in the basal part of the zone. *Globorotalia scitula* (Brady) appears first in the upper part of the zone.

**Globorotalia fohsi lobata Zone**

**Type Locality:** Cipero type section, between 1,500 and 1,700 feet from fixed point (see p. 103). Type sample JS 32 (TTOC 193786). Rz 425 (TTOC 61418), the type sample for Cushman and Stainforth’s Zone III, (*Globorotalia fohsi* zone) comes from the same section.

**Lithology:** Light bluish grey marl with black streaks.

**Remarks:** *Globorotalia fohsi lobata* Bermudez, the zonal marker, develops from *Globorotalia fohsi fohsi* Cushman and Ellisor in the basal part of the zone.

**Globorotalia fohsi robusta Zone**

**Type Locality:** Cipero type section, between 850 and 1,400 feet southwest of fixed point (see p. 103) south
of the small promontory, the type locality of the Globigerinatella insuetà zone. Type sample Bo 354 (TTOC 207274).

Lithology: Light bluish grey marl with black streaks.

Remarks: Globorotalia fohsi robusta Bolli, the zonal marker, is restricted to the zone. It develops from Globorotalia fohsi lobata Bermudez, which becomes extinct in the basal part of the zone. Samples containing Globigerinoids rubra (d'Orbigny) but without Globorotalia fohsi robusta are occasionally encountered at the top of the zone. Typical Globorotalia menardii (d'Orbigny) appears late in the Globorotalia fohsi robusta zone and continues into the Lengua formation. Such typical species as Sphaeroidinella rutschi Cushman and Renz, Hastigerina cf. aequilateralis (Brady), Globigerina nepenthes Todd, and Globorotalia lenguensis Bolli, new species, commence in the lower Lengua; they have not been observed in the Cipero formation. The lithology grades from a highly calcareous marl in the Cipero formation to a calcareous clay in the Lengua formation.

The Lengua Formation

The Lengua formation of south Trinidad (Renz, 1942, p. 560) formerly known as “Green Clay” and “Sphaeroidinella Clay,” consists predominantly of a greenish, calcareous clay, weathering buff to yellow grey in color. The Lengua formation overlies the Cipero formation, often with an apparently normal contact. In certain areas the lower part of the Lengua formation can be replaced by the more clayey-silty Karamat formation which also may replace part of the uppermost Cipero. Upwards, the Lengua formation becomes gradually replaced by the clays, silts, and sands of the Cipero formation which are practically void of planktonic Foraminifera. Marl-boulder and clay-breccia beds of great thickness (Rio Claro boulder bed) are known from the Lengua formation.

The zonation of Trinidad sediments based on planktonic Foraminifera which, almost without interruption, can be applied from the Cretaceous onwards, comes to an end at the top of the Lengua formation. With few exceptions, the later conditions were no longer locally suitable for planktonic Foraminifera. Preliminary investigations in more favorable sections of the Agua Salada group in Falcón, Venezuela, show, that such characteristic species as Globigerina nepenthes Todd, Sphaeroidinella grimsdalei Keijzer, Globocuvadrina altispina altispina (Cushman and Jarvis), Globocuvadrina dehiscens (Chapman, Parr, and Collins) became extinct between upper Lengua time and the Recent. Numerous other planktonic species, e.g., Globigerina bulloides d'Orbigny, Globigerina epigera Rhumbler, Globorotalia truncatulinoides (d'Orbigny), and Globorotalia tumida (Brady), originate during this time interval.

As is the case with the Cipero formation, the thickness of the zones of the Lengua formation is subject to considerable variation. The whole formation may attain a thickness of over 2,000 feet but is usually less. For instance in the Barrackpore-Penal area the average thickness of the Globorotalia menardii zone is 600 feet and of the Globorotalia mayeri zone 150 feet.

The Lengua formation is here divided into the following zones (from bottom to top):

Globorotalia mayeri Zone

Type Locality: In a ditch on the east side of the Cunjal Road, about 150 feet from its junction with the Realize Road, about 2½ miles south southeast of Lengua Settlement, south Trinidad. Coordinates N:205000 links; E:419600 links. Type sample KR 23422 (TTOC 160021, 160634).

Lithology: Buff to yellow grey, calcareous clay, gyspiferous and limonitic.

Remarks: The zonal marker Globorotalia mayeri Cushman and Ellisor ranges from the Globorotalia opima opima zone through the Cipero formation into the lower Lengua; the top of the Globorotalia mayeri zone is marked by the extinction of this long-ranging form. The following species appear first in the Globorotalia mayeri zone and continue into the Globorotalia menardii zone: Globigerina nepenthes Todd, Globorotalia lenguensis Bolli, new species, Sphaeroidinella rutschi Cushman and Renz, Globigerinoida morugaensis Bronnimann and Hastigerina cf. aequilateralis (Brady).

Globorotalia menardii Zone

Type Locality: In a ditch on the east side of the road leading from Lengua Settlement to Cipero - Ste. Croix, about 150 feet from the road junction in Lengua Settlement, about 1 mile south of Princes Town, south Trinidad. Coordinates N:208900 links; E:413600 links. Type sample KR 23425 (TTOC 178590).

Lithology: Buff to yellow grey, calcareous clay, gyspiferous and limonitic.

Remarks: The only distinction between the Globorotalia menardii zone and the underlying Globorotalia mayeri zone is the absence of Globorotalia mayeri Cushman and Ellisor in the Globorotalia menardii zone.

Age of Cipero and Lengua Formations

Until recently the Cipero formation was generally regarded as entirely Oligocene in age (Cushman and Stainforth, 1945; Stainforth, 1948b, etc.). Globorotalia fohsi, originally described from the Miocene, was considered to be a typical representative of the upper Oligocene in the Caribbean region. A recent paper on the Miocene-Oligocene boundary by Eames (1953) initiated a controversy on the placement of that boundary in the Caribbean region. Comments on the problem were subsequently made by Stainforth (1954), Eames (1954, 1955), Kugler (1954), and Drooger (1954, 1956). Evidence brought forward by some of these contributors indicates that the Oligocene-Miocene boundary in the Caribbean region had been placed too high when compared with that of Europe and other areas. Considering the reasons
given by several of the authors, the present writer tentatively places the Oligocene-Miocene boundary between the Globorotalia kugleri and Catapsydrax dissimilis zones of the Cipero formation. This level approximately coincides with a marked increase in planktonic species and with the first occurrence of the genus Globigerinoides. This alone may not be sufficient reason for placement of the Oligocene-Miocene boundary, and further careful studies of the faunas of the classical localities and comparison with their equivalents in the Caribbean region will have to be made before a more conclusive correlation can be offered.

Type Section of Cipero Formation

The first detailed description of the Cipero formation was published by Stainforth (1948b). He used the same three zones as proposed earlier by Cushman and Stainforth (1945). In addition he distinguished a "Flat Rock tongue" of different lithological aspect separating Zones I and II. This "Flat Rock tongue" was formerly also known as "Bamboo silt."

In order to obtain an up-to-date interpretation of the Cipero type area, based on the present subdivision of the formation, a complete revision became necessary. In addition to the reidentification of existing augerhole samples from the area east and northeast of the type section, 110 new surface samples were collected from the type section along the coastline and several additional auger lines were run further inland. The reassessment of the coastal section is summarized below and the interpretation of the complete survey is shown on the map and section in text-figure 19.

In this connection it is imperative to note that marine erosion along the Cipero coast amounts to at least 2 feet per year. This ingress leads to a changing picture at least as far as the northern part of the section is concerned.

The fixed point from which all measurements were taken is the southeasternmost of a number of iron rails driven into the marls along the beach. This iron rail is 140 feet south southeast from the present south end of the sea wall. The coast line along which the type section is exposed runs approximately in a northeast-southwest direction, the fixed point being 60 feet southwest of the northernmost exposure. From the fixed point a chain was run along the coastline in a southwest direction to the "Cipero Nose" (a distance of 823 feet); from there 87 feet to the east and then again 2293 feet to the southwest. The composition of the type section is as follows:

From 60 ft. NE. to 2 ft. SW.: Marl; Globigerina ciperoensis ciperoensis zone.
From 28 to 325 ft. SW.: Marl; Globigerina opima opima zone.
From 250 to 368 ft. SW.: Clay, silty clay, marl lenses; Globigerina ampliapertura zone, upper part ("Flat Rock tongue").
At 406 ft. SW.: Pebble bed with whitish marl pebbles. Diagnostic Foraminifera of the bed are Globorotalia fohsi barisanensis Le Roy, Globorotalia fohsi fohsi Cushman and Ellisor, Globigerinoides triola (Reuss) group, ?Orbulina sp., Globigerinoides rubra (d'Orbigny). The youngest components are of Globorotalia fohsi fohsi zone age. This pebble bed appears to belong to the large slump-mass which occurs further to the south.

From 433 to 536 ft. SW.: Marl and dark brown silty clay, with rounded, iron-rich mudstone pebbles and thin pebble beds. Globigerina ampliapertura zone, occasionally with younger faunas ("Flat Rock tongue").

From 536 to 758 ft. SW.: Strongly heterogeneous interval; predominantly dark, silty clay with marl lenses and pebble beds. Samples taken here represent either mixed faunas of Globigerina ampliapertura zone to Globorotalia fohsi fohsi zone age or, if taken from larger slump-masses or pebbles, may be pure faunas from any zone within the above named interval. Between 613 and 679 feet is a lens of Upper Eocene Hospital Hill marl.

From 759 to 815 ft. SW.: Large slump-mass of indurated marl forming the prominent "Cipero Nose" promontory, Globigerinatella insueta zone.

From 848 to 913 ft. SW.: Pebble bed. Oldest component, Globorotalia opima opima zone; youngest, Globorotalia fohsi robusta zone. This pebble bed may be regarded as the base of a large slump-mass resting unconformably on the Globorotalia fohsi robusta zone.

From 937 to 1483 ft. SW.: Marl; Globorotalia fohsi robusta zone.

From 1583 to 1774 ft. SW.: Marl; Globorotalia fohsi lobata zone.

From 1780 to 1794 ft. SW.: Marl; Globorotalia fohsi fohsi zone, lower part.

From 1815 to 1835 ft. SW.: Pebble bed. Oldest component—Globigerinatella insueta zone, youngest—Globorotalia fohsi fohsi zone.

From 1845 to 2052 ft. SW.: Marl; Globigerinatella insueta zone.

From 2154 to 3203 ft. SW.: Marl; Catapsydrax stainforthi zone.

The type section can best be divided into the three major units described below:

1. The southern part of the section beginning in the south with the Catapsydrax stainforthi zone and ending with the Globorotalia fohsi robusta zone. This is a normal sequence except that the Globorotalia fohsi barisanensis zone is missing. A reduced Globorotalia fohsi fohsi zone rests with a basal pebble bed directly on the Globigerinae
tella insueta zone.

2. The large slump-mass beginning with a pebble bed lying on the Globorotalia fohsi robusta zone immediately south of the "Cipero Nose" promontory and extending to the northernmost pebble bed 406 feet south of the fixed point. Pebbles or larger slump-masses representing upper Eocene Hospital Hill marl and almost every zone of the Cipero formation are found in this complex unit. These pebble beds and slump-masses were apparently deposited late in Globorotalia fohsi robusta time (late Cipero), or at the beginning of Lengua time and thus may well be an equivalent of the Rio Claro boulder bed which occurs in the Globorotalia mayeri zone of the Lengua formation in the eastern part of the island.

No planktonic Foraminifera younger than Globorotalia fohsi fohsi zone age have been found thus far in the slump-mass and pebble bed complex north of the "Cipero Nose," which itself is a large slumped unit of the Globigerinatella insueta zone. It is thus possible.
that the northern part of the slump-mass may in fact be of the Globorotalia fohsi fohsi zone. If so, it might be related to the Globorotalia fohsi fohsi beds and underlying pebble bed which are found farther south in the type section.

Stainforth (1948b, p. 1302) mentions an intraformational marl breccia within the Cacatro member, consisting of angular pieces of greenish marl, mostly polished or slickensided, in a marl matrix. During the recent survey, 16 samples were collected from this pebble bed between 848 and 913 feet, just south of the “Cipero Nose” and resting on the Globorotalia fohsi robusta zone, consisting of single pebbles and matrix containing small pebbles. Almost every zone from the Globorotalia opima opima zone to the Globigerinatella insueta zone is represented by these pebbles. The matrix and pebble samples showed faunas ranging from the Globorotalia opima opima zone to the Globorotalia fohsi fohsi robusta zone.

This pebble bed is now regarded as the base of the large slump-mass extending from 848 feet to the northermmost pebble bed at 406 feet. This interval contains Stainforth’s Zone II (between his Zone III and the “Flat Rock tongue”).

During the recent survey, a pebble bed was also found to be present between Stainforth’s southern Zone II complex and his Zone III. This pebble bed marks a stratigraphic break between the Globigerinatella insueta zone and the Globorotalia fohsi fohsi zone.

3. The northernmost portion of the section, where the basal three zones (Globigerina ampliapertura zone to Globigerina ciproensis ciperoensis zone) of the Cipero formation appear in normal succession.

Stainforth (1948b, p. 1300) divided the Cipero formation at the type section into a lower (Zone I) Paradise member and an upper (Zones II, III) Cacatro member, the two being separated by the “Flat Rock tongue” which was regarded as being probably in normal stratigraphic position. Stainforth separated the two members solely on the existence of the “Flat Rock tongue” and not on lithological differences which he considered negligible. The study of the planktonic Foraminifera of the “Flat Rock tongue” has now revealed that the northern part of the tongue (northeast of the pebble bed at 406 feet) is equivalent to the Globigerina ampliapertura zone in age and apparently is in normal contact with the overlying Globorotalia opima opima zone. It has to be placed below Cushman and Stainforth’s Zone I, rather than between Zones I and II as suggested by Stainforth. Southwest of the pebble bed at 406 feet the “Flat Rock tongue” contains other small and irregular pebble beds. Globigerina ampliapertura Bolli, new species, and Globigerina parva Bolli, new species, occur here together with such younger forms as Globorotalia opima opima Bolli, new species, new subspecies, Globorotalia fohsi fohsi Cushman and Ellisor and ?Orbulina sp. Here the rich orbitoidal faunas mentioned by Stainforth are found. The pebble beds and the heterogeneous faunas indicate that this portion of the “Flat Rock tongue” is a part of the large slump-mass extending from 406 to 913 feet.

The age of the “Flat Rock tongue” has been discussed in several publications and unpublished reports. It was given as upper Eocene by several earlier authors. Renz (1942) and Stainforth (1948b) attributed a middle Oligocene age to it, based on the identification of larger Foraminifera by B. Caudri (private reports) and Vaughan and Cole (1941), and of the molluscan fauna by R. Rutsch (unpublished report). Stainforth (1948b) admits that the evidence for placing the “Flat Rock tongue” in the middle Oligocene is not entirely conclusive and suggests as an alternative the possibility that it could be an upfaulted block of the youngest part of the San Fernando formation. This view brings the stratigraphic position of the tongue much nearer to the present interpretation. Stainforth placed the bulk of Zone I in the lower Oligocene with the bottom part possibly topmost Eocene and the upper part middle Oligocene. Zone II was given a middle to upper Oligocene age and Zone III a probable upper Oligocene age.

Although the basal part of the Cipero formation is exposed in the type section, no contact with the underlying Eocene is visible. Such contacts may, however, be studied further to the north, in the Vista Bella area of San Fernando. Natural outcrops are scarce, but much information has been obtained from lines of augerholes and two shallow boreholes. About 500 feet of marls and marly clays or silty, muddy marls of the basal Cipero Globigerina ampliapertura zone are found to rest on approximately 300 feet of Mount Moriah silt of the upper Eocene San Fernando formation. Members of this formation may be developed in a conglomeratic, sandy, silty, glauconitic or reefal limestone (Vista Bella Quarry) facies. In the Vista Bella area the Globigerina ampliapertura zone is overlain normally by about 300 feet of marls of Globorotalia opima opima and Globigerina ciproensis ciperoensis zone age. Although not well exposed, this section appears to be one of the best in Trinidad for a study of the basal Cipero and its contact with the uppermost Eocene.

Stainforth (1948b, p. 1297) states that the Cipero formation rests basinward on the Hospital Hill marl, which is now regarded as the top member of the Navet formation. Although such contacts may occur, they are not regarded as normal. Based on the occurrence of planktonic Foraminifera, it is believed that the Hospital Hill marl and the San Fernando formation are not synchronous, but that the San Fernando formation is younger, representing the topmost Eocene and thus lying between the Hospital Hill marl and the basal Cipero.

The lower Oligocene basal part of the Cipero formation is faunistically distinguished from the topmost Eocene beds of the San Fernando formation by the absence of Hantkenina, Globorotalia centralis Cushman
and Bermudez, and Globorotalia cocoaensis Cushman. There are also numerous upper Eocene benthonic species, e.g., Bulimina jacksonensis Cushman, that do not cross the Eocene-Oligocene boundary. Cassigerinella chipolensis (Cushman and Ponton) and the Globigerina ciperoensis Bolli group on the other hand appear for the first time in the lower Oligocene Globigerina ampullapertura zone.

Apparently normal contacts between the Cipero and Lengua formations have been observed at various localities, such as in trenches in the Barrackpore area. The extinction of Globorotalia fohsi robusta, the change to a more clayey lithology, and the presence in certain areas of pebble beds and slump-masses of considerable thickness are indications not only of environmental changes but also of tectonic and possibly of turbidity flow activities at the end of Cipero time.

The structural complexities in the area of the type section and further to the north (see text-fig. 19) make extremely difficult a satisfactory interpretation of the existing tectonic conditions. The complex pattern as exposed along the Cipero type section is also characteristic for the whole Naparima area further to the east. With the introduction of the present zonation it has become more and more evident that many of the complications in the area are not of a tectonic nature but are probably caused by penecontemporaneous large scale slumping (Kugler, 1953).

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**Figure 19.**—Type section of the Cipero formation, Trinidad, B. W. I.
Stratigraphic Correlation of Cipero and Lengua with Other Formations

Trinidad

Stratigraphic correlations of the Cipero and Lengua formations with formations of the same age have been offered by several authors, most recently by Stainforth (1948b), Suter (1951) and Kugler (1953). In several of the age equivalents, e.g., the Brasso formation, we find the same characteristic planktonic foraminiferal markers, though often in smaller numbers. Others, such as the Nariva or Karamat formations may be completely void of planktonic Foraminifera. Interfingering or over- and underlying beds containing planktonic faunas have, however, identified their stratigraphic position in relation to the Cipero and Lengua zones. The arenaceous Cipero facies is a clay characterized by an arenaceous foraminiferal fauna. It is lithologically almost indistinguishable from the Nariva clay, which is characterised by Gravellina narivaensis Bronnimann and Aveovoamulinella pozonensis (Cushman and Renz). This Nariva fauna is commonly of Catapsydrax dissimilis zone age but it may also be slightly older (Globorotalia kugleri zone) or slightly younger (Catapsydrax stainforthi zone). The arenaceous Cipero facies may occur throughout the entire Cipero formation. Geographically, the Nariva formation is largely restricted to the Central Range area, where it underlies the Brasso formation.

Intercalations of sands of mostly lenticular nature occur in certain areas in the Globigerinatella insueta and Catapsydrax stainforthi zone of the Cipero formation. They are known as Retrench sands, a name that originates from the Retrench trigonometrical station, south of San Fernando, where the Globigerinatella insueta zone is developed in a radiolarian facies and is known as Retrench beds. Radiolarian-rich assemblages have also been found in the Globorotalia fohsi barisanensis zone, e.g., at the type locality (see p. 101).

The Herrera sands and conglomerates range in age from the Globorotalia fohsi fohsi zone to the lower part of the Globorotalia fohsi robusta zone. Occasional thin sands which may be attributed to the Herrera are also found in the Globorotalia fohsi barisanensis zone. The Karamat formation with Jarvisella karamatensis Bronnimann as marker fossil ranges from the upper part of the Globorotalia fohsi robusta zone (top Cipero) into the Globorotalia mayeri zone (lower Lengua).

It is of interest to note that formations such as the Karamat or Nariva, which may attain several thousand feet in thickness, were deposited within a comparatively short time interval.

The Brasso formation, in contrast to the Cipero formation contains more calcareous benthonic Foraminifera, though planktonic forms commonly occur in sufficient numbers to allow correlation with the faunal zones of the Cipero and Lengua formations. The Brasso formation consists predominantly of clays with their main development in the Central Range area. Renz (1948, p. 89) recognized the following members from top to bottom: Los Atajos, Navarro River, Tunnel Hill, and Esmeralda. These members are here tentatively considered to range in age from the Globigerinatella insueta zone to the Globorotalia mayeri zone (see text-fig. 20).

Recently the Los Atajos member has been placed in the lower part of the Manzanilla formation, which starts with the Brasso conglomerate. The Tamana formation consists of a coralliferous algal reef limestone interfingering with the Globorotalia mayeri and Globorotalia menardii zones of the Lengua formation.

The Ste. Croix formation, originally described as a series of foraminiferal silts and clays with minor beds of sand, is now regarded as a member of the Brasso formation. It is slightly older than the Esmeralda member and represents an extension to the south of the Central Range where it is commonly found inter-bedded in the Cipero formation. Cushman and Renz (1947) described the foraminiferal fauna of the Ste. Croix formation, recording 10 planktonic species, including Globigerinatella insueta Cushman and Stainforth from the Trinidad Point calcareous clay locality. On the basis of this species, this part of the Ste. Croix formation was correlated with Cushman and Stainforth's Globigerinatella insueta zone (Zone II), whereas the Ste. Croix calcareous clay from the type locality was considered to be slightly younger. In addition to Globigerinatella insueta, Bronnimann (1950, p. 81) also reported Catapsydrax dissimilis from the Ste. Croix calcareous clay locality; hence these beds are in the Catapsydrax stainforthi zone.

Caribbean and Gulf Coast Region

Correlations of the Cipero and Lengua formations with formations of the Caribbean region outside Trinidad are here restricted to sections either studied by the author himself or discussed with other workers.

One of the most complete and best described sections is doubtless that of the Agua Salada group in the State of Falcón, Venezuela (Renz, 1948). The general aspect of the rich foraminiferal fauna is more like that of the Brasso formation of Trinidad, which is rich in benthonic Foraminifera. However, no difficulties have been found in correlating Renz's Agua Salada zones with those of the Cipero and Lengua formations (see text-fig. 20).

Beckmann (1953) described the Foraminifera from the Eocene-Oligocene Oceanic formation of Barbados. Discussions with this author indicate that the Oligocene part of the Oceanic formation, which is rich in planktonic Foraminifera, can readily be correlated with the zones of the lower part of the Cipero formation (see text-fig. 20). The Bissex Hill formation is an age equivalent of the Globigerinatella insueta zone and the overlying Globigerina maris of the lower Globorotalia fohsi zone, sensu lato.

Several samples from the Antigua limestone of Antigua were found to contain Globigerina ciperoensis Bolli, sensu lato. These beds may therefore be cor-
related with the *Globigerina ciperoensis ciperoensis* or the *Globorotalia opima opima* zones of the Cipero formation.

An attempt has also been made to correlate Gulf Coast sediments of Oligocene-Miocene age with the Cipero formation (see text-fig. 20). This is based on discussions with W. H. Akers and on his (1955) report on the subject. Samples from the Vicksburg stage which correlate with the *Globigerina ampliapertura* zone have also been examined by the present author.

It is well known that the Oligocene-Miocene planktonic Foraminifera which are here described from Trinidad are not restricted to the Caribbean and Gulf Coast region. For example, identical forms have been described from Colombia (Petters and Sarmiento, 1956) and from Peru (Stainforth, 1948a). An attempt has recently been made by Drooger (1956) to arrive at a transatlantic correlation of the Oligo-Miocene by means of Foraminifera. He places special emphasis on the planktonic Foraminifera and some encouraging preliminary results have already been obtained.

Such studies as Le Roy’s (1948, 1952) indicate that similar or identical planktonic foraminiferal assemblages also occur in Oligocene-Miocene sediments of the Far East. Thus, it may safely be concluded, as with the Cretaceous and lower Tertiary forms, that the Oligocene-Miocene planktonic Foraminifera have a worldwide distribution, limited only by locally adverse environmental conditions. They offer, where present, an excellent means for age determination, zonation and long range correlation.

**Systematic Descriptions**

Sixty planktonic foraminiferal species and subspecies belonging to fifteen genera are described or listed. A full description is given only for the new species and subspecies. Synonymy lists are restricted to the original description and to species or subspecies described from the Caribbean and Gulf Coast region.

The stratigraphic range within the Cipero and Lengua formations is given for each species or subspecies. Several species occur also in the upper Eocene, and this is mentioned in the specific descriptions.

With the change of the ecologic conditions at the end of the Lengua time all planktonic Foraminifera disappeared locally. Some of them may have become extinct at this time, but it is known that many species continued to live in other more favourable regions, and several of these species are known from Recent seas.
Family Hantkeninidae Cushman, 1927

Subfamily Hastigerininae Bolli, Loeblich, and Tappan, 1957

Genus Hastigerina Thompson, 1876
Hastigerina cf. aequilaterals (Brady)

**PLATE 22, FIGURES 1a–2b**


**STRATIGRAPHIC RANGE (in Lenga formation):** _Globorotalia mayeri_ zone to _Globorotalia menardii_ zone.

**LOCALITY:** Figured specimens (USNM P5601a,b) from the _Globorotalia menardii_ zone, from a subsurface section.

**REMARKS:** Scarce specimens of _Hastigerina_ are found in the Lenga formation. They are slightly more involute than Brady's types and are therefore listed as _H. cf. aequilateralis_.

Subfamily Cassigerinellinae Bolli, Loeblich, and Tappan, 1957

Genus Cassigerinella Pokorný, 1955
_Cassigerinella chipolensis_ (Cushman and Ponton)

**PLATE 22, FIGURES 3a–c**


**STRATIGRAPHIC RANGE (in Cipero formation):** _Globigerina ampliapertura_ zone to _Globorotalia fohsi robusta_ zone.

**LOCALITY:** Figured hypotype (USNM P5602) from the type section of the _Globorotalia opima opima_ zone, sample JS 20 (TTOC 193263).

**REMARKS:** _Cassigerinella chipolensis_ is restricted to the Cipero formation. The very small species is easily recognizable.

Family Orbulinidae Schultze, 1854

Subfamily Globigerininae Carpenter, 1862

Genus Globigerina d’Orbigny, 1826
Globigerina ampliapertura Bolli, new species

**PLATE 22, FIGURES 4a–7b**

Shape of test trochospiral; spiral side almost flat to slightly convex, umbilical side convex; equatorial periphery lobate; axial periphery rounded. Wall calcareous, perforate, surface finely pitted. Chambers spherical in the early stage, becoming somewhat compressed laterally in the last whorl; about 12, arranged in 2½ whorls; the usually 4 chambers of the last whorl increase rapidly in size. Sutures on spiral side radial to oblique, depressed; on umbilical side radial, depressed. Umbilicus fairly small, deep. Aperture a high, distinct arch; interiomarginal, umbilical. Coiling random. Largest diameter of holotype 0.55 mm.

**STRATIGRAPHIC RANGE (in Cipero formation):** _Globigerina ampliapertura_ zone.

**LOCALITY:** Holotype (USNM P5603) and figured paratype (USNM P5604), sample Bo 314A (TTOC 215658) and figured paratypes (USNM P5605a,b), sample JS 19 (TTOC 193264), all from the _Globigerina ampliapertura_ zone, Cipero type section, Trinidad.

**REMARKS:** _Globigerina ampliapertura_, new species, is distinguished from _G. venezuelana_ in having a larger, distinctly arched aperture. It differs from _G. apertura_ Cushman, which was described from the Miocene, in having the chambers of the last whorl somewhat compressed laterally and in the aperture being smaller in relation to the chamber size. The _G. apertura_ mentioned by Bronnimann (1950, p. 80) from the Cipero formation is a _G. ampliapertura_. The new species occurs also in the upper Eocene.

_Globigerina parva_ Bolli, new species

**PLATE 22, FIGURES 14a–c**

Shape of test small, medium to high trochospiral; equatorial periphery distinctly lobate. Wall calcareous, perforate, surface smooth to very finely pitted. Chambers spherical; 10–12, arranged in about 2½ whorls; the 4 or occasionally 5 chambers of the last whorl increase moderately in size. Sutures on spiral side radial, depressed; on umbilical side radial, depressed. Umbilicus small. Aperture a medium to low arch; interiomarginal, umbilical. Coiling random. Largest diameter of holotype 0.25 mm.

**STRATIGRAPHIC RANGE (in Cipero formation):** _Globigerina ampliapertura_ zone.

**LOCALITY:** Holotype (USNM P5606) from the _Globigerina ampliapertura_ zone, Cipero type section, Trinidad, sample Bo 314A (TTOC 215658).

**REMARKS:** _Globigerina parva_, new species, is separated from the _G. ciperoensis_ subspecies in being more trochospiral and in having usually 4 instead of 5 chambers in the last whorl. The new species occurs also in the upper Eocene.

_Globigerina ciperoensis_ Bolli

A considerable variation is observed within the species _Globigerina ciperoensis_ Bolli. The forms included originally in this species (Bolli, 1954) have a characteristically large umbilicus; they are now given subspecies rank (_G. ciperoensis ciperoensis_). All gradations occur to forms with a small umbilicus associated with the typical representatives, but those with smaller umbilicus become predominant towards the end of the _Globigerina ciperoensis ciperoensis_ zone, where the typical _G. ciperoensis ciperoensis_ disappear. They continue into the _Globorotalia kugleri_ zone and lower part of the _Catapsy-
Globigerina ciperoensis angustiumbilicata.

Another subspecies, Globigerina ciperoensis angulusurturalis has been erected for specimens that show deep, angular, U-shaped sutures between the chambers of the last whorl. Transitional forms to G. ciperoensis ciperoensis are common. The new subspecies appears to be restricted to the Globorotalia opima opima zone and the Globigerina ciperoensis ciperoensis zone.

Globigerina ciperoensis ciperoensis Bolli

Plate 22, Figures 10a–b


Globigerina concina Reuss, Nuttall, Journ. Paleontol., vol. 6, No. 1, p. 29, pl. 6, figs. 9–11, 1932.—Franklin, Journ. Paleontol., vol. 18, No. 4, p. 317, pl. 48, fig. 5, 1944.


Stratigraphic range (in Cipero formation): Globigerina ampliapertura zone to Globigerina ciperoensis ciperoensis zone.

Locality: Figured hypotype (USNM P5607) from the Globorotalia opima opima zone, sample Bo 273 (TTOC 201222).

Remarks: The subspecies Globigerina ciperoensis ciperoensis includes the forms as described originally with a large umbilicus and without the angular, U-shaped sutures of the subspecies angulusurturalis.

Globigerina ciperoensis angulusurturalis Bolli, new subspecies

Plate 22, Figures 11a–c

Shape of test very low trochospiral; equatorial periphery almost circular, lobate, with deep, angular, U-shaped sutures between the chambers; axial periphery rounded. Wall calcareous, perforate, surface very finely pitted. Chambers spherical; about 10, arranged in 2 to 2½ whorls; the 5 chambers of the last whorl increase moderately in size. Sutures on spiral side depressed, radial; on umbilical side depressed, radial. Umbilicus fairly wide. Aperture arched; interiomarginal, umbilical. Coiling random. Largest diameter of holotype 0.19 mm.

Stratigraphic range (in Cipero formation): Globorotalia opima opima zone to Globigerina ciperoensis ciperoensis zone.

Locality: Holotype (USNM P5608) from the type section of the Globorotalia opima opima zone, Trinidad, sample Bo 306A (TTOC 215657).

Remarks: Globigerina ciperoensis angulusurturalis, new subspecies, is distinguished from G. ciperoensis ciperoensis by having deep cut, angular, U-shaped sutures.

Globigerina ciperoensis angustiumbilicata Bolli, new subspecies

Plate 22, Figures 12a–13c

Shape of test very low trochospiral; equatorial periphery distinctly lobate, axial periphery rounded. Wall calcareous, perforate, surface smooth or very finely pitted. Chambers spherical; about 12, arranged in about 2½ whorls; the 4–5 chambers of the last whorl increase moderately to fairly rapidly in size. Sutures on spiral side depressed, radial; on umbilical side depressed, radial. Umbilicus small. Aperture a medium to low arch; interiomarginal, umbilical, often with a thin lip. Coiling random. Largest diameter of holotype 0.24 mm.

Stratigraphic range (in Cipero formation): Globigerina ampliapertura zone to Catapsydrax dissimilis zone.

Locality: Holotype (USNM P5609) and figured paratype (USNM P5610) from the type section of the Globorotalia ciperoensis ciperoensis zone, Trinidad, sample Bo 291A (TTOC 215656).

Remarks: Globigerina ciperoensis angustiumbilicata, new subspecies, is distinguished from G. ciperoensis ciperoensis by having a small umbilicus. The aperture, which is umbilical in position, may in some specimens show a tendency towards an umbilical—extraumbilical position.

Globigerina Rohri Bolli, new species

Plate 23, Figures 1a–4b


Shape of test trochospiral; equatorial periphery slightly lobate; because of the lateral compression of the chambers, the test has a somewhat spherical appearance. Wall calcareous, perforate, surface finely pitted. Chambers spherical, those of last whorl laterally compressed; about 12, arranged in about 2½ whorls; the 3 or occasionally 4 chambers of the last whorl increase very rapidly in size; in large specimens the final chamber is commonly reduced in size. Sutures on spiral side curved in early stage, radial or oblique later, depressed; on umbilical side radial, depressed. Umbilicus small, deep; rugosities or short thick spines are found around the umbilical edge. Aperture arched; interiomarginal, umbilical; because of the almost closed umbilicus not well visible. Coiling random. Largest diameter of holotype 0.73 mm.

Stratigraphic range (in Cipero formation): Globigerina ampliapertura zone to Catapsydrax dissimilis zone.

Locality: Holotype (USNM P5611) and figured paratypes (USNM P5612a–c) from the type section of the Globorotalia opima opima zone, Trinidad, sample JS 20 (TTOC 193265).

Remarks: Globigerina rohri, new species, is distinguished from G. venezuelana Hedberg by having usually 3 instead of 4 chambers in the last whorl, by the rugosities or short spines around the umbilical edge and by having the chambers of the last whorl laterally more compressed.

The species is named for Dr. K. Rohr in recognition of his geological work in Trinidad.
Plate 23, Figures 6a–8b

_Globigerina venezuelana_ Heidberg

**Locality:** Figured hypotypes (USNM P5613) from the _Globorotalia fohsi robusta_ zone, sample JS 46 (TTOC 194056); (USNM P5614) from the type section of the _Globorotalia fohsi lobata_ zone, sample JS 32 (TTOC 193786); and (USNM P5615) from the type locality of the _Globorotalia menardii_ zone, sample KR 23425 (TTOC 178890).

**Remarks:** Considerable variation in size and shape of chambers is found in _Globigerina venezuelana_. The differences, however, appear not to be constant enough to allow a further division of the species. It is found for instance that the chambers of _G. venezuelana_ are generally more spherical in the _Globorotalia opima opima_ zone to the _Globorotalia kugleri_ zone and again in the _Globorotalia fohsi lobata_ zone to the _Globorotalia menardii_ zone. In the _Catapdyrax dissimilis_ zone to the _Globorotalia fohsi fohsi_ zone the specimens are often somewhat compressed laterally. The same is also true for the _Globigerina ampliapertura_ zone, where many specimens have only 3 chambers in the last whorl instead of the usual 4.

A small, rudimentary final chamber (see pl. 23, figs. 7b, 8b) commonly occurs in _Globigerina venezuelana_. It is attached in the conventional way and does not cover the umbilicus and therefore can not be regarded as a bula.

_Globigerina cf. trilocularis_ d’Orbigny

Plate 22, Figures 8a–9c


**Locality:** Figured specimens (USNM P5616a,b) from the _Catapdyrax dissimilis_ zone, core at 4,548–48 feet of Trinidad Northern Area well Charuma No. 1 (TTOC 198467).

**Remarks:** The Trinidad specimens resembling the figures of _Globigerina trilocularis_ given by Fornasini are for the present placed in this species. They are restricted in Trinidad to the lower (Oligocene) part of the Cipero formation, whereas d’Orbigny’s type might be from a different level. From observations made on material from the _Globorotalia kugleri_ zone, it appears probable that the _Globigerina cf. trilocularis_ can be regarded as the ancestor of _Globigerinoides tribo_ (Reuss). Specimens of _Globigerina trilocularis_ and _Globigerinoides tribo_ immatura Le Roy were found to be indistinguishable in this zone, except that the latter showed a supplementary suture aperture in the last chamber.

_Globigerina juvenilis_ Bolli, new species

Plate 24, Figures 5a–6

Shape of test moderately to distinctly trochospiral; equatorial periphery distinctly lobate. Wall calcareous, perforate, surface smooth to very finely pitted. Chambers spherical to ovate; about 12, arranged in about 3 whorls; the 3–4 chambers of the last whorl increase rapidly in size. Sutures on spiral side curved to radial in the early stage, radial in the last whorl, depressed; on umbilical side radial, depressed. Umbilicus very small. Aperture a low elongate slit, often with a thin lip; interomarginal, umbilical. Coiling random. Largest diameter of holotype 0.29 mm.

**Locality:** Holotype (USNM P5617) from the type section of the _Globorotalia fohsi robusta_ zone, Trinidad, sample JS 16 (TTOC 193261); figured paratype (USNM P5618) from the type section of the _Globorotalia fohsi lobata_ zone, sample JS 32 (TTOC 193786).

**Remarks:** _Globigerina juvenilis_, new species, appears to be related to _G. bradyi_ Wiseiner, but is less distinctly trochospiral. Transitional forms between the two species may be observed. It is also possible that _Globigerina juvenilis_ represents the juvenile stage of _Globigerinopsis naparimaensis_ Bronnimann, where the bulla is not yet developed (for comparison see Bolli, Loeblich and Tappan, 1957, pl. 8, figs. 1a–c).

_Globigerina bradyi_ Wiesener

Plate 23, Figures 5a–c


**Locality:** Figured hypotype (USNM P5619) from the type locality of the _Globorotalia menardii_ zone, sample KR 23425 (TTOC 178890).

**Remarks:** The Trinidad specimens here described as _Globigerina bradyi_ seemingly agree well in size and general shape with Brady’s figures of _Globigerina sp._, which later were named by Wiesener as _G. bradyi_. Occasionally, specimens are seen that have one or several secondary suture apertures on the last chamber. They should probably be placed in _Globigerinoides minuta_ Natland. The two species seem to be synony-
mous, with the exception that G. minuta has sutureal apertures on the final chamber, which might be a gerontic stage. More detailed work will be required to establish possible relationships between Globigerina bradyi and Globigerinoides minuta on the one hand and Globigerina juvenilis and G. bradyi on the other. In this connection, possible relationships between G. juvenilis and Globigerinita naparainsis Bronnimann and between Globigerinoides minuta and Globigerinita morugaensis Bronnimann should also be studied.

Globigerina foliata Bolli, new species

PLATE 24, FIGURES 1a-c

Shape of test low trochospiral; equatorial periphery strongly lobate. Wall calcareous, perforate, surface very finely pitted. Chambers spherical; 8 to 10, arranged in about 2 whorls; the 4 chambers of the last whorl increase very rapidly in size. Sutures on spiral side radial, deeply depressed; on umbilical side radial, deeply depressed. Umbilicus fairly small. Aperture a medium to low arch, often with a thin lip; interiomarginal, umbilical. Coiling random. Largest diameter of holotype 0.56 mm.

Stratigraphic range (in Cipero and Lenga formations): Catapsydrax dissimilis zone to Globorotalia menardii zone.

Locality: Holotype (USNM P5620) from the type section of the Globorotalia fohsi robusta zone, Trinidad, sample JS 16 (TTOC 193261).

Remarks: Globigerina foliata, new species, is characterized by having almost discrete spherical chambers. The sutures between the four chambers of the last whorl are deeply incised.

Globigerina nephtes Todd

PLATE 24, FIGURES 2a-c


Stratigraphic range (in Lenga formation): Globorotalia mayeri zone to Globorotalia menardii zone.

Locality: Figured hypotype (USNM P5621) from the type locality of the Globorotalia mayeri zone, sample JS 16 (TTOC 193261).

Remarks: Globigerina nephtes is restricted in Trinidad to the upper part of the Globorotalia mayeri zone and to the Globorotalia menardii zone. Although it is found in the transitional beds of the Lenga and Cruse formations and would under more favourable conditions probably have a longer range, it is here an excellent index fossil for the Lenga formation.

Genus Globobuquadrina Finlay, 1947

Globobuquadrina altispira (Cushman and Jarvis)
**Remarks:** *Globorotalia altispira* globosa, new subspecies, is distinguished from *G. altispira altispira* (Cushman and Jarvis) by having more globular chambers.

**Genus Hastigerinella Cushman, 1927**

Hastigerinella bermudezi Bolli, new species

**Plate 25, Figures 1a–e**


Shape of test very low trochospiral; equatorial periphery very strongly lobate. Wall calcareous, perforate, surface finely pitted. Chambers: early ones spherical to ovate, the ultimate ones becoming club-shaped; 12–15, arranged in about 2½ whorls; the 4–5 chambers of the last whorl increase rapidly in size. Sutures on spiral side slightly curved to radial, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, shallow. Aperture a low arch or slit; interiomarginal, umbilical-extraumbilical; a faint lip is visible in well preserved specimens. Coiling trends slightly to dextral in specimens counted from the type locality. Largest diameter of holotype 0.7 mm.

**Stratigraphic Range (in Cipero formation):** Globorotalia foksi barisanensis zone.

**Locality:** Holotype (USNM P5628) from the type locality of the Globorotalia foksi barisanensis zone, Trinidad, sample Bo 202 (TTOC 193125).

**Remarks:** *Hastigerinella bermudezi*, new species, differs from *H. digitata* Rhumbler (= *H. rhumbleri* Galloway) in its lower trochospiral form and less elongate chambers. The *Hastigerinella* species of similar aspect described from the Eocene (*H. eocana* Nuttall, *H. colombiana* Petters) are not fully preserved specimens and the position of the aperture of the ultimate chamber is not clearly visible. It appears likely that these Eocene forms belong to *Clavigerinella* which possesses an interiomarginal, symmetrical aperture. No typical species of *Hastigerinella* are known from the Cretaceous; those described from the Cretaceous belong largely to *Hastigerinoides* or *Praeglobotruncana* (see Bolli, Loeblich, and Tappan, 1957). It seems probable that true *Hastigerinella* does not appear before the Miocene.

The name is given for Dr. Pedro J. Bermudez in recognition of his contributions to the micropaleontology of the Caribbean region.

**Genus Globigerinoides Cushman, 1927**

Globigerinoides triloba (Reuss)

Globigerinoides sacculifera (Brady) and *G. sacculifera immatura* Le Roy are closely related to *G. triloba* (Reuss). Forms transitional between those species are often difficult to place with certainty. The members of the group appear almost simultaneously in the Cipero formation towards the top of the Globorotalia kugleri zone. For these reasons *Globigerinoides sacculifera* and *G. sacculifera immatura* are here treated as subspecies of *G. triloba* which has priority as a specific name. A fourth subspecies, *G. triloba altaipertura*, is here described as new. Spiral and umbilical views of the subspecies of *G. triloba*, *G. rubra* (d'Orbigny) and *G. obliqua*, new species, are shown in text-figure 21. *G. triloba* differs from *G. triloba immatura* in having a final chamber that is larger than all the earlier chambers combined. *G. triloba sacculifera* differs from *G. triloba immatura* in having a terminal, elongate, sacklike chamber. *G. triloba altaipertura* differs from *G. triloba immatura* in having a high arched, primary aperture.

Globigerinoides rubra (d'Orbigny) differs from the *G. triloba* group and *G. obliqua*, new species, in the position of the primary interiomarginal, umbilical aperture and supplementary sutural apertures. In *G. rubra* each aperture is a fairly high arch symmetrically placed above the suture between two earlier chambers (see text-fig. 21, Nos. 6a,b); in the subspecies of *G. triloba* and *G. obliqua* each aperture is placed above the two sutures between three earlier chambers (see text-fig. 21, Nos. 4a,b, 5a,b) or distinctly asymmetrical above the suture between two earlier chambers (see text-fig. 21, No. 1a).

![Figure 21](image-url)

**Plate 25, Figures 2a–c; Text-figure 21, No. 1**


**Stratigraphic Range (in Cipero and Lengua forma-**
Globigerinoides triloba immatura Le Roy

**Plate 25, Figures 3a–4c; Text-figure 21, No. 2**


**Stratigraphic range** (in Cipero and Lenga formations): *Globorotalia kugleri* zone to *Globorotalia menardii* zone.

**Locality:** Figured hypotypes (USNM P5630a, b) from the type section of the *Globorotalia fohsi robusta* zone, sample JS 46 (TTOC 194056).

Globigerinoides triloba sacculifer (Brady)

**Plate 25, Figures 5a–6; Text-figure 21, No. 4**


**Stratigraphic range** (in Cipero and Lenga formations): *Globorotalia kugleri* zone to *Globorotalia menardii* zone.

**Locality:** Figured hypotypes (USNM P5631a, b) from the type section of the *Globorotalia fohsi lobata* zone, sample JS 32 (TTOC 193786).

Globigerinoides triloba altiapertura Bolli, new subspecies

**Plate 25, Figures 7a–8; Text-figure 21, No. 3**

Shape of test trochospiral; equatorial periphery distinctly lobate (trilobate); axial periphery rounded. Wall calcareous, perforate, surface finely pitted. Chambers spherical; about 12, arranged in about 2½ whorls; the 3 chambers of the last whorl increase rapidly in size. Sutures on spiral side between early chambers radial, later slightly curved and oblique, depressed; on umbilical side: radial, depressed. Umbilicus fairly narrow, deep. Primary aperture, a high, distinct arch, interomarginal, umbilical; the last few chambers show one supplementary sutural aperture about opposite the primary aperture. Coiling random. Largest diameter of holotype 0.55 mm.

**Stratigraphic range** (in Cipero formation): *Catapsydrax dissimilis* zone to *Catapsydrax staithsii* zone.

**Locality:** Holotype (USNM P5632) and figured paratype (USNM P5633) from the type locality of the *Catapsydrax dissimilis* zone, Trinidad, sample Bo 267 (TTOC 201216).

**Remarks:** *Globigerinoides triloba* altiapertura, new subspecies, is distinguished from *G. triloba immatura* Le Roy by having a larger, higher arched, primary aperture.

Globigerinoides obliqua Bolli, new species

**Plate 25, Figures 9a–10c; Text-figure 21, No. 5**

Shape of test trochospiral; equatorial periphery distinctly lobate; axial periphery rounded. Wall calcareous, perforate, surface finely pitted. Chambers spherical, except the ultimate ones, which are compressed in a lateral oblique manner; 12–15, arranged in about 3 whorls; the 3, in large specimens 4, chambers of the last whorl increase rapidly in size; in large specimens the last chamber may be reduced again in size. Sutures on spiral side radial to oblique, depressed; on umbilical side radial, depressed. Umbilicus small. Primary aperture a distinct, often fairly high arch, interomarginal, umbilical; one or occasionally two supplementary sutural apertures are visible in the last few chambers. Largest diameter of holotype 0.5 mm.

**Stratigraphic range** (in Cipero and Lenga formations): *Globorotalia kugleri* zone to *Globorotalia menardii* zone.

**Locality:** Holotype (USNM P5634) and figured paratype (USNM P5635) from the type locality of the *Globorotalia mayeri* zone, Trinidad, sample KR 23422 (TTOC 160634).

**Remarks:** *Globigerinoides obliqua*, new species, is distinguished from the *Globigerinoides triloba* group by having the ultimate or the last few chambers compressed in a lateral, oblique manner. In *Globigerinoides triloba* they remain spherical and in the subspecies *sacculifera* become elongate, sack-like shaped.

Globigerinoides rubra (d'Orbigny)

**Plate 25, Figures 12a–13b; Text-figure 21, No. 6**


**Stratigraphic range** (in Cipero formation): *Catapsydrax dissimilis* zone to *Globorotalia fohsi robusta* zone.

**Locality:** Figured hypotypes (USNM P5636) from the *Globorotalia fohsi robusta* zone, sample KR 20464G (TTOC 96722), and (USNM P5637) from the *Globigerinitella insueta* zone, core 7,419–39 feet of United British Oilfields of Trinidad, Ltd. (now Shell Trinidad, Ltd.), well Penal No. 92.

**Remarks:** *Globigerinoides rubra* is a characteristic species ranging in the Cipero formation from the *Catapsydrax dissimilis* zone to the *Globorotalia fohsi robusta* zone. It is easily recognizable by the position of the primary and supplementary sutural apertures, which are always symmetrically placed above the suture between two earlier chambers (see text-fig. 21,
Nos. 6 a, b). Typical Globigerinoides rubra specimens of Cipero age appear indistinguishable from Recent forms. However, in Trinidad the species disappears at the close of the Cipero time, shortly after the extinction of Globorotalia fohsi robusta, and is not found in the Lenga formation. Globigerinoides rubra apparently made its return to Trinidad again in late Miocene time. Together with Globigerina bulloides d’Orbigny it is found in the Upper Miocene Melajo formation. An explanation for the absence of Globigerinoides rubra in the Lenga formation might be found in assuming that the environmental conditions of the Lenga sea were not favorable for the life habits of the species.

Globigerinoides diminuta Bolli, new species

Plate 25, Figures 11 a–c

Shape of test trochospiral; equatorial periphery almost subquadrate; axial periphery rounded. Wall calcareous, perforate, surface finely pitted. Chambers spherical in early stages, later becoming laterally somewhat compressed; about 10, arranged in about 2½ whorls; the 3 chambers of the last whorl increase moderately in size. Sutures on spiral side radial, slightly depressed; on umbilical side radial, slightly depressed. Umbo small. Primary aperture small, almost circular, symmetrically above the suture line of the two previous chambers; interiomarginal, umbilical; supplementary sutural apertures, usually 2 of which are visible, are of similar shape and occupy the same symmetrical position over the sutures of earlier chambers. Coiling random. Largest diameter of holotype 0.27 mm.

Stratigraphic range (in Cipero formation): Globigerinatella insueta zone.

Locality: Holotype (USNM P5638) from the Globigerinatella insueta zone, Trinidad, core 7419–39 feet of United British Oilfields of Trinidad, Ltd. (now Shell Trinidad, Ltd.), well Penal No. 92.

Remarks: Globigerinoides diminuta, new species, is separated from Globigerinoides rubra (d’Orbigny) by its constantly very small size and more compact shape. The position of the apertures symmetrically above the suture between two earlier chambers is a characteristic feature in both species. In contrast to Globigerinoides rubra, the new species is confined to the Globigerinatella insueta zone (probably to the lower part).

Globigerinoides mitra Todd

Plate 26, Figures 1a–d


Stratigraphic range (in Cipero and Lenga formations): Catapsydrax dissimilis zone to Globorotalia menardii zone.

Locality: Figured hypotypes (USNM P5639a–c) from the Globorotalia menardii zone and (USNM 5640) from the Globorotalia fohsi fohsi zone, sample KWB 6572 (TTOC 100219).

Remarks: Scarce specimens of the large Globigerinoides mitra may occur from the Catapsydrax dissimilis zone onward. In the transitional beds between the Lenga formation and the Cruse formation, where they are more often encountered than deeper in the section, the tests of Globigerinoides mitra are usually pyritized. It appears possible that these abnormally large forms have developed from Globigerinoides obliqua, new species, by the development of additional chambers. The large specimen of Globigerinoides obliqua (pl. 25, figs. 9a–c) and Globigerinoides species (pl. 26 figs. 5a–c) (USNM P5641) are possibly transitional forms.

Globigerinoides bispherrica Todd

Plate 27, Figures 1a–b


Stratigraphic range (in Cipero formation): Upper part of the Globigerinatella insueta zone.

Locality: Figured hypotype (USNM P5642) from the Globigerinatella insueta zone; sample KWB 7446A (TTOC 125125).

Remarks: Globigerinoides bispherrica is regarded as the ancestor of the Porticulatesphaera glomerosa (Blow) group and the genus Orbulina, (See Blow, 1956).

Genus Sphaeroidinella Cushman, 1927

Sphaeroidinella grimsdalei (Keijzer)

Plate 26, Figures 8–12c


Stratigraphic range (in Cipero and Lenga formations): Globorotalia fohsi barisanensis zone to Globorotalia menardii zone.

Locality: Figured hypotypes (USNM P5643a–c) from the type locality of the Globorotalia fohsi fohsi zone, sample Bo 185A (TTOC 193121), and (USNM P5644a, b) from the type locality of the Globorotalia mayeri zone, sample KR 23422 (TTOC 160634).

Remarks: Sphaeroidinella grimsdalei is rather variable in size and in number of chambers comprising the final whorl. Stratigraphically early specimens are usually small with 3 chambers in the last whorl. During the course of evolution, the tests tend to become larger and the last whorl may consist of 3 and 4, occasionally even 5 or 6, chambers. Sphaeroidinella rutschi Cushman and Renz probably branched off from Sphaeroidinella grimsdalei. An apparently transitional form is shown on plate 26, figures 13a, b (USNM P5646).
Sphaeroidinella rutschi Cushman and Renz

**Plate 26, Figures 6a–7b**

*Sphaeroidinella rutschi* Cushman and Renz, Contr. Cushman Lab. Foram. Res., vol. 17, pt. 1, p. 23, pl. 4, fig. 5, 1941.—

Renz, Geol. Soc. Amer., Mem. 32, p. 107, pl. 10, figs. 1a–c.


**Stratigraphic range** (in Lengua formation): Globorotalia mayeri zone to Globorotalia menardii zone.

**Locality:** Figured hypotypes (USNM P5645a,b) from the Globorotalia menardii zone; ditch sample at 1,938 feet of Trinidad Leaseholds, Ltd. (now The Trinidad Oil Company), well Barrackpore 332 (TTOC 194771).

**Remarks:** *Sphaeroidinella rutschi* has probably developed from the *Sphaeroidinella grimsdalei* Keijzer group and may be regarded as the ancestor of *Sphaeroidinella dehiseens* (Parker and Jones).

**Subfamily Orbulinginae Schultze, 1854**

Genus *Portularisphaera* Bolli, Loeblich, and Tappan, 1957

In a paper on the evolution of the genus *Orbula* Blow (1956) described a number of forms under the genus *Globigerinoides* that are regarded as transitional between *Globigerinoides* and *Orbula*. They resemble *Orbula suturalis* Bronnimann in having a strongly embracing inflated final chamber and small sutural supplementary apertures, but differ in the absence of areal supplementary apertures. They resemble *Globigerinoides* in having sutural supplementary apertures, but differ in possessing a final, strongly embracing chamber which has no distinct primary umbilical aperture. These intermediate forms fit into the definition given for the short-lived middle Eocene genus *Portularisphaera*. Although there is no genetic relation between the middle Eocene and the lower Miocene forms, Blow’s transitional species are here placed in *Portularisphaera*. Possibly further comparative studies will reveal differences between the Eocene and Miocene forms that will allow the separation of Blow’s species as a distinct genus.

For detailed species and subspecies descriptions and evolutionary trends, reference is made to Blow (1956).

*Portularisphaera* glomerosa *curva* (Blow)

**Plate 27, Figure 7**

*Globigerinoides* glomerosa *curva* Blow, Micropaleontol., vol. 2, No. 1, p. 64, text-fig. 1, Nos. 9–14, 1956.

**Stratigraphic range** (in Cipero formation): Upper part of the *Globigerinatella insueta* zone to the basal part of the *Globorotalia fohsi barisanensis* zone.

**Locality:** Figured hypotype (USNM P5647) from the *Globigerinatella insueta* zone; sample KWB 7446A (TTOC 125125).

*Portularisphaera* glomerosa *glomerosa* (Blow)

**Plate 27, Figure 8**

*Globigerinoides* glomerosa *glomerosa* Blow, Micropaleontol., vol. 2, No. 1, p. 65, text-fig. 1, Nos. 15–19, text-fig. 2, Nos. 1–2, 1956.

**Stratigraphic range** (in Cipero formation): Uppermost part of the *Globigerinatella insueta* zone to the basal part of the *Globorotalia fohsi barisanensis* zone.

**Locality:** Figured hypotype (USNM P5648) from the *Globigerinatella insueta* zone, sample KWB 7446A (TTOC 125125).

*Portularisphaera* glomerosa *circularis* (Blow)

**Plate 27, Figure 2**


**Stratigraphic range** (in Cipero formation): Topmost part of the *Globigerinatella insueta* zone to the lower part of the *Globorotalia fohsi barisanensis* zone.

**Locality:** Figured hypotype (USNM P5649) from the *Globigerinatella insueta* zone, sample KWB 7446A (TTOC 125125).

*Portularisphaera* transitoria (Blow)

**Plate 27, Figure 3**


**Stratigraphic range** (in Cipero formation): Upper part of the *Globigerinatella insueta* zone.

**Locality:** Figured hypotype (USNM P5650) from the *Globigerinatella insueta* zone, sample KWB 7446A (TTOC 125125).

Genus *Orbula* d’Orbigny, 1839

*Orbula suturalis* Bronnimann

**Plate 27, Figure 4**

*Orbula suturalis* Bronnimann, Contr. Cushman Found. Foram. Res., vol. 2, pt. 4, p. 135, text-fig. 2, figs. 1–2, 5–8, 10; text-fig. 3, figs. 3–8, 11, 13–16, 18, 20–22; text-fig. 4, figs. 2–4, 7–12, 15–16, 19–22, 1951.—Blow, Micropaleontol., vol. 2, No. 1, p. 66, text-fig. 2, Nos. 5–7, 1956.


**Stratigraphic range** (in Cipero and Lengua formations): Topmost part of the *Globigerinatella insueta* zone to the *Globorotalia menardii* zone.

**Locality:** Figured hypotype (USNM P5651) from the type locality of the *Globorotalia menardii* zone, sample KR 23425 (TTOC 178890).

*Orbula* univarsa d’Orbigny

**Plate 27, Figure 5**


**Stratigraphic range** (in Cipero and Lengua for-
Globigerina biobata (d'Orbigny)

Plate 27, Figure 6

Globigerina biobata n'Orbigny, Foraminifères fossiles du bassin tertiaire de Viene, p. 164, figs. 11-14, 1846.


Biobulina biobata (d'Orbigny), Blow, Micropaleontol., vol. 2, No. 1, pp. 69-70, text-fig. 2, No. 16, 1956.

Stratigraphic range (in Cipero and Lengu formations): Topmost part of the Globigerinatella insueta zone to the Globorotalia menardii zone.

Locality: Figured hypotype (USNM P5653) from the Globorotalia foki barisanensis zone, sample Bo 201 (TTOC 161336).

Subfamily Catapsydracinae Bolli, Loeblich, and Tappan, 1957

Genus Catapsydrax Bolli, Loeblich, and Tappan, 1957

Catapsydrax dissimilis (Cushman and Bermudez) ²


Catapsydrax dissimilis (Cushman and Bermudez), Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 36, pl. 7, figs. 6-8, 1957.

Stratigraphic range (in Cipero formation): Globigerina ampliapertura zone to Catapsydrax stainforthi zone.

Locality: Figured hypotypes (USNM P4218a, b) from the type section of the Globigerina ciperoensis ciperoensis zone, sample Bo 271A (TTOC 215656).

Catapsydrax unicorn Bolli, Loeblich, and Tappan


Stratigraphic range (in Cipero formation): Globigerina ampliapertura zone to Catapsydrax stainforthi zone.

Locality: Holotype (USNM P4216) from the Globigerina ciperoensis ciperoensis zone, sample Bo 270 (TTOC 201219).

Catapsydrax stainforthi Bolli, Loeblich and Tappan


Stratigraphic range (in Cipero formation): Catapsydrax dissimilis zone to Globigerinatella insueta zone.

Locality: Holotype (USNM P4840) from the type section of the Catapsydrax stainforthi zone, sample K 9397, (TTOC 193790).

Catapsydrax parvulus Bolli, Loeblich and Tappan


Stratigraphic range (in Cipero and Lengu formations): Catapsydrax dissimilis zone to Globorotalia menardii zone.

Locality: Holotype (USNM P4219) from the type locality of the Globorotalia menardii zone, sample KR 23422 (TTOC 160634).

Genus Globigerinata Bronnimann, 1951

Globigerinata naparimaensis Bronnimann


Stratigraphic range (in Cipero and Lengu formations): Catapsydrax dissimilis zone to Globorotalia menardii zone.

Locality: Holotype (USNM 64182) from the Globorotalia menardii zone. Core at 5,423 feet of Trinidad Leaseholds, Ltd. (now The Trinidad Oil Company), well Morne Diablo No. 34 (TTOC 161214).

Genus Globigerinatella Bronnimann, 1952

Globigerinatella morugaensis Bronnimann


Stratigraphic range (in Lengu formation): Globorotalia menardii zone to Globorotalia menardii zone.

Locality: Holotype (USNM P3913) from the Globorotalia menardii zone, sample GF 4028 (TTOC 3514).

Genus Globigerinatellina Cushman and Stainforth, 1945

Globigerinatellina insueta Cushman and Stainforth


Stratigraphic range (in Cipero formation): Catapsydrax stainforthi zone to Globigerinatellina insueta zone.

Locality: Figured paratypes (Cushman Coll. 44043a, b) from the Globigerinatellina insueta zone; figured topotype (USNM P3932b) from the Globigerinatellina insueta zone.
Globorotaloides Bolli, new genus

**Type species**: *Globorotaloides variabilis* Bolli, new genus, new species.

Test free, trochospiral, chambers ovate to spherical, sutures depressed, surface smooth or pitted; primary aperture in the early stage interiomarginal, umbilical-extramarginal, later becoming umbilical. Ultimate chamber often smaller than penultimate, may cover part or entire umbilicus and become almost indistinguishable from a bulla. This ultimate chamber normally has a single aperture though multiple ones may occur.

**Remarks**: *Globorotaloides*, new genus, shows in stages the characteristic feature of three planktonic genera. The first stage is that of a *Globorotalia* with a distinct interiomarginal, umbilical-extramarginal primary aperture, followed by a Globigerina-like stage, where the aperture becomes umbilical. The presence of a bulla-like final chamber covering a part or the whole umbilicus indicates the final Catapsydrax-like stage.

Specimens featuring the early *Globorotalia* stage only (pl. 27, figs. 15b, 17b) or the following Globigerina-like stage (pl. 27, fig. 19b) were found commonly in the samples studied. The close relationship of these stages with the fully developed *Globorotaloides* becomes evident when studying a large number of specimens. The mature stage does not depend on the size of the specimen; it may be found in small and large forms. In small specimens with a bulla-like final chamber (pl. 27, fig. 16b) the Globigerina stage may be missing.

*Globorotaloides*, new genus, differs from *Globorotalia* in the interiomarginal umbilical position of the primary aperture in the final chamber and in the possession of a bulla-like small chamber that covers part or all of the umbilicus.

It differs from *Globigerina* in having an early *Globorotalia* stage and a bulla-like small final chamber.

*Globorotaloides* resembles Catapsydrax in having a bulla-like small final chamber but differs in having an early *Globorotalia* stage.

**Globorotaloides suteri** Bolli, new species

**Plate 27, Figures 9a–13b**

Shape of test low trochospiral, biconvex; equatorial periphery lobate, in small specimens somewhat elongate; axial periphery rounded. Wall calcareous, perforate, surface finely cancellate. Chambers ovate to spherical; about 11–14, arranged in 2–2½ whorls; the 4–5 chambers of the last whorl increase fairly rapidly in size. Sutures on spiral side slightly curved to radial, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, open in immature specimens, in mature specimens partly or completely covered by a bulla-like chamber. Aperture a slit or low arch; interiomarginal, umbilical-extramarginal in early stage, later becoming umbilical, which in the mature stage becomes covered by a bulla-like chamber with one infralaminar aperture. Coiling random. Largest diameter of holotype 0.45 mm.

**Stratigraphic range** (in Cipero formation): Most common and typical in the Globigerina ampliapertura zone, ranging to the Globigerinatella insueta zone.

**Locality**: Holotype (USNM P5654) and figured paratypes (USNM P5655a–d) from the Globigerina ampliapertura zone, Cipero type section, Trinidad, sample Bo 314A (TTOC 215658).

**Remarks**: *Globorotaloides suteri*, new species, is distinguished from *G. variabilis*, new species, by the more inflated early chambers, less curved sutures and fewer chambers.

The species is named for Dr. H. H. Suter in recognition of his contribution to the geology of Trinidad.

**Globorotaloides variabilis** Bolli, new species

**Plate 27, Figures 15a–20c**

Shape of test low trochospiral, biconvex; equatorial periphery lobate, in small specimens somewhat elongate; axial periphery subacute in immature specimens, rounded in mature specimens. Wall calcareous, perforate, surface very finely cancellate. Chambers subangular to ovate in early stage, later becoming ovate to spherical; about 15–18, arranged in 2–2½ whorls; the 5–7 chambers of the last whorl increase fairly rapidly in size. Sutures on spiral side distinctly curved in early stage, later becoming more radial, depressed; on umbilical side slightly curved in early stage, later becoming radial, depressed. Umbilicus fairly wide, open in immature specimens, in mature specimens partly or completely covered by a bulla-like chamber. Aperture a slit or low arch; interiomarginal, umbilical-extramarginal in early stage, later becoming umbilical, which in the mature stage becomes covered by a bulla-like chamber with one infralaminar aperture. Coiling random. Largest diameter of holotype 0.45 mm.

**Stratigraphic range** (in Cipero and Lenga formations): *Globorotalia foksi barisanensis* zone to *Globorotalia menardii* zone. Most typical and common in the Lenga formation.

**Locality**: Holotype (USNM P5657) and figured paratypes (USNM P5658a–e) from the *Globorotalia menardii* zone, Lenga formation, road cutting, Concord area, Pointe-a-Pierre, Trinidad, sample Rz 502 (TTOC 65629).

**Remarks**: *Globorotaloides variabilis*, new species, is distinguished from *G. suteri*, new species, by having more compressed early chambers, more curved sutures and a greater number of chambers. It is likely that *G. suteri*, which is restricted to the lower and middle part of the Cipero formation, is the ancestor of *G. variabilis*, new species.

**Family Globorotaliidae** Cushman, 1927

**Genus Globorotalia** Cushman, 1927

Globorotalia opima opima Bolli, new species, new subspecies

**Plate 28, Figures 1a–2**

Shape of test very low trochospiral; equatorial periphery slightly lobate; axial periphery rounded; due
to the rapid increase in size of the chambers in the last whorl, the spiral side often appears slightly concave. Wall calcareous, perforate, surface finely pitted. Chambers spherical, 10–12, arranged in about 2½ whorls; the 4–5 chambers of the last whorl increase rapidly in size. Sutures on spiral side radial, depressed; umbilical side radial, depressed. Umbilicus narrow, deep. Aperture a fairly low arch, a slight rim or lip is only occasionally observed, interiomarginal, umbilical-extraumbilical. Coiling random. Largest diameter of holotype 0.55 mm.

**Stratigraphic Range (in Cipero formation): Globorotalia opima opina zone.**

**Locality:** Holotype (USNM P5659) and figured paratype (USNM P5660) from the type section of the Globorotalia opima opina zone, Cipero type section, Trinidad, sample JS 20 (TTOC 193265).

**Remarks:** Globorotalia opima opina, new species, new subspecies, is distinguished from G. mayeri Cushman and Ellisor by the greater thickness of the test and in having 4–5 chambers in the last whorl, instead of 5–6. The apertural lip, which is usually present in G. mayeri, is only occasionally seen in the new subspecies. G. opima opina has a very restricted range whereas G. mayeri can be followed through most of the Cipero formation into the lower Lengua. G. opima opina differs from G. opina nana, new species, new subspecies, by its larger size. It has a more restricted stratigraphic range.

Globorotalia opima nana Bolli, new species, new subspecies

**Plate 28, Figures 3a–c**

Shape of test very low trochospiral; equatorial periphery slightly lobate; of a somewhat quadrangular aspect in four-chambered specimens; axial periphery rounded. Wall calcareous, perforate, surface finely pitted. Chambers spherical; about 10, arranged in about 2 whorls; the 4–5 chambers of the last whorl increase fairly rapidly in size. Sutures on spiral side radial, depressed; on umbilical side radial, depressed. Umbilicus narrow, deep. Aperture a low arch, a rim or lip is often present; interiomarginal, umbilical-extraumbilical. Coiling random. Largest diameter of holotype 0.3 mm.

**Stratigraphic Range (in Cipero formation): Globigerina ampliapertura zone to Globigerina ciperoensis ciperoensis zone.** Similar forms occur sparsely in the higher zones of the Cipero formation.

**Locality:** Holotype (USNM P5661) from the type section of the Globorotalia opima opina zone, Cipero type section, Trinidad, sample JS 20 (TTOC 193265).

**Remarks:** Globorotalia opima nana, new species, new subspecies, is distinguished from G. mayeri Cushman and Ellisor by greater relative thickness of test and by having 4–5 chambers in the last whorl, instead of 5–6. The range of the new subspecies is restricted to the lower part of the Cipero formation, while that of G. mayeri extends into the lower Lengua. G. opima nana differs from G. opima opina, new species, new subspecies, by its smaller size. It has a more extended stratigraphic range.

**Globorotalia mayeri Cushman and Ellisor**

**Plate 28, Figures 4a–c**


**Stratigraphic Range (in Cipero and Lengua formations): Globigerina opima opina zone to Globorotalia mayeri zone.**

**Locality:** Figured hypotype (USNM P5662) from the Catapsydrax dissimilis zone, sample Bo 267 (TTOC 201216).

**Remarks:** Globorotalia mayeri has a remarkably long range compared with other Oligocene and Miocene species and subspecies of the genus. A close relation to G. opima nana, new species, new subspecies, is likely and it is also possible that G. fohsi barisanensis Le Roy branches off from this form in the Catapsydrax dissimilis zone.

**Globorotalia kugleri Bolli, new species**

**Plate 28, Figures 5a–6**

Shape of test very low trochospiral; equatorial periphery slightly lobate; axial periphery rounded or with a tendency to become subangular. Wall calcareous, perforate, surface finely pitted. Chambers ovate; 18–20, arranged in 2½–3 whorls; the 6–8 chambers of the last whorl increase slowly in size. Sutures on spiral side: curved, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow. Aperture a distinct arch, a lip may be present; interiomarginal, umbilical-extraumbilical. Coiling random. Largest diameter of holotype 0.3 mm.

**Stratigraphic Range (in Cipero formation): Globorotalia kugleri zone.**

**Locality:** Holotype (USNM P5663) and figured paratype (USNM P5664) from the Globorotalia kugleri zone, type locality area, Trinidad, sample KWB 8672 (TTOC 138659).

**Remarks:** Globorotalia kugleri, new species, is distinguished from G. fohsi barisanensis Le Roy by having more chambers in the last whorl. G. kugleri became extinct shortly after the first occurrence of G. fohsi barisanensis.

The species is named for Dr. H. G. Kugler in recognition of his contributions to the geology of Trinidad.

Globorotalia fohsi Cushman and Ellisor

Reference is made to Bolli (1950) for species and subspecies descriptions of Globorotalia fohsi and the discussion of evolutionary trends.
Globorotalia fohsi barisanensis Le Roy

Plate 28, Figures 8a–c


Stratigraphic range (in Cipero formation): Catapsydrax dissimilis zone to the basal part of the Globorotalia fohsi fohsi zone.

Locality: Figured hypotype (USNM P5666) from the type locality of the Globorotalia fohsi barisanensis zone, sample Bo 202 (TTOC 193125).

Globorotalia fohsi fohsi Cushman and Ellisor

Plate 28, Figures 9a–10c


Stratigraphic range (in Cipero formation): Globorotalia fohsi fohsi zone to the basal part of the Globorotalia fohsi fohsi lobata zone.

Locality: Figured hypotypes (USNM P5667, P5668) from the type locality of the Globorotalia fohsi fohsi zone, sample Bo 185A (TTOC 193121).

Globorotalia fohsi lobata Bermudez

Plate 28, Figures 13a–14b


Stratigraphic range (in Cipero formation): Globorotalia fohsi fohsi lobata zone to the basal part of the Globorotalia fohsi fohsi robusta zone.

Locality: Figured hypotypes (USNM P5669a, b) from the type section of the Globorotalia fohsi fohsi lobata zone, sample JS 32 (TTOC 193786).

Globorotalia fohsi robusta Bolli

Plate 28, Figures 16a–c


Stratigraphic range (in Cipero formation): Globorotalia fohsi robusta zone.

Locality: Figured hypotype (USNM P5671) from the Globorotalia fohsi robusta zone, sample JS 46 (TTOC 194056).

Globorotalia obesa Bolli, new species

Plate 29, Figures 2a–3

Shape of test very low trochospiral; equatorial periphery strongly lobate; axial periphery rounded. Wall calcareous, perforate, surface finely pitted, in well preserved specimens with fine, short spines. Chambers strongly inflated, spherical; 10–12 arranged in 2–2½ whorls; the 4–4½ chambers of the last whorl increase rapidly in size. Sutures on spiral side radial, strongly depressed; on umbilical side radial, strongly depressed. Umbilicus fairly wide, deep. Aperture a medium to high arch without lip or rim; interiomarginal, umbilical-extramarginal. Coiling random. Largest diameter of holotype 0.5 mm.

Stratigraphic range (in Cipero and Lengua formations): Catapsydrax dissimilis zone to Globorotalia menardii zone.

Locality: Holotype (USNM P5673) from the type section of the Globorotalia fohsi robusta zone, Cipero type section, Trinidad, sample JS 16 (TTOC 193261); figured paratype (USNM P5674) from the type locality of the Globorotalia fohsi fohsi zone, sample Bo 185 (TTOC 153997).

Remarks: Globorotalia obesa, new species, differs from G. mayeri Cushman and Ellisor in having fewer and more inflated chambers in the last whorl.

Globorotalia minutissima Bolli, new species

Plate 29, Figures 1a–c

Shape of test very low trochospiral; equatorial periphery lobate; axial periphery rounded. Wall calcareous, very finely perforate, surface smooth. Chambers ovate; 10–12, arranged in about 2 whorls; the 5 chambers of the last whorl increase moderately in size. Sutures on spiral side radial to slightly curved, depressed; on umbilical side radial, depressed. Umbilicus small, shallow. Aperture a narrow slit, often with a lip or rim; interiomarginal, umbilical-extramarginal. Coiling random. Largest diameter of holotype 0.2 mm.

Stratigraphic range (in Cipero and Lengua formations): Catapsydrax stainforthi zone to Globorotalia menardii zone.

Locality: Holotype (USNM P5775) from the type locality of the Globorotalia fohsi fohsi zone, sample Bo 185 (TTOC 153997).

Remarks: Globorotalia minutissima, new species, is distinguished from other Globorotalia species of similar shape (e. g., G. mayeri Cushman and Ellisor, and G. obesa, new species) by its very small size and smooth surface.

Globorotalia archeomenardii Bolli, new species

Plate 28, Figures 11a–c

Shape of test low trochospiral, compressed; equatorial periphery slightly lobate; axial periphery acute with a
thin but distinct keel. Wall calcareous, very finely perforate, surface smooth. Chambers angular rhombo-
oid, strongly compressed; 12–15, arranged in about 3 whorls, the 4–5 chambers of the last whorl increase
fairly rapidly in size. Sutures on spiral side strongly
curved; on umbilical side radial to slightly curved,
depressed. Umbilicus small, fairly shallow. Aperture
a low slit; interiomarginal, umbilical-extraumbilical.
Coiling random. Largest diameter of holotype 0.3 mm.

Stratigraphic range (in Cipero formation): Upper
part of the Globigerinatella insueta zone to the lower
portion of the Globorotalia fohsi fohsi zone.

Locality: Holotype (USNM P5676) from the type
locality of the Globorotalia fohsi fohsi burisanensis zone,
Trinidad, sample Bo 202 (TTOC 193125).

Remarks: Globorotalia archeomenardii, new species,
is distinguished from G. menardii (d’Orbigny) and G.
praemenardii Cushman and Stainforth by having a
more convex spiral side and in being less lobate. The
range in size of the specimens of the new species is
very small in contrast to that of the other two species.
Typical G. archeomenardii disappear with the first
appearance of G. praemenardii. It is probably the
ancestor of the G. praemenardii–menardii suite.

Globorotalia praemenardii Cushman and Stainforth

Plate 29, Figures 4a–c

Globorotalia praemenardii Cushman and Stainforth, Cushman
Lab. Foram. Res., Spec. Publ. 14, p. 70, pl. 13, figs. 1a–c,
1945.—Cushman and Bermudez, Contr. Cushman Lab.
Foram. Res., vol. 25, pt. 1, p. 31, pl. 5, figs. 17–19, pl. 6,
figs. 1–3.

Stratigraphic range (in Cipero formation): Globorotalia
fohsi fohsi zone to Globorotalia fohsi robusta zone.

Locality: Figured hypotypes (USNM P5677) from the
type locality of the Globorotalia fohsi fohsi zone,
sample Bo 218 (TTOC 153997).

Globorotalia menardii (d’Orbigny)

Plate 29, Figures 6a–10b

modèle No. 10, 1826.

Globorotalia menardii (d’Orbigny), Nuttall, Journ. Paleontol.,
vol. 6, pp. 29–30, pl. 4, fig. 16, 1932.—Cortell and Rivero,
Journ. Paleontol., vol. 14, p. 336, pl. 42, figs. 34, 35, 1940.—
Renz, Geol. Soc. Amer. Memoir 32, p. 137, pl. 10, figs.
3a–e, 1943.—Cushman and Bermudez, Contr. Cushman
Lab. Foram. Res., vol. 25, pt. 1, pp. 29–30, pl. 5, figs. 4–6,
1949.

Stratigraphic range (in Cipero and Lengua forma-
tions): Globorotalia fohsi robusta zone to Globorotalia
menardii zone.

Locality: Figured hypotypes (USNM P5678a–e)
from the type locality of the Globorotalia menardii
zone, sample KR 23425 (TTOC 178890).

Remarks: The considerable variation in size within
the species is shown on the plate. All figured speci-
mens are from the same sample.

Globorotalia scutula (Brady)

Plate 29, Figures 11a–12c

vol. 9, pl. 103, figs. 7a–c, 1884).

Globorotalia canariensis (d’Orbigny), CUSHMAN and StAINFORTH,
figs. 12a–b, 1945.—Renz, Geol. Soc. Amer., Memoir 32,
p. 136, pl. 11, figs. 5a–b, 1945.

Stratigraphic range (in Cipero and Lengua forma-
tions): Globorotalia fohsi fohsi zone to Globorotalia
menardii zone.

Locality: Figured hypotypes (USNM P5679, P5680),
from the Globorotalia Mayeri zone, sample GF 3655
(TTNC 3320).

Remarks: Globorotalia scutula was previously de-
scribed from the Cipero formation (Cushman and
Stainforth, 1945) as G. canariensis (d’Orbigny). D’Orbigny
describes this form (Rotalia canariensis) as
delon-gate-depressed and carinate which brings it close
to the G. menardii (d’Orbigny) group. Compared
with this group, the equatorial periphery of G. scutula
is more circular and the axial periphery is rounded to
subangular. The Trinidad specimens are slightly
larger than the type which was described from the
Faroe Channel. Specimens of the same size as those
found in Trinidad are today living predominantly in
warm waters. Temperature and other ecological
factors probably account for the variation in size.

Globorotalia lenguensis Bolli, new species

Plate 29, Figures 5a–c

Shape of test low trochospiral; equatorial periphery
almost circular, not or only very slightly lobate; axial
periphery angular to subangular, often with a faint
keel. Wall calcareous, finely perforate, surface smooth.
 Chambers strongly compressed; 15–20, arranged in
2½–3 whorls; the 6–7 chambers of the last whorl
increase moderately in size. Sutures on spiral side
strongly curved, occasionally slightly depressed; on
umbilical side radial to slightly sigmoidal, depressed.
 Umbilicus very narrow, almost closed. Aperture a
low arch often with a lip; interiomarginal, umbilical-extra-
 umbilical. Coiling apparently random in the
Globorotalia Mayeri zone; almost exclusively sinistral in
the Globorotalia menardii zone. Largest diameter of holo-
type 0.3 mm.

Stratigraphic range (in Lengua formation): Glo-
orotalia Mayeri zone to Globorotalia menardii zone.

Locality: Holotype (USNM P5681) from the type
locality of the Globorotalia menardii zone, Trinidad,
sample KR 23425 (TTNC 178890).

Remarks: Globorotalia lenguensis, new species, re-

seems *G. canariensis* var. *minima* Akers but differs in its less convex umbilical side and more circular equatorial periphery. *G. canariensis* var. *minima* has been described from the Cibicides *carstensi* var. *opimus* zone (*Globorotalia foksi* barisanensis zone to *Globorotalia foksi* foksi zone of the Cipero formation), whereas *Globorotalia lenquensis* is restricted to the Lengua formation. The new species differs from *G. menardii* (d’Orbigny) in its smaller size, less lobate and more circular equatorial periphery.

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Some Planktonic Foraminifera of the Type Danian and Their Stratigraphic Importance

By J. C. Troelsen

Introduction

Before discussing the biostratigraphy of the Danian stage, it may be well to give a brief description of the development of the stage in its type area (see text-fig. 22). The Danian stage was proposed by E. Desor (1846, p. 181) for the limestone deposits which in Denmark lie above the Maestrichtian White Chalk. The type localities are Stevns Klint and Fakse (= Faxe = Fax6e), both of which are located some 40 miles south-southwest of Copenhagen in eastern Denmark. The island of Saltholm, east of Copenhagen, is sometimes cited as the type locality of the Danian, but this interpretation of Desor’s text seems to be untenable.

The Danian deposits are known from a belt that stretches in a northwest-southeasterly direction across Denmark and southern Sweden. The belt (including deposits lying under the Cenozoic sediments) is now about 100 miles wide, and there is evidence to suggest that this is not far from the original width. The Danian sediments were thus laid down in a narrow sound, whose southeastern extension may be found in Poland (Pozaryska, 1954). Farther to the southeast, the sound may have been connected with the sea in which the Danian sediments of the Crimean Peninsula were laid down (Bettenstaedt and Wicher, 1956, p. 515).

The Danian deposits in the type area may be characterized as very pure limestones, which range from calcilutites to calcirudites. Many of them may also be classified as coccolithic limestones, bryozoan reef limestones or coral reef limestones. The almost complete absence of terrigenous detritus, which is so marked a character not only of the Danian limestones but also of the underlying White Chalk, is probably connected with the peneplanation of the land and the consequent low gradient of the rivers in late Cretaceous and early Cenozoic times. Bailey and Weir (1939, pp. 462–463) infer the probability of arid conditions in northwest Europe in this period of time. The latter theory finds support in the fact that planktonic Foraminifera occurred, although in varying numbers, in the narrow Danian sea. Examples from Recent seas show that Globigerinae rarely enter sounds or embayments unless the salinity of the water is high. We may therefore assume that but little fresh water flowed into the Danian sea (see also Said, 1950). The regular occurrence of benthonic organisms in all parts of the Danian stage further shows that the bottom waters must have been well aerated.
The Paleocene deposits ("Sélandian," Rosenkrantz, 1924, p. 34), which with a complete change in facies and a (minor?) hiatus overlie the Danian limestones, are composed of terrigenous detritus with some glauconite. The Paleocene sea was a rather narrow embayment (Grönwall and Harder, 1907). Its fauna contained a great many marine molluscs (Ravn, 1939), besides benthonic Foraminifera (Brotzen, 1948), but true planktonic Foraminifera have not been found, except for some specimens which from their appearance must be assumed to have been reworked from the Danian rocks. Brotzen’s report (1948, p. 30) of Globigerininae in the Kerteminde marl of Denmark has not been confirmed. (Globorotalites lobata Brotzen from the Danian and Sélandian beds of Denmark-Sweden and in fact the entire genus Globorotalites, is not here considered to be a planktonic form.) The cause of their absence may well have been the influx of freshwater of which the terrigenous detritus is evidence.

In Denmark and southern Sweden, the lithostratigraphic unit which corresponds to the Danian stage is the Danskekalk formation (Ödum, 1935, p. 14; the name simply means “Danish limestone”). Since this is in the type area, the limits of the stage coincide with those of the formation. The composite section given in text-figure 23 is based upon the type localities at Stevns Klint and Fakse combined with occurrences in or near Copenhagen (Rosenkrantz, 1937, p. 201).

**Biostatigraphy**

A few remarks on the planktonics of the Danian stage of Sweden have been published by Muntho (1896) and Brotzen (1940, 1945, 1948), but only the important articles by Bronnimann (1953) and Reichel (1953) give any information on the occurrence of these organisms in the type Danian. Reichel, who examined two pieces of limestone from Fakse, seems to have been the first to correlate, in a general way, the type Danian with the zone of small Globigerininae which in the Tethys area commonly occurs between the Globotruncanosa assemblage of undoubted Maestrichtian age and the Globigerinina-Globorotalia assemblage of assumed Paleocene age (see also Z. Reiss (1952, 1954, 1955), J. Schweighauser (1953, p. 28), S. E. Nakad (1955), Bettenstaedt and Wicher (1956, p. 501, 514–515), and others). Bronnimann (1953) lists the following Globigerinina species which he found in a sample of Danian coccolithic limestone from Daubbjerg in northwest Denmark and which also occur in the Lizard Springs formation of Trinidad, B. W. I.: G. pseudobuloides Plummer, G. triloculinaoides Plummer, G. linaperta Finlay, G. hornibrookii Bronnimann, G. stainforthi Bronnimann, G. daubjergensis Bronnimann, and G. compressa Plummer (another sample from Hjerno contained only two poorly preserved species).

Globigerinina occur throughout the Danian stage, whereby the theory that the Danian sea was at one time transformed into a completely enclosed basin seems to have been refuted (Ravn, 1939, p. 23, and others). In the Danian of eastern Denmark, the only horizons in which Globigerininae are even fairly abundant are, however, the base of the zone of Tylocidaris ódhumi and the greater part of the zone of Tylocidaris vexilifera (the latter occurrence has already been observed by Brotzen, 1940). Even within these zones, only a few samples have yielded well-preserved tests and it has therefore been rather difficult to procure enough material for the following analysis.

Although the underlying White Chalk of Maestrichtian age is characterized by the abundant occurrence of Rugoglobigerina, "Globigerinella," Pseudotextularia, striated Guembelinae, and, in certain strata, Globotruncanosa (s. l.), the only planktonics to occur in the type Danian are small Guembelinae and Globigerininae, of which only the latter will receive further attention in the present article. The change from one faunizone to the other is very abrupt and occurs at the hiatus between the White Chalk and the Danskekalk formation (text-fig. 23). The fact that the basal few inches of the Danskekalk formation contain occasional specimens (presumably reworked) of Rugoglobigerina and "Globigerinella" does not alter the impression of a fundamental difference between the two deposits (see also Troelsen, 1955a). On the evidence of the planktonic Foraminifera, the present writer is therefore inclined to agree with those who place the Danian stage in the Cenozoic.

For the present analysis the writer has endeavored to procure samples from the type localities of the Danian stage and from all the major fossil zones. Only the samples representing the zone of Tylocidaris vexilifera had of necessity to be collected outside the type localities since this zone is not represented there. In order to avoid bias, only samples in which even the smallest Foraminifera were well preserved and identi-
fiable have been included in the analysis. Such material is rarely found in the Danskekalk formation, and in the case of the zone of T. vexilifera it became necessary to use material from Östra Torp in Sweden since the Copenhagen area failed to yield any samples with perfectly preserved Globigerinae. Under these circumstances it has not been possible to analyze more than six samples. From each sample, 100–150 Globigerinae were picked at random to secure a reasonably reliable census of the fauna, the only exceptions being samples 4 and 6, in which no more than 23 and 32 specimens, respectively, could be found. A certain correlation therefore exists between the number of Globigerinae counted and their relative abundance in the samples. An examination of numerous samples of Danian Foraminifera from other parts of Denmark and Sweden shows that the species listed in text-figure 24 are typical of the Danian stage in this part of the world.

As it will appear from the descriptive part of this article, not all the species which Bronnimann found in the limestone at Daubjerg (listed in a previous paragraph) occur in the samples examined by the present writer. The cause of this discrepancy may be that Bronnimann’s material came from a horizon which is not represented in the material extensive though it is, available to the present writer, or it may be due to personal variation as to the concept of the species.

Among those species found by the present writer, Globigerina pseudobulloides Plummer is of stratigraphic importance since it was originally described from the Midway group of the Gulf Coastal Plain. An examination of a number of foraminiferal faunas of Danian and Paleocene age has shown, however, that G. pseudobulloides Plummer has a considerably more restricted distribution than a survey of the literature would lead one to believe. Of still greater value for stratigraphic purposes is G. davbjergensis Bronnimann, which in the type Danian is most abundant in the upper part of the stage. It occurs in the basin Midway group (“Along north-south road N. of Austin-Elgin highway, W. of Elgin, Texas,” H. J. Plummer), and it is rather abundant in the upper part of the Clayton formation or the lower part of the Porter’s Creek formation (“2.3 miles S. of Thomaston, Alabama, on Alabama Highway 99, Marengo Co., Alabama,” J. W. West and G. E. Murray) and in the Mexia clay member of the Wills Point formation, i.e., the lower part of the upper Midway group (“Mexia clay pit, Mexia, Texas,” D. E. Feray; and “Branch of Tehuacana Creek, 2 miles N. W. of Mexia, Texas,” O. L. Bandy). The distribution of G. compressa Plummer and G. triloculinoide Plummer, of which we have specimens from the above-mentioned samples of the Mexia clay, offer a similar correlation. Specimens of G. compressa and G. triloculinoide were also obtained from the lower Lizard Springs formation of Trinidad, B. W. I. (“Rz. 283 (50316) and Rz. 286–291 (50505–10),” H. H. Renz). Brotzen (1948, pp. 32–33) has correlated the upper part of the Danskekalk formation with the North American Kincaid formation (lower part of the Midway stage). The above-mentioned evidence indicates, however, that also the Wills Point formation (i.e., the upper part of the Midway group), or at least the lower portion of that formation, may be correlated with the upper part of the Danskekalk formation. It is necessary to point out, however, that one of the bases used by Brotzen in correlating the Paleocene of Denmark-Sweden with the upper Midway group, viz., the occurrence in both deposits of Epistominia (Hoglundia) scalaris Franke, Lamarkia naeoleonis Cushman and Todd, Ceratobulimina perplea (Plummer) and Epistominoides midwayensis Plummer (Brotzen, 1948, p. 33), is partly invalid, inasmuch as all these species have aragonite tests (Troelsen, 1955b) and therefore could not possibly have been preserved in the limestone of the Danskekalk formation, although they may conceivably have lived in the area in late Danian time. Brotzen’s list of stratigraphically important species is thus reduced to two, viz., Elphidiella prima (ten Dam) and “Allomorpha” (i.e., Quadrimorpha) halli Jennings.

The question of the first appearance of Globorotalia (sensu lato) in relation to the Danian-Montian (or Danian-Selandian) boundary is difficult or impossible to solve on the basis of the evidence of the type Danian. There are two obvious reasons for this: one is the previously mentioned absence of planktonic Foraminifera in the Paleocene (Selandian) stage of Denmark-Sweden (planktonic Foraminifera are likewise practically absent in the type Montian); the other is that Globorotalia probably never reached this Boreal area.

<table>
<thead>
<tr>
<th>TYLOCIDARIS</th>
<th>ZONES</th>
<th>SAMPLE</th>
<th>NUMBER</th>
<th>SPECIMENS</th>
<th>GLOBIGERINA SPECIES</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>davbjergensis</td>
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<tr>
<td>T. vexilifera</td>
<td>Schlüter</td>
<td>I</td>
<td>54</td>
<td>94</td>
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<tr>
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<td>Ravn</td>
<td>V</td>
<td>23</td>
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</tr>
<tr>
<td>T. idumni</td>
<td>Brünnich Nielsen</td>
<td>V</td>
<td>163</td>
<td></td>
<td>1%</td>
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<tr>
<td>no Tylocidaris</td>
<td></td>
<td>V</td>
<td>32</td>
<td></td>
<td>52%</td>
</tr>
</tbody>
</table>

**Figure 24**—Diagram illustrating the vertical distribution of Globigerinae within the Danian stage of east Denmark and South Sweden. Sample numbers: 1, Östra Torp, Sweden; calcarenite, horizon with many sponges. II, Östra Torp, 2 meters below sample I. III, Falke; unconsolidated limy mud (lagoonal deposit) in coral-reef limestone. IV, Boesdal, Stevns Klint; bryozoan limestone filling cavities in chert nodule. V, Boesdal, Stevns Klint; bryozoan limestone filling cavities in underlying cemented calcilutite. VI, N. of Holtug quarry, Stevns Klint; calcilutite. (Reworked specimens of Rugoglobigerina and “Globigerinella” not included.)
(see Bettenstaedt, 1949, p. 156). We have no very
definite evidence as to the temperature of the sea in
Danian time (see Lowenstam and Epstein, 1954, pp.
244, 246). If one keeps these difficulties in mind, the
correlation of the type Danian with what Grimsdale
(1951, fig. 1) terms the "? Danian" of the Middle East
and the "Paleocene—Lower and Upper Midway" of
the Gulf of Mexico-Caribbean area can be made with
a fair degree of accuracy. Bettenstaedt and Wicher's
subdivision of the Danian-Montian into Danish I and
Danian II is undoubtedly practicable for the Tethys
area but can hardly be applied to Denmark-Sweden
or for that matter even to southern Belgium, which
is the type area of the Montian. The present writer
therefore favors a unification of the Danian and the
Montian into one stage.

Acknowledgments

The writer wishes to thank the Danish State Re-
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preparation of the material and of the drafting of the
illustrations. Gratitude is also expressed to the Danish
State Research Foundation, the Rask-Ørsted Foun-
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Copenhagen for having made possible a visit to the
United States National Museum in Washington, where
type specimens were examined. The writer is happy
to acknowledge a debt to Alfred R. Loeblich, Jr., and
Helen Tappan Loeblich for much help, advice, and
hospitality; and to O. L. Bandy, P. Bronnimann,
J. G. Carlsson, C. Drooger, Brooks F. Ellis, H. Hagn,
Philip Morey, Grover E. Murray, A. Nørvang, the late
H. J. Plummer, A. Rosenkrantz, and E. Wind for
material for comparison. Miss Gunni Jørgensen pre-
pared the drawings of the Foraminifera with her usual
skill and care.

Figured hypotypes are deposited in the U. S. National
Museum collections, Washington, D. C. Additional
hypotypes from all samples are in the Mineralogisk-
Geolokisk Museum, Copenhagen, Denmark.

Systematic Descriptions

Globigerina daubjergensis Bronnimann

PLATE 30, FIGURES 1–2

Globigerina daubjergensis Bronnimann, Ecol. Geol. Helvetiae,
? Globigerina daubjergensis Reichel, Ecol. Geol. Helvetiae,
vol. 45, No. 2, p. 344, fig. 1, 1953.
? Globigerina triloculinoides Plummer, Brozeen, Sveriges Geol.

REMARKS: This species occurs throughout the Danian
stage of Scandinavia but is particularly abundant in the
upper part, where it commonly dominates the planktonic
fauna (text-fig. 24). Three topotypes, kindly presented by P. Bronnimann, permitted an accurate
identification of this somewhat variable but nevertheless
distinct species. The constant characters of the species
are (1) the finely spinose wall surface, (2) the trochoid
early chambers, (3) the small and shallow umbilicus,
and (4) the small subcircular aperture which is not
surrounded by a lip and which opens into the umbilicus.
Two main morphological types have been observed,
one of them having a trochoid spire and, in the last
voluton, 4 subglobular chambers which increase gradu-
ally in size; the other, a low spire and 3 to 3 ½ rapidly
increasing chambers in the last volution. The low
spire is commonly produced by an involution of the
trochoid early chambers or by a rotation of the axis
of the test during growth. In the material at hand (a
few hundred specimens), the two types grade imper-
cently into each other, and it has not been possible to
detect any pattern in their stratigraphic distribution
within the type Danian.

Small accessory apertures commonly occur along the
sutures of the final chamber, but the writer has never-
theless refrained from referring the species to the (probably polyphyletic) genus Globigerinoides.

The occurrence of G. daubjergensis in the Midway
group of the Gulf Coastal Plain has been mentioned
above. It may be added that in the Mexia clay member
only small trochoid specimens occur, while in the other
samples large specimens with inflated end chambers are
also present.

COILING RATIO: Zone of Tylcocidaris brunnichi:
Fakse, 56 percent dextral (±5.7). Zone of T. vexilitera:
Östra Torp, south Sweden, sample 1 (see text-
fig. 24), 52.7 percent dextral (±5.2); same locality,
sample 2, 55 percent dextral ±5.8); same locality,
exact level unknown, 40.9 percent dextral (±4.7).

DIMENSIONS: The specimens range in greatest diam-
eter of the test as follows: Basal Danian (Bøgelund and
Stevns Klint), 0.11–0.12 mm.; zone of T. odumi (Stevns
Klint), 0.21 mm.; zone of T. abildgaardi (Stevns Klint),
0.19–0.32 mm.; zone of T. brunnichi (Fakse), 0.19–0.27
mm.; zone of T. vexilitera (Torp, Østra Torp), 0.17–
0.26 mm.

Globigerina pseudobulloidies Plummer

PLATE 30, FIGURES 6–8

Globigerina pseudobulloidies, Plummer, Univ. Texas Bull. 2644,
pp. 133–134; pl. 8, figs. 9a–c, 1926.

REMARKS: The specimens from the Danskkekalk
formation have been compared with a large number of
specimens of typical G. pseudobulloidies (some of them
identified by H. J. Plummer) from various parts of the
Midway group of the Gulf Coastal Plain. Although the
Danish specimens fall within their range of variation,
they differ so much from the majority of the topotype
specimens that it is considered desirable to add the
following partial description:

Spiral side flattened, initial whorl either slightly
compressed or somewhat convex. Umbilical side strongly
convex. Umbilicus very narrow. Periphery moderately to strongly lobate and broadly rounded. Chambers inflated, 9–13 in number, all visible spirally, only 4 to 4½ (very rarely 5) of last whorl visible on umbilical side. Sutures distinct and depressed, straight and radial except in initial whorl where they are curved backward. Wall calcareous, thin, finely perforate, practically always perfectly smooth. Aperture large, an arch at base of final chamber, extending from umbilicus to a point near periphery, bordered by distinct lip. Aperture of penultimate chamber occasionally visible in umbilicus. Gerontic specimens develop strongly inflated chambers in last whorl; final chamber is displaced toward umbilical side, and occasionally carries accessory aperture on spiral side.

This species is characteristic of theDanian stage in Denmark and Sweden and does not occur in the underlying Maestrichtian White Chalk. In the basal part of the overlying Selandian beds, reworked (?) specimens have been observed.

The present form might be considered a chronological subspecies, but it might also be a geographical subspecies, produced by the hydrographic conditions in the enclosed Danian sea (cfr. G. bulloides, which according to Brady (1884, pl. 79, figs. 1–7) develops a dwarfed and smooth (?) test near the British coast).

COILING RATIO: Basal Danish: Bøgelund, 49. percent dextral (±4.9); north of Holtug quarry, Stevns Klint, 48. percent dextral (±9.). Zone of Tylocidaris odumi: Højerup, Stevns Klint, 56.9 percent dextral (±6.); Boesdal, Stevns Klint, 51. percent dextral (±3.9). Zone of T. brünichii: Fakse, 76.9 percent dextral (±11.7).

DIMENSIONS: Specimens range in greatest diameter of the test as follows: Zone of Tylocidaris odumi (Stevns Klint), 0.29–0.34 mm. (gerontic specimens, 0.40 mm.); Zone of T. odumi (Hjerm), 0.26–0.34 mm.; Zone of T. abildgaardii (Stevns Klint), 0.17–0.19 mm.; Zone of T. brünichii (Fakse), 0.17–0.20 mm.; Zone of T. vexilifera (Östra Torp), 0.16–0.24 mm.

Globigerina triloculinoides Plummer

Plate 30, Figure 4
Globigerina triloculinoides Plummer, Univ. Texas Bull. 2644, pp. 134–135, pl. 8, fig. 10, 1926.

REMARKS: The distinctive features of this highly variable species are (1) the pitted (reticulate) surface, (2) the inflated, globular chambers, (3) the small and shallow umbilicus, and (4) the small aperture, which is covered by a distinct lip.

The occurrence of the species in the Midway group of North America has been mentioned above.

The species reported by Brotzen (1948) from the Danian stage of Sweden as G. triloculinoides has a somewhat trochoid spire and the volutions increase more slowly in width than do those of the typical G. triloculinoides. Brotzen’s specimens may perhaps be referable to G. daubjergensis Bronnimann.

COILING RATIO: Zone of T. brünichii: Fakse, 100 percent dextral (11 specimens counted). Zone of T. vexilifera: Östra Torp, south Sweden, sample 2 (see text-fig. 24), 47.8 percent dextral (±7.); same locality, exact level unknown, 81.8 percent dextral (±11.6). Additional data are needed before the question of the variation in coiling ratio of this species can be satisfactorily answered.

DIMENSIONS: Specimens range in greatest diameter of the test as follows: Zone of Tylocidaris odumi (Hjerm), 0.20–0.27 mm.; Zone of T. brünichii (Fakse), 0.19–0.22 mm.; Zone of T. vexilifera (Östra Torp), 0.14–0.26 mm.

Globigerina compressa Plummer

Plate 30, Figure 5
Globigerina compressa Plummer, Univ. Texas Bull. 2644, pp. 135–136, pl. 8, fig. 11, 1926.

REMARKS: Bronnimann (1953) placed this species in the genus Globorotalia, but the present writer agrees with Brotzen (1948, p. 90) that it should be referred to the genus Globigerina as inasmuch as it possesses “a distinct umbilicus and umbilical apertures, covered by small lips on the base of the last chambers.” This character also has been observed in specimens from the Mexia clay member of the Wills Point formation (Upper Midway group). There is good agreement in all respects between the specimens from the Danskekalk formation and those from the Midway group.

COILING RATIO: Zone of Tylocidaris odumi: Hjerm, only 3 specimens available. Zone of T. vexilifera: Östra Torp, south Sweden, sample 1 (see text-fig. 24), 1 specimen; same locality, sample 2, 50 percent dextral (±14.); same locality, exact level unknown, 63.6% dextra (±14.5).

DIMENSIONS: Specimens range in greatest diameter of the test as follows: Zone of Tylocidaris odumi (Hjerm), 0.22–0.26 mm.; Zone of T. vexilifera (Östra Torp), 0.16–0.30 mm.
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Said, R.

Schweighauser, J.

Tøbeløn, J. C.
A Revision of the Foraminiferal Family Heterohelicidae

By Eugenia Montanaro Gallitelli

Introduction

The family Heterohelicidae, as established by Cushman (1927a), is accepted at present by only a few authors (Coltom, 1946, Le Calvez, 1953), and they agree to accept it only provisionally. Cushman included in the family an homogeneous group of genera related to the type genus, Heterohelix, but he also placed in it a number of forms which actually should have been placed among the "incertae sedis" because of transitional or poorly known morphological or anatomical characters.

Emendations of this family of considerable interest have been proposed in revisions of the systematics of Foraminifer by Galloway (1933), and chiefly by Glaessner (1936, 1937, 1945), followed without fundamental change by Sigal (1952) and Pokorný (1954). But many conclusions are still unsatisfactory.

The analytical research of Loeblich (1951) on the coiling in some Heterohelicidae, and by Hofker (1951a) concerning the toothplate in Bolivinida and Bolivinoides, must be mentioned as indicative that this confusion is partially due to an absence of knowledge of morphological and structural characters of many genera of fundamental significance in the systematics of this family. A careful restudy of all the type species is required before a new systematical arrangement can be proposed.

Acknowledgments

A grant from the Italian National Research Council and a Fulbright travel grant allowed the writer to make this study at the National Museum in Washington. The writer found the collections and library facilities there to be the best available anywhere for such a study. And above all, the writer is deeply indebted to Dr. Alfred R. Loeblich, Jr., for his assistance and suggestions during her stay and study in Washington, for suggesting the present research topic, and for allowing the use of his undescribed material and illustrations. Dr. Helen Tappan Loeblich has kindly read, corrected, and edited the manuscript and has discussed with the writer various systematic and morphologic questions in connection with this research.

Illustrations are camera-lucida drawings made by Mr. Lawrence B. Isham and Mrs. Patricia Isham, scientific illustrators, U. S. National Museum.

Material Examined

The recent visit of the writer to Washington made possible a reexamination of all the types of the Heterohelicidae Cushman, then deposited in the U. S. National Museum; almost all the type species of the various genera are there represented. Of the type species 11 are represented by holotypes, 7 by paratypes or topotypes and 5 by hypatypes. Other congeneric species more or less related to these type species have also been restudied when necessary.

The type species of Heterohelix Ehrenberg (H. americana (Ehrenberg)) and of Plectofrondicularia Liebus (P. concava Liebus) are not available; consequently, some well known related species were examined (Heterohelix navarroensis Loeblich and Plectofrondicularia garzaensis Cushman).

Three genera (Bolivinopsis Yakovlev, Nodomorphina Cushman, and Nodogenerina Cushman) are represented in the Museum only by doubtfully congeneric species; of these Bolivinopsis is considered an arenaceous form by Pokorný and Sigal; thus these genera have not been taken into consideration here.

The following genera have been invalidated in the present research: Guembelina Egger (=Heterohelix Ehrenberg), Rectoguembelina Cushman (=Tubitectularia Sulc), Ventilabrella Cushman (=Planoglobulina Cushman), Bronnivannella Montanaro Gallitelli (=Pseudotextularia Rzehak).

Three related and more recently described genera, which were not included in the Heterohelicidae by Cushman, are added for discussion: Tosaia Takayanagi, Tappanina Montanaro Gallitelli, and Trachelinella Montanaro Gallitelli.

The genus Pseudotextularia Rzehak is emended and a new genus, Racemiguembelina is proposed.

Method of Study

The examinations were made by use of the highest magnification (X 216) available for the stereobinocular. The previous use solely of low magnifications explains many of the misinterpretations in these extremely small Foraminifera.

When the arrangement of the early chambers was not otherwise clear, specimens were immersed in anise oil, a method found to be very successful in emphasizing

1 University of Modena, Italy.
the inner structures, although any trace of external feature then becomes temporarily concealed. It is therefore difficult to make a comparative examination between external sculpture and internal arrangement of the chambers by this method.

In studying the internal structures (inner characters of the wall, columnar process, toothplate, cribrate or radiate feature of the aperture) the best results were obtained by dissection by use of dilute hydrochloric acid mixed with a small quantity of gum tragacanth glue (a method used and described by Troelsen). This method avoids a dangerous extension of the dissolution of the test as may happen when diluted acid is used alone on very tiny tests. Some of the specimens here illustrated represent dissections obtained by this method, which in many cases can be substituted advantageously for the use of thin sections, and this has made possible many corrections to previous structural interpretations.

Statistical method was only occasionally applied, for it is hardly applicable in many cases, due to the small size of the specimens and the lack of measurable elements. It was used in the investigation of the genus *Gumbelina*, in order to establish the percentage of coiled specimens in the different species and so to evaluate the validity of that genus in comparison with *Heterohelix*. For this purpose, more than 3,000 specimens were statistically examined.

**Systematic Relationships**

With regard to previous interpretations of the relationships in the Heterohelicidae, Cushman (1927a, p. 59) described the family Heterohelicidae as follows: "Test in the more primitive forms planospiral in the young, later becoming biserial, in the more specialized genera the spiral stage and even the biserial stage may be wanting and the relationships shown by other characters; wall calcareous, perforate, ornamentation in higher genera bilaterally symmetrical; aperture when simple, usually large for the size of the test, without teeth, in some forms with apertural neck and phialine lip." With a range of variability as great as thus stated, almost every perforate foraminifer could be included. In contrast with this too wide allowance of systematic variability for the family, very subtle generic distinctions were accepted between very closely related forms, such as *Heterohelix* and *Gumbelina*, which were placed by Cushman in two different subfamilies because of a distinct early coil in the first and less frequent early coiling in the latter.

Galloway (1933, p. 342) notes with some humor that "It would be possible to consider the whole group as one without subfamilies, or to make nearly as many subfamilies as there are genera, depending upon the caprices of the systematist." But some of these genera are quite unrelated. The positions of Pseudiovigerina and Siphogenerinoides were corrected by Galloway, but no substantial changes to the general arrangement of the family were suggested.

Glaessner (1936, p. 126) divided the Heterohelicidae, sensu stricto, into two subfamilies: the Heterohelicinae, containing *Heterohelix* and *Spiroplectodes*, and the Gumbelininae, including *Gumbelina*, *Gumbe- linia*, Tubitextularia, and Pseudotextularia.

Later, Glaessner (1945, p. 86) observed: "A few families such as the Heterohelicidae and Cassidulinidae are artificial as they include genera whose structural and genetic affinities lie elsewhere." He separated some of the Heterohelicidae of Cushman into two different superfamilies: Rotaliidea (in which he placed the Gumbelinidae near the Globigerinidae and Hantkeninidae) and Buliminidea, family Buliminidae (in which he placed the subfamilies Bolivininae, Plectofrondiculariinae and Uvigerininae). In this publication he used the family name Gumbelinidae, in place of Heterohelicidae. Glaessner's subdivision was the greatest advance to date in the systematics of the so-called Heterohelicidae, for unrelated forms were here definitely separated from the globular-chambered forms related to *Heterohelix*.

Sigal (1952) and Pokorny (1954) followed Glaessner's classification in general, both these authors place the family Gumbelinidae (with *Gumbelina*) in the superfamily Rotaliidea, and place the family Heterohelicidae (with *Heterohelix*) in the superfamily Buliminidea. They continued to interpret Bolivinida, Bolivinella, and Bolivinella as an homogeneous group within the Heterohelicidae.

The recent tentative classification of a group of Heterohelicidae from the Upper Cretaceous of the Pyrenees, made by Kikoïne (1948), is based upon such erroneous interpretations as the biseriality of *Gum- belina*. Moreover, Kikoïne considered only six genera, leaving undisputed the trio Bolivinida, Bolivinoides, and Bolivinella, and he failed to discuss their most important characters.

No systematic rearrangement is possible without a previous revision of the genera on the basis of their type species. In this connection some recent contributions must be mentioned. Loeblich (1951) emphasized and illustrated the presence of coiling in "Gum- belina," and "Ventilabrella," and noted the biserial, rather than triserial, initial stage in *Equiigerina*. Hofker (1951b) examined the structure of Bolivinoides and the "toothplate" in *Bolivinida*, discussing new morphologic elements. Stone (1946) described the inner structure of Siphogenerinoides in comparison with Siphogenerinera.

These few analytical contributions clearly demonstrate the exactness of the statement by Loeblich (1951, p. 106) that "few families among the Foraminifera contain genera as poorly known as are several genera belonging to the family Heterohelicidae."

**Basis of Present Revision**

The following variable elements have been considered in this study: (1) Coiling in the early stage; (2) shape of the test and arrangement of chambers in neanic and adult stage (acceleration, etc.); (3) position and shape
of the aperture; (4) presence, development and shape of the “toothplate” or columellar process.

Coiling in the early stage is present more or less frequently in: *Heterohelix americana* (fide Ehrenberg), *H. navarroensis*, *Guembelina globulosa*, *G. globocarinata*, *G. planata*, *G. striata*, *G. glabrans*, and *G. pseudotesserata* (=*G. pulchra* Brotxen). Both *Heterohelix navarroensis* and *Guembelina* spp. also have a variable percentage of specimens with the early stage uncoiled. Considering that no other differences previously separated *Guembelina* from *Heterohelix* (Galloway 1933, p. 343) states that “*Guembelina* differs from *Heterohelix* only in the absence of the spiral, early stage”), there is no further reason to uphold their generic separation: consequently *Guembelina* Egger is here considered a junior synonym of *Heterohelix* Ehrenberg.

An occasional or constantly coiled early stage in *Tubitextularia*, *Pseudotextularia*, *Gublerina*, *Pseudoguembelina*, *Planoglobulina*, and the new genus *Racemi-guembelina* is here demonstrated. This character is documented for each genus in the illustrations.

Loeblich (1951) demonstrated that *Eovigerina* has no coiling in the early stage. This observation is confirmed by the present investigation and in addition three other genera, described previously as “coiled,” are demonstrated to be constantly and clearly biserial: *Bolivina* (according to Cushman (1929, p. 28) “in the microspheric form the young [is] apparently planispiral”), *Bolivinoides* and *Plectofrondicularia*. Among the “*Heterohelicidae*,” therefore, coiling is present only in the genera related also by other characters to the genus *Heterohelix*.

The exact position and shape of the aperture is here described for each genus. This important character has been neglected or erroneously described in some genera; in others neither the description nor the figures give any indication as to the aperture characters. The present investigation, involving some thousands of specimens demonstrates that (1) the genera closely related to *Heterohelix* have a simple basal arched aperture as previously described; of this group, only the unclassified genus *Tubitejstularia*, with an adult uniserial stage, has an obviously terminal aperture and this is always simple, without a lip; (2) a basal aperture with lip is present in *Bolivinoides*, *Bolivinula* (the drawings by Hofker are discussed in the systematic description), and *Tappania*; (3) a simple, open terminal aperture is present in the genera *Eovigerina* and *Trachelinella*; (4) a terminal aperture, reduced to an elliptical opening by internal tubercles or costae, is observed in *Bolvinini-tella* and *Plectofrondicularia*; and (5) a radiate cribrate aperture is observed in *Amphimorphina* and a typically cribrate aperture seems to be occasionally present in *Bolvinella*.

No internal columellar processes (the “toothplate” of Hofker) were mentioned by Cushman (1927a, p. 64) for this family but Hofker (1951b) recently described the “toothplate” in *Bolivinula* and, less carefully, in *Bolivinoides*. Stone (1946) illustrated the same character for *Siphogenerinoides*. In the present investigation an internal process is also demonstrated for *Eovigerina* and *Pseudouvigerina*. *Bolivinoides* has no “plate” but a continuous tube arising from the first chamber. *Bolivinula* has a “plate” (spout) which is extremely variable in shape, size, concavity, position in the apertural cavity, and development in the final “spatula.” In *Siphogenerinoides* the internal “tube” is actually a spoutlike discontinuous interapertural process, whose single divisions alternate in opposite tangential positions to the aperture, with the concavity always turned towards the wall. This character gives a peculiar appearance to the apertural outline, which was misinterpted by Stone. *Eovigerina* has a very thin columellar process, apparently tubular and continuous, beginning with the youngest stage. *Pseudouvigerina* has a discontinuous spoutlike process, which is very clear in the final chamber. Such a great variability of this inner skeleton seems to require further study in order to establish its value in the systematics of Foraminifera.

The internal characters of the wall in the genus *Bolivinoides* were investigated by Hofker (1952), and some corrections of his observations concerning the morphology and structure of the septa are given here. In addition, it is noted here that the internal surface of the wall is irregularly tuberculate, a most distinctive peculiarity of this genus, which is thus considered entirely valid, and not synonymous with *Bolivina* as affirmed by Hofker (1951b), Glaessner (1945), Sigal (1952), and others.

Morphological Types Recognized

The present revision does not presume to give a satisfactory reclassification of all the 23 genera included by Cushman (1948) in the family *Heterohelicidae*. A complete revision of all the type species and of a large number of specimens is necessary; the same has to be done for the related families and superfamilies of Foraminifera and the results compared. Moreover we do not know at present which character or characters in the Foraminifera have an actual genetic value, and in this respect the research of Arnold, Grell, and others on living Foraminifera is welcome.

It is possible here only to give an emendation of the family *Heterohelicidae*, and a short systematic discussion of the other genera formerly included in that family, with some new information as to their structural details.

Many specimens, in addition to those here illustrated, were partially acid-treated in order to show series of transitional forms and structural details. It was impossible to illustrate all these, hence references to these additional slides in the collections of the U. S. National Museum, are given in the systematic descriptions.

The terminal aperture is found in this family, as here restricted, only as an expression of an accelerated development from a typical “guembelinioid” genus, as in *Tubitejstularia pulex* (= *Rectoguembelina Cushman*) where the first heterohelicoid stage is clearly visible. Five different morphological types are distinguishable:
(1) triserial (subfamily Guembelitrininae)
(a) constantly triserial
   Guembelitria
(b) with proliferation
   Guembelitriella

(2) biserial or planispiral (subfamily Heterohelicinae)
(a) with average proportion of thickness to breadth 1:2
   Heteroheliz
   Pseudoguembelina
   Tubitexularia
(b) proliferation in the adult stage, average proportion of thickness to breadth = 1:1
   Racemiguembelina
(c) frequently planispiral in early stage then proliferated, average proportion of thickness to breadth
   1:4 to 1:7
   Guembelina
   Planoglobulina
(d) planispiral and biserial, average proportion of thickness to breadth 1.5:1 to 4:1
   Pseudotexularia

Bolivinella, Plectofrondicularia, and Amphimorphina have in common an early biserial stage (continued to the mature stage in Bolivinella), absence of a columellar process, aperture reduced by tuberculations or even subcircular.

The subfamily Plectofrondicularinae Cushman can be maintained, but it has no relationship to the Heterohelicidae as presently emended. We do not know how closely the apertural character is concerned with conditions of life, but the shape of the test, the biserial early arrangement of the generally flat chambers, the peculiar reduction of the lumen in the aperture, and the lack of a columellar process have led us to here consider the former subfamily Plectofrondicularinae as a distinct family, the Plectofrondicularidae.

Bolivinita Cushman, Bolivioides Cushman, and Tappanina Montanaro Gallitelli are interrelated by having the test biserial, costate or carinate; chambers not globular; aperture basal, central, narrow. Columellar processes are sinuous and discontinuous. Bolivinitella Marie is only an example of convergence with Bolivinita, and must be separated from this quite different group, as is discussed more fully below. These three genera belong to the subfamily Bolivinitinae.

The subfamily Eouvigerininae (type genus Eouvigerina Cushman) is placed within the family Buliminae after the subfamily Bolivinitinae. The original description of Eouvigerina is also emended, with description of an internal columellar process.

Siphogenerinoides Cushman is initially biserial, not triserial as formerly described, and must be placed only provisionally near the Eouvigerininae until more information is available as to the genetic value and the ratio of variability of the columellar process. Also, its placement in the family Plectofrondicularidae seems at present at least premature because of the substantially different structure of the columellar process. The name Siphogenerinoides is not exact from the point of view of the character it recalls, as the columellar process is not a siphon but a large discontinuous spout.

Zeouvigerina Finlay, Trachelinitella Montanaro Gallitelli, and Bolivinitella Marie are biserial, with apertural neck, without columellar process, and are still incertae sedis, perhaps near the Bolivinidae, from which they are distinguished by the terminal aperture and neck.

Of the Tertiary Tosaia Takayanagi only three paratypes were examined. It is possible that there is a trochoid initial stage, but this requires further investigations. All the specimens seem have a quite buliminoid aperture. There is no relationship to Guembelitria or other true Heterohelicidae; on the other hand a relationship with the Buliminidae seems quite probable.

Pseudouviigerina Cushman must be placed unquestionably in the Uvigerininae, as was done by Glassner (1945). It has a triserial test, terminal aperture with neck and lip, columellar process, and longitudinal ornamentation. The genus is closely related to Angulogerina.

Systematic Descriptions

Family Heterohelicidae Cushman, 1927, emended

Test calcareous, perforate; chambers inflated, spheroidal, globular or reniform; early stage either planispiral, biserial, or triserial, not trochoid; serial reductions or proliferations are occasionally present; aperture relatively large, simple and basal in biserial or triserial forms, terminal only in accelerated uniserial forms. Columellar processes absent.

Subfamily Guembelitrininae Montanaro Gallitelli, new subfamily

Test triserial; chambers globular; aperture basal, arched, simple.

Genus Guembelitria Cushman, 1933

Plate 31, Figures 1, 2


Type species: Guembelitria cretacea Cushman, 1933,

Upper Cretaceous Navarro (Maestrichtian), from pit of Seguin Brick and Tile Company, 0.8 mile south of McQueeney Station, Guadalupe County, Texas.

Diagnosis: Test calcareous, triserial. Chambers generally globular, more or less regularly aligned in three series throughout development. Aperture basal, arched, simple.

Discussion: An examination of all the specimens of Guembelitria in the U. S. National Museum shows that neither initial coil nor initial biserial stage are present. Only a single specimen is dubious, but even when immersed in anise oil it does not give the appearance of a true biserial initial stage.

On the other hand, specimens where the alignment of the three series of chambers is irregular are not rare. Guembelitria vivans Cushman, a living form, is not a true Guembelitria, although triserial and with globular chambers. The aperture is extremely narrow, elongated perpendicular to the suture, and turned inwards, as in certain Buliminidae (see fig. 2). Guembelitria
minuta Natland, also living, is not a Guembelitria but because of the clearly trochoid coiling probably is a Globigerinid.

Genus Guembelitriella Tappan, 1940

Plate 31, Figures 3, 4


Type species: Guembelitriella graysonensis Tappan, 1940, Cretaceous Grayson formation (Cenomanian), from Grayson Bluff, 3½ miles northeast of Roanoke, Denton County, Texas.

Original diagnosis: “Test free, small, triserial in the early stage, similar to Guembelitria, later becoming multiserial on the top; chambers globular, increasing rapidly in size; sutures distinct, depressed; wall calcareous, finely perforate; aperture at base of the final chamber.”

Discussion: No addition to the diagnosis given by Tappan is necessary. This genus is a further development from Guembelitria, becoming multiserial in the adult, a development parallel to that shown by Planoglobulina from the Heterohelix group. Consequently, the separation of this genus by Tappan has the same validity as the separation of Planoglobulina from Heterohelix. It is of some interest that Tappan also noted the presence of accessory apertures in this genus. A discussion of this general character is given in the discussion of Pseudo guembelina Bronnmann and Brown.

Subfamily Heterohelicinaceae Cushman, 1927

Genus Heterohelix Ehrenberg, 1841

Plate 31, Figures 5–20


Type species: Spiroplecta americana Ehrenberg, 1844, Cretaceous, from Missouri and Mississippi, North America (not since recognized).

Diagnosis: Test calcareous, biserial or planispiral in the early stage, always biserial in the adult stage. Chambers generally inflated, globular to reniform. Wall calcareous, perforate, surface smooth or striate. Aperture basal, relatively large, with simple margin.

Discussion: Heterohelix and Guembelina were considered by Cushman (1927a, p. 59) as representative of two different subfamilies of the Heterohelicidae, i.e., Heterohelicinae and Guembelininae. The distinctive character was considered to be the presence in the Heterohelicinae of a coiled early stage, “forming a considerable portion of the test.” For Guembelina, the test was indicated as “in the early stage of the microspheric form planispiral, often skipped in the megalo- spheric form.”

Galloway (1933, p. 343) adopted the same systematic subdivision, stating that Guembelina “differs from Heterohelix only in the absence of the spiral, early stage.” Glaessner (1945) does not cite the genus Heterohelix.

Sigal (1952) even placed Heterohelix and Guembelina in two different superfamilies. Heterohelix he placed in the superfamily Buliminidea, family Heterohelicidae, subfamily Heterohelicinaceae, with Bolivinopsis and Nodoplanus—and included in the family the two subfamilies Bolivinitinaceae and Plectofrondiculariinae of Cushman, emended. Guembelina was placed in the superfamily Rotaliidea, family Guembelinnidae, between the families Globorotaliidae and Elphidiidae.

Thus, the previous separation of the two genera was based substantially on the presence of a well-developed, coiled early stage in Heterohelix, and rare or no coiling in Guembelina.

Loeblich (1951) published a discussion of the phylogenetic relationships of the Heterohelicidae of Cushman, and illustrated specimens with a coiled early stage not only in Heterohelix, but also in Guembelina (G. globulosa (Ehrenberg)), and Ventilabrella (=Planoglobulina) (V. carseyi Plummer). Concerning G. globulosa he noted (1951, p. 108) “an extremely tiny initial coil of about five chambers, followed by 11 to 12 biserially arranged chambers,” and for Heterohelix (1951, p. 107) “five to six chambers of the coil,” with “six to eleven biserially arranged chambers.” For the present study, more than 3,000 specimens of Heterohelix and Guembelina were examined under high magnification (x 216) and, when necessary, also by immersion in anise oil. No critical examination was made of the validity of the numerous species of both Heterohelix and Guembelina, as this was aside from the main purpose of this study; therefore, in the following lists there may be some specific names which may later be proven to be synonymous. The total number of specimens examined, and the number and percentage of specimens with an initial coil are given below for the various species:

<table>
<thead>
<tr>
<th>Name</th>
<th>Specimens</th>
<th>Number coiled</th>
<th>Percent coiled</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. globulosa</td>
<td>447</td>
<td>113</td>
<td>25.3</td>
</tr>
<tr>
<td>G. globocarinata</td>
<td>1,067</td>
<td>175</td>
<td>16</td>
</tr>
<tr>
<td>G. carinata</td>
<td>4</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>G. planata</td>
<td>5</td>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>G. striata</td>
<td>130</td>
<td>5</td>
<td>3.8</td>
</tr>
<tr>
<td>G. glabrana</td>
<td>6</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>G. reussi</td>
<td>2,000</td>
<td>12</td>
<td>0.5</td>
</tr>
<tr>
<td>G. pseudotessera (= G. pulchra)</td>
<td>137</td>
<td>8</td>
<td>3.9</td>
</tr>
<tr>
<td>G. eubensis</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. ultimatumida</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. venezuelana</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. trinitatensis</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. wilcoxensis</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is necessary to remark, in considering these statistical data, that only the specimens with absolutely clear coiling are indicated in the percentage of the spiral forms. Many specimens have an asymmetrical enlargement of the test, with a slightly curved initial stage and sometimes an additional asymmetrical chamber near the proloculus. Nevertheless they were not added to the “spiraling” list. Many specimens from the early upper Cretaceous (ex. G. moremani Cushman) have a poorly preserved test, commonly
crystallized, so that a determination of the early stage is almost impossible. Many specimens have a very tiny coiled stage and the two or three tiny chambers below the proloculum may be partially or entirely destroyed, resulting in a falsely biserial appearance. Examples of this modification are not rare in the collection. In spite of these negative elements, and of the precautions taken in the statistical examination, the percentage of coiled specimens in more than 3000 specimens of Guembelina is only 8.2 percent, a value that, with further investigation, may increase but will not decrease. Guembelina globulosa, G. globocarinata, and G. planata, are the most closely related by general shape to typical Heterohelix. In G. globulosa 25 percent of the specimens are coiled; in G. globocarinata, 16 percent. In many cases the well-developed specimens also have well-developed coiling. Nine of the 14 species of Guembelina examined may have a clearly coiled early stage, and although most of the paratypes of Heterohelix navarroensis Loeblich were found to be coiled, some uncoiled specimens also occur in this species.

In the present study only the early Cretaceous Guembelina have been found to be without coiling in the early stage, or show it only rarely. The name Heterohelix could thus possibly be restricted to only the coiled forms of the uppermost Upper Cretaceous. However, the name Guembelina could not be used for the uncoiled species of the Lower Cretaceous because the type species of Guembelina shows an early coil and is late Upper Cretaceous in age.

Morphologically, their separation is also unwarranted, because not only Guembelina and Heterohelix have an early coiled stage, as was demonstrated previously by Loeblich for Guembelina and Ventilabrella (= Planoglobulina), and as the present study has shown also for Tubotextularia, Pseudoguembelina, Gublerina and Raccemiguembelina. Furthermore the entire group of the biserial Heterohelicidae (Guembelina-Heterohelix) are homogeneous in all other characters: the chambers tend to become globular, the surface may become striate by the alignment of the very fine spines in thin striae; there may be an initial coil of as many as 5 to 6 chambers, and there is a simple aperture.

Other differences are only minor, such as the statistically larger number of biserial chambers in Guembelina (in fact Loeblich cites Heterohelix navarroensis with 11 biserial chambers also, and the present writer observed a specimen of G. globulosa (Cushman Coll. 24400), with only four chambers following the coil), and the larger frequency of coiled specimens in Heterohelix (which has however fewer representatives in species and specimens). These differences can only justify specific separation. Consequently Guembelina cannot be separated from Heterohelix as representing a different superfamly, family, or subfamily, and is not even a distinct genus. As Heterohelix has priority, the name Guembelina must be considered a junior synonym.

**Genus Pseudotextularia Rzehak, 1891, emended**

**PLATE 33, FIGURE 6**


**Type species:** Cuneolina elegans Rzehak, 1891. Fixed by subsequent monotypy, Rzehak, 1891. From the Upper Cretaceous (Altierttiar, Paloegean), glaukonitisher Tegelsand, from Bruderndorf, Niederosterreich, Germany.

**Diagnosis:** Test calcareous, generally coiled in the early stage, later biserial, cuneiform, chambers rapidly increasing in size as added. Later chambers increase very rapidly in thickness and become comparatively strongly compressed laterally, so that the original proportion of breadth to thickness is inverted, reaching an extreme of 1:4. The last chamber may be deflected from the normal biserial alignment and become nearly central in position. Aperture broad, becoming almost linear in the most apressed forms. Aberrant specimens may have an additional smaller aperture at the top of the last chamber.

**Discussion:** The generic name *Pseudotextularia* was first used by Rzehak (1886, p. 8) for a form resembling Textularia, but regarded as either a monstrosity or a new genus. No species were placed in the genus until 1891 (p. 4) when Rzehak described *Cuneolina elegans,* remarking that it should perhaps be placed in a distinct genus, for which he had previously proposed the name *Pseudotextularia. Cuneolina elegans,* as the first species placed in the genus, thus becomes the type species, as was noted by Ellis and Messina (1940), being designated by subsequent monotypy. Rzehak included in this species both biserial forms and those with chamber proliferation. He later (Rzehak, 1895, p. 217) described *Pseudotextularia varians,* but as he included his earlier *Cuneolina elegans* in its synonymy, *P. varians* is an invalid synonym. This publication gave the earliest illustrations, the figs. 1a, b being of a biserial specimen, and figs. 2, 3 showing a form with chamber proliferation at the top. This description considered the biserial form to represent a youthful stage of a species whose adult form was proliferated. Later workers considered them to represent two different species, and White (1929, p. 40) restricted *Pseudotextularia varians* to the figs. 2, 3 of Rzehak, and placed the biserial form (Rzehak's figs. 1a, b) in *Guembelina elegans* (Rzehak).

Galloway (1933, p. 348) considered *Pseudotextularia varians* to be the type by monotypy of *Pseudotextularia,* also considering Rzehak's fig. 1 to be of *Guembelina elegans;* in this he was followed by later writers (Cushman, 1948, p. 256; Pokorny, 1954, p. 245).
Glaessner (1936, p. 99) considered varians to be only a variety of elegans, and copied Rzehak's figs. 1a, b as typical Pseudotextularia elegans, Rzehak's fig. 2 as P. elegans var. varians, and Rzehak's fig. 3 as P. elegans var. acerulinoides (Egger). Glaessner included within Pseudotextularia Rzehak, 1891, both the forms with and without proliferation, included therein by Rzehak, and also the genera Planoglobulina, 1927, and Ventilabrella Cushman, 1928, which also show chamber proliferation. Ventilabrella is here considered to be a synonym of Planoglobulina, but the latter is regarded as distinct from both Pseudotextularia and the new genus here described as Racemiguembelina.

As mentioned above, the type species of Pseudotextularia is Cuneolina elegans, and the lectotype of the type species is Rzehak's figs. 1a, b from the description of Pseudotextularia varians. As mentioned above and as noted by Ellis and Messina (1940), P. varians is merely a junior synonym of C. elegans, and the proliferated form requires a new name.

Following the earlier but erroneous type designation by Galloway, Cushman, Ellis and Messina, and others, the present writer recently proposed the generic name Bronnimannella for the biserial species with later lateral compression, type Guembelina plummerae Loetterle. The designation of the type specimen of Pseudotextularia elegans as Rzehak's fig. 1 of the 1895 publication, makes the species Guembelina plummerae Loetterle a junior synonym, as it is of similar size, proportions and ornamentation. Thus, the type species of Bronnimannella is conspecific with the type of Pseudotextularia, and the generic name Bronnimannella becomes a junior subjective-objective (genotype species are believed to be the same) synonym.

The early stage suggests the relationship of Pseudotextularia to Heterohelix, but in the mature test a gradual but complete change occurs in the proportion of breadth to thickness, with extreme specimens having the proportion of breadth to thickness of 1:4. Possibly another species could be separated, representing the maximum lateral constriction (1:5:5), but a careful investigation of several hundred specimens of the species did not show any sharp discontinuity between the moderately and strongly compressed specimens, although the two extremes look quite different in shape. The ornamentation consists of similar axial ridges, sometimes more prominent in the young stage, and the initial coil is frequent both in the less and in the more compressed forms. Also the deflection of the final chamber to a central position is found in specimens of both extremes of the lateral compression. An example with final central chamber was illustrated recently as Bronnimannella plummerae (Loetterle) (by Montanaro Gallitelli, 1956) and hence is not here figured.

The constant characters of this genus are a distinctive lateral compression of the test, of great or lesser intensity, culminating in an inversion of the usual proportion of breadth to thickness as known for the Heterohelicidae; and a biserial arrangement of the adult chambers.

Pseudotextularia differs from Planoglobulina in the inversion of the proportions of lateral compression of the test, and an absence of chamber proliferation. Racemiguembelina, new genus, is separated from Pseudotextularia by the conical shape (proportion of breadth to thickness of 1:1) and the crown of chamberlets at the top of the test.

The perfect preservation and the normal increase in the young stage of all the specimens exclude the possibility of mechanical deformation of the test during fossilization.

Kikoine (1948, pl. 1, figs. 5 and 8) figured specimens of this genus from the Upper Cretaceous of Hendaye and Gars (Southern Pyrenees). He interprets the specimen of his figure 5 as a new variety of Guembelina striata (Ehrenberg), G. striata var. deformis Kikoine, and noted that this variety represents "l'aboutissement de l'évolution de G. plummerae," and that only the ornamentation of the variety is comparable with the species striata. The figures given by Kikoine clearly show his form to be identical with G. plummerae (=Pseudotextularia elegans), and his variety invalid.

Genus Pseudoguembelina Bronnimann and Brown, 1953

PLATE 31, FIGURES 21–23


TYPE SPECIES: Guembelina exocolata Cushman, 1926. Upper Cretaceous Mendez shale, from Mexico.

DIAGNOSIS: Test biserial, rarely may be coiled in the early stage; chambers subglobular, becoming lobate in the mature test and compressed laterally near the aperture. Wall calcareous; surface with straight longitudinal costae. Aperture arched, sinuous, extended down into the lateral lobes of each mature chamber, and producing a sort of accessory aperture which may be covered by tiny flaps.

DISCUSSION: The presence and the frequency of accessory apertures in the different genera of the Heterohelicidae has been studied, as a basis upon which to confirm or deny the validity of the genus Pseudoguembelina. Accessory apertures may occasionally be present in the penultimate or last chamber of various globose species, but it is always a rare feature. Such is the case for Guembelina striata, where the accessory apertures are not the rule. Rare accessory apertures were also observed by Tappan in Guembelitricella Tappan, are not rare in Ventilabrella, and can also be observed in Pseudotextularia elegans (Rzehak). Consequently, as this character is not constant, with related peculiarities of shape and position, and as it is not accompanied by other constant morphological or structural characters, it cannot be accepted as a character of generic importance.

However, in Pseudoguembelina costulata (Cushman),
P. excolata (Cushman) and P. palpebra Bronnimann and Brown, the accessory apertures are present from the very first stages, are connected with a peculiar feature of the chambers, and, finally, have a quite different appearance from the accessory apertures we observe occasionally in other Heterohelicidae. A specimen of P. costulata was chosen to show the peculiarity of this character. The reniform chambers become constricted near the axial area, then extend laterally in two lobes, which are tubuliform when well developed, and curved to meet the lower chambers. When the lobes are small, one may observe (fig. 22) that they originate from a conspicuous extension of the aperture, with two more or less marked constrictions near the two lateral extremities of the aperture. In such a situation, the chambers lose their original globular appearance. The morphological transition from globular to reniform to lobate chambers may be observed in the populations of Heterohelix (Gubelina) globulosa and H. planata, and H. pseudolitttorea (=H. pulchra) (Brotzen, 1936; see Montanaro Gallitelli, 1955b, p. 188). Consequently, the genus Pseudogubelina Bronnimann and Brown is considered to be a valid genus, but is restricted to include only those forms with a strong modification in the shape of the terminal basal part of the chambers and of the aperture, which give rise to peculiar accessory apertures, differing in their origin from the accessory apertures occasionally found in other species and genera of the Heterohelicidae. For this reason, P. striata and P. punctulata are not considered to be typical Pseudogubelina, but are here considered to belong to Heterohelix.

Bonnimann and Brown (1953, p. 153) stated that "Textularia striata Ehrenberg is the only species of Pseudogubelina n. gen. in which coiling has been observed." The present study has shown that it occurs also in P. excolata (Cushman), the type species of the genus (fig. 23).

**Genus Gublerina Kikoïne, 1948**  

Plate 32, Figures 1-9


Type species: Gublerina cuvillieri Kikoïne, 1948 (= Ventilabrella ornatisissima Cushman and Church, 1930), Upper Cretaceous (Maestrichtian), from the region of Orthez and to the south of Gan, northern edge of the Pyrenees, France.

Diagnosis: Test compressed, rapidly increasing in breadth but not flabelliform, presenting a fairly broad triangular outline. Early stage frequently coiled; in the later stage the chambers are arranged in two diverging series, commonly widely separated by a broad, nonseptate, incompletely divided or occasionally bubbled central area which only finally becomes camerate. Proliferation of chambers occurs at the top of the test, with 4-8 final bulbous chambers. Sutures well developed, limbate, generally granulate on the surface, sometimes strongly projecting. Wall calcareous, surface opaque, rough, especially in the early stage, except for the initial coil which is generally smooth and transparent. Aperture not visible in the paratypes available.

Discussion: Comparison of the holotype and paratypes of Ventilabrella ornatisissima Cushman and Church with the toptotypes of Gublerina cuvillieri, in the National Museum collections, showed that the specific name cuvillieri is also invalid as it is a synonym of Gublerina ornatisissima (Cushman and Church). The morphologic characters of this genus brought out in this paper prove its validity, although the genus must be somewhat emended from the original description. Recognition of these characters was made possible by etching away in hydrochloric acid the external part of the wall in two specimens of Gublerina cuvillieri (=G. ornatisissima).

Thus, a coiled early stage may be present (fig. 3), followed by the young biserial stage. The first two to four pairs of chambers are overlapping, then the two series of chambers become more and more divergent, leaving a broad internal communication between the chambers and the wide undivided central cavity (fig. 7). True internal chambers are not developed at first in this central area, which becomes irregularly more or less "bubbled" in appearance (fig. 4). The granulated, suturelike median costae were dissolved at the surface by hydrochloric acid in order to verify the presence of a median series of chambers, but no internal chambers were found to correspond with these superficial costae (fig. 2). Another partially dissolved specimen (fig. 1) and three complete specimens (figs. 5, 7, 3) show the sequence from a flat, depressed, and unornamented central area to a subcostate to a final bubbled one. In figure 4 granulated intermediate costae and the final polycamerate stage can be seen.

A specimen of Ventilabrella ornatisissima Cushman and Church, similarly treated (figs. 6a, b), shows that the two series of chambers openly communicate in the central area, and that a third incomplete arched suture appears in the central area, immediately below the final proliferation.

Ventilabrella decoratissima de Klasz is a Gublerina with strongly developed granulated sutures, and a biserial arrangement of chambers nearly to the top of the test, which shows the usual final proliferation. Paratypes of this species from the Santonian of Eisenärzt, Bavaria (de Klasz Coll.) show the Gublerina arrangement of the chambers and the surface sculpture (fig. 8).

The constant characters of Gublerina are, therefore, the biserial arrangement of the chambers almost to the top of the test, with the two gradually diverging series separated by an intervening noncamerate cavity; and the limbate sutures, frequently granulate on the surface,
opening internally and leaving a broad opening between the chambers and the central area. *Gublerina* thus represents one of the most distinctive genera in the family Heterohelicidae.

Variable characters are (1) the width of the central cavity, where an incomplete central chamber occasionally appears, and the broad opening from the chambers into the wide central cavity; (2) the development of the granulated ornamentation; (3) the presence, size, depression, and evidence of bubbles in the central area; and (4) the external lateral inflation of the chambers and consequently the sharpness of the transverse section. A comparison of *G. ornamentissa* and *G. decoratissima* emphasizes the constant and the variable characters of this very distinctive genus.

Some other synonyms of species of *Gublerina* have been suggested by Bronnimann and Brown (1954). *Gublerina hedbergi* Bronnimann and Brown was stated to be a synonym of *G. acuta robusta* de Klazs, and *Gublerina* aff. *G. cuvillieri* Kikoine described by de Klazs (1953, p. 248, footnote 1, pl. 8, figs. 2a, b) is the same as *G. glaessneri* Bronnimann and Brown.

The investigation of the structure of the central area of the test, and the statement that central internal chambers do not occur in *Gublerina* but are so simulated by more or less irregular bubbles and external ornamentation, suggest the advisability of reexamining many of the specimens interpreted as *Gublerina* and figured with one or more completely developed central chambers. Such a character (central internal chambers), when actually occurring in flabelliform specimens, represents *Planoglobulina*, not *Gublerina*. On the other hand, specimens where the reniform chambers are arranged in two diverging series, separated by a non-septate central area but without proliferation at the top of the test, are representatives of aberrant forms (although still of *Gublerina*) which tend toward the extreme limits of variability of the genus *Heterohelix* (H. tessera, H. pulchra, H. lata).

A paratype of *Gublerina hedbergi* (= *G. acuta robusta* de Klazs) examined for this study shows that following an early coiled stage there are eight chambers with a typical gumbelinoïd development (chambers inflated and sutures deep and narrow). The four mature chambers which follow become reinfinit and depressed in the central area, simulating, because of their irregularity, the presence of one or more internal chambers. Actually an observation of both sides of the test by transmitted light shows no traces of sutures in this area. The fragmentary final two chambers in this paratype show only a bicameral end stage, not multichamberate as in *Gublerina*, even though the wide central area, typical of this genus, is present. A comparison with forms like *Heterohelix pseudotessera* (= *H. pulchra*) and *H. lata* can be made through the illustrations given here.

Thus, the genus *Gublerina* can be interpreted as very distinctive, with its morphological and genetic position between *Heterohelix* and *Planoglobulina*.

Genus *Planoglobulina* Cushman, 1927

Plate 32, Figures 10-13


**Type species:** *Guembelina acervulinoides* Egger, 1900. Upper Cretaceous Senonian of Bavarian Alps. Numerous localities and horizons were listed, none designated as type. The synonymous *Ventilabrella* was also defined without citation of a type specimen, horizon, or locality in either the generic definition or the description of the type species, *V. eggeri* Cushman.

**Diagnosis:** Test biserial in the young stage, later with a more or less abundant proliferation of globular chambers, which spread out in the plane of biseriality, giving a flabelliform shape to the test. Wall calcareous, finely perforate, and commonly striate on the surface. Aperture multiple on the final series of chambers, which may be numerous.

**Discussion:** This genus can easily be distinguished from *Gublerina* by the absence of costate sutures and the globular and completely developed chambers in the area of proliferation.

A comparison of the figures of complete and sectioned specimens of *Gublerina* and *Planoglobulina* emphasizes these differences better than does a discussion. Specimens from the Cushman Collection (31839 and 31861) also demonstrate these elements well.

According to the present redescription and emended diagnosis of the genus *Gublerina*, *Ventilabrella decoratissima* de Klazs is a typical *Gublerina*. The figure given by de Klazs (1953) seems to represent a real *Ventilabrella* (= *Planoglobulina*). However, examination of a paratype in the de Klazs collection in the U. S. National Museum, shows somewhat different ornamentation and character of chambers, and an internal structure typical of a *Gublerina*.

A young specimen of *Planoglobulina eggeri* (Cushman) var. *glabrata* (Cushman) shows the derivation of *Planoglobulina* from a globulosa-like *Heterohelix*.

The generic name *Ventilabrella* has commonly been used for this group of species, but is a synonym of *Planoglobulina*. Both genera were described by Cushman, who stated that *Planoglobulina* arose from a *Pseudotextularia* stage and *Ventilabrella* from a *Guembelina* stage. *Planoglobulina* was defined in 1927, and the type designated as *Guembelina acervulinoides* Egger. Cushman (1927b) stated that it had a planospiral early stage, followed by a biserial stage and finally a proliferation of chambers in a single plane. The following year Cushman (1928) defined *Ventilabrella*, citing as type the new species *V. eggeri*, and stating that it developed from a biserial stage, with later proliferation of chambers in a single plane. In his description of the type species he also stated that the microspheric form probably also was planospiral in the early stage.
Within the description of *Ventilabrella eggeri*, Cushman (1928) also discussed *Planoglobulina* and selected Egger's figure 20 as the type of the species *P. acervulinoides* Egger. This specimen shows well developed proliferation following a biserial early stage. The figure is not sufficiently clear to note the presence or absence of an early coil. Although he selected a type for Egger's species, Cushman apparently neglected to do so for *V. eggeri*, for no holotype or paratype specimens of *V. eggeri* occur in the Cushman collection or U. S. National Museum collections, and no type specimen is listed in the text in this or later papers of Cushman. Furthermore, no type horizon or locality were cited for *V. eggeri*, although Cushman stated (1928, p. 3) that "species of *Ventilabrella* occur often in great numbers in certain horizons of the Taylor marl of Texas."

In 1946, Cushman did illustrate specimens of *V. eggeri*, from the Taylor, but also placed in the synonymy of *V. eggeri*, *Planoglobulina acervulinoides* Egger (part), and included Egger's figure 20! He thus placed the specimen he himself had selected as type for Egger's species in his later species, so that the type species of *Ventilabrella* (*V. eggeri*) is a junior synonym of the type species of *Planoglobulina* (*P. acervulinoides*), the two genera thus being identical.

Galloway (1933) placed *Ventilabrella* in the synonymy of *Planoglobulina*, but was not followed in this by most other workers, who recognized both genera. Species referred to the two generic names are identical in development, with a biserial stage, or more rarely coiled to biserial, followed by chamber proliferation in a single plane, resulting in a flabelliform test.

As *Planoglobulina* has priority, and the type species are synonymous, the name *Ventilabrella* must be suppressed as a junior subjective-objective (genotype species are believed to be the same) synonym.

**Genus Racemiguembelina Montanaro Gallitelli, new genus**

**Plate 32, Figures 14, 15**


**Type species:** *Gümbelina fructicosa* Egger, 1900, Upper Cretaceous (Senonian) of Bavarian Alps, Germany.

**Diagnosis:** Test calcareous, conical in shape; rarely planispiral in the early stage, later biserial, increasing regularly and equally in thickness and breadth, finally proliferated with a varying number of additional globular chambers, the last of which form a crown at the top of the test and are provided with a series of arcuate, basal apertures. No spiral arrangement of the adult chambers is evident. Ornamentation consists of longitudinally developed costae.

**Discussion:** This genus includes species that develop a final chamber proliferation, giving rise to a conical test, such as have been placed in the genus *Pseudotextularia* Rzeakh by various authors. As the emendation of the genus *Pseudotextularia*, earlier in the present paper, on the basis of its type species, *P. elegans* (Rzeakh), restricts that genus to species which are biserial in the adult, with a lateral compression of the test in its later stages, the forms with chamber proliferation require a new generic assignment, and the present genus is proposed to fill that necessity.

As noted above, in the discussion of *Pseudotextularia*, specimens of this type were originally included with specimens of a biserial genus in Rzeakh's description (1891, p. 2) of *Cuneolina elegans*, and later both forms were figured by Rzeakh (1895) as *Pseudotextularia varians*.

Because Rzeakh (1895) included in his synonymy of *Pseudotextularia varians*, the prior name *Cuneolina elegans*, he obviously considered them identical, hence the specific name *varians* must be suppressed as a junior synonym of *elegans*, as was later noted by Ellis and Messina (1940). It cannot be later resurrected for part of the group included therein by Rzeakh. The biserial specimen of Rzeakh (1895, pl. 7, fig. 1) was referred to the restricted *Cuneolina elegans* (= *Pseudotextularia*) by White (1929, p. 40), and is thus the lectotype of that species.

Cushman (1938, p. 22) considered *Guembelina fructicosa* Egger (misspelled as fructicosa) to be identical with *Pseudotextularia varians*. Thus the first valid name available for the proliferated form of Rzeakh (commonly but erroneously referred to previously as *Pseudotextularia varians*), is *fructicosa*, and the correct name thus becomes *Racemiguembelina fructicosa* (Egger).

The enlargement of the test in *Racemiguembelina* produces a form which is circular or subcircular in transverse section. This circular section, together with the high degree of chamber proliferation in the mature stage, are characters, peculiar to this genus, which justify its separation from those forms with a completely biserial chamber arrangement and lateral compression.

If we do not consider as generic distinctions both these peculiarities—the conical enlargement and the final proliferation of the chambers, and accept within its range of variability the forms without proliferation and also those more or less compressed or extended, the majority of the globular-chambered *Heterohelicidae* could be placed within a single genus. As there is no biological proof to confirm or deny the "natural" value of these characters in extinct forms, we must accept the morphological features of the test as a basis for a usable taxonomy, and the compressed biserial forms are here considered to belong to the genus *Pseudotextularia*, emended, whereas those with chamber proliferation belong to the present genus *Racemiguembelina*.

Although many authors cite a spiral arrangement of the chambers in this proliferated genus, none is visible either in their published figures nor in the types examined, hence this is discounted.
The generic name comes from *racemus*, Latin, bunch or cluster of grapes—*Guembelina*, genus of Foraminifera; gender, feminine. The name refers to the later chamber proliferation as in a bunch of grapes, following an early development like *Guembelina* (=*Heterohelix*).

**Genus Tubitextularia** Sulc, 1929

**Plate 33, Figures 1-5**


**Type species**: *Pseudotextularia bohemia* Sulc, 1929, Upper Cretaceous Senonian, of Vinice, Czechoslovakia.

**Diagnosis**: Test with initial stage coiled or more commonly biserial, consisting of two to eight chambers followed by an uniserial stage of two to five chambers. Chambers inflated. Wall calcareous, perforate, smooth. Aperture simple, terminal.

**Discussion**: The genus *Rectoguembelina* Cushman has identical characters and is a synonym of *Tubitextularia* as was correctly stated by Glassner (1936, p. 108). The only differing character cited by Cushman is the presence of a neck in *Rectoguembelina*. However, even the figure given by Cushman (after Sulc) shows the last chamber in *Tubitextularia*, as in *Rectoguembelina*, becoming elongate and rather constricted in a sort of large neck, which is broken. Consequently only a specific separation can be admitted. This genus can be considered as an example of genetic reduction in the number of chambers, which has a parallel in other families. The modification of the apertural position from basal to terminal is an obvious consequence of the change in chamber arrangement. Other than position, the character of the aperture is identical to that of other Heterohelicidae, i.e., simple, without lip, tooth, or internal laminae. That it is clearly derived from a heterohelicoid form is shown by the occasional remnant of the primitive basal aperture at the end of the young biserial stage.

In addition to the type species, only *Tubitextularia cretacea* (Cushman) and *T. texana* (Cushman) definitely belong to this genus, as shown by the clearly heterohelicoid young stage. A much accelerated specimen identified by Cushman as *T. texana*, has only a coiled first stage followed, without a biserial stage, by a uniserial stage of four chambers. Another specimen has only three initial chambers which are doubtfully biserial with an oblique axis before the uniserial stage. In this latter example, the heterohelicoid stage has practically disappeared but there are all gradations from the genus *Heterohelix* (*H. globulosa*) to *Tubitextularia*, which can thus be interpreted as a problematic development of *Heterohelix*, but not as a stratigraphical evolution from it.

**Family Plectofrondiculariidae** Cushman, 1927

**Subfamily Plectofrondiculariinae** Cushman, 1927

**Genus Bolivinella** Cushman, 1927

**Plate 33, Figures 12-13**


**Type species**: *Textularia agglutinans* d'Orbigny var. _folium_ Parker and Jones, 1865, from Recent shore sand, near Melborne, Australia.

**Diagnosis**: Test biserial, compressed, flabelliform. Proloculum spherical in megalospheric specimens, elongate or ovoidal, provided with one or two spines. No coiling present. Chambers depressed, slightly overlapping, narrow and much elongate laterally, generally sigmoid. Sutures well developed, limbate, more or less projecting. Wall calcareous, perforate. There is no simple basal aperture, but a series of tiny openings at the base of the final chamber, surrounded by numerous papillae commonly aligned in series radiating from the apertural area.

**Discussion**: The genus is placed by Galloway and Cushman near *Bolivinella*, in the Boliviniidae. Sigal maintains its placement in the Heterohelicidae (superfamily Buliminidea). Pokorny puts *Bolivinella* in the same superfamily, but in the subfamily Plectofrondiculariinae.

Galloway (1933, p. 350) referred to the early stage as "in the microspheric forms doubtfully planispiral" and Cushman (1927b, p. 79) described the aperture as "transverse to the compression of the test, with numerous papillae at the base of the opening".

Sigal (1952, p. 224) considers *Bolivinella* closely related to *Bolivinida* and *Boliviniliida*, as all the three genera "saутent le stade planispirale." The present research, made at high magnification on several hundred specimens and sections now gives a more complete documentation of the morphological characters. As stated by Sigal, a coiled initial stage is definitely excluded, as none was shown in the specimens examined. The proloculum is spherical, ovoidal, or reniform; provided with one or two spines, and partially broken spines give the appearance of the "rectangular" proloculum described by Cushman. Partial dissolution by hydrochloric acid shows the two symmetrical chambers following the proloculum.

New information is available concerning the aperture. The original figures of the type species show a generalized simple aperture, as Cushman (1927b, p. 79) described vaguely. The diagnosis of the numerous species of Cushman give no description or figure of the aperture. The aperture consists of a row of small openings at the central part of the base of the final chamber. Investigation of the apertural area has been
made either at a magnification of $\times 216$ with the stereobinocular microscope or with transmitted light. Acid treatment has also been used to make the apertural area visible and free of ornamentation. The aperture consists of 2 to 4 minute openings aligned at the base of the final chamber and the adjoining upper surface is covered by numerous papillae or minute spines aligned in radiating rows. These rows continue over the entire apertural face, the ridges running between the pores at the base of the face and touching the opposite chamber surface. An open elongate aperture, as described by Cushman and figured by Parker and Jones, is visible only when the specimen has been damaged, and is not present in any stage of the development of the test, as proved by dissection of specimens. The tiny apertural openings are visible only at high magnification, but this apertural character and the radiating papillae are both present in different species, demonstrating that they do not represent an abnormality. The amount of ornamentation and the number and size of the pores are variable characters.

Concerning the ornamentation, Cushman considers the lateral spines to be frequent, those of the proloculum rare. However, the spines of the proloculum represent the rule, and the lateral spines, sometimes modified into alar expansions, represent a specific character, and may be absent altogether. As is understandable, no toothplate is present in this genus.

The completely different apertural character as here described proves that no relationship exists between Bolivinella and the groups of Bolivinida and Bolivinitida.

Genus Plectronofrondicularia Liebus, 1903

**Plate 33, Figures 10,11**


**Type species**: *Plectronofrondicularia concava* Liebus, 1903, Tertiary (upper glass sand) Promberger Schichten?, from Probe 69, southeast of Heimberg bei Meischbach, Oberbayern, Germany.

**Diagnosis**: Test elongate or frondicularian, biserial in the early stage, later uniserial, much compressed; sutures limbate. Wall calcareous, smooth or longitudinally costate; aperture terminal with an elliptical margin, internally depressed and radially dentate: the teeth are frequently anastomosed at the interior of the aperture, which becomes reduced to one or more small, irregularly distributed, elliptical openings.

**Discussion**: No specimens of the type species were available in the U. S. National Museum and the figures given by Liebus show an incomplete specimen with an early biserial stage. Nevertheless, Cushman describes a planispiral early stage for the genus. An examination of all specimens of other species of *Plectronofrondicularia* in the National Museum showed none with an early coiled stage. In the elongate forms the biserial stage has a Bolivina-like arrangement; in the more enlarged species (*P. garzaensis* Cushman and Siegfus) the first two or three chambers embrace the proloculum. This arrangement, which must not be confused with a planispiral development, is here illustrated. The third chamber is then placed above the first two chambers, and is followed by the symmetrical uniserial development of the mature stage.

The aperture was previously described only as terminal, elliptical. The elliptical lip is easily visible and may be rather well developed. The aperture is concave; the lip is internally thickened, with a variable number of radiating teeth which reach the center of the aperture and may become anastomosed there, so that the aperture is reduced to one or more small openings. No internal tube or toothplate are present. This apertural character is identical in different species (*P. floridana*, *P. californica* and *P. garzaensis*), so that it may be considered a constant character of generic significance.

The character of the aperture and the first stage of the test both show a relationship to the completely biserial Bolivinella, and demonstrate that there is no relationship between these genera and the Heterohelicidae, s. s.

Glassner (1945) placed *Plectronofrondicularia* in his superfamily Buliminidea, family Buliminidae, subfamily Plectronofrondiculariniae, and in this was followed by Pokorny (1954). Sigal (1952) considered this genus to belong to the Heterohelicidae, with Bolivinella. The subfamily is here elevated to family status.

**Genus Amphimorphina Neugeboren, 1850**

**Plate 33, Figures 7-9**


**Type species**: *Amphimorphina hauerina* Neugeboren, 1859, Miocene, from Lapugy, Hungary.

**Diagnosis**: Test elongate, more or less compressed in the early stage, which is uniserial in the megalospheric form and clearly biserial in the microspheric form, including the six to ten early chambers. Chambers frondicularian in the young stage, then may be inflated; sutures limbate and centrally crossed by a rather large lumen. Ornamentation longitudinal, with more or less lamellate costae, situated near the margins of the test. Aperture in the early stages consists of grooves radiating from the center, and in the later stages consists of 3 to 6 pores separated by the converging ribs, which meet terminally.

**Discussion**: The biseriality of the early stage of the type species of *Amphimorphina* was not noted by Neugeboren, although Cushman (1927, p. 63) stated that the microspheric form "may show traces of the biserial stage."

There is nevertheless a clearly biserial early stage, as shown in the figures. One specimen was observed which has a single asymmetrical chamber following the proloculum, that could be interpreted as a subcoiled stage, but in reality it is only an abnormal accelerated increase giving rise immediately to a third
completely developed chamber which occupies the full breadth of the test. Megalospheric specimens are also figured for the same species.

Neither Neugeboren nor Cushman figured complete specimens. The aperture in the early stages consists of radiating grooves from the mid-point of the apertural region. The ribs between these grooves converge in later growth, meeting centrally and leaving open 3 to 6 pores between the strong radial costae, forming a cribleate aperture. A similar aperture was described and figured by Glaessner (1936, p. 117, pl. 2, figs. 9, 14). No internal plates or tubes are visible.

The characters as now described suggest a close relationship of *Amphimorpha* and *Plectofrondicularia*, as stated by Glaessner (1936, p. 120; 1945, p. 138) and Pokorný (1954). Because of their striking morphological similarity, the two genera are here placed in the Plectofrondiculariinae.

The type species of *Nodomorpha* Cushman, 1927, is *Nodosaria compressiuscula* Neugeboren, 1852. No specimens of this species were available in the U. S. National Museum. However, the generic diagnosis given by Cushman strongly suggests that this genus is synonymous with *Amphimorpha* Neugeboren. The only difference cited by Cushman is the complete uniseriality of the test (the quadrangular section of the test in the early stage is a common character in *Amphimorpha* also). But most specimens of *Amphimorpha* are megalospheric, and also show an uniserial arrangement of the chambers. The similarity of all the other characters suggests much doubt as to the separate validity of this generic name, and its suppression is recommended.

**Family Buliminidae Jones, 1876**

**Subfamily Bolivinitinae Cushman, 1927**

**Genus Bolivinoides Cushman, 1927**

**Plate 33, F Gures 14-16**


**Type species**: *Bolivina draco* Marsson, 1878, Cretaceous Weisse Schreibkreide, from the Isle of Rügen, Germany.

**Diagnosis**: Test biserial from the early stage, cuneiform, gradually increasing in breadth, with final chamber umbonate. Initial chambers near the proloculum more or less arched, and sometimes enveloping. Sutures oblique, slightly curved, at a 45-degree angle with the horizontal, thickened, flat. Wall calcareous, minutely perforate, internally tuberculate, and externally costate and tuberculate, giving a generally strong longitudinal ornamentation. Aperture narrow, generally basal, symmetrical, frequently provided externally with a lamellar lip and internally with a columellar toothplate, disposed axially between the two series of chambers and extending from the proloculum.

**Discussion**: This Cretaceous and Paleocene genus was incompletely described, and was originally placed in the Heterohelicidae. This systematic position was corrected by Glaessner (1945) who placed the genus in the superfamily Buliminidea, family Buliminidae, subfamily Bolivininae, considering *Bolivinoides* only a subgenus of *Bolivina*. The same position was accepted by Sigal.

In the last few years Höfler und Koch (1950), Reiss (1954) and Edgell (1954) published statistical researches on the stratigraphical variability of this genus, with particular attention to the variability in shape and ornamentation. Höfler (1952) noted the existence of a “toothplate” and attempted a reconstruction of the internal structure of the test.

The present work partially confirms Höfler's results, and gives some new structural information. The biseriality of the early stage is confirmed. Höfler und Koch (1950, p. 598) suppose that “der scheinbar planispirale Aufbau der Embryonal-kammern findet sich nach unserem Material nur bei einen kleinen Teil der Individuen und ist auch bei megalospherischen Formen zu beobachten.” The simulated appearance of a coiled initial stage can be explained, because in the most extended forms of this genus, as for instance, *Bolivinoides draco draco* (Marsson), the first two chambers formed after the proloculum are almost completely enveloping, in both the micro- and megalospheric forms. Actually, the biseriality is a constant character.

The aperture was correctly described by Höfler. In the specimens observed, the aperture is proportionally narrower and more reduced than was figured by Höfler und Koch. Furthermore the margin of the aperture is reduced at the surface to a thin lip, which can become lamellar in the better preserved specimens. This lamellar lip is not continuous, but is generally situated on the side opposite to that of the toothplate. The aperture is surrounded by a narrow depressed area.

The toothplate is externally visible in many specimens. Internally it is modified to form a tubular columnella, which is visible in the figured sectioned specimen (fig. 14), and also in others not here figured but prepared with acid by the writer (Cushman Coll. 16267, 12108).

Höfler und Koch (1950, p. 597) described the internal structure as follows: “jede Kammer überdeckt die darunter liegende mit ihrer ausser etwas herabgezogenen Kammerbasis; die Einzelkammern besitzen eine Anzahl zu ihrer Basis rechtwinklig angeordnete Kammeroversätze, die auf die darunter liegende Kammer übergreifen; diese bilden die Skulptur und treten als Knoten oder Rippen auf. . . . ; die Suturen werden dadurch entsprechend verdeckt und sind bei ausgesprochenen Rippenkolumna sogar unsichtbar. . . . Kammerraum langlich halbmondformig; Anfangsteil verjüngt, manchmal etwas verdreht.”

Höfler (1952, p. 379, figs. 3 and 4) gives an interpretation which needs correction. His figure 3b indicates thin sutures crossed by perpendicular processes. In figure 3c (“in optischen Schnitt”) septal marginal folds
are drawn ("Überlappendungen"), with correspondent costae ("darüber ungelagerten Kalkrippen"). His figure 4b shows the same character.

Some new internal characters were recognized in the present study. Specimens were examined in transmitted light at ×216 magnification, and in order to obtain more complete evidence of the septal surfaces, some specimens were progressively acid-treated until final dissolution of the septa allowed an examination of the internal surface of the wall. In longitudinal section the chambers are semilunar or strongly arched, depending on their position as related to the proloculum and to the lateral extension of the test. The septa are very thick; they have often the same thickness as the chamber cavities themselves in the young stage; in the adult stage they gradually become thinner. The septal surface is flat, not undulated. The marginal undulation is simulated by the septa encountering an internally tuberculate wall (fig. 14). The large tubercules are present also in the central area and are aligned with the external sculpture.

In conclusion, the present investigation confirms the validity of the genus Bolivinoides Cushman. It should not be placed near Bolivina, because of its very distinctive characters, the structure of the wall, sculpture, test shape and proportion, and it comprises an homogeneous group of species with a distinctive stratigraphical development.

Hiltermann and Koch (1950, p. 626) consider Bolivina waterei Cushman as an extreme form of Bolivinioidea. However, B. waterei, which has a neck and terminal aperture, has recently been made the basis for a distinct genus, Trachelinella Montanaro Gallitelli.

Genus Bolivinita Cushman, 1927

Plate 33, Figures 17–20


Type species: Textularia quadrilatera Schwager, 1866, lower Tertiary, from Kar Nikobar, "British India."

Diagnosis: Test biserial, elongate, gradually enlarging in size, rectangular in transverse section and more or less compressed, with four strongly developed and sometimes lamellar axial costae at the angles; broader sides flat or moderately concave. Chambers elongate, irregularly pyriform or reniform, more inflated laterally. Earliest chamber with one basal spine in the microspheric and two or more spines in the megaspheric forms. Sutures straight and thin at the narrow sides, occasionally strongly limbate and oblique in the broader faces, where they form an angle of about 90 degrees, strongly arched and fused one to another at the lateral end of the broader faces, forming the lamellar longitudinal costae. Wall thin, calcareous, completely covered with minute pores and sporadic larger ones; frequently spinose and sometimes vertically costate in the early stage. Aperture basal, subcircular, elliptical, with major axis perpendicular to the suture and provided with a fairly well developed lip which may be present also in the sutureal area. Apertural tooth moderately or not projecting, somewhat arched at the upper surface, enlarged internally in an oblique spout (toothplate), which is developed along either one or another of the sides of the chamber, and may be spatulate at the free lower end.

Discussion: A plesiotype incorrectly figured by Cushman is here refigured. The other specimens are similar to those studied and illustrated by Hofker (1951b, p. 104) for comparison in following his morphological and structural studies. They probably represent a different species but the generic characters are constant. The results obtained by Hofker concerning the toothplate were substantiated, but other new structural details were also observed. The plate is variable in size, concavity, position in the apertural cavity, and development of the final spatula. One correction is necessary. Text-fig. 61d of Hofker (1951b, p. 105) represents the aperture limited in the ventrodorsal direction by a strongly limbate, arched septum. Not one of the approximately one hundred specimens of Bolivinita quadrilatera investigated from a single sample present such a character. In fact, the anterodorsal portion of the septum between the penultimate and the final chamber is not visible externally because it is situated internally to the aperture; the arch of the aperture ends in contact with a fold of the upper terminal surface of the penultimate chamber.

The conclusion of Hofker (1951b, p. 102) as to the systematic invalidation of this genus and its placement within the genus Bolivina seems hardly acceptable, at least until more is known about the importance of the toothplate, and until a correlation between the variability of this structure and that of other morphological characters is established. Investigations at high magnification, by thin sections and dissections, even in very minute specimens now show that internal processes are more common than was previously suspected, and we need much more evidence before establishing a new systematics on this basis alone. Furthermore, a systematics based only on toothplates and pores cannot consider the vast number of fossil Foraminifera where these characters are lacking or concealed by the process of fossilization, or obscure due to their minute size. Without further evidence, such a revision would result in confusion rather than order.

The toothplate represents only a single character, just as does the position and form of the aperture, the chamber arrangement, or the chamber shape. In a group of specimens from a single sample, the position, development, and shape of the toothplate may be quite variable.

Hofker (1951b, p. 107) stated "There is no reason why we should create a new genus only distinguished from the central genus by an ornamentation of the wall." Nevertheless, the presence of four vertical carinae is more than a question of ornamentation; it is the consequence of a completely different chamber shape. The chambers in Bolivina are generally reniform.
or more or less depressed and are more inflated toward the axis of the test. In Bolivinita the chambers are pyriform in section, but have the more inflated portion at the external side of the test. This gives rise to flat or even concave broader faces of the test, and the strongly oblique chambers allow the lateral fusion of the limbate frontal sutures to form four vertical costae or lamellae. This character is present in different genera (Bolivinitella, Eowigerina plummerae) which are easily distinguishable by such other morphological elements as the aperture and the chamber arrangement.

For these reasons, an invalidation of the name Bolivinita seems at least premature, and it is here recognized as a valid genus.

**Genus Tappanina Montanaro Gallitelli, 1955**

**Plate 33, Figure 21**


**Type species:** *Bolivinita selmensis* Cushman, 1933, Upper Cretaceous Selma chalk, from New Corinth highway, 13.5 miles South of Selmer, McNairy County, Tennessee.

**Diagnosis:** Test biserial, rectangular or rhomboidal or deformed in transverse section. Chambers depressed, cuneiform, apparently concave on the broad sides, more or less inflated laterally, with a well developed and sometimes fringed or lamellar carina which is horizontal or arched on the lateral margin then deflected and paralleling the long axis of the chambers. Chambers thin, depressed, straight or arched. Wall calcareous, finely perforate. Surface appears rough when carinae are strongly developed. Aperture narrow, elongate, at the center of the base of the last chamber.

**Discussion:** The cuneiform shape of the adult chambers, with laterally subhorizontal or arched carinae, the deflection of the carinae on the broader faces, giving a rectangular transverse section to the test, and the independence of the carinae from the sutures are constant characters of this genus. Variable characters are the lateral convexity of the chambers, the development of the carinae and the more or less angular deflection at the beginning of the broader faces, and the deformation of the test in section from rectangular to rhomboidal or elliptical.

The group of forms allied to the type species have fundamentally different characters than do either Bolivinita Cushman or Bolivinitella Marie. Distinctive elements peculiar to the genus Tappanina are the presence of strong horizontal carinae, the narrow and deep sutures, the degeneration of the four axial lamellar sutural costae, characteristic of Bolivinita and Bolivinitella, into discontinuous thickenings and the character of the aperture.

Neither Cushman nor the later authors who examined specimens of this widespread species (Tappanina selmensis has also been found in the Upper Cretaceous and Paleocene of Europe) recognized the actual distinction between the lateral thin sutures and the strongly developed horizontal arched carinae, which are relatively close to the preceding suture, and which give the tectiform appearance to the test.

The description of *Bolivinita selmensis* given by Cushman (1940, p. 114) is as follows: "Test minute, gently tapering from the subacute initial end, broad faces distinctly concave, the narrow sides strongly convex; chambers distinct, increasing gradually in size as added; sutures distinct, somewhat limbate; wall smooth, very finely perforate, translucent, especially in the middle of the chambers on the flattened faces; aperture narrow, at the inner margin of the last-formed chamber."

An analogous description was given for the very similar *Bolivinita costifera* Cushman (1946, p. 115): "Test small, about twice as long as broad, gradually tapering from the subacute initial end to the greatest breadth slightly above the middle, thence tapering slightly to the apertural end, periphery broadly rounded, strongly serrate in front view, in transverse section somewhat rhomboid, broader faces flattened or concave; chambers very distinct, increasing gradually in size as added, earlier chambers flattened and compressed, later chambers concave on the broader faces, and convex on the periphery, greatly increasing in thickness; sutures distinct, slightly curved in the early stages, more strongly so in the adult, slightly limbate; wall smooth and polished, except for the basal angle of the chamber in the adult, which has a sharp angle that may develop into a raised costa-like ridge; aperture narrow, elongate, at the base of the inner margin of the apertural face."

The holotype of *Tappanina selmensis* is here refigured. The holotype of *Eowigerina excavata* Cushman consists of a specimen of *T. selmensis* with the last chamber broken and thus simulating a neck. This confirms the doubt of Brotzen (1948) about the validity of the species *excavata*. Only a "paratype" of the species *selmensis*, figured by Cushman and refigured by Brotzen (1948, text fig. 16, specimen on the left) is perhaps a true *Bolivinita*, characterized by the slender test and the typical sutures and sculpture, but the absence of other specimens compels a further investigation as to the existence of a toothplate.

Brotzen proposed a list of synonyms for *selmensis*: *Bolivinita crawfordensis* Jennings, *B. exigua* Glaessner, *B. costifera* (read costifera) Cushman. However, after examining many paratypes and hypotypes from the Kemp Clay, the writer believes *Tappanina costifera* to be a valid form, although closely related to the type species. *B. exigua* Glaessner from the Upper Cretaceous of the Caucasus appears from the figures and descriptions to be a synonym of *T. selmensis*. *B. crawfordensis* Jennings, from the lower Eocene of New Jersey, cannot be satisfactorily compared with *T. selmensis* because of the insufficient description and figure of the former.

In addition to the holotype of *Tappanina selmensis* (Cushman), the writer (Montanaro Gallitelli, 1956,
pl. 7, figs. 3-7) recently refigured the conspecific "holotype" of Eouvigerina eozavata Cushman and the holotype and two hypotypes of the congeneric T. costifera (Cushman), hence these are not here refigured.

Subfamily Eouvigerininae Cushman, 1927

Genus Eouvigerina Cushman, 1926

PLATE 34, FIGURES 1-7


Type species: Eouvigerina americana Cushman, 1926, Upper Cretaceous Taylor marl, from pit of Dallas Brick Company, ½ mile west of Mesquite, Dallas County, Texas.

Diagnosis: Test small, biserial throughout, commonly twisted and thus may simulate an appearance of triseriality. The chambers immediately following the proloculum are reniform and arranged longitudinally on opposite sides of the proloculum, giving a round outline and a false coiled appearance to the neanic stage. In the adult the commonly loosely arranged chambers are more inflated, assuming a pyriform or, if carinate, subtrireangular shape. When the chambers are overlapping and carinate, the test becomes subrectangular in cross section. The final chamber is nearly central in position. Wall calcareous, surface finely perforate and frequently more or less spinose. Strong carinae may be present in the mature stage, following the length and the curvature of the chambers and consequently becoming horizontal, arched and finally subvertical or vertical.

Aperture terminal, with a more or less well developed neck and lip. One or two thin transverse ridges may appear on the surface of the neck. Internally the aperture has a thin columellar process (fig. 2) which is also visible in the young stage.

Discussion: Loeblich (1951, p. 109), after restudying the types, substantiated the description of Glaessner (1945, p. 138), correcting the original generic diagnosis of Cushman by recognizing the absence of a coiled early stage, and the complete biseriality of this genus, tending to a uniserial development.

The use of high magnification and numerous partially acid-treated specimens in the present study revealed the presence of an internal columnellar process, extending from the very young chambers of the test up to the aperture. Because of the small size of the test, the tubular nature of this process is visible only in the last chamber and the shape of this very thin "toothplate" and the position of its departure from the aperture could not be determined.

Another investigation of some interest concerned the relationship of the external shape in the different species of Eouvigerina to the (1) shape and position of each chamber, and (2) presence, position and development of the carinae, which are more or less well developed in nearly all the species.

There is a great variability in the form of the test, and a separation into different species often cannot easily be made. If the Paleocene species Eouvigerina eozavata Cushman, which is conspecific with Tappanina selmensis (Cushman), is excluded, it can be said of Eouvigerina that the test is frequently twisted, a fact that lead Cushman and others to believe it triserial; and the change in shape in the mature stage is gradual, and is related to the development and the overlap of the pyriform chambers, and the strength of the carinae. An example without carinae is E. fragilis (Terquem), which has uvigeriniform later chambers. When the carinae are strongly developed, the pyriform chambers become subtrireangular in top view, which may lead to different test shapes, according to the more or less close arrangement of the chambers. Chambers closely arranged and carinate, but not large or much arched, have a Tappanina-like appearance, subtrireangular in cross section and depressed on the broader faces, as in E. serrata (Chapman) and E. americana Cushman (part). When the chambers are carinate, loosely arranged, twisted (as in USNM P4887), and tend to become almost uniserial, a false triserial appearance is given, when viewed from above, as in typical E. americana Cushman.

Eouvigerina plummerae is a very distinctive form. As the present research is an analytical restudy of the genera as based on their type species, a discussion of each species is out of place. Nevertheless as some "transitional" specimens are in the U. S. National Museum, it is perhaps of some interest for further discussion to show such specimens, and two aberrant specimens of E. americana for comparison. If this species belongs to another genus—as there is evidence to believe—it must in any case be related to Eouvigerina. The chambers are elongate and strongly arched, losing the lateral portion of the carinae (as is also true in aberrant E. americana, figs 3, 5), become closely appressed and overlapping, with fusion of the arched carinae on the sides of the broader faces from the early stage, giving four sharp vertical Bolivinita-like lamellae, although the species is clearly distinguishable from Bolivinita by the different aperture. An appearance of similarity seems to exist between E. plummerae and Bolivinitella. Nevertheless the latter genus has a quite different aperture and lacks an apertural or columnellar process.

The results of the studies of this genus by Glaessner (1945), Loeblich (1951) and the present study all show clearly that neither the morphological nor structural characters of Eouvigerina show any relationship to the true Heterohelicidae.

Genus Siphogenerinoides Cushman, 1927

PLATE 34, FIGURES 8-10


Type species: Siphogenerina plummeri Cushman, 1927, Upper Cretaceous, Maestrichtian, from bank of Walker Creek, 6 miles N.15° E. of Cameron, about 1
mile upstream from intersection of Walker Creek and Cameron-Clarkson road, Milam County, Texas.

Diagnosis: Test elongate, straight, constantly biserial in the early stage in both microspheric and megaspheric forms. Chambers rather inflated. Sutures slightly depressed, subhorizontal. Wall calcareous, perforate, surface crossed by numerous continuous costae, which may become lamellar and thickened near the sutures. Aperture terminal, elliptical or reniform, frequently interrupted by fusion with the columellar spout, which is arched in cross section and may rarely give the appearance of two teeth. Columellar process well developed, spoutlike in shape, developed from the early stage, each successive simple intercameral spout with its concave side facing in the opposite direction to that of the spout immediately preceding, and each apertural lip, except that of the final chamber, connects to the extremities of two sections of spout, the terminal end of the inferior one and the base of that in the succeeding chamber situated diametrically opposite in the circular opening and both having their convex surface oriented toward the opening.

Discussion: A study of numerous topotypes was made. Acid-treated specimens show clearly the characters of the "siphon" described by Plummer (1931) and Stone (1946) and of the early stage. The early stage is always biserial, even in megaspheric forms. No specimen showed a triserial beginning. The biserial stage is very short in the megaspheric forms (2 to 6 chambers), and more fully developed in microspheric ones (as many as 10 chambers).

A longitudinal acid-section shows (fig. 10) the internal alignment of the columellar process. The section was purposely not completely axial, and the previous interpretations of the internal structure are corrected as follows: The internal process is not a "tube" as described by both Plummer and Stone, who gave extremely small figures; it is an hemicylindrical subvertical process (spout), joining from one opening to another of two adjacent chambers. The spout always lies with the convexity oriented toward the apertural opening and is not continuous; there are single sections for each chamber, and each opening, except that of the last chamber, receives on one side the terminal portion of one section of spout and on the other side the beginning of the superjacent one. This alignment is very regular and is shown in the figures.

The position and the direction of the convexity of the spout explains the secondary small opening observed by Plummer. The aperture of the last chambers receives only the end of one section of spout. In the region of the termination of the spout the apertural lip may be reduced or absent, and the section of the end of the spout (which has the convexity facing the aperture) may be secant and simulate a second small opening. According to the different position of adherence of the spout to the apertural lip, different shapes of apertural outline (subcircular, reniform, irregular) may arise.

A relationship of Siphogenerinoides with triserial genera must be excluded. The presence and the nature of the columellar process, the biseriality of the early stage, and the apertural features are the characters important for its systematic placement. According to the present morphological revision, a close relation with Siphogenerina now appears probable. Only the character of the columellar process seems still to distinguish Siphogenerinoides from Siphogenerina. Sigal (1952, p. 219, fig. 80, p. 220, pl. 16, figs. 17a,b) states that Siphogenerinoides (which he includes in the Uvigerininae, with triserial initial stage) has the columellar process "external" to the aperture, instead of "internal" as in Siphogenerina. A further investigation as to the variability of the joining position of the columellar process to the aperture in both Siphogenerina and Siphogenerinoides is recommended.

Genus Zeauvigerina Finlay, 1939

Plate 34, Figures 11, 12


Type species: Zeauvigerina zelandica Finlay, 1939, middle-upper Eocene, Danneverke area, New Zealand.

Diagnosis: Test small, subcircular to elliptical in cross section. Chambers biserially arranged, minute and depressed in the early stage, rather inflated in the mature stage; sutures horizontal to oblique, with an angle of up to 15 degrees from the horizontal. Final chamber frequently less inflated than the penultimate, flask-shaped, tending to become central and provided with a neck, which is commonly almost as large as the last chamber. Apertural margin proportionally thick, circular or elliptical, internally provided with fine tuberculate ridges, commonly reducing the aperture to an elliptical opening. Wall calcareous, surface fairly rough, rarely finely spinulate.

Discussion: Only three paratypes were available in the U. S. National Museum collection, consequently an analysis of the internal structure of the test was practically impossible. Finlay based the separation of this genus from Uvigerina Cushman on the complete biseriality of the new genus, compared to the "coiled" first stage and the "triserial" arrangement of the mature stage in Uvigerina. The critical review made by Loeblich (1951) recognized that neither coiled early stage nor triseriality are present in Uvigerina. Consequently, Loeblich considered Zeauvigerina a synonym. The present investigation revealed the presence of a toothplate in Uvigerina. The same internal character may be present in Zeauvigerina also, but it is still unrecognized; the three paratypes examined are internally filled with sand, and an investigation by transmitted light was inconclusive.

If all external characters were identical to those of Uvigerina, the generic name of Finlay doubtless should be invalidated, and the problem of the presence of the toothplate set aside for the present, as we do not yet know how widespread is this single character in the
smaller Foraminifera, nor what is its systematic importance. But in Zeauvigerina (at least in the paratypes studied) the chambers are strongly compressed, with almost horizontal sutures, instead of having the rather loosely appressed chambers of Eouvigerina; the last chamber is smaller in size than the penultimate in Zeauvigerina, the neck is considerably larger and the apertural cavity more reduced than in Eouvigerina. Consequently, these features have led the writer to maintain, although with many doubts, the name Zeauvigerina, until a complete structural, morphological, and, if possible, statistical investigation of abundant material of both “genera” is made, showing transitional forms between the two populations.

Genus Trachelinella Montanaro Gallitelli, 1956

Plate 34, Figure 13


Type species: Bolivina waltersi Cushman, 1927, Upper Cretaceous Navarro (Maestrichtian), Core A-D-1 (Sun Oil Co.), from east of Richlands, Navarro County, Texas.

Diagnosis: Test elongate, flaring gradually, commonly twisted as much as 90 degrees, thickest in median line; periphery subacute, generally carinate, or more rarely serrate. First chamber with a basal spine and rarely two opposing median costae; adult chambers strongly arched. Suture narrow, arched, deep. Wall calcareous, finely perforate, smooth. Sculpture well developed, with prominent, rough, somewhat spinose carinae, aligned along the major extension and inflation of the chambers and consequently strongly arched, commonly fused at the lateral margins, which become carinate or serrate. Aperture terminal, round or slightly elliptical, with a short neck and a lip. No apertural internal teeth visible, at a magnification of more than 200 diameters.

Discussion: This genus is very abundant in the Upper Navarro Kemp clay. The holotype of “Bolivina” waltersi Cushman is a specimen with a broken apertural neck, giving an erroneous Bolivina-like appearance. A short apertural neck is visible at high magnification on one of the two broad faces of this specimen.

This genus differs from Bolivina in the presence of a well developed neck which may relate it to the Eouvigerininae. The oblique axis, the short neck of the last chamber, and the biseral arrangement of the chambers also suggest a relationship with Bolivinitella, although the latter genus has a peculiar rectangular section, concave broader faces, and four vertical lamellar costae, features not characteristic of Trachelinella.

Additional specimens of the type species were recently figured by the writer, hence are not here figured.

Genus Bolivinitella Marie, 1941

Plate 34, Figures 14-17


Type species: Bolivinita elephi Cushman, 1927, Upper Cretaceous Brownstown marl, 8.1 miles west of Arka- delphia, Clark County, Arkansas.

Diagnosis: Test elongate, biserial throughout, rectangular in section and compressed. Broader sides flat or concave, chambers reniform, strongly overlapping and arched in the mature stage, tending to become uniserial. Last chamber strongly compressed at the upper portion. Sutures limbate, strongly arched on the broad sides and fused at the four angles to form four longitudinal carinae. Aperture terminal, linear or elliptical, may have a lip, the apertural cavity finely tuberculate.

Discussion: Hofker’s peculiar conclusions concerning this genus are not supported by sufficient observation. He invalidated the present generic name and placed Bolivinitella with Siphogaudryina, which has, however, an arenaceous test and a triserial early stage. As the test of Bolivinitella is calcareous and soluble in dilute hydrochloric acid, a diagnosis of the so-called secondary material (granules) by optical and X-ray methods is required. When partially acid-treated the test shows a transparent shell material at high magnification.

Dissections by acid and observations of the generation B of Hofker did not show any triserial early arrangement of the chambers in any of the numerous specimens in the National Museum collections. However, a strongly tuberculate or more rarely costate ornamentation at the beginning of the test is very frequent.

The absence of a toothplate is substantiated, not unexpectedly, because of the extremely thin anterodorsal section of the final portion of the last chamber. If a toothplate is present in the young stage (because of the smallness of the specimens, this could not be demonstrated at X 216 magnification or by acid-treatment) it must be obviously absent in the apertural extension of the chamber. The aperture is not exactly as described by Hofker, but is more frequently linear and occasionally elliptical, and provided with a lip. In the best preserved specimens the lip shows internally a relatively well developed granulation which may obliterate the aperture and perhaps even cause it to become cibrate.

For these reasons the consideration of Bolivinitella as a synonym of Siphogaudryina is discounted, and the genus is here held to be valid. The position and feature of the aperture, and the shape of the chamber are constant and distinctive generic characters, despite the absence of the toothplate.
Family Buliminidae Jones, 1876
Genus Tosaia Takayanagi, 1953

Plate 34, Figure 18

Type species: Tosaia hanzawa Takayanagi, 1953, Pliocene Nobori formation, from cliff 100 miles east of Nobori, Hane-muri, Aki-gun, Kochi Prefecture, Japan.

Diagnosis: Test rapidly enlarging, triserial or occasionally biserial in last three chambers. Early stage obscure, not improbably trochoid. Early chambers depressed, rather inflated, last three or four chambers more inflated, with sutures consequently more depressed. Wall calcareous, smooth, finely perforate. Aperture basal, relatively small, provided with a fairly rough lip.

Discussion: Only three specimens were available for the present investigation: one relatively large paratype here figured, and two smaller, completely triserial specimens. Consequently very little can be added to the original diagnosis and only a statistical investigation as to the variability of this genus can decide if the final biserial arrangement is an aberration or not.

Takayanagi compares this genus to Guembelitria, of which the triserial arrangement and the basal aperture are suggestive; that the triseriality is only a matter of convergence is shown by other important characters, namely: the reduction to a biserial arrangement in the final stage; the vertical compression of the young chambers, resulting in subhorizontal sutures; the extension of the wall in a liplike plate at the aperture (without the compact structure of the usual lip); and, finally, the much larger test than in Guembelitria, which is characterized by its very small size. A very uncertain character, at present, is the arrangement of the early chambers. The specimens available were too scarce, so that a partial dissolution by acid-treatment was impossible. Immersion in anise oil seems to reveal a trochoid early portion, although this appearance may be due to reflections, and further investigation of numerous and well preserved specimens must be awaited.

Family Uvigerinidae Galloway and Wissler, 1927
Subfamily Uvigerininae Galloway and Wissler, 1927

Genus Pseudouvigerina Cushman, 1927

Plate 34, Figures 19–22

Type species: Uvigerina cristata Marsson, 1878, Cretaceous of Rügen Island (Pomerania). Figured hypotype from the Upper Cretaceous, Gerhardtsreuter Schichten (Maestrictian), Starzmühl near Teisendorf, Upper Bavaria, Germany.

Diagnosis: Test small, triserial throughout, triangular in cross section. Chambers normally inflated, externally triangular in section because of the presence of three strong double vertical costae disposed along the line of major inflation of the chambers. Sutures limbate, distinct, slightly depressed; between the sutures the wall is covered by numerous tubercles, which may become well developed and proportionally large. Aperture circular or subelliptical, with a short neck. Internally, a narrow columellar plate is developed from the early stage, and connected to the aperture (where no tooth is visible).

Discussion: Cushman described an early biserial stage for Pseudouvigerina. An investigation of hypotypes from the Upper Cretaceous of Bavaria showed the early stage to be triserial in both generations.

Furthermore, a partial dissolution by hydrochloric acid revealed the presence of an internal plate, somewhat oblique and free at its lower end. The plate has no tooth at the apertural end, but terminates at the base of the neck.

The genus Pseudouvigerina possesses no characters for separation from the Uvigerininae. A generic identity of Anguloferina with Pseudouvigerina is at present only suspected. Sigal (1952, p. 219) follows Galloway in stating that Anguloferina differs from Pseudouvigerina in tending to become uniserial. No comparison in this respect between species of both genera has been made here to confirm this difference. If a tendency to become uniserial should be demonstrated also in Pseudouvigerina, Anguloferina would become a junior synonym of Pseudouvigerina.

Class Crustacea
Order Isopoda

Genus Nodoplanulis Hussey, 1943

Plate 34, Figure 23

Type species: Nodoplanulis elongata Hussey, 1943, Eocene, Cane River formation, La Salle Parish, Louisiana.

Diagnosis: Test elongate, transparent, depressed, with lateral margins parallel. Basal portion flat, depressed, provided with a series of four or five complanate spines. The test consists of six vertically arranged sections; on the base of each a crown of irregularly developed, rarely spinate tubercles is present. Each section appears separated from the others at the surface by a variable and irregularly developed band. The upper end is provided with a “neck” and terminates in an elongate aperture with lip.

Discussion: Only the holotype was available for study; consequently no sections to show the internal structure were made. Nevertheless the good preservation of the fossil allows some discussion of the diagnosis given by Hussey.
The specimen does not show any spiral early stage. Immersed in anise oil it shows only a spinulate, compact basal region, followed by a single hollow section of the test. No traces of sutures appear in transmitted light, nor is there any suggestion of minute chambers, spiral or otherwise. The arrangement is then, in any case, uniserial. The "sutures" are not clear; they are neither limbate nor linear, but appear like a band of opaque material, variable in size in the different positions but not regularly enlarging from the base to the top. The absence of other specimens prevented the preparation of thin sections to determine if septa are present internally. Viewed in transparency this character is concealed. At the top, a flat neck is provided with a lip and an elliptical narrow opening.

Because of the obscure morphology of the "sutures" and of the other general characters of the specimen (base with comblike arrangement of spines, character of the tubercles at the base of each segment) some doubt arose as to the actual foraminiferal nature of this fossil. Dr. Fenner A. Chase, Division of Marine Invertebrates, U. S. National Museum, kindly agreed to examine this specimen and concluded that there were no characters preventing an interpretation of this fossil as the base of the flagellum (first or second antenna) of a Crustacean, probably an Isopod.

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Tappan, H.

Troelsen, J. C.

White, M. P.
Planktonic Foraminifera from the Eocene Navet and San Fernando Formations of Trinidad, B. W. I.

By Hans M. Bolli

Introduction

This paper contains the results of a study of planktonic Foraminifera and their stratigraphic distribution in the Eocene Navet and San Fernando formations. It represents the link between similar investigations in the Paleocene-lower Eocene Lizard Springs formation and the Oligocene-Miocene Cipero and Lengua formations. Planktonic Foraminifera have been chosen for the biostratigraphic subdivision of the Navet and San Fernando formations on account of their abundance and the short life ranges of many species. The species and subspecies of the genera *Hanckenina*, *Cribrohanckenina*, *Chiloguembelina* and related genera are omitted because they have previously been described in detail by Bronnimann (1950a, b) and by Beckmann (1957). The stratigraphic distribution of the Chiloguembelinae given by Beckmann is based on the same zonation as is proposed here; that of the Hanckeninae and Cribrohanckeninae was given in more generalized terms by Bronnimann and a few remarks on how the more characteristic species fit into the present zonation are made.

The smaller Foraminifera of the Navet formation have previously been described by Cushman and Renz (1948). The Orbulinidae were purposely left out by these authors, and of the Globorotaliidae only 4 species were included. The Ramdat marl, which is now placed in the Lizard Springs formation (Bolli, 1957a), was regarded as the basal part of the Navet formation and the Hospital Hill marl, now included in the Navet formation, was treated as a formation of its own. The fauna described by Cushman and Renz was collected from several isolated outcrops in the Central Range and Naparima area of Trinidad, each containing a distinct foraminiferal assemblage based on which the authors proposed a tentative stratigraphic sequence.

Unlike the Upper Cretaceous formations, the Paleocene-lower Eocene Lizard Springs formation, and the Oligocene-Miocene Cipero and Lengua formations, in all of which some comparatively undisturbed surface or subsurface sections are known, the Navet and San Fernando formations outcrop only in small, isolated masses in tectonically strongly disturbed areas. At the present time not one reasonably complete surface or subsurface section is known.

Because of this virtual absence of continuous sections the present investigations had to be confined to isolated outcrops and subsurface samples, altogether about 50 in number. This was found to be a great handicap for detailed biostratigraphic and evolutionary studies. Only because many planktonic species have a short life range or show rapid morphological changes during their evolution has it been possible to establish the proposed zonation of the middle and upper Eocene of Trinidad. It still remains doubtful whether the zones given here represent a complete sequence of beds.

Acknowledgments

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The author wishes to thank Dr. H. G. Kugler, consulting geologist to the Central Mining Investment Corporation and Mr. J. B. Saunders, paleontologist of The Trinidad Oil Company, for reading and discussing the manuscript. Dr. K. Rohr kindly made the sketch map showing Navet localities in the Central Range. Through discussions and exchange of material Dr. P. J. Bermudez of the Creole Petroleum Corporation has aided the author in the determination of several species. Thanks are due to Dr. A. R. Loeblich, Jr., of the U. S. National Museum and to Mrs. Helen Tappan Loeblich, Research Associate, Smithsonian Institution, for their help extended in the completion of the paper.

Mr. R. A. Pallant, senior draftsman of The Trinidad Oil Company, supervised the preparation of the table and text figure. The plate illustrations are camera lucida drawings by Patricia and Lawrence Isham, scientific illustrators, U. S. National Museum, Washington, D. C.
Stratigraphy

Navet Formation

The term Navet formation was introduced by Renz (1942) for the characteristic light grey to greenish-grey, khaki-weathering, nodular marls occurring between the Paleocene-lower Eocene Lizard Springs formation and the upper Eocene San Fernando formation. They contain a very rich fauna of smaller Foraminifers, especially planktonic forms, and at some levels are also rich in Radiolaria.

In their paper on the Eocene Foraminifera of the Navet and Hospital Hill formations of Trinidad, Cushman and Renz (1948) described the fauna from seven isolated localities. Tentative stratigraphic positions based on faunistic evidence for these localities were given from top to bottom as follows:

Penitence Hill marl
Fitt Trace—Navet River—Nariva River marls
Friendship Quarry—Dunmore Hill marls
Ramdat marl

For faunistic and lithologic reasons the Ramdat marl has been moved to the Lizard Springs formation (Bolli, 1957a, p. 64). No clear break has been recognized between the Lizard Springs and Navet formations. The Globorotalia palmerae zone, here placed in the basal Navet, occupies a somewhat transitional position between the two formations. The calcium carbonate content as measured at the type localities does not exceed 10 to 15 percent in the lower Lizard Springs and 25 percent in the upper Lizard Springs but increases to 36 percent in the Globorotalia palmerae zone and between 50 and 70 percent in the higher Navet beds.

The Hospital Hill marl was treated by Cushman and Renz as a separate formation. However, it is lithologically so similar to the Navet formation that it is here considered to represent its topmost zone. To the author's knowledge, no contacts are exposed between the marls of the Navet formation and the clays, silts, sands, and boulder beds of the younger San Fernando formation. The Navet formation is here regarded as comprising the uppermost part of the lower Eocene, the middle Eocene, and the lower part of the upper Eocene.

The complete absence of continuous sections in the Navet formation and the difficulty in establishing biostratigraphic sequences from isolated, small outcrops and subsurface occurrences has already been pointed out in the introduction. The large number of samples studied has counterbalanced these unfavourable conditions to some degree. The additional material studied has enabled the erection of two more zones to the subdivisions suggested by Cushman and Renz (1948):

The Globorotalia palmerae zone: This zone shows affinities to the Globorotalia aragonensis zone of the uppermost Lizard Springs but contains in addition Globorotalia aspensis (Colom) and the short-lived Globorotalia palmerae Cushman and Bermudez. The genera Hankenina and Clavigerinella, both restricted to the middle and upper Eocene are not found here. It is regarded as uppermost lower Eocene (basal Navet).

The Truncorotaloides rohri zone: This zone still contains the spinose forms of the Truncorotaloides rohri Bronnimann and Bermudez group and small specimens of Globorotalia lehneri Cushman and Jarvis but no longer Globigeropsis kugleri Bolli, Loeblich, and Tappan and the zonal marker of the Porticulasphaera mexicana zone. Some species known in the upper Eocene and lower Oligocene begin to appear, but the zonal marker of the Globigeropsis semiinvoluta zone (Hospital Hill marl) is not yet present. It is considered to be of uppermost middle Eocene age.

Seven zones, based on the distribution of planktonic Foraminifera, are distinguished in the proposed biostratigraphic subdivision of the Navet formation. The following tabulation (see also text-figures 25 and 26) shows the Navet marl localities described by Cushman and Renz in relation to the new zonation. They are from top to bottom:

<table>
<thead>
<tr>
<th>Globaligerapsis semiinvoluta zone</th>
<th>Hospital Hill formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truncorotaloides rohri zone</td>
<td>Penitence Hill marl</td>
</tr>
<tr>
<td>Porticulasphaera mexicana zone</td>
<td>Fitt Trace marl—Navet</td>
</tr>
<tr>
<td>Globoorotalia lehneri zone</td>
<td>River marl</td>
</tr>
<tr>
<td>Globigerapsis kugleri zone</td>
<td>Dunmore Hill marl—</td>
</tr>
<tr>
<td>Hankenina aragonensis zone</td>
<td>Nariva River marl</td>
</tr>
<tr>
<td>Globorotalia palmerae zone</td>
<td>Friendship Quarry marl</td>
</tr>
</tbody>
</table>

Some of the Navet marl localities given by Cushman and Renz contain poorly preserved faunas, this is especially true for the Friendship Quarry marl. One of them, the Penitence Hill marl locality, is no longer accessible. Therefore, in addition to the Cushman and Renz localities which are here maintained as type localities, a number of outcrops which contain better preserved faunas are proposed as cotype localities. A very suitable area for such outcrops is found between mileposts 12 and 12% of the Brasso-Tamana Road and the Navet River in the Central Range (see text-fig. 25). All but one zone of the Navet formation, including a new type locality, are here exposed in a very restricted and comparatively easily accessible area. Most of the outcrops lie in two small ravines leading into the Navet River. A few are found along the Navet River and two more are situated further north, one on the Brasso-Tamana Road, near milepost 12%, the other west of the road, on the slope of a small marl hill. Although almost every zone is represented in this area, they are not in any normal stratigraphic sequence, the Navet being present as slip-masses in the upper Oligocene-lower Miocene Nariva formation.

Globorotalia palmerae Zone

Type locality: Trinidad Petroleum Development well Esmeralda 1, eastern Central Range, Trinidad (coordinates N.270297 links; E.415893 links), type sample: core 9,386–9,405 feet (TTOC 228911).
SKETCH MAP
SHOWING
EXPOSURES OF NAVET
IN THE
CENTRAL RANGE, TRINIDAD
by K. Rohr

LEGEND

Zones of the Navet Formation
1. Globigerapsis semiinvoluta
2. Truncorotaloides rohri
3. Porticulaspbera mexicana
4. Globorotalia lehneri
5. Globigerapsis kugleri
6. Hanckenina aragonensis
7. aff. Hanckenina aragonensis

▌ Area under review

⊙ Eocene Plaisance conglomerate blocks

-disabled Extensive landslips in argillaceous areas

▲ Hill tops

→ Saddles on watersheds

♦ Old test pit

→ Mile Post

Figure 25.—Exposures of the Navet formation in the Central Range, Trinidad, B.W.I.
Lithology: Dark red, indurated marl type with pale green blotches.

Remarks: At present the Globorotalia palmerae zone is known in Trinidad only from the subsurface. The planktonic fauna still shows strong affinities to the underlying Globorotalia aragonensis zone (Ramdat marl) of the Lizard Springs formation. Species that make their first appearance are the zonal marker, Globorotalia aspensis (Colom) and "Globigerinoides" higginsei Bolli, new species.

Hantkenina aragonensis Zone

Type Locality: Friendship Quarry (Friendship Quarry marl of Cushman and Renz, 1948) near milepost 5 of the Naparima-Mayaro Road between San Fernando and Princes Town, in tea plantation, (coordinates N:241000 links; E:391900 links), type sample Rz 336 (TTOC 52767).

Cotype Localities: In small ravines between mileposts 12 and 12½ of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25), samples K 8775, 8781, 8783, 8820, 8823, 8911, 8914.

Lithology: White to light grey marl, in part indurated, chalklike.

Remarks: The Friendship Quarry is maintained as the type locality for the Hantkenina aragonensis zone because of easy accessibility. The chalklike beds of this locality contain a fairly poorly preserved foraminiferal fauna. Better faunas are found in the above mentioned cotype localities in the Central Range.

The Hantkenina aragonensis zone is characterized by the first occurrence of species of the genera Hantkenina and Clavigerinella together with a number of other planktonic species such as Globigerina boweri Bolli, new species, Globorotalia bulbikuri Bolli, new species, G. spinulosa Cushman, G. pseudomayeri Bolli, new species, and G. spinuloinflata (Bandy). G. palmerae Cushman and Bermudez, which is typical for the underlying Globorotalia palmerae zone, has disappeared together with a number of other species which persisted from the Lizard Springs formation.

A few outcrops (e.g., K 8817, 9002 of text-fig. 25) were found to contain planktonic assemblages apparently intermediate between those of the Globorotalia palmerae and the Hantkenina aragonensis zones. In this intermediate fauna Globorotalia palmerae is already extinct while Hantkenina aragonensis Nuttall has not yet appeared. Globorotalia pseudomayeri and small Clavigerinella with club-shaped chambers are common. The latter are probably ancestral forms of Clavigerinella akeri Bolli, Loeblich, and Tappan.

Globigerapsis kugleri Zone

Type Locality: Hindustan-Monkey Town Road Junction, Dunmore Hill area, south Trinidad (coordinates N:229700 links; E:434500 links), type sample Rz 476 (TTOC 63610) (Dunmore Hill marl of Cushman and Renz, 1948).

Cotype Localities: Nariva River, eastern Central Range (coordinates N:314460 links; E:488945 links), samples Gunther 7865, 7200–7204 (Shell Trinidad) (Nariva River marl of Cushman and Renz, 1948); in small ravine between mileposts 12½ and 12½ of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25), samples K 8821, 8824.

Lithology: Light grey, yellowish weathering marl, with indurated layers.

Remarks: Globigerapsis indicus (Finlay), Globigerapsis kugleri Bolli, Loeblich, and Tappan, Globorotalia lehneri Cushman and Jarvis, and Globorotalia centalis Cushman and Bermudez make their first appearance in the Globigerapsis kugleri zone, while several species, e.g., Globorotalia aragonensis Nuttall, Globorotalia brodermanni Cushman and Bermudez, Globigerina boweri Bolli, new species, and "Globigerinoides" higginsei Bolli, new species, become extinct at the top of this zone.

Globorotalia lehneri Zone

Type Locality: Outcrop on roadside near Fitt Trace on the Cunapo Southern Road, near milepost 17½, eastern Trinidad (coordinates N:311300 links; E:528110 links), type sample ES 233 (TTOC 18360) (Fitt Trace marl of Cushman and Renz, 1948).

Cotype Localities: Navet River, eastern Central Range (coordinates N:317120 links; E:500660 links), sample KR 4347a (TTOC 1245). (Navet River marl of Cushman and Renz, 1948). In small ravine between mileposts 12 and 12½ of the Brasso-Tamana Road and the Navet River, Central Range, and west of the Brasso-Tamana Road, between mileposts 12½ and 12½ (see text-fig. 25), samples K 8780, 8815, 8822, 8983.

Lithology: Light grey, yellowish weathering, soft marl.

Remarks: In addition to the zonal marker the Globorotalia lehneri zone is characterized by Globigerapsis kugleri Bolli, Loeblich and Tappan and Globigerinatheka barri Bronnimann which makes its first appearance in this zone. Globorotalia aragonensis Nuttall and Globorotalia brodermanni Cushman and Bermudez do not extend into this zone.

Porticulasphaera mexicana Zone

Type Locality: Outcrop in road cut near milepost 12½ of the Brasso-Tamana Road, Central Range, type sample K 8814 (see text-fig. 25).

Cotype Localities: In small ravines between the mileposts 12 and 12½ of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25), samples K 8777, 8778, 8779, 8785, 8825.

The Penitence Hill marl of Cushman and Renz (1948) which falls in the Porticulasphaera mexicana zone is no longer accessible. It was described from the foundation of the Town Hall, Penitence Hill, San Fernando, south Trinidad.

A small block of Porticulasphaera mexicana zone, Navet, containing an exceptionally well preserved
fauna was found reworked in the upper Oligocene to lower Miocene Nariva formation in the cutting west of tank 127, situated south of The Avenue and 850 feet west of its junction with Bon Accord Road, Pointe-a-Pierre. Many of the specimens illustrated in this paper are from this block, which is no longer existant. (Sample Hg 8851, TTOC 215782).

**Lithology:** Light grey, yellowish weathering, soft marl.

**Remarks:** *Porticulasphaera mexicana* (Cushman) is restricted to this zone. *Globorotaloides suteri* Bolli and *Globigerina venezuelana* Hedberg occur for the first time, while *Globorotalia spinulosa* Cushman, *Globorotalia spinuloinflata* (Bandy), *Truncorotaloides topilensis* (Cushman), and *Globigerapsis kuqleri* Bolli, Loeblich, and Tappan become extinct at the top of the zone.

**Truncorotaloides rohri Zone**

**Type Locality:** Outcrop (see text-fig. 25) in Navet River, Central Range (coordinates N:316640 links; E:592260 links), type sample K 8834 (TTOC 177773), outcrop K 8833 contains an identical fauna.

**Lithology:** Yellowish grey, soft marl.

**Remarks:** The *Truncorotaloides rohri* zone is characterized by the persistence of the spinose *Truncorotaloides rohri* Bronnimann and Bermudez group and small specimens of the strongly compressed *Globorotalia lehneri* Cushman and Jarvis. In contrast to *Globigerapsis indica* (Finlay) and *Globigerinatheca barri* Bronnimann, these species do not continue into the overlying *Globigerapsis simiinvoluta* zone. *Globigerina senni* (Beckmann) also becomes extinct at the top of the zone.

**Globigerapsis semiinvoluta Zone**

**Type Locality:** Hospital Hill marl, on east side of road running from Kings Wharf, San Fernando, to Point Bontour and the Cipero Coast, 235 feet northeasterly from small bridge, 0.2 miles south of Kings Wharf (coordinates N:234860 links; E:355650 links), type sample Rz 75 (TTOC 23130) (Hospital Hill formation of Cushman and Renz).

**Cotype Localities:** In small ravine between mileposts 12% and 12% of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25), samples K 8829, 8830, 8832 (TTOC 177769, 177770, 177771).

**Figure 26.—Distribution of planktonic Foraminifera in the Eocene Navet and San Fernando formations of Trinidad, B.W.I.**
UNITED STATES NATIONAL MUSEUM BULLETIN 215

Lithology: Yellowish-grey, nodular marl.

Remarks: The Globigerapsis semiinvoluta zone is characterized by the zonal marker, and by the absence of the middle Eocene spinoz Truncorotaloides rohari Bronnimann and Bermudez group and the strongly compressed Globorotalia lehneri Cushman and Jarvis.

San Fernando Formation

The term San Fernando beds was introduced by Guppy (1866). These beds, later elevated to formation rank, are best exposed in the San Fernando area, south Trinidad, where they are developed as glauconitic calcareous clays, clays, silts, sands, boulder beds, and small complexes of reefal limestone. As might be expected, these varied lithologic units, together comprising a thickness of up to 800 feet, carry equally varied foraminiferal faunas including completely arenaceous, predominantly planktonic, and shallow reefal assemblages. The larger Foraminifera of the limestones have been described by Vaughan and Cole (1941). Reworked Foraminifera, especially from the Navet formation, occur almost throughout the formation.

The Mount Moriah formation is considered synonymous with Guppy's San Fernando formation. The term “Mount Moriah” is today only used in member status for the silts, sands, and boulder beds of the San Fernando formation.

In some sections in the San Fernando area (see Bolli, 1957b, p. 98) the calcareous clays of the San Fernando formation are overlain, apparently without a distinct lithologic break, by calcareous clays and marls of the Globigerina ampliapertura zone, Cipero formation. Faunistically, the separation is clearly shown by the disappearance of the typical Eocene planktonic and bentonic marker Foraminifera such as Hantkenina, Globorotalia cocoensis Cushman, Globorotalia centralis Cushman and Bermudez, Balaminia jacksonensis Cushman et al. The only planktonic species which appear for the first time in the basal Cipero are Globigerina ciperoensis ciperoensis Bolli and Cassigerinella chipolensis (Cushman and Ponton).

In the San Fernando area the San Fernando formation rests unconformably on the lower part of the Navet formation or on the Lizard Springs formation.

Because of the varied foraminiferal assemblages in the San Fernando formation and the strong reworking of Foraminifera from older formations, no subdivision into biozones is possible with the sections available at the present time.

Globorotalia cocoensis Zone

Type Locality: Steep bank on east (waiting rooms) side of San Fernando Railway Station (coordinates N:237060 links; E:356425 links), type sample KR25684 (TTOC 233769).

Lithology: Dark grey-brown calcareous silt.

Remarks: The zone is characterized by the presence of Globorotalia cocoensis Cushman, Hantkenina primitiva Cushman and Jarvis and Cribrohantkenina bermudezi (Thalmann) and the absence of Globigerapsis semiinvoluta (Keijzer).

Evolutionary Trends and Direction of Coiling

More complete sections than those available in Trinidad would be necessary to study in detail the evolutionary trends and patterns of coiling in the middle and upper Eocene. However, the following condensed remarks on observation made on the Trinidad material will suffice to show that the rapid tempo in evolution and distinct patterns in preferred coiling directions as shown for many planktonic species in the upper Paleocene and lower Eocene (Bolli, 1957a) also persist through the middle and upper Eocene. The same trends were found again in the Oligocene and Miocene (Bolli, 1950, 1951).

The species of the genera Globigerapsis, Globigerina, and Porticalasphaera obviously represent a related group. Transitional specimens indicate that Globigerapsis kugleri Bolli, Locelich, and Tappan branched off from the long-ranging Globigerapsis index (Finlay) and later developed into Porticalasphaera mexicana (Cushman). Globigerina hantkenai barri Bronnimann is closely related to Globigerapsis kugleri, differing only in the possession of sutural bullae. Although no transitional specimens were observed in Trinidad between Globigerapsis index (Finlay) and Globigerapsis semiinvoluta (Keijzer) it is likely that the latter branched off from the former in early upper Eocene time.

The fact that over 90 percent of the specimens of the species belonging to the genera Globigerapsis, Globigerinathea, and Porticalasphaera coil dextrally is further proof for close genetic relationship.

The earliest recorded species of Truncorotaloides in the upper Paleocene coil almost exclusively dextrally. This trend seems to persist throughout the lower Eocene. The lower middle Eocene Globorotalia bullbrooki Bolli, new species, (probably a Truncorotaloides) still shows a preference for dextral coiling, although this is much less pronounced than in the older Truncorotaloides. A rapid change towards sinistral coiling in Truncorotaloides apparently occurs at the end of the Hantkenina aragonensis zone. The ratio of sinistral to dextral coiling of T. rohari Bronnimann and Bermudez and T. topilensis (Cushman) in the Globigerapsis kugleri to Truncorotaloides rohari zones is over 90 percent.

The strong preference for sinistral coiling (over 90 percent) shown by Globorotalia aragonensis Nuttall and Globorotalia brodermanni Cushman and Bermudez in the uppermost Lizard Springs (Bolli, 1957a) is found to continue in the Navet formation until the two species become extinct at the top of the Globigerapsis kugleri zone. Of approximately 100 specimens of Globorotalia renzi Bolli, new species, counted in samples throughout the recorded range, all were found to coil dextrally.
**Systematic Descriptions**

**Family Hantkeninidae Cushman, 1927**

**Subfamily Hastigerininae Bolli, Loeblich, and Tappan, 1957**

**Genus Hastigerina Thomson**

**Hastigerina micra** (Cole)

**Plate 35, Figures 1a–2b**


**Stratigraphic range:** Hantkenina aragonensis zone, Navet formation to Globorotalia cocaoensis zone, San Fernando formation.

**Locality:** Figured hypotypes (USNM P5698a,b) from the Porticula-sphaera mexicana zone, Navet formation; block in the upper Oligocene-lower Miocene Nariva formation, in cutting west of tank 127, north of The Avenue and 850 feet west of its junction with Bon Accord Road, Pointe-a-Pierre. Sample Hg 8581 (TTOC 215782). The block is no longer existent.

**Remarks:** With the exception of the Globorotalia palmerae zone, Hastigerina micra (Cole) occurs through-out the Navet and San Fernando formations but does not continue into the Oligocene-Miocene Cipero formation. GLAESNER (1937) changed the generic status of this species to Globigerinella which is now regarded as a junior synonym of Hastigerina (Bolli, Loeblich, and Tappan, 1957, p. 29).

**Genus Clavigerinella Bolli, Loeblich, and Tappan, 1957**

**Clavigerinella akersi** Bolli, Loeblich, and Tappan

**Plate 35, Figure 4**


**Stratigraphic range:** Hantkenina aragonensis zone to Globigeropsis kugleri zone, Navet formation.

**Locality:** Figured topotype (USNM P5699) from the Hantkenina aragonensis zone, Navet formation; in small ravine between mileposts 12¾ and 12½ of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25). Sample HGK 8820 (TTOC 177760).
Remarks: Clavigerina akersi Bolli, Loeblich, and Tappan is distinguished from C. jarvisi (Cushman) by having the later, elongate chambers distinctly inflated at the outer ends. It is more restricted in its range and may be regarded as a characteristic index fossil.

Peters (1954, p. 40) described Hastigerinella colombiana from the middle Eocene Carreto formation of Colombia. The figures for the species show the chambers to be club-shaped though not as distinctly so as in Clavigerina akersi; the aperture is not visible on the figure, but is described as “a rather wide arched slit with a slight lip at base of last-formed chamber, slightly ventrally of periphery.” Similar or identical forms possessing an equatorial aperture which occur in the middle Eocene of Trinidad could possibly represent a juvenile stage of Clavigerina akersi or an intermediate stage between C. jarvisi and C. akersi. (See pl. 35, figs. 3a,b; specimen (USNM P5700) from the Hantkenina aragonensis zone, Navet formation, between mileposts 12½ and 12¾ of the Brasso-Tamana Road, Central Range, sample K 8775 (TTOC 177647).) It may also be assumed that Hastigerinella colombiana Nuttall belongs to Clavigerina, although the aperture is not preserved on the types figured by Nuttall.

Clavigerina jarvisi (Cushman)

Plate 35, Figures 5–6

Hastigerinella jarvisi Cushman, Cushman Lab. Foram. Res., vol. 6, p. 18, pl. 3, figs. 8–11, 1930.


Stratigraphic range: Hantkenina aragonensis zone to Globigeropsis semiinvoluta zone, Navet formation.

Locality: Figured hypotype (USNM P5701a, b) from the Globorotalia lehneri zone, Navet formation; Navet River marl and Fitt Trace marl (see Cushman and Renz, 1948, p. 3); samples KR 4437, KS 233 (TTOC 1285, 18360).

Family Orbulinidae Schultze, 1854

Subfamily Globigerininae Carpenter, 1862

Genus Globigerina d’Orbigny, 1826

Globigerina soldadoensis Brunniann

Plate 35, Figures 9a–c


Stratigraphic range: Globorotalia velascoensis zone, Lizard Springs formation to Globorotalia palmerae zone, Navet formation.

Locality: Figured hypotype (USNM P5704) from the Globorotalia palmerae zone, Navet formation; Pit sample from a block reworked in the Oligocene-Miocene Cipero formation; 2,900 feet south of the Naparima-Mayaro Road and Corial Road junction, Malgetout Estate, west of Princes Town, south Trinidad (coordinates N:235390 links; E:398620 links); sample KTO 145 (TTOC 143701).
Globigerina senni (Beckmann)

**PLATE 35, FIGURES 10a–12**

*Sphaeroidinella senni* Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, pp. 394–95, pl. 26, figs. 2–4, text-fig. 20, 1953.

**STRATIGRAPHIC RANGE:** Globorotalia palmerae zone to Truncorotaloides rohri zone, Navet formation.

**Locality:** Figured hypotypes (USNM P5705a–c) from the Porticulasphaera mexicana zone, Navet formation; same locality as given for Hastigerina micra (Cole) (p. 161); sample Hg 8581 (TTOC 215782).

**Remarks:** Globigerina senni was originally described by Beckmann as a *Sphaeroidinella*. Sutural supplementary apertures and chamber flanges, which are typical for the genus *Sphaeroidinella*, do not exist in this species. It is therefore placed in *Globigerina*. The species is found in all Navet zones except the highest. It is likely that it developed from the upper Lizard Springs *Globigerina taroubaensis* Bronnimann, a species lacking the granular particles usually seen surrounding the umbilical area in *Globigerina senni*.

Globigerina linaperta Finlay

**PLATE 36, FIGURES 5a–b**


**STRATIGRAPHIC RANGE:** Globorotalia pseudomenardii zone, Lizard Springs formation to Globigeraspis semiinvoluta zone, San Fernando formation.

**Locality:** Figured hypotype (USNM P5715) from the Porticulasphaera mexicana zone, Navet formation; Brasso-Tamana Road, near milepost 124, Central Range (see text-fig. 25); sample K 8814 (TTOC 177755).

Globigerina boweri Boll, new species

**PLATE 36, FIGURES 1a–2b**

Shape of test low trochospiral; equatorial periphery distinctly lobate (trilobate); axial periphery rounded. Wall calcareous, perforate, surface very finely pitted. Chambers spherical, early ones somewhat compressed and slightly subangular; about 12, arranged in about 2½ whorls; the 3–3½ chambers of the last whorl increase rapidly in size. Sutures on spiral side: in early stage radial to slightly curved, in late stage radial or oblique, depressed; on umbilical side radial, depressed. Umbilicus narrow. Aperture a distinct arch, commonly with a short lip or rim; interiomarginal, umbilical, with a tendency to become umbilical-extraumbilical. Coiling predominantly dextral (90 percent or more) in the *Hantkenina aragonensis* and *Globigeraspis kugleri* zone, Navet formation. Largest diameter of holotype 0.4 mm.

**STRATIGRAPHIC RANGE:** *Hantkenina aragonensis* zone to *Globigeraspis kugleri* zone, Navet formation.

**Locality:** Holotype (USNM P5711) from the *Hantkenina aragonensis* zone, Navet formation; outcrop on left side of right branch of Nariva River, about 450 feet from its junction, Central Range, Trinidad (coordinates N:314350 links; E:487360 links); sample K 9077 (TTOC 178166). Figured paratype (USNM P5712) from the *Hantkenina aragonensis* zone, Navet formation; in small ravine between mile posts 12½ and 12% of the Brasso-Tamana Road and the Navet River, Central Range (see text fig. 25); sample HGK 8820 (TTOC 177760).

**Remarks:** Globigerina boweri, new species, differs from *G. linaperta* Finlay in having a higher arched aperture which has the tendency to be slightly extraumbilical in position. Especially the earlier chambers are somewhat compressed which gives them a slightly subangular aspect.

The species is named for Mr. T. H. Bower, senior exploitation geologist of The Trinidad Oil Company.

Globigerina yeguaensis Weinzierl and Applin

**PLATE 35, FIGURES 14a–15c**

*Globigerina yeguaensis* Weinzierl and Applin, Journ. Paleontol., vol. 3, No. 4, p. 408, pl. 43, figs. 1a–b, 1929.

**STRATIGRAPHIC RANGE:** *Hantkenina aragonensis* zone, Navet formation to *Globorotalia cocoensis* zone, San Fernando formation.

**Locality:** Figured hypotype (USNM P5708) from the type locality of *Globigeraspis semiinvoluta* zone, Navet formation (see p. 159); sample Ky 7 (TTOC 144343). Figured hypotype (USNM P5707) from the Porticulasphaera mexicana zone, Navet formation; same locality as given for Hastigerina micra (Cole) (p. 161); sample Hg 8581 (TTOC 215782).

**Remarks:** There is considerable variation in the specimens regarded as belonging to *Globigerina yeguaensis*. All forms are distinctly lobate, display a fairly open umbilicus and have the apertures of the last, occasionally also of earlier chambers protected by a fragile lip.

In typical forms the 3–3¾ chambers of the last whorl increase rapidly in size (fig. 14a–c); in others with 4 chambers the increase is more moderate (figs. 15a–c). *G. venezuelana* Hedberg is a more compact form than *G. yeguaensis*. It has a less open umbilicus and shows no apertural lips. *G. yeguaensis* has not been seen with a rudimentary final chamber, a feature often present in *G. venezuelana*.

Globigerina cf. trilocularis d’Orbigny

**PLATE 36, FIGURES 3a–b**

**STRATIGRAPHIC RANGE:** *Globorotalia lehneri* zone, Navet formation to *Catapsydrax dissimilis* zone, Cipero formation.

**Locality:** Figured specimen (USNM P5713) from the *Globorotalia cocoensis* zone, San Fernando formation; Soldado Rock Island (see Kugler, 1938); sample K3741 (TTOC 190838).
Globigerina venezuelana Hedberg

PLATE 35, FIGURES 16a-17


Stratigraphic range: Poritculapheana mexicana zone, Navet formation to Globorotalia menardii zone, Lenga formation, probably continuing into younger beds.

Locality: Figured hypotypes (USNM P5709a-b) from the Poritculapheana mexicana zone, Navet formation; same locality as given for Hvidugerea microa (Cole) (p. 161); sample Hg 8581 (TTOC 215732).

Globigerina parva Bolli

PLATE 36, FIGURES 7 a-c


Stratigraphic range: Truncorotaloids rohri zone, Navet formation to Globigerina ampliapertura zone, Cipero formation.

Locality: Figured hypotype (USNM P5717) from the type locality of the Globigerapsis semiinvoluta zone, Navet formation (see p. 159); sample Ky 7 (TTOC 144343).

Remarks: This small, strongly lobate, fairly high spired form with four chambers in the last whorl is typical for the upper Eocene and basal Oligocene. Globigerina ovaticaentis Howe and Wallace, described from the upper Eocene is probably very close to this species.

Globigerina ampliapertura Bolli

PLATE 36, FIGURES 8 a-c


Stratigraphic range: Globorotalia cocoaensis zone, San Fernando formation to Globigerina ampliapertura zone, Cipero formation.

Locality: Figured hypotype (USNM P5718) from the Globorotalia cocoaensis zone, San Fernando formation; augerhole, Jarvis Street, San Fernando; sample KR 25636 (TTOC 238132).

Remarks: Globigerina ampliapertura, which appears in the uppermost Eocene and continues into the basal Oligocene, seems to be genetically related to Globorotalia centralis Cushman and Bermudez. Intermediate forms (USNM P5719a,b) showing the aperture in a transitional position, are commonly found in the Globorotalia cocoaensis zone (pl. 36, figs. 9, 10). The species might represent a geronic stage of the G. centralis-G. cocoaensis strain, reverting before its extinction to a globigerinid form and also to random coiling.

Globigerina ciperoensis angustiambilicata Bolli

PLATE 36, FIGURES 6a-b


Stratigraphic range: Globorotalia cocoaensis zone (probably upper part), San Fernando formation to Catapsydrax dissimilis zone, Cipero formation.

Locality: Figured hypotype (USNM P5716) from the Globorotalia cocoaensis zone, San Fernando formation; Soldado Rock Island (see Kugler, 1938); sample K 3741 (TTOC 190838).

Globigerina rohri Bolli

PLATE 36, FIGURES 4a-b


Stratigraphic range: Globorotalia cocoaensis zone, San Fernando formation to Catapsydrax dissimilis zone, Cipero formation.

Locality: Figured hypotype (USNM P5714) from the Globorotalia cocoaensis zone, San Fernando formation, Kern Trinidad Oilfields well C-609, core 4,425–36 feet (TTOC 192784).

"Globigerinoides" bigginsi Bolli, new species

PLATE 36, FIGURES 11a-13b

Shape of test high trochospiral; equatorial periphery distinctly lobate. Wall calcareous, perforate, surface finely pitted, in well preserved specimens with very minute spines. Chambers spherical, later ones often somewhat ovate, 12–15, arranged in about 2½ whorls; the last whorl of about 4 chambers increasing moderately in size, the ultimate chamber may be smaller than the penultimate (see fig. 12). Sutures on spiral side radial, deeply incised; on umbilical side radial, deeply incised. Umbilicus narrow, deep. Primary aperture a high arch, interiomarginal-umbilical; in well preserved specimens a supplementary sutureal aperture is seen between the penultimate and ultimate chambers and occasionally also between earlier chambers of the last whorl. Coiling random in the Globorotalia palmerae zone; a preference for dextral coiling of over 90 percent in the Hantkenina aragonensis and Globigerapsis kugleri zone, Navet formation. Largest diameter of holotype 0.5 mm.

Stratigraphic range: Globorotalia palmerae zone to Globigerapsis kugleri zone, Navet formation.

Locality: Holotype (USNM P5720) from an Eocene core, lat. 30° 43' N., long. 62° 28' W.; depth of water 1,554 meters; depth of sample in core, 120–122 cm. Figured paratypes (USNM P5721a, b) from the Hantkenina aragonensis zone, Navet formation; outcrop on left side of right branch of Narr River, about 450 feet
from its junction, Central Range, Trinidad (coordinates N.314300 links; E.487360 links); sample K 9077 (TTOC 178166).

Remarks: According to the generic definition of Globigerinoides, "Globigerinoides" higginisi, new species, should be included here. This is only done provisionally because no genetic relation is apparent between this lower-middle Eocene form and the main group of Globigerinoides species which appears only at the close of the Oligocene or in the early Miocene. More detailed studies on well preserved material might reveal differences that justify a generic separation of "Globigerinoides" higginisi from Globigerinoides. It has been thought that "Globigerinoides" higginisi might possibly be the ancestor of the Globigerapsis group. However, it differs from Globigerapsis index (Finlay), which is the oldest representative of that genus, in the possession of a large umbilical aperture, higher spire, and more globular chambers.

Through the courtesy of Dr. A. R. Loeblich, U.S. National Museum, an excellently preserved specimen from an Eocene core from the Atlantic Ocean was made available to the author (pl. 36, figs. 11a–b). It possesses two sutural supplementary apertures, and the surface is covered with very minute spines. It has been chosen as the holotype.

The species is named for Mr. G. E. Higgins, senior exploration geologist of The Trinidad Oil Company.

Subfamily Orbulininae Schultze, 1854

Genus Globigerapsis Bolli, Loeblich and Tappan, 1957

Globigerapsis index (Finlay)

Plate 36, Figures 14a–18b


Stratigraphic Range: Globigerapsis kugleri zone to Globigerinoides semiinvoluta zone, Navet formation; ?Globorotalia cocoaensis zone, San Fernando formation.

Locality: Figured hypotypes (figs. 14, 15; USNM P5722a–b) from the Globigerapsis kugleri zone, Navet formation; in small ravine between mileposts 12½ and 12½ of the Brasso–Tamana Road and the Navet River, Central Range (see text-fig. 25); sample HGK 8224 (TTOC 177764). Figured hypotypes (figs. 16–18; USNM P5723–5725) from the Porticulasphaera mexicana zone, Navet formation; same locality as given for Hastigerina miera (Cole) (p. 161); sample Hg 8581 (TTOC 215782).

Remarks: Globigerapsis index differs from G. kugleri Bolli, Loeblich, and Tappan in having a smaller final chamber covering the umbilicis and in higher arched sutural supplementary apertures.

Globigerapsis kugleri Bolli, Loeblich, and Tappan

Plate 36, Figures 21a–b


Stratigraphic Range: Globigerapsis kugleri zone to Porticulasphaera mexicana zone, Navet formation.

Locality: Figured hypotype (USNM P5727) from the Globorotalia lehneri zone, Navet formation; Nariva River, Central Range; sample K 9071 (TTOC 178160).

Globigerapsis semiinvoluta (Keijzer)

Plate 36, Figures 19–20


Globigerapsis semiinvoluta (Keijzer), Bolli, Loeblich, and Tappan, U.S. Nat. Mus. Bull. 215, p. 34, pl. 6, figs. 7a–e, 1957.

Stratigraphic Range: Globigerapsis semiinvoluta zone, Navet formation.

Locality: Figured hypotypes (USNM P5726a–b) from the type locality of the Globigerapsis semiinvoluta zone, Navet formation (see p. 159); sample Ky 7 (TTOC 144343).

Genus Porticulasphaera Bolli, Loeblich and Tappan, 1957

Porticulasphaera mexicana (Cushman)

Plate 37, Figures 1a–b.


Stratigraphic Range: Porticulasphaera mexicana zone, Navet formation.

Locality: Figured hypotype (USNM P5728) from the Porticulasphaera mexicana zone, Navet formation; same locality as given for Hastigerina miera (Cole) (p. 161); sample Hg 8581 (TTOC 215782).

Genus Catapsydrax Bolli, Loeblich, and Tappan, 1957

Catapsydrax echinatus Bolli, new species

Plate 37, Figures 2a–5b

Shape of test low to medium trochospiral; equatorial periphery lobate; axial periphery rounded, more rarely becoming slightly subangular. Wall calcareous, perforate, surface covered with short, thin spines. Chambers spherical or slightly compressed, 10–15 in about 2½ whorls; the last whorl of about 4 chambers increasing fairly rapidly in size. Sutures on spiral side radial or slightly oblique, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, covered by a bulla. Primary aperture covered by umbilical bulla, interiomarginal, umbilical; accessory apertures of bulla very small medium to low arches, one or two in number, occasionally more, infralaminal, situated above sutures between earlier chambers. Coiling in over 90 percent
of specimens sinistral in the *Porticulasphaera mexicana* zone. Largest diameter of holotype 0.37 mm.

**Stratigraphic range:** *Globorotalia lehneri* zone to *Truncorotaloides rohri* zone, Navet formation.

**Locality:** Holotype (USNM P5729) and figured paratypes (USNM P5730a–c) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina micra* (Cole) (p. 161); sample Hg 8581 (TTOC 215782).

**Remarks:** *Catapsydrax echinatus*, new species, is distinguished from *C. dissimilis* (Cushman and Bermudez) and *C. unicusus* Bolli, Loeblich, and Tappan by having a distinctly spinose surface. This type of surface ornamentation is characteristic for many upper Paleocene to middle Eocene planktonic species. The balsa, which varies considerably in size may be smooth (see fig. 5b) or spinose (see figs. 2b, 3b). Most specimens observed are smaller than the average size of *C. cf. dissimilis* found in the upper part of the Navet and San Fernando formations.

*Catapsydrax unicusus* Bolli, Loeblich, and Tappan

**Plate 37, Figures 7a–b**


**Stratigraphic range:** *Truncorotaloides rohri* zone, Navet formation to *Catapsydrax stainforthi* zone, Cipero formation.

**Locality:** Figured specimen (USNM P5732) from the *Truncorotaloides rohri* zone, Navet formation; near junction of small ravine with Navet River (see text fig. 25); sample K 8833 (TTOC 177772).

*Catapsydrax cf. dissimilis* (Cushman and Bermudez)

**Plate 37, Figures 6a–b**

**Stratigraphic range:** *Truncorotaloides rohri* zone, Navet formation to *Catapsydrax stainforthi* zone, Cipero formation.

**Locality:** Figured specimen (USNM P5731) from the type locality of the *Globigeropsis semiinvoluta* zone, Navet formation (see p. 159); sample Ky 7 (TTOC 144343).

**Remarks:** The middle and upper Eocene forms differ from the *Catapsydrax dissimilis* of the Oligocene-lower Miocene in having somewhat more globular chambers. The umbilical balsa have commonly only two and more rarely only one infralaminar accessory aperture, whereas the balsa of Oligocene-lower Miocene specimens often display three or four accessory apertures. *C. unicusus* Bolli, Loeblich, and Tappan, whose balsa has one accessory aperture, is smaller in size and its chambers are less inflated than those found in *C. cf. dissimilis*. The direction of coiling in the Eocene specimens is apparently random, whereas the Oligocene-lower Miocene specimens show a strong preference for dextral coiling.

**Genus Globigerinatheka Bronnimann, 1952**

*Globigerinatheka barri* Bronnimann

**Plate 37, Figures 8–9**


**Stratigraphic range:** *Globorotalia lehneri* zone to *Globigeropsis semiinvoluta* zone, Navet formation, ?*Globorotalia cocoaensis* zone, San Fernando formation.

**Locality:** Figured hypotypes (USNM P5733a,b) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina micra* (Cole), p. 161; sample Hg 8581 (TTOC 215782).

**Genus Globorotaloides Bolli, 1957**

*Globorotaloides suteri* Bolli

**Plate 37, Figures 10a–12**


**Stratigraphic range:** *Porticulasphaera mexicana* zone, Navet formation to *Globigerinatella insueta* zone, Cipero formation.

**Locality:** Figured hypotypes (USNM P5744a–c) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina micra* (Cole) (p. 161); sample Hg 8581 (TTOC 215782).

**Family Globorotaliidae Cushman, 1927**

**Genus Globorotalia Cushman, 1927**

*Globorotalia palmerae* Cushman and Bermudez

**Plate 38, Figures 2a–c**


**Stratigraphic range:** *Globorotalia palmerae* zone, Navet formation.

**Locality:** Figured hypotype (USNM P5740) from the type locality of the *Globorotalia palmerae* zone, Navet formation (see p. 156); sample from core 9,386–9,405 feet (TTOC 228911).

**Remarks:** The preservation of the specimens found so far in Trinidad is poor; the characteristic *Hantkenina*-like peripheral spines are partially eroded.

*Globorotalia aspenalis* (Colom)

**Plate 37, Figures 18a–c**


**Stratigraphic range:** *Globorotalia palmerae* zone to *Globigeropsis kugleri* zone, Navet formation.
Locality: Figured hypotype (USNM P5738) from the Globorotalia palmerae zone, Navet formation; same locality as given for Globigerina soldadoensis Bronnemann (p. 162); sample KTO 145 (TTOC 143701).

Remarks: The position of the apertures in the type specimens of Globigerina aspersis figured by Colom is interiomarginal, umbilical—extraumbilical. For this reason the species is here placed in Globorotalia. Colom’s specimens show considerable variation in size, number of chambers in the last whorl (5–7) and shape of chambers (spherical to subangular). A similar range of varieties is found in the lower Navet of Trinidad. It appears likely that the species has developed from Globigerina soldadoensis angulosa Bolli. Detailed studies of this group in areas where more complete sections are available might show that differences in the stratigraphic ranges of the varieties justify the erection of a number of subspecies.

Globorotalia broedermanni Cushman and Bermudez

Plate 37, Figures 13a–c


Stratigraphic range: Globorotalia rex zone, Lizard Springs formation to Globigerapsis kugleri zone, Navet formation.

Locality: Figured hypotype (USNM P5735) from the Globorotalia palmerae zone, Navet formation; same locality as given for Globigerina soldadoensis Bronnemann (p. 162); sample KTO 145 (TTOC 143701).

Globorotalia aragonensis Nuttall

Plate 38, Figures 1a–c


Stratigraphic range: Globorotalia formosa formosa zone, Lizard Springs formation to Globigerapsis kugleri zone, Navet formation.

Locality: Figured hypotype (USNM P5739) from the Hantkenina aragonensis zone, Navet formation; Baccus River, Central Range; sample K 8854 (TTOC 177804).

Globorotalia pseudomayeri Bolli, new species

Plate 37, Figures 17a–c

Shape of test low trochosiral; equatorial periphery slightly lobate; axial periphery rounded. Wall calcareous, perforate, surface very finely pitted. Chambers spherical; 10–12, arranged in about 2½ whorls; the 4 or 5 chambers of the last whorl increase fairly rapidly in size. Sutures on spiral side curved or oblique in early portion, later radial, depressed; on umbilical side radial, depressed. Umbilicus narrow. Aperture a medium to low arch, with or without a faint lip; interiomarginal, umbilical-extraumbilical. Coiling random. Largest diameter of holotype 0.4 mm.

Stratigraphic range: Hantkenina aragonensis zone, Navet formation.

Locality: Holotype (USNM P5737) from the Hantkenina aragonensis zone, Navet formation; in upper part of small ravine between mileposts 12¾ and 12½ of the Brasso-Tamana Road and the Navet River (see text-fig. 25); sample K 8817 (TTOC 177758).

Remarks: Globorotalia pseudomayeri, new species, is morphologically very close to G. opima nana Bolli and G. mayeri Cushman and Ellisor. It differs from the former in that the chambers of the last whorl increase more rapidly in size. The last whorl consists of 4 to 4½ chambers, whereas in G. mayeri it has 5 or 6. G. pseudomayeri is restricted to the Hantkenina aragonensis zone of the Navet formation, whereas G. opima nana is found from the Truncorotaloides rohri zone, Navet formation to the Globigerina ciperoensis ciperoensis zone, Cipero formation. Globorotalia mayeri is restricted to the Cipero formation and lower part of the Lengua formation.

Globorotalia bullbrookii Bolli, new species

Plate 38, Figures 4a–5c

Shape of test on spiral side almost flat or low trochosiral, umbilical side strongly convex, subangular. Wall calcareous, perforate, surface covered with short, blunt spines. Chambers subangular, inflated; about 12–15, arranged in about 2½ whorls; the 4 chambers of the last whorl increase fairly rapidly in size. Sutures on spiral side oblique or radial, depressed; on umbilical side radial, depressed. Umbilicus narrow, deep. Aperture a low arch, interiomarginal, umbilical-extraumbilical. Coiling without distinct pattern in the preliminary study of eight isolated samples belonging to the Hantkenina aragonensis zone. In four of these samples, 70–90 percent of the specimens coiled dextrally, in two a preference for sinistral coiling was observed and in the other two the specimens coiled at random. It may be of interest to note that in the samples with a predominance of dextrally coiled specimens, Clavigerinella was found but Hantkenina was absent. To gain a clear picture of the coiling pattern in Globorotalia bullbrookii, it will be necessary to make further investigations in a more nearly complete stratigraphic section. Largest diameter of holotype 0.5 mm.

Stratigraphic range: Hantkenina aragonensis zone to Globigerapsis kugleri zone, Navet formation.

Locality: Holotype USNM P5742, and figured paratype (USNM P5743) from the Hantkenina aragonensis zone, Navet formation; holotype from outcrop on left side of right branch of Nariva River, about 450 feet from its junction, Central Range, Trinidad.
Globorotalia spinulosa Cushman

**Plate 38, Figures 6a–7c**


**Stratigraphic Range:** Hantkenina aragonensis zone to *Porticulasphaera mexicana* zone, Navet formation.

**Locality:** Figured hypotypes (USNM P5744a, b) from the *Hantkenina aragonensis* zone, Navet formation; in small ravin between mileposts 12½ and 12½ of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25); sample K8820 (TOC 177760).

**Remarks:** Globorotalia spinulosa Cushman is likely to be the ancestor of *G. lehneri* Cushman and Jarvis. Forms transitional between the two species are common. Typical *G. spinulosa* are umbilicoconvex; *G. lehneri* is very strongly compressed with both sides about equally convex.

Globorotalia spinuloinflata (Bandy)

**Plate 38, Figures 8a–c**


**Stratigraphic Range:** Hantkenina aragonensis zone to Porticulasphaera mexicana zone, Navet formation.

**Locality:** Figured hypotype (USNM P5745) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina micra* (Cole) (p. 161); sample Hg 8581 (TOC 215782).

**Remarks:** The figure of the holotype of *Globigerina spinuloinflata* Bandy shows a subangular test with an interiomarginal, umbilical-extrumbilical aperture; for these reasons it is placed in *Globorotalia*. Although the Trinidad specimens are often somewhat more angular than the figure given by Bandy (1949), they are here included in this species.

Globorotalia renzi Bolli, new species

**Plate 38, Figures 9a–c**

Shape of test very low trochospiral; equatorial periphery almost circular, only very slightly lobate; axial periphery angular with a thin keel. Wall calcareous, finely perforate, surface smooth or very finely pitted. Chambers strongly compressed; 15–18, arranged in about 2½ whorls; the chambers of the last whorl, usually 6 in number, increase fairly rapidly in size. Sutures on spiral side curved; on umbilical side radial or very slightly curved, slightly depressed between last chambers. Umbilicus very narrow, shallow. Aperture a low arch, often with a distinct lip, interiomarginal, umbilical-extrumbilical. Coiling almost 100 percent dextral throughout the observed range in the Navet formation. Largest diameter of holotype 0.23 mm.

**Stratigraphic Range:** Hantkenina aragonensis zone to Truncorotaloides rohri zone, Navet formation.

**Locality:** Holotype (USNM P5741) from the *Porticulasphaera mexicana* zone, Navet formation; block in the upper Oligocene-lower Miocene Nariva formation, in cutting west of tank 127, north of The Avenue and 850 feet west of its junction with Bon Accord Road, Pointe-a-Pierre; sample Hg 8581 (TOC 215782). The block is no longer extant.

**Remarks:** Globorotalia renzi Bolli, new species, is distinguished from *G. lehneri* Cushman and Jarvis by its small size and spineless periphery. It usually has 6 chambers in the last whorl compared with 4–5 in small specimens of *G. lehneri*.

The species is named for Dr. H. H. Renz of the Mene Grande Oil Company, in recognition of his contributions to micropaleontology in the Caribbean region.
Globorotalia bolivariana (Peters)

PLATE 37, FIGURES 14a–16


Stratigraphic range: Hantkenina aragonensis zone to Truncorotaloides rohri zone, Navet formation.

Locality: Figured hypotypes (USNM P5736a–c) from the Porticularaphera mexicana zone, Navet formation; same locality as given for Hantkenina micra (Cole) (p. 161); sample Hg 8581 (TTOC 215782). Figured hypotype (fig. 4; USNM P5749) from the Globorotalia cocoaensis zone, San Fernando formation; road cut at intersection of Naparima—Mayaro Road and San Fernando Bypass Road, east of San Fernando; sample KR 206521a (TTOC 113248).

Remarks: Globorotalia centralis Cushman and Bermudez shows considerable variation. During the evolution of the species there is a change in chamber shape from rounded towards subangular. The more subangular specimens may be regarded as transitional to G. cocoaensis Cushman. High spired specimens (figs. 2a–b) begin to occur in the upper part of the Navet formation. It has already been pointed out (p. 164) that specimens transitional between G. centralis and Globigerina ampliapertura Bolli are found in the Globorotalia cocoaensis zone, San Fernando formation. Further studies on the Globorotalia centralis group and related species will have to be carried out before it will be possible to establish definitely the genetic relationships. It may then be possible to erect a number of subspecies of stratigraphic value.

Globorotalia bolivariana nana Bolli


Stratigraphic range: Truncorotaloides rohri zone, Navet formation to Globigerina ciperoensis ciperoensis zone, Cipero formation.

Globorotalia cocoaensis Cushman

PLATE 39, FIGURES 5a–7b


Stratigraphic range: Globigeropsis semiinevoluta zone, Navet formation to Globorotalia cocoaensis zone, San Fernando formation.

Locality: Figured hypotypes (USNM P5750a–c) from the type locality of Globorotalia cocoaensis zone (see p. 160); sample KR 256584 (TTOC 238769).

Genus Truncorotaloides Bronnimann and Bermudez, 1953

After completion of the present study on the plankt tonic Foraminifera of the Navet formation, some excellent preserved material of Eocene and Paleocene age from Mid-Pacific seamounts became available for examination through the courtesy of Dr. E. L. Hamilton, U. S. Navy Electronics Laboratory, San Diego, California, and the Scripps Institution of Oceanography.

The predominantly planktonic fauna of Mid-Pacific
expedition core 25E–1 (19°40' N., 168°32' W.) described by Hamilton (1953) is almost identical with that of the *Hantkenina aragonensis* zone or the basal part of the *Globigerapsis kugleri* zone of the Navet formation. Many of the specimens which are otherwise indistinguishable from those described here as *Globorotalia bullbrooki* Bolli, new species, show distinct supplementary sutural apertures on the spiral side, a feature that could not be seen in the Trinidad specimens due to poor preservation. It seems most likely therefore, that *Globorotalia bullbrooki* from the Navet formation should be placed in the genus *Truncorotaloides*.

The fauna of dredge sample 33C (17°45' N., 174° 16' W.), described by Hamilton as Paleocene, is comparable with that of the *Globorotalia velascoensis* zone of the Lizard Springs formation of Trinidad (Bolli, 1957a). Another possibility is that it represents a horizon between the Paleocene *Globorotalia velascoensis* zone and the lower Eocene *Globorotalia rex* zone of the Lizard Springs formation, where a stratigraphic break is indicated in the Trinidad section. Together with *Globorotalia velascoensis* (Cushman), numerous *Truncorotaloides* types were found in the well preserved material. The study of the dredge sample would suggest that there are *Truncorotaloides* types identical with or very close to species described under the names *Globorotalia wilcoxiens* Cushman and Ponton, *G. formosa gracilis* Bolli, and *G. aequa* Cushman and Renz.

The fact, that *Truncorotaloides* appears in the Paleocene makes it likely that some lower Eocene species, so far attributed to the genus *Globorotalia*, might also possess supplementary sutural apertures on the spiral side which have not been observed because of poor preservation. One such species likely to belong to *Truncorotaloides* is *Globorotalia quetra* Bolli.

All known *Truncorotaloides* species belong to the group of distinctly spinose forms which appeared in the upper Paleocene and apparently become extinct at the end of the middle Eocene.

**References**

**Bandy, O. L.**


**Beckmann, J. P.**


**Bermudez, P. J.**


**Truncorotaloides rohri** Bronnimann and Bermudez

**Plate 39, Figures 8–12c**


**Stratigraphic range:** *Hantkenina aragonensis* zone; *Globigerapsis kugleri* zone to *Truncorotaloides rohri* zone, Navet formation.

**Locali ty:** Figured hypotypes (USNM P5751a–e) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina microa* (Cole) (p. 161); sample Hg 8581 (TTTOC 215782).

**Remarks:** In addition to *Truncorotaloides rohri*, Bronnimann and Bermudez (1953) described three varieties of this species which illustrate the variation of chamber and test shape ranging from rounded to angular forms. In *T. rohri* var. *guara^araensis* are included specimens with spherical chambers. *T. rohri* var. *piparoensis* is an intermediate form between *T. rohri* var. *guara^araensis* and *T. rohri*. The chambers of *T. rohri* var. *mayaensis* are angular conical, the test umbilico-convex. This variety may be regarded as related to *T. topolensis* (Cushman).

*Truncorotaloides topolensis* (Cushman)

**Plate 39, Figures 13–16b**


**Stratigraphic range:** *Globigerapsis kugleri* zone to *Porticulasphaera mexicana* zone, Navet formation.

**Locality:** Figured hypotypes (USNM P5752 a–d) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina microa* (Cole), (p. 161); sample Hg 8581 (TTTOC 215782).

**Remarks:** The Trinidad specimens of *Truncorotaloides topolensis* (Cushman) compare closely with the holotype of *Globigerina topolensis* Cushman, except that many specimens possess sutural, supplementary apertures on the spiral side, such as characterize the genus *Truncorotaloides*. 
BOLLI, H. M.

BRONNIMANN, P.

BROTTMANN, P., and BERMUDEZ, P. J.

COLE, W. S.

COLOM, G.

CUSHMAN, J. A.
CUSHMAN, J. A., and BERMUDEZ, P. J.
CUSHMAN, J. A., and JARVIS, P. W.
CUSHMAN, J. A., and RENZ, H. H.

GLAESNER, M. F.
GUPPY, R. J. L.  

HAMILTON, E. L.  

KUGLER, H. G.  

NUTTALL, W. L. F.  

PETTERS, V.  

RENZ, H. H.  

STAINFORTH, R. M.  

SUTER, H. H.  

VAUGHAN, T. W., and COLE, W. S.  

WEISS, L.  
Planktonic Foraminifera of Paleocene and Early Eocene Age from the Gulf and Atlantic Coastal Plains

By Alfred R. Loeblich, Jr., and Helen Tappan

Introduction

There has long been controversy concerning the geologic age of nearly every formation throughout the world referable to an age somewhere between the Upper Cretaceous Maastrichtian and the Eocene Ypresian. This is none the less true of the formations here discussed which occur along the Gulf and Atlantic Coastal Plains. The differing methods used in the past to determine the age and correlation, range from solely lithologic and structural evidence to paleontologic correlations variously based on brachiopods, mollusks, bryozoa, ostracods, and Foraminifera.

Because the planktonic Foraminifera have come to be recognized in recent years as exceptionally valuable tools for regional and world wide correlations, the writers have made a study of these forms that occur in certain Paleocene and lower Eocene strata. These planktonic species are then made the basis for an inter-regional correlation. The stratigraphic nomenclature and age designations used in this report do not necessarily follow the usage of the U. S. Geological Survey.

Strata from which planktonic species are here described include the Velasco formation of Mexico, the Kincaid and Wills Point formations of the Midway group of Texas; the Pine Barren and McBryde members of the Clayton formation, the Matthews Landing marl member of the Porters Creek clay, the Coal Bluff marl member of the Naheola formation and the Salt Mountain limestone, all of the Midway group of Alabama; the Nanafalia formation of the Wilcox group of Alabama; the Brightseat formation of Maryland, the Aquia formation of Maryland and Virginia, and the Hornerstown and Vincentown formations of New Jersey. For purposes of comparison, the planktonic species of the type Danian of Denmark are also described and illustrated. The Wilcox group of Texas and the Porters Creek clay and the Oak Hill member of the Naheola formation of Alabama contained no planktonic Foraminifera, in the samples studied, hence are not further discussed in the present report. Samples of the underlying Cretaceous horizons were also examined in each area, but their quite different faunas are not here described.

Previous Correlations and Age Assignments

Velasco Formation

The Velasco formation of the Tampico embayment of Mexico was first separated from the Upper Cretaceous Mendez formation by Cushman and Trager (1924) and was then thought to be related to the Taylor marl of Texas. Later (1926), Cushman stated that it was equivalent to the Navarro of Texas. Dumble and Applin (1924) described the same sequence of beds as Tamesf and considered them as lower Eocene.

Midway Group

The Midway group was originally described from Alabama, and since 1894 has been generally recognized as including the oldest Tertiary beds of the Gulf Coastal Plain. It was long considered by the U. S. Geological Survey to be lower Eocene in age (Wilmarth, 1938, p. 1366). However, about 30 years ago, Gayle Scott (1926, p. 161) had correlated the Midway group of the Gulf Coast with the Danian, placing the nautiloid *Enclimatoceras urichi* White in the synonymy of *Hercoglossa danica* (Schlotheim). He considered (1934, p. 1158) that the Midway was therefore of Cretaceous age, as the Danian was then generally regarded as late Cretaceous. Gardner (1933, p. 92) first placed the Midway group in the Paleocene, the lower Midway (Kincaid) being considered Montain, and the Upper Midway (Wills Point) correlated with the Landenian. She stated (p. 99) that “The existence of marine deposits of Danian age in either of the Americas has not been established.” Brotzen (1948, p. 32) considered the Kincaid as of Danian age, and the Wills Point as Seelandian. He also considered the lower Wilcox to represent the Thanetian and younger stages. His correlations were largely based on benthonic Foraminifera although he mentioned that the Midway “Globigerinidae” occur in the lower Paleocene of Sweden.

Wilcox Group

The Wilcox group is recognized by the U. S. Geological Survey (Wilmarth, 1938, p. 2333) to be of lower Eocene age, and to designate “deposits overlying the Midway and underlying the Claiborne in the Gulf

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1 Helen Tappan Loeblich, U. S. Geological Survey and Research Associate, Smithsonian Institution.
Coastal Plain.” Recent studies (Murray, 1955) have shown that the “basal Wilcox” of some areas is a “late Midway” time equivalent. The recognizable sedimentary facies of the Midway and Wilcox groups are thus not entirely time equivalents. The Wilcox is considered to be lower Eocene, yet strata in other areas have been referred to the Wilcox, on lithologic bases, which are faunally much closer to the Midway (Paleocene).

As was demonstrated by Murray (1955), confusion has arisen by the varying usage of the terms Midway and Wilcox by some authors in a lithologic sense (rock unit) and by others in a time connotation (time-rock unit). The greater use of the European stage names or of faunal zones in determining correlations would avoid these misinterpretations.

Salt Mountain Limestone

The Salt Mountain limestone of Alabama is recognized by the U. S. Geological Survey to be of lower Eocene age and to belong to the Wilcox group (Wilmarth, 1938, p. 1898). It is regarded as lying between the Tuscaloosa sand and the Nanafalia formation, although it does not appear in contact with these formations, the only known outcrops being at Salt Mountain and in its immediate vicinity. Toulmin (1941, p. 569) recorded 99 species of Foraminifera from the Salt Mountain, of which 19 were common to the upper Wilcox greensand at Ozark, Alabama, 10 occurred also in the upper Wilcox (Bashl) of Woods Bluff, Alabama, 11 occurred in the lower Midway (Kincaid) of Texas, 18 in the upper Midway of Texas, and 14 were found in common with a Midway fauna in Alabama. Thus the Salt Mountain limestone has about the same number of species in common with the Midway elsewhere as it does with the Wilcox, although Toulmin considered that at least the upper part was younger than Midway and probably of early Wilcox age.

Aquia Formation

The Aquia formation of Maryland has been considered by the U. S. Geological Survey to be lower Eocene in age. Cooke and Stephenson (1928) considered the Vincentown formation of New Jersey to be the equivalent of the Aquia formation of Maryland, considering both to be of Wilcox Eocene age. Miller (1956) concurred in this determination, on the basis of megafossils. Shiflet (1948) described the Foraminifera of the Aquia, and stated (p. 17) that the Aquia was “considered equivalent to the lower Wilcox of the Gulf Coast and to the Ypresian of Europe.” She recorded nine species of planktonic Foraminifera.

Brigsheat Formation

The Brightseat formation of Maryland was recently described as of Paleocene age, and underlies the Aquia formation.

Vincentown and Hornerstown Formations

Both the Vincentown and Hornerstown formations of New Jersey were originally described as of late Cretaceous age (Clark, Bagg, and Shattuck, 1897, p. 326), but younger than the Upper Cretaceous of the Gulf Coastal region, and the equivalent of the European Danian stage. Cooke and Stephenson (1928, p. 141) placed these strata in the Eocene (in 1928 the U. S. Geological Survey did not recognize the Paleocene as a distinct epoch), on the basis of macrofossil evidence, as well as diastrophic evidence that the Hornerstown marl transgressed southward on successively older Cretaceous beds. They also correlated the Vincentown formation with the Aquia formation of Maryland. Canu and Bassler (1933, p. 3) correlated the Vincentown with the Maestrichtian and Danian (Upper Cretaceous) of Europe, on the basis of the Bryozoa, but also noted a similarity of the fauna to that of the Aquia of Maryland and the Clayton formation (lower Midway) of the Gulf Coast. Broten (1948, p. 32) correlated the Vincentown with the Thanetian, Landenian (Paleocene) and the Ypresian (lower Eocene). McLean (1953, p. 1) identified Paleocene bentonic Foraminifera in the Vincentown, as well as some species suggestive of the Wilcox Eocene, and believed the Vincentown to represent transitional strata.

Fox and Olsson (1955, p. 736) placed the Hornerstown formation in the Paleocene and the Vincentown was said to contain a “mixture of typical Paleocene forms in association with new Eocene elements characteristic of the upper part of the Vincentown.” They considered the Vincentown to be “clearly Eocene in age.” Hofker (1955, p. 1) listed 22 species of Foraminifera common to the Vincentown and the Paleocene of Europe, and considered the Vincentown to be lower Paleocene.

Miller (1956, p. 731) studied the invertebrate fauna of the Vincentown and concluded that the “strongest affinities are to the Lower Eocene (Aquia) of Maryland and the Danian of Denmark.” He recorded 18 species common to the Vincentown and Aquia, including bryozoans, ostracods, alcyonarids, and mollusca. However, as the Aquia was considered lower Eocene, he also correlated the Vincentown with the lower Eocene. He stated (p. 732) that the “Nautilus” danicus, bryozoans and alcyonarids were also found in the Danian of Europe, but he considered them “facies fossils.”

Correlation by Planktonic Foraminifera

There is no longer any reason for questionable correlations of marine deposits at the Cretaceous-Tertiary boundary. Wherever planktonic Foraminifera occur they show a very pronounced faunal break. The planktonic genera characteristic of the Cretaceous (Globotruncanina, Rugoglobigerina, Hastigerinoides, etc.) are never found in the Cenozoic, and do not occur in the type Danian or in any Paleocene strata. Typical Cenozoic Globorotalia and Globigerina, such as are found in the Paleocene (Danian, Midway, etc.) the world over, do not appear anywhere in the Cretaceous. Thus a Cretaceous age is definitely excluded for strata in which they appear.

As has been shown by Bolli, Loeblich, and Tappan...
The Paleocene is here regarded as including the Danian (=Montian) and Landenian stages of the standard European time scale. Typical Paleocene species of planktonic Foraminifera are *Globigerina triloculinoidea* and *Globorotalia pseudobulloides*. The former ranges throughout the Paleocene and the latter in about the lower one-half.

The Danian stage, or lower Paleocene, contains a planktonic assemblage of *Globigerina*, *Globigerinoides*, and *Globorotalia* with rounded periphery. The planktonic species found in the type Danian of Denmark also occur in the Kincaid and Wills Point formations of Texas, the Pine Barren and McBryde members of Alabama and the Brightseat formation of Maryland (text-fig. 27). The faunal lists given by Muir (1936) which were prepared by Helen Jeanne Plummer show a restricted *Globigerina* fauna, like that of the Danian, in the lower part of the Velasco (or Tamesi) formation of Mexico. All these formations are therefore regarded here as lower Paleocene. Species most typical of this

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**Figure 27.**—Range chart of planktonic Foraminifera in the Paleocene and lower Eocene of the Gulf and Atlantic coastal regions. Location of formations in the chart, within each assemblage, does not necessarily imply their relative stratigraphic position, which is given in fig. 28. Ranges of species in the Velasco formation are given only for the upper part (the *Globorotalia velascoensis* zone), although the Velasco also includes older strata, representative of the *Globigerina* assemblage.
this lowermost faunal zone, and restricted to it, are *Globorotalia compressa, Globigerinoides daubjergensis* and *Chiloguembelina morsei*. *G. midwayensis* appears in the upper part of the zone.

The Landenian stage (upper Paleocene) contains a *Globigerina*-keeled *Globorotalia* assemblage, and is typified by the species *Globorotalia angulata*. Species typical of the *angulata* zone, which range almost throughout its extent include *Globorotalia angulata, G. aequa, G. elongata* and *G. pseudomenardii*, in addition to the longer ranging *G. perclara* and *Globigerina triloculinoides*. The *angulata* zone may be further subdivided into subzones, the oldest of which is characterized by *Globorotalia pseudobulloides*. This species first appeared in the late Danian, but does not range above this lower subzone of the Landenian. In addition to the continuance of *Globorotalia pseudobulloides* and and *Globigerina triloculinoides*, the subzone notes the first appearance of *Globorotalia angulata, elongata, pseudomenardii* (all first appearing in the Matthews Landing marl in the Alabama section), and *G. aequa, reissi*, and *irrorata* (all appearing first in the Coal Bluff). The *angulata* zone thus represents the beginning of the group of keeled *Globorotalia* which become increasingly numerous in later strata.

The upper subzone of the Paleocene is commonly referred to as the *Globorotalia velascoensis* zone, and is characterized by that very angular and ornate species, and the similar *G. aequa*. The typical *velascoensis* does not range far north of its type region in Mexico, although it does occur in Trinidad. In the Atlantic and Gulf Coastal States it is replaced by the similar *G. aequa*, which has been considered by some to be merely a subspecies of *G. velascoensis*. In the region here studied the faunal subzone is perhaps better typified by *Globigerina spiralis*, which ranges throughout the subzone.

The Hornerstown formation is somewhat transitional between the mid-Paleocene *pseudobulloides* subzone and the upper Paleocene *velascoensis-spiralis* subzone. *Globorotalia pseudobulloides*, *compressa*, and *varia* have disappeared, as have *Chiloguembelina morsei*, and *midwayensis*. The species *Chiloguembelina crinita, Globigerina spiralis, and Globorotalia angulata, aequa, and conveza* have taken their place. However, the *G. aequa-velascoensis* group, *G. pseudoscutula, ocellata*, and *Globigerina mckannai* do not appear until after the close of Hornerstown time. These species all are present in the upper Velasco, Salt Mountain, Aquia, and Vincentown formations, which thus are closely related faunally.

The lowermost Eocene (Ypresian) typically contains a *Globigerina*-*Globorotalia-Truncorotaloides* assemblage. In the Gulf and Atlantic coastal region here studied, the lower Eocene is in many places represented by nonmarine sediments, and the only fossiliferous material used in the present study is that of the Nanafalia formation of Alabama. It contains 17 species of planktonic Foraminifera, some of which are holdovers from the upper Paleocene, but many of the most typical Landenian species are absent. The close of the Paleocene was marked by the disappearance of *Globorotalia triloculinoides* (it is replaced in many regions by the similar *G. inaperta*, which is possibly a derivative), *mekannai, and spiralis*, and *Globorotalia velascoensis, aequa, angulata, ocellata, and pseudoscutula*. The lower Eocene is characterized by the appearance of *Globorotalia reez* (elsewhere also considered a zone fossil for the Ypresian) and *G. pseudotopulensis*. The Landenian, in more offshore marine sections, is also recognized by the first appearance of the genus *Truncorotaloides*, which resembles a sharply angled *Globorotalia*, but with supplementary apertures on the spiral side. True *Truncorotaloides* has not yet been observed in the Nanafalia, although the species, *Globorotalia pseudotopulensis* Subbotina, is similar to those which elsewhere did develop the supplementary apertures.

**Summary**

The Danian stage of the lower Paleocene (*compressa-daubjergensis* faunal zone of the *Globigerina* assemblage) is represented by the lower Velasco formation of Mexico; the Kincaid and Wills Point formations, Midway group of Texas; the Pine Barren and McBryde members of the Clayton formation, lower part of the Midway group of Alabama, and the Brightseat formation of Maryland (text-fig. 28).

The lower Landenian stage (Thanetian substage), or middle Paleocene (*angulata* faunal zone, *pseudobulloides* subzone of the *Globorotalia* assemblage), is not represented at the surface in Texas, Maryland, Virginia, or New Jersey. In Alabama it consists of the Porters Creek clay and Naheola formation, the upper part of the Midway group as previously recognized.

The upper Landenian stage (Sparnacian substage) or upper Paleocene (*angulata* faunal zone, *velascoensis-spiralis* subzone) represents the most controversial part of the section. On the basis of the placement elsewhere of the *Globorotalia velascoensis* zone as the uppermost Paleocene, and in view of the greater faunal break above than below this zone, it is here regarded as upper Paleocene. This zone includes the upper Velasco formation of Mexico, the Salt Mountain limestone of Alabama (which is thus shown to be older rather than younger than the Nanafalia formation of the Wilcox group, and is here included as the upper formation of the Midway group although younger than the outcropping Midway of Texas), the Aquia formation of Maryland and Virginia, and the Hornerstown and Vincentown formation of New Jersey.

The lower Eocene (Ypresian stage) is mostly represented by nonmarine sediments in this region, marine strata studied including only the Nanafalia formation of Alabama, which represents the *reex* faunal zone of the *Truncorotaloides* assemblage.


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<th>Plankton Faunal Assemblage</th>
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<tr>
<td>DANIAN</td>
<td>Globigerina assemblage</td>
<td>compresso-angulosa zone</td>
<td>Méndez fm group</td>
<td>Navarro group</td>
<td>Ripley fm group</td>
<td>Manmouth fm</td>
<td>Manmouth group</td>
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<tr>
<td>CRETACEOUS MAESTRICHTIAN</td>
<td>Globotruncan assemblage</td>
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Figure 28.—Correlation table of Paleocene and lower Eocene strata of the Gulf and Atlantic Coastal regions, based on the included planktonic species. Material has been examined from each of the formations marked ◆; all post-Cretaceous planktonic occurrences are shown in the range chart in fig. 27; correlation of those strata which did not contain planktonic species is based on relative stratigraphic position.

Acknowledgements

This paper is one of the series on planktonic Foraminifera and their stratigraphic application for which technical assistance and illustrative work have been in part financed by grants-in-aid of research from the California Research Corp., Carter Oil Co., Gulf Oil Corp., and the Humble Oil and Refining Co., to which we express our gratitude.

The writers also gratefully acknowledge the assistance of Dr. J. B. Troelsen, Copenhagen, Denmark, who supplied material from the type Danian; of Mr. R. Wright Barker, Shell Development Co., Houston, Texas, who furnished some excellently preserved upper Velasco material used in the present study; of Dr. Stephen Fox of Rutgers University, New Brunswick, New Jersey, and of Dr. Norman Sohl of the U. S. Geological Survey, who accompanied Alfred R. Loeblich Jr., in field study of the Vincentown formation, and in collecting material from the Vincentown and Horners-town formations of New Jersey; and of Mr. Richard Page, Smithsonian Institution, for field assistance in collecting material from the Brightseat and Aquia formations of Maryland and Virginia.

We also are grateful to Dr. John Imbrie of Columbia University, New York City, for making available the type specimens of the Velasco species described by Maynard White, for some of which lectotypes have here been selected and reillustrated.

Illustrations on the plates are camera lucida drawings, prepared by Patricia and Lawrence Isham, scientific illustrators, U. S. National Museum.

A total of 43 species of planktonic Foraminifera are described and illustrated. Of these, 8 belong to the genus Globigerina and one to Globigerinoides, in the family Orbiniidae. The family Globorotaliidae is represented by 26 species of Globorotalia, and the family Heterohelicidae by 1 Heterohelix, 4 Chiloumbelina, 2 Tubitextulario, and 1 Woodringina. Of the species described, 13 are new.

In the following descriptions, only partial synonymies are given. The original reference is cited and additional references are given only to the local occurrences. Solely on the basis of the literature, it is impossible to state with certainty the actual occurrence of a species without reference to the figured and described material. Therefore, when a reference is given in the synonymies which follow, the type specimens have in general been compared by us with our material. Only the Russian types of certain of the Paleocene species have not been personally studied by us.
Systematic Descriptions

Family Heterohelicidae Cushman, 1927

Subfamily Guembeliitriinae Montanaro Gallitelli, 1957

Genus Woodringina Loeblich and Tappan, 1957

Woodringina claytonensis Loeblich and Tappan

PLATE 40, FIGURE 6


Test free, tiny, flaring rapidly; early stage with a single whorl of three chambers (reduced "triserial"), commonly followed by three, or more rarely up to five, pairs of biserial chambers, the plan of biserially slightly twisted in development; chambers few in number, subglobular, increasing rapidly in size; sutures distinct, constricted; wall calcareous, finely perforate and very finely hispid; aperture a low, arched slit bordered above by a slight lip, somewhat asymmetrical in position.

Length of holotype 0.15 mm., greatest breadth 0.12 mm. Other specimens vary from 0.12 to 0.22 mm. in length.

Remarks: This species superficially resembles Tosaia hanzawai Takayanagi from the Pliocene of Japan, but differs in being about one-third as large, in having a reduced "triserial" stage of three chambers, and better developed biserial stage, whereas the Japanese form has a trochoid whorl, followed by a triserial stage, and only an occasional specimen has the poorly developed biserial stage. The chambers of the present species are also more inflated and subglobular.

Types and occurrence: Holotype (USNM P56855) from the Fine Barren member of the Clayton formation, blue-black micaceous clay exposed in road cut opposite small country store, 0.8 mile west of Alabama River bridge on Alabama state highway 28, Wilcox County, Alabama. Collected by Alfred R. Loeblich, Jr., July 1956.

Subfamily Heterohelicinae Cushman, 1927

Genus Heterohelix Ehrenberg, 1841

Heterohelix wilcoxensis (Cushman and Ponton)

PLATE 56, FIGURES 2a, b


Test free, small, flaring rapidly, with 3 to 5 pairs of nearly globular chambers biserially arranged; sutures distinct, deeply depressed; wall calcareous, finely but distinctly perforate, with perforations aligned in very fine longitudinal striae; aperture a broad symmetrical and relatively high arch.

Length of figured hypotype 0.18 mm.

Remarks: The figured specimen is only about one-half the size of the holotype, but may be a juvenile specimen as it is identical in all characters to the earlier portion of the holotype. This species is characterized by the perforations aligned in fine longitudinal striae, the globular chambers, and flaring test.


Genus Chiloguembelina Loeblich and Tappan, 1956

Chiloguembelina crinita (Glæssner)

PLATES 49, FIGURE 1; 51, FIGURES 1a-3; 56, FIGURES 1a, b; 60, FIGURE 6; 62, FIGURE 1


Gümbelina wilcoxensis CUSHMAN and PONTON, SHIFFLETT, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 60, pl. 3, fig. 8, 1948.

Test free, small, flaring rapidly; 4 to 6 pairs of biserially arranged chambers slightly twisted in development, early chambers relatively low and broad, later ones higher and ovate to subglobular; sutures distinct, depressed, straight and slightly oblique; wall calcareous, finely perforate, surface smooth in the early part, with the terminal part finely hispid; aperture a broad open arch, with a narrow lip at one side expanding into a broad apertural flange at the opposite edge, causing the aperture to be directed toward one of the flat sides of the test.

Hypotypes range from 0.20 to 0.30 mm. in length.

Remarks: This species differs from C. midwayensis (Cushman) in being more flaring, in having higher and more globular chambers and a finely spinose wall, especially in the terminal portion.

It differs from C. morsei (Kline) in having a more flared and more twisted test, and in the early chambers being broad and low, only the later ones becoming inflated. The apertural flange is also more prominent at one side of the aperture in the present species.

The specimen referred to Gümbelina wilcoxensis Cushman and Ponton by Shifflett (1948, p. 60) also belongs to the present species, and differs from Heterohelix wilcoxensis (Cushman and Ponton) in lacking the symmetrical aperture characteristic of true Heterohelix. Heterohelix wilcoxensis also is a much larger and more robust species, with more nearly globular chambers.

Types and occurrence: Figured hypotypes (USNM P5115a-c) from the Vincentown limesand, along north bluff of Rancocas Creek, 0.3 to 0.5 mile northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.
Figured hypotype (USNM P5116) from the *Ostrea thirsea* beds of the Nanafalia formation, 56 feet above the Midway contact, in road cut 1.2 miles east of Kimbrough Station, and 0.2 mile east of the Turkey Creek bridge, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.


Figured hypotype (USNM P5853) from the Horners-town formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5890) from the Velasco formation, middle bed at road crossing of arroyo half-way between San José de las Rusionas and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

This species also occurs in the Salt Mountain limestone of Alabama, and has been recorded from the Aqua formation of Friendly, Maryland.

It was originally described from the Paleocene of the northwest Caucasus, USSR.

**Chiloguembelina midwayensis** (Cushman)

Plates 41, Figure 3; 43, Figures 7a, b; 45, Figures 9a, b


Test free, small, flaring rapidly, commonly with about five pairs of biserially arranged, broad and relatively low chambers; sutures distinct, slightly depressed and oblique; wall calcareous, finely perforate, surface smooth, but terminal face of the last pair of chambers may be finely hispid; aperture at the base of the final chamber, a broad open arch, with a prominent apertural flap at one side, causing the aperture to appear directed to one side of the test.

Hypotypes range in length from 0.23 to 0.25 mm.

**Remarks:** In an earlier paper the present writers (Loeblich and Tappan, 1956, p. 340) considered this species a synonym of *C. midwayensis* (Cushman). Additional material has shown that *C. morsei* can be distinguished by the narrower test, more globular chambers and more deeply constricted sutures. It differs from *C. crinita* (Glaessner) in the less rapidly flaring test and in having globular rather than somewhat low and broad chambers.

**Types and Occurrence:** Figured hypotype (USNM P5854) from the Danian, calcarenite at Erslev, Mor, north of the village, west of Tøving road, Denmark. Collected by J. C. Troelsen.

Figured hypotype (USNM P5855) from the McBryde limestone member of the Clayton formation, in bed of Rock Creek, 0.8 miles south of the junction of Alabama state highways 28 and 10 on Alabama highway 10, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5856) from the Kineaid formation, in a small stream bank on the east side of the road to Lund, 3 miles northwest of Elgin on the Bastrop-Travis county line, 0.5 miles north of the junction with the Austin-Elgin highway, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5857) from the Wills Point formation, 200 feet east of the bridge over Tehuacana Creek, 4 miles north of Mexia on the Mexia-Wortham road, Limestone County, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5858) from the type locality of the Brightseat formation, 1 mile west-southwest of Brightseat and 0.2 mile south of Sheriff Road,
of Clayton formation of Alabama.

Chiloguembelina species

PLATE 47, FIGURE 1

Remarks: A single specimen of Chiloguembelina was obtained from the Salt Mountain limestone, which is somewhat poorly preserved, and not here identified specifically. It is larger, thicker and more robust than C. midwayensis (Cushman), and is less flaring. It is smaller and less flaring than Heterohelix wilcozensis (Cushman and Ponton), has the eccentric aperture with flap at one side characteristic of Chiloguembelina, and the surface is smooth rather than with coarse perforations aligned in longitudinal striae.

Length of figured specimen 0.25 mm.

Types and occurrence: Figured specimen (USNM P5832) from the Salt Mountain limestone, in a limestone sink, 3/4 mile north of Salt Mountain, in the NW¼ NW¼ Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Genus Tubitextularia Sulc, 1929

Tubitextularia alabamensis (Cushman)

PLATE 41, FIGURE 7


Test free, tiny, elongate, early portion generally consisting of 5 pair of biserial chambers followed by 3 cuneate-appearing uniserial chambers; chambers inflated, increasing gradually in size; sutures distinct, depressed, somewhat oblique in both biserial and uniserial stages; wall calcareous, perforate, surface finely hispid; aperture terminal, slightly eccentric, bordered with a slight lip.

Length of figured hypotype 0.23 mm.

Remarks: This species was originally described from Midway chalk overlying the Ostrea pulaskensis bed in Alabama. The species is relatively rare in the Clayton formation of Alabama.

Types and occurrence: Figured hypotype (USNM P5886) from the McBryde limestone member of the Clayton formation, in bed of Rock Creek, 0.8 mile south of the junction of Alabama highways 28 and 10, on highway 10, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Tubitextularia laevigata Loeblich and Tappan, new species

PLATE 41, FIGURE 6

Test free, small, elongate, early part flaring rapidly, with 4 to 5 pairs of biserially arranged chambers followed by 2 or rarely 3 subglobular uniserial chambers, of somewhat lesser breadth than the preceding biserial stage; sutures distinct, slightly depressed, nearly horizontal; wall calcareous, finely perforate, surface smooth; aperture in the biserial stage at the base of the final chamber, terminal in the uniserial stage of the adult test, produced on a short fragile neck which is commonly broken.

Length of holotype 0.25 mm.

Remarks: Tubitextularia laevigata, new species, is closest in appearance to T. midwayensis (Cushman) with which it is associated. It differs in the larger and more flaring test, more globular uniserial chambers and the smooth rather than hispid wall surface.

Types and occurrence: Holotype (USNM P5820) from the McBryde limestone member of the Clayton formation, in bed of Rock Creek, 0.8 mile south of the junction of Alabama highways 28 and 10, on highway 10, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Family Orbulinidae Schultze, 1854

Subfamily Globigerininae Carpenter, 1862

Genus Globigerina d'O orbigny, 1826

Globigerina aquensis Loeblich and Tappan, new species

PLATES 51, FIGURES 4a-5c; 56, FIGURES 4a-6c

Test free, trochospiral, subglobular to relatively high-spired, periphery broadly rounded, peripheral outline lobulate, umbilicus open; commonly with four subglobular chambers in the final whorl, and may have a smaller thin-walled final chamber somewhat resembling a bulla, but with a normal aperture; sutures distinct, depressed, slightly curved; wall calcareous, perforate, surface finely hispid, most prominently in the umbilical region; aperture umbilical, with a narrow lip, a fairly high open arch.

Holotype 0.28 mm. in diameter, 0.23 mm. in thickness.

Remarks: G. aquensis, new species, is similar to G. spiralis Bolli in being high spired, but differs in being considerably smaller, with fewer and more globular chambers per whorl, and in being finely hispid.


Figured paratypes (USNM P5840a, b) from same locality as above but from 6 to 9 feet above base of the exposure.

Figured paratypes (USNM P5841a, b) from the Vincentown formation, north bank of Rancocas Creek, 0.3 to 0.5 miles northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Globigerina chascanona Loeblich and Tappan, new species

PLATES 49, FIGURES 4a-5c; 61, FIGURES 4a-c

Test free, trochospiral, subglobular to high spired, periphery rounded, peripheral outline lobulate, all
chambers of the 2 1/2 to 3 whorls visible on the spiral side, with earlier whorls distinctly elevated above the level of the 4 to 5 chambers of the final whorl, only the final whorl visible on the umbilical side, final chamber may be somewhat reduced in size and bulla-like; sutures distinct, depressed, slightly curved; aperture a small umbilical arch bordered with a narrow lip.

Greatest diameter of holotype 0.20 mm., height of spire 0.23 mm.

Remarks: G. chascanona, new species, differs from G. aquensis, new species, and G. spiralis Bolli in having a very prominently spinose surface, smaller umbilical area, lower aperture, and in being much smaller in size.

The specific name is from the Greek name for cocklebur, chascanon.

Types and Occurrence: Holotype (USNM P5842) and figured paratype (USNM P5843) from the Horrnerton formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured paratype (USNM P5844) from the Nanafalia formation, basal 6 feet of formation, road cut, 0.2 mile east of Turkey Creek bridge, and 1.2 miles east of Kimbrough Station, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Also occurs in the Aquia formation of Virginia.

Globigerina inaequispira Subbotina

Plates 49, Figures 2a–c; 52, Figures 1a–2c; 56, Figures 7a–c; 61, Figures 3a–c; 62, Figures 2a–c


Test free, consisting of rapidly enlarging chambers in a low trochospiral arrangement; chambers subglobular, all visible on the spiral side, only the 3 to 4 chambers of the final whorl visible on the umbilical side; sutures distinct, depressed; wall calcareous, finely perforate, surface finely spinose, becoming coarsely spinose in the umbilical region; aperture interiomarginal and umbilical, and may have a narrow bordering lip.

Hypotypes range from 0.23 to 0.48 mm. in greatest diameter and from 0.15 to 0.33 mm. in thickness.

Remarks: Originally described from the “Lower to Middle Eocene” of Russia in a zone with Globorotalia velascoensis, Globorotalia pseudocinctula, and Globigerina triloculinoides this species is here considered to be of Paleocene age, as the G. velascoensis zone is so considered elsewhere. G. inaequispira differs from G. triloculinoides Plummer in lacking the coarsely reticulate surface and in being finely to prominently spinose.

G. inaequispira is similar to G. linaperta Finlay which also has a spiny surface, but in G. linaperta the surface also shows a reticulate pattern.

The specimens referred to G. triloculinoides Plummer by Shifflett (1948) are typical G. inaequispira, having the characteristic spiny surface which is not found in true G. triloculinoides.

G. inaequispira has a somewhat more restricted geologic range than does G. triloculinoides and is found only in strata of middle to late Paleocene (Landian) age, not in the underlying lower Paleocene (Danian) strata.

Types and occurrence: Hypotype (USNM P5729) from the Salt Mountain limestone in a limestone sink, 3/4 mile north of Salt Mountain in the NW/4 NW, sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5730) from the Ostrea thirsae beds of the Nanafalia formation, top of section exposed, approximately 56 feet above the Midway contact, in road cut 0.2 mile east of Turkey Creek bridge, 1.2 miles east of Kimbrough Station, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.


Figured hypotype (USNM P5732) from the Horrnerton formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5117a,b) from the Vincentown formation, along north bluff of Rancocas Creek, 0.3 to 0.5 mile northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5881) from the upper Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

Globigerina mckannai White

Plates 47, Figures 7a–c; 53, Figures 1a–2c; 57, Figures 8a–c; 62, Figures 5a–7c

Globigerina mckannai White, Journ. Paleontol., vol. 2, p. 194, pl. 27, figs. 16a–c, 1928.


Test free, subglobular to slightly compressed, spiral side convex, in a low trochospiral coil of 2 1/2 whorls, umbilical side convex with broad open umbilicus, peripheral margin broadly rounded to subtruncate, peripheral outline lobulate; 5 to 6 globular to ovate chambers in the final whorl, commonly 5, increasing regularly in size; sutures distinct, depressed, slightly curved back-
wards on the spiral side, radial on the umbilical side; wall calcareous, surface finely spinose, the spines most prominent in the umbilical region, an occasional specimen has a smaller final chamber which is thin-walled and nearly smooth; aperture interiomarginal, umbilical, in some specimens showing a tendency to extend somewhat to an extrumbilical position, with apertures of earlier chambers all remaining open into the umbilicus.

Hypotypes range from 0.28 to 0.48 mm, in diameter, and 0.20 to 0.35 mm, in thickness.

**Remarks:** Originally placed in *Globigerina*, this species was placed in *Globorotalia* by Bolli (1957, p. 79). However, the early umbilical position of the aperture, inflated chambers, rounded periphery, and coarsely spinose surface all show a stronger relationship to *Globigerina* (and the type species *Globigerina bulloides*) than to *Globorotalia* (typified by *Globorotalia tumida*). The gradual migration of the aperture from completely umbilical to a somewhat extrumbilical position can be found in nearly every species of *Globigerina*, if a large suite of specimens is examined. This species is closest in appearance to *Globigerina soldadoensis* Bronnimann, which Bolli did leave in *Globigerina*, although even the holotype of this species has an asymmetrical aperture.

Bolli (1957, p. 72) recorded *Globigerina gravelli* Bronnimann as occurring in Trinidad throughout the lower Eocene part of the Lizard Springs formation, although the holotype of Bronnimann’s species was from the lower Lizard Springs formation (Paleocene, *Globorotalia velascoensis* zone, sample Rz 287). The specimen figured by Bolli from the upper Lizard Springs formation (of lower Eocene age) as well as the holotype of *gravelli* would both easily fall within the variation of *Globorotalia mckannai* White at its type locality (Velasco formation of Mexico, *Globorotalia velascoensis* zone).

*Globigerina meckannai* shows a tendency to develop the somewhat truncate chamber form typical of *Globoguadrina*, but differs in lacking the toothlike apertural flaps. This appearance also suggests a relationship with the Orbulinidae, rather than the Globorotaliidae.

*Globigerina soldadoensis* Bronnimann commonly has fewer chambers per whorl, a more rapid increase in chamber size, and thinner chambers.

Specimens of *G. esnehensis* identified by S. E. Nak-kady show it to be synonymous with the present species.

**Types and Occurrence:** Figured hypotypes (USNM P5119a,b) from the Vincentown formation, along north bluff of Rancocas Creek, 0.3 to 0.5 miles northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.


Figured hypotype (USNM P5833) from the Salt Mountain limestone, in a limestone sink, ½ mile north of Salt Mountain, in the NW½ NW¼, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Lectotype (Columbia Univ. 19878), here designated, from the Velasco formation, Columbus Station on the Tampico-Monterey railroad line, Mexico.

Figured hypotypes (USNM P5884a,b) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rúas and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

*Globigerina* cf. *G. soldadoensis* Bronnimann

**Plate 53, Figures 4a–c**

Test free, of medium size, globose, periphery broadly rounded; chambers increasing rapidly in size, only the 3½ chambers of the final whorl visible around the deep and open umbilicus of the umbilical side; sutures distinct, slightly depressed, somewhat oblique on the spiral side, radial on the umbilical side; wall calcareous, finely perforate, surface covered with short blunt spines, aperture interiomarginal, umbilical, or extending slightly to an extrumbilical-umbilical position.

Figured specimen 0.33 mm. in diameter.

**Remarks:** This form differs from typical *G. soldadoensis* Bronnimann in being more globose, with more evenly rounded chambers and less incised sutures. It is somewhat similar to the associated *G. mckannai* White, but differs in having fewer chambers per whorl, a more broadly rounded periphery and a flatter spire.

**Types and Occurrence:** Figured specimen (USNM P5130) from the Vincentown formation, north bluff of Rancocas Creek, 0.3 to 0.5 miles north of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

*Globigerina spiralis* Bolli

**Plates 47, Figures 3a–c; 49, Figures 3a–c; 51, Figures 6a–9e; 53, Figures 3a–c**


Test free, the high trochospiral coiling resulting in a nearly globular test; chambers globular, increasing rapidly in size, those of the 2 to 3 whors all visible on the spiral side, only the 4 to 6 chambers of the final whorl visible on the umbilical side, umbilicus open, rare specimens may have the umbilicus nearly closed (pl. 51, fig. 6); sutures distinct, depressed; wall calcareous, perforate, surface finely to moderately spinose, most prominently so in the umbilical region; aperture a broad umbilical interiomarginal arch in the final chamber, those of previous chambers also remaining open into the umbilicus.

Greatest diameter of hypotypes ranges from 0.18 to 0.38 mm.

**Remarks:** *Globigerina spiralis* Bolli is distinguished by the globular test and the extremely prominent spire,
the early whorls standing somewhat above the general level of the surface on the spiral side. The somewhat smaller, smooth and thin-walled final chamber is also a characteristic feature.

According to Bolli (1957, p. 70) this species is restricted to the Globorotalia uncinata zone of the Lower Lizard Springs (lower Paleocene). In the Gulf and Atlantic coast Paleocene it occurs somewhat higher in the section in the uppermost Paleocene, and no similar forms occur in lower Paleocene samples. It occurs in the Salt Mountain limestone, Aquia, Hornerstown and Vincentown formations.

**Types and occurrence:** Figured hypotypes (USNM P5121a–e) from the Vincentown formation, along north bluff of Rancocas Creek, 0.3 to 0.5 mile northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Soil.

Figured hypotype (USNM P5122) from the Salt Mountain limestone, in a limestone sink, ½ mile north of Salt Mountain, in the NW-¼ Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5838) from the Hornerstown formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Soil.

This species also occurs in the Aquia formation of Virginia.

**Globigerina triloculinoides Plummer**

Plates 40, Figures 4a–c; 41, Figures 2a–c; 42, Figures 2a–c; 43, Figures 5a–c; 4a–c; 45, Figures 3a–c; 46, Figures 1a–c; 47, Figures 2a–c; 52, Figures 3–7; 56, Figures 8a–c; 62, Figures 3a–4c.


**Globigerina bullioideis** d’Orbigny, Jennings, Bull. Amer. Paleontol., vol. 23, No. 78, p. 193, pl. 31, fig. 7, 1936.


**Globigerina hornibrooki** Bronnmann, Bull. Amer. Paleontol., vol. 34, p. 183, pl. 12, figs. 4–6, 1952.


Test free, composed of rapidly enlarging chambers in a low trochospiral arrangement; chambers subglobular, the two whorls of chambers visible on the flattened spiral side, only the 3 to 3½ chambers of the final whorl visible on the umbilical side, with the final one occupying ½ to ⅔ the side; sutures distinct, depressed; wall calcareous, finely perforate, surface prominently reticulate; aperture interiomarginal, umbilical, with a distinct and prominent lip, the aperture in some specimens showing a tendency to become extraumbilical-umbilical.

Hypotypes range from 0.23 to 0.43 mm. in greatest diameter and 0.15 to 0.33 mm. in thickness.

**Remarks:** Globigerina triloculinoides Plummer is characterized by the tripartite appearance of the umbilical side, with the exceptionally large and inflated final chamber and the typical pitted or reticulate surface. The aperture is typically umbilical, but in some specimens extends somewhat more forward, tending to become extraumbilical-umbilical, as is true of occasional specimens in many other species of Globigerina.

An examination of a large suite of specimens from a single locality shows considerable variation in minor features, but these variations are obviously within the limits of a single population. For this reason, we consider as synonyms here certain of these variations which have been given distinct names in the past even though they occur together in a single assemblage or are of the same age.

Bolli (1957, p. 70) considered Globigerina finlayi Bronnmann a synonym of G. linaperta Finlay and G. hornibrooki Bronnmann a synonym of G. triangularis White. He considered G. stainforthi transitional between G. triloculinoides Plummer and G. pseudobiloides Plummer. Globigerina stainforthi, G. hornibrooki, G. finlayi, G. triangularis, and G. pseudotrilocula White all are here considered synonyms of G. triloculinoides Plummer as all have relatively few chambers, rapidly increasing in size, and a coarsely reticulate surface.

Globigerina linaperta Finlay is a middle Eocene instead of a Paleocene species, and is characterized by an almost equatorial aperture. The similarity to G. triloculinoides Plummer in chamber development and coarsely punctate surface, and the tendency of some specimens of G. triloculinoides to develop an extraumbilical aperture, strongly suggest that G. linaperta is a descendant of the earlier G. triloculinoides. The specimens referred to G. linaperta by Bronnmann (1952) from the lower Lizard Springs are typical G. triloculinoides, not linaperta, and are of Paleocene age. Globigerina pseudobiloides Plummer does not have a coarsely reticulate surface, has more chambers per whorl, a gradual rate of increase in chamber size and a more definitely extraumbilical aperture.

Globigerina hornibrooki Bronnmann is probably a synonym of G. triangularis White as was stated by Bolli, but we regard both as synonyms of G. triloculinoides. The type specimens of these species show a more gradual increase in chamber size than does the original figure of G. triloculinoides, as the type specimens of G. triangularis White have 4 chambers in the final
whorl, resulting from less rapid increase in chamber size than in *G. triloculinosides*. A large suite of topotypes of *G. triloculinosides* contains specimens with all of these variations and many others. *Globigerina hornibrookii* was defined as differing in having the final chamber smaller than the penultimate one, but the gerontic character of a final chamber of reduced size is common to many species and not of specific importance.

*Globigerina velascoensis* Cushman var. *compressa* White is merely *Globigerina triloculinosides* Plummer with somewhat flattened final chamber. This varietal name is a homonym of *G. compressa* Plummer, 1926. Bell (1957, p. 78) renamed this homonym as *Globorotalia tortiva* Bolli, new name, but the specimen he figured is a species distinct from that of White and thus must either be otherwise identified or itself made the basis of another specific name.

**Types and Occurrence:** Figured hypotype (USNM P5814) from the lower Danian, zone of *Tylcocaridaris odumii* Brunnich Nielsen, Hjerm (western quarry), northwestern Denmark. Collected by J. C. Troelsen.

Figured hypotype (USNM P5815) from the Kincade formation, in a small stream bank on the east side of the road to Lund, 3 miles northwest of Elgin on the Bastrop-Travis County line, 0.5 mile north of the junction with the Austin-Elgin highway, Texas. Collected by A. R. Loeblich, Jr.

Figured topotype (USNM P5816) from the Wills Point formation, shallow ditch at the road corner southeast of the new Corsicana Reservoir, on the road to Mildred, Navarro County, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5817) from the Mexia clay member of the Wills Point formation, in abandoned pit of the Mexia Brick Works at Mexia, Limestone County, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5818) from the McBryde limestone member of the Clayton formation, in bed of Rock Creek, 0.8 mile south of junction of Alabama highways 28 and 10, on Alabama highway 10, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5819) from the Matthews Landing marl member of the Porters Creek clay at Naheola Landing on the Tombigbee River, SE ¼, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5697) from the Coal Bluff marl member of the Naheola formation in creek bottom, just west of store at Caledonia, about ¼ mile south of center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stearns MacNeil.

Figured hypotype (USNM P5698) from the Salt Mountain limestone, in a limestone sink, ¼ mile north of Salt Mountain, in the NW ¼ NW ¼, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5699) from the type locality of the Brightseat formation, 1 mile west-southwest of Brightseat and 0.2 mile south of Sheriff Road, Prince Georges County, Maryland. Collected by A. R. Loeblich, Jr. and Richard A. Page.


Figured hypotypes (USNM P5123a–c) from the Vincentown limestones, along north bluff of Rancocas Creek, 0.3 to 0.5 mile northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

The species also occurs in the Hornerstown formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey.

**Lectotype:** (Columbia Univ. 19882), here designated, of *Globigerina velascoensis* var. *compressa* White from the Velasco formation, Columbus Station on the Tampico-Monterey railroad line, Mexico.

Figured hypotype (USNM P5883) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rúdas and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

Globigerina species

**Plate 50, Figures 2a–c**

**Remarks:** A juvenile specimen of a finely spinose Globigerina is figured, but it is not certain to which species it should be referred. As compared to the associated species, it is less high spired and has fewer chambers per whorl than does *G. spiralis* Bolli, is much thicker and with fewer chambers per whorl than *Globorotalia perclara*, new species, and has a more bluntly rounded periphery and less oblique sutures on the spiral side than does *Globorotalia convexa* Subbotina. This form is too rare to be described as a distinct species, however.

Figured specimen 0.18 mm. in diameter.

**Types and Occurrence:** Figured specimen (USNM P5849) from the Hornerstown formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

*Genus Globigerinoides* Cushman, 1927

Globigerinoides daubjergensis (Brommann)

**Plates 40, Figures 1a–c, 8a–c; 41, Figures 9a–c; 42, Figures 6a–7c; 43, Figures 1a–c; 44, Figures 7–8c**


Test free, small, trochospiral, high spired; chambers few in number, globular, increasing rapidly in size, forming about two whorls with 3½ to 4 chambers in the final whorl; umbilicus small, commonly open, but may become closed by a somewhat overlapping final chamber; sutures distinct, depressed; wall calcareous,
finely perforate, surface spinose; primary aperture a
small high arch, interiomarginal and umbilical in po-
osition, secondary apertures tiny along the sutures on
the spiral side. Specimens range from 0.15 to 0.35
mm. in greatest diameter.

Remarks: This species was originally described
from the Danian of Jutland, Denmark, and was placed in
the genus Globigerina d'Orbigny, as the small sup-
plementary apertures of the spiral side were not ob-
erved. These openings have since been noted on type
Danian specimens by Troelsen (1957), and are here
shown in specimens from the Danian of Sweden, as
well as from those of the Gulf and Atlantic Coast
Paleocene. In his original description Bronnmann
(1953, p. 339) stated that the type Danian contains
"a small number of characteristic Globigerina and
Globorotalia species, which, with the exception of
Globigerina daubjergensis n. sp., are known from the
Paleocene of Texas . . ." This characteristic species
is also quite abundant in both the Kincaid and Wills
Point formations of the Midway group in Texas,
probably having been overlooked in the past due to
its small size. It occurs also in the Pine Barren and
McBryde members of the Clayton formation of Al-
abama, and in the Brightseat formation of Maryland.

Types and occurrence: The holotype was de-
scribed from the Danian at Daubjerg, quarry south-
west of Stavnsbjerg Farm, Denmark. Originally
stated to be deposited in the Cushman Collection,
U. S. National Museum, Washington, D. C., but
not as yet deposited therein.

Figured hypotype (USNM P5709) from the upper
Danian, zone of Tyllocidaris vexilfera Schlüter, from
calcareite at Östra Torp, Sweden. Collected by J.
G. Carlsson.

Figured hypotype (USNM P5710) from the Kincaid
formation in a small stream bank on the east side
of the road, 3 miles northwest of Elgin, on the secondary
road leading to Lund, and lying on the Bastrop-Travis
County line, about 0.5 mile north of its junction with
the Austin-Elgin highway, Texas. Collected by A. R.
Loeblich, Jr.

Figured hypotype (USNM P5711) from the Wills
Point formation, 200 feet east of the bridge over
Tehuacana Creek in bank of creek, 4 miles north of
Mexia on the Mexia-Wortham road, Limestone
County, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5712) from the Mexia
clay member of the Wills Point formation, in abandoned
pit of Mexia Brick Works at Mexia, Limestone County,
Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5713) from the Pine
Barren member of the Clayton formation, blue-black
micaceous clay in road cut opposite country store,
0.8 mile west of Alabama River Bridge on Alabama
Highway 28, Wilcox County, Alabama. Collected by
A. R. Loeblich, Jr.

Figured hypotype (USNM P5714) from the Mc-
Bryde limestone member of the Clayton formation,
in bed of Rock Creek, 0.8 mile south of junction of
Alabama Highways 28 and 10, on Highway 10, Wilcox
County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotypes (USNM P5715a,b) from
the type locality of the Brightseat formation, 1 mile west-
southwest of Brightseat and 0.2 mile south of Sheriff
Road, Prince Georges County, Maryland. Collected
by A. R. Loeblich, Jr., and Richard A. Page.

Family Globorotaliidae Cushman, 1927

Genus Globorotalia Cushman, 1927

Globorotalia acuta Toulmin

Plates 47, Figures 5a-c; 55, Figures 4a-5c; 58, Figures 5a-c

Globorotalia wilcozensis Cushman and Ponton var. acuta Toul-
min, Journ. Paleontol., vol. 15, p. 608, pl. 82, figs. 6-8,
1948.—Shiflet, Maryland Dep. Geol., Mines and Water
Resources Bull. 3, p. 73, pl. 4, figs. 23a-c, 1948.

Globorotalia (Truncorotalia) laceri Cushman and Renz, Hofek

Test free, planoconvex, umbilicoconvex, periphery
keeled, umbilical shoulder sharply angled and strongly
spinose, umbilicus relatively wide and open; chambers
angular conical in shape, increasing gradually in size
and angularity, all the 2 to 2½ whorls visible on the
flat spiral side, only the 4 to 6 chambers of the final
whorl visible on the angularly convex umbilical side;
sutures distinct and thickened, but flush with the sur-
face, oblique and directed sharply backwards on the
spiral side, radial and depressed on the umbilical side;
wall calcareous, distinctly and coarsely perforate, sur-
face spinose, with a somewhat sugary appearance
especially in the earlier chambers, peripheral margin
with a spinose keel and highly ornamented, very sharply
angled or even keeled umbilical shoulder; aperture
interiomarginal, extrumbilical-umbilical, with a dis-
tinctly triangular toothlike lip, earlier apertures remain-
ing open into the wide umbilicus.

Hypotypes range in diameter from 0.20 to 0.55 mm.
in diameter and in thickness from 0.13 to 0.28 mm.

Remarks: This species has in the past been variously
referred to as a variety (or subspecies) of Globorotalia
wilcozensis (by Toulmin, 1941, p. 608) or as a variety
of G. velascoensis (by Grimsdale, 1951, p. 471). Boll-
li (1957) regards it as synonymous with G. velascoensis,
as he stated that a gradation occurs between these forms
in the Velasco shale of Mexico. Although both forms
do occur in the Velasco, we regard the two species as
distinct, for in more northern regions only specimens
like the typical G. acuta have been observed. This is
true of the Salt Mountain limestone of Alabama where
G. acuta was first described, the Aquia formation of
Virginia, and the Vincentown formation of New
Jersey; in each region G. acuta is abundantly repres-
ented, whereas there are no specimens similar to the
type of velascoensis.

Globorotalia acuta Toulmin differs from G. velascoensis
(Cushman) in being somewhat smaller and in having a
less pronounced peripheral keel than does G. velascoensis.
Globorotalia acuta has a more rapid increase in chamber
size, with the final chamber commonly occupying ¾ to
¾ of the umbilical side, and the final chamber of *G. velascoensis* comprises ¾ to ¾ of the umbilical side, the ornamentation of the umbilical shoulder is more highly ornamented in *G. velascoensis*, and the sutures of the spiral side are limbate, elevated, and beaded. The sutures of *G. acuta* are flush with the spiral side.

**Types and occurrence:** Figured hypotypes (USNM P5141a, b) from the Vincentown formation, north bluff of Rancocas Creek, 0.3 to 0.5 miles north of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5142) from the Salt Mountain limestone, in a limestone sink ¾ mile north of Salt Mountain, in the NW ¼ NW ¼, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

The species also occurs in the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.


**Globorotalia acuta** Cushman and Renz

**Plates 46, Figures 7a–8c; 50, Figures 6a–c; 55, Figures 3a–c(7); 59, Figures 6a–c; 60, Figures 3a–c; 64, Figures 4a–c**


Test free, trochospirals, spiral side flat or slightly convex, umbilical side strongly convex, periphery sharply angled with a narrow keel, peripheral outline strongly lobulate; chambers increasing rapidly in size, lunate in spiral view, rhomboidal and truncate in section, sharply angled at the umbilical shoulder around a relatively wide and open umbilicus, lower margin of final chamber commonly constructed against the earlier whorl, the chamber expanding above in width, sutures distinct, gently curved, slightly thickened and beaded on the spiral side, each chamber being attached somewhat below the level of the anterior margin of the preceding one, giving the appearance of a depression at the sutures, sutures radial and constructed on the umbilical side; wall calcareous, finely perforate, keel and sutures on spiral side thickened and nodose, remainder of surface somewhat granular in appearance although final chamber may be somewhat smoother; aperture interiomarginal, extrumbilical-umbilical, in well preserved specimens with a thin and delicate subtriangular lip.

Hypotypes range from 0.30 to 0.40 mm. in diameter.

**Remarks:** *Globorotalia acuta* differs from *G. rex* Martin in having higher chambers, fewer per whorl, more lobulate periphery, more angular umbilical shoulder and wider umbilicus, more spinose keel and pustulose surface. The spiral side of *G. rex* is flat and sutures flush, whereas in *G. acuta* the chambers are somewhat imbricated in appearance, and the sutures thickened and nodose.

Rarely, a specimen may show a dwarfed instead of the more usual large and prominent final chamber, such as that shown on plate 55, figure 8. This final chamber somewhat resembles the bullae developed by some orbulinids, in the thin wall, lessened ornamentation and tendency to cover the previous aperture. The aperture of this final chamber is nearly umbilical in position. However, it retains the characteristic surface of the species, and the final chamber is visible on both the spiral and umbilical sides. Typical simple bullae, such as found in Catapsydrax are distinctly umbilical in position, completely covering the former aperture and the umbilicus, and commonly lack the ornamentation of the true chambers. The small chamber here shown is thus undoubtedly only a senile development of the specimen and not of generic or specific importance.

**Types and occurrence:** The hypotype (USNM P5888) figured on plate 55 is questionably referred here. It is from the Vincentown limesand, north bluff of Rancocas Creek, 0.3 to 0.5 mile north of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5889) from the Horrenstown formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5894) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

Figured hypotype (USNM P5125) from the Aqua formation, 15 to 17 feet above the base of the exposed section, west bank of Potomac River, near mouth of Aqua Creek, S. 10° E. of Brent Point on U. S. Geological Survey Nanjemoy Md.-Va. Quadrangle, 1:62,500, 1913, reprinted 1945.

Figured hypotype (USNM P5863) from the Nanafalia formation, south valley wall of Shoal Creek, 5.5 miles southeast of Camden, along the Camden-Fatama road, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotypes (USNM P5864a, b) from the Coal Bluff marl member of the Nahanola formation, in creek bottom, just west of store at Caledonia, about ¾ mile south of the center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stearns MacNeil.

The species was originally described from the Soldado formation (Paleocene) of Trinidad, B. W. I.
Globorotalia angulata (White)

**PLATES 45, FIGURES 7 a–c; 48, FIGURES 2a–c; 50, FIGURES 4a–c; 55, FIGURES 2, 6, 7; 58, FIGURES 2a–c; 64, FIGURES 5a–c**


Test free, trochospirally coiled, peripheral margin truncate and sharply angled, peripheral outline lobulate, biconvex to umbilicoconvex, umbilicus small, rounded and deep; chambers lunate in spiral view, cuneate in umbilical view, angular rhomboid in edge view, umbilical shoulder acutely angled, 4 to 4½ chambers per whorl, increasing rapidly in size; sutures distinct, curved and oblique on the spiral side, strongly depressed, straight and radial on the umbilical side and very strongly incised in the peripheral area; wall calcareous, finely perforate, surface smooth to lightly spinose on the spiral side, more prominently spinose on the umbilical side, and at the peripheral margins; aperture interiomarginal, extraumbilical-umbilical, a high arch directed somewhat forward, with a narrow bordering lip preserved in some specimens.

Hypotypes range in diameter from 0.30 to 0.45 mm, and in thickness from 0.20 to 0.28 mm.

**Remarks:** *Globorotalia angulata* (White) differs from *G. rex* Martin in having a more angled and elevated umbilical shoulder, the chambers are slightly inflated on the spiral side, with sutures depressed, and have an imbricated appearance, the posterior margin of each succeeding chamber attaching below the anterior margin of that preceding, whereas in *G. rex* the spiral chamber surface forms a plane.

**Types and Occurrence:** Figured hypotypes (USNM P5127a–c) from the Vincentown limesand, north bluff of Rancocas Creek, 0.3 to 0.5 miles north of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5126) from the Salt Mountain limestone, in a limestone sink ½ mile north of Salt Mountain in the NW ¼ NW ¼, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.


Figured hypotype (USNM P5891) from the Velasco formation, middle bed at road crossing of arroyo, halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

Figured hypotype (USNM P5892) from the Matthews Landing marl member of the Porters Creek clay at Naheola Landing on the Tombigbee River, SE ¼, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5893) from the Horners-town formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

**Globorotalia anaptheasma** Loeblich and Tappan, new species

**PLATES 48, FIGURES 1a–c; 55, FIGURES 1a–c; 58, FIGURES 4a–c; 59, FIGURES 1a–c**

*Globorotalia ct. angulata* (White) Shifflett, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 72, pl. 4, figs. 18a–c, 1948.

Test free, trochosiral, planocovent, umbilicoconvex, with rather wide, deep and open umbilicus, periphery subacute, peripheral outline lobulate; chambers hemispherical, flattened to gently convex and appearing lunate in side view from the spiral side, strongly inflated to subangular on the umbilical side, 4 to 5 in the final whorl, commonly somewhat obliquely overlapping earlier chambers, the forward margin of each chamber protruding slightly above the general level of the spiral side, the posterior margin of the succeeding chamber beginning at a slightly lower level; sutures distinct, strongly curved and slightly depressed on the spiral side, radial and strongly depressed on the umbilical side, wall calcareous, rather coarsely perforate, surface spinose, most strongly on the umbilical side; aperture interiomarginal, extraumbilical-umbilical, a broad arched opening, with a narrow bordering lip present in well preserved specimens.

Hypotypes range from 0.23 to 0.45 mm in diameter and from 0.15 to 0.33 mm in thickness.

**Remarks:** *Globorotalia anaptheasma*, new species, differs from *G. acuta* Toulmin in lacking a peripheral keel, in having a spinose surface, less angular chambers, more convex spiral side, and less ornamented umbilical shoulder.

*Globorotalia angulata* (White) differs in being larger, in having fewer chambers and more rapid increase in chamber size and the chambers are more angular in spiral view, more inflated in umbilical view, with a more truncate periphery and a more finely spinose surface.

The specific name is from the Greek *apanthesma*, a plucked flower.

**Types and Occurrence:** Holotype (USNM P5860) and figured paratype (USNM P5868) from the Aquia formation, 10 to 13 feet above the base of the exposed section, west bank of Potomac River, near mouth of Aquia Creek, S. 10° E. of Brent Point on U. S. Geological Survey Nanjemoy Md.-Va. Quadrangle, 1:62,500, 1913, reprinted 1945. Collected by A. R. Loeblich, Jr., and Richard A. Page.

Figured paratype (USNM P5861) from the Vincentown formation, north bluff of Rancocas Creek, 0.3 to 0.5 miles north of Vincentown, Burlington Co., New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured paratype (USNM P5862) from the Salt
Mountain limestone, in a limestone sink, ½ mile north of Salt Mountain in the NW½NW¼ Sec. 34, T. 6 N., R. 2 E., Clarke Co., Alabama. Collected by H. T. and A. R. Loeblich, Jr.

*Globorotalia compressa* (Plummer)

PLATES 40, FIGURES 5a-c; 41, FIGURES 5a-c; 42, FIGURES 5a-c; 44, FIGURES 9a-10c

_Globigerina compressa_ PLUMMER, Univ. Texas Bull. 2644, p. 135, pl. 8, figs. 11a–c, 1926.


Test free, trochospiral, compressed, umbilical side with small deep umbilicus, periphery subacute, peripheral outline lobulate; chambers moderately inflated, more so on the umbilical side, enlarging rapidly in size as added, of nearly equal breadth and height, arranged in about 2 whorls, commonly 5 occur in the final whorl; sutures distinct, gently curved, slightly depressed; wall calcareous, distinctly perforate, surface smooth; aperture interiomarginal, exumbilical-umbilical, an arched opening extending nearly to the periphery, and bordered above with a narrow lip.

Hypotypes range in diameter from 0.28 to 0.38 mm.

Remarks: This species has been misinterpreted by some workers. Bronnimann (1952, p. 25, pl. 12, figs. 19–24) referred to _G. compressa_ specimens with a more angular or keeled periphery, rapid increase in chamber size, relatively large final chamber, and larger test; these latter forms are here referred to _Globorotalia elongata_ Glaessner. The holotype of _Globorotalia ehrenbergi_ Boll is identical in appearance to metatypes of _G. compressa_ Plummer, and this specific name is therefore considered a synonym.

Typical _G. compressa_ (as shown by metatypes and topotypes) is very similar to _Globigerina pseudobulloides_ Plummer, differing in being smaller and with somewhat more angular peripheral margin (compressed) and smooth, very finely perforate wall instead of the more coarsely perforate and pitted wall of _G. pseudobulloides_.

_Globorotalia imitata_ Subbotina is also similar to the present species but has a rounded rather than subacute periphery, and a more flattened spiral side, more curved sutures and lower chambers.

Types and occurrence: Figured hypotype (USNM P5716) from the Danian calcareite at Östratorp, Skåne, Sweden. Collected by J. C. Troelsen.

Figured hypotypes (USNM P5717a,b) from the Wills Point formation, in road cut near top of hill on the Corsicana-Navarro road just south of the junction with the Mildred road, Navarro County, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5718) from the McBryde limestone member of the Clayton formation, in bed of Rock Creek, 0.8 mile south of junction of Alabama Highways 28 and 10, on Highway 10, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5719) from the type locality of the Brightseat formation, 1 mile west-southwest of Brightseat and 0.2 mile south of Sheriff Road, Prince Georges County, Maryland. Collected by A. R. Loeblich, Jr., and Richard A. Page.

_Globorotalia convexa_ Subbotina

PLATES 48, FIGURES 4a–c; 50, FIGURES 7a–c; 53, FIGURES 6a–8c; 57, FIGURES 5a–6c; 61, FIGURES 4a–c; 63, FIGURES 4a–c


Test free, ovate in outline, trochospirally coiled, inflated, peripheral margin rounded, peripheral outline slightly lobulate; chambers gradually enlarging, all whorls visible on the flattened spiral side, only the 4 to 6 chambers of the final whorl visible around the nearly closed umbilicus on the umbilical side; sutures somewhat indistinct, strongly curved backwards on the spiral side, radial on the umbilical side; wall calcareous, perforate, entire surface spinose; aperture interiomarginal, extrumbilical-umbilical, a low arched opening extending about halfway to the periphery, with a narrow lip above.

Hypotypes range in greatest diameter from 0.23 to 0.30 mm. and in thickness from 0.13 to 0.25 mm.

Remarks: _Globorotalia convexa_ Subbotina is similar to _Globigerina mckannai_ White in its surface texture and number of chambers per whorl, but differs in the smaller size, more strongly curved but somewhat obscure and less incised sutures, more broadly rounded periphery, and nearly closed umbilicus.

It differs from _Globorotalia albeari_ Cushman and Bermuda in being smaller, in having fewer chambers per whorl, a more rounded periphery, less distinct sutures, flatter spiral side, and more spinose surface.

It is similar in appearance to _Globorotalia brodermanni_ Cushman and Bermuda from the lower Eocene Capdevila formation of Cuba, but differs in being only about ½ as large and in having a more closed umbilicus, and a lower and much smaller apertural opening. The present species is probably ancestral to the lower Eocene species.

Types and occurrence: Figured hypotypes (USNM P5129a–c) from the Vincentown formation, north bluff of Rancocas Creek, 0.3 to 0.5 miles north of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5845) from the Horners-town formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.


Figured hypotype (USNM P5847) from the Salt
Globorotalia, bottom, Bluff Jachin, River, remaining thickened test; calcareous, final equal of coiled, Globorotalia Plates of formation, lich, R. of Mountain Types 49, Remarks: It Figured hypertype (USNM P5848) from the Nanafalia formation, basal 6 feet of formation just above Midway group, road cut 0.2 mile east of the Turkey Creek bridge, 1.2 miles east of Kimbrough Station, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr. Figured hypertype (USNM P5885) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker. It was originally described from the “lower Eocene” of Russia, where it occurred in the Globorotalia velascoensis zone, a zone here considered to be of Paleocene age. Globorotalia elongata Glassner Plates 45, Figures 5a-c; 46, Figures 5a-c; 48, Figures 5a-c; 49, Figures 7a-c; 54, Figures 1a-5c; 59, Figures 4a-e; 60, Figures 9a-c; 63, Figures 2a-c. Globorotalia pseudocostata Glassner var. elongata Glassner, Studies in Micropaleontol., Univ. Moscow Lab. Paleontol., vol. 1, fasc. 1, p. 33, text-figs. 3d-f, 1937. Globorotalia elongata Glassner, Bolli, U. S. Nat. Mus. Bull. 215, p. 77, pl. 20, figs. 11-13, 1957. Globorotalia compressa (Plummer) Toulmin, Journ. Paleontol., vol. 15, No. 6, p. 607, pl. 82, figs. 1, 2. 1941. Test free, biconvex but compressed, trocho spirally coiled, somewhat elongated, peripheral margin rounded to subacute, peripheral outline lobulate; all chambers of the 2 whorls visible on the spiral side, early coils somewhat depressed, only the 4 to 5 chambers of the final whorl visible on the umbilical side, which has a relatively wide and open umbilicus, chambers of nearly equal breadth and height, increasing rapidly in size, final chamber comprising about two-fifths of the entire test; sutures distinct, depressed, gently curved; wall calcareous, finely perforate, surface smooth; aperture interiomarginal, extraumbilical-umbilical, extending to the periphery and may even extend slightly onto the spiral side, with a distinct lip, portions of earlier lips remaining visible around the umbilicus. Hypotypes range in greatest diameter from 0.20 to 0.55 mm., and in thickness from 0.08 to 0.23 mm. Remarks: Globorotalia elongata differs from G. pseudodomenardii Bolli in lacking the peripheral keel and thickened sutures and in having a more incised spiral suture. Types and occurrence: Figured hypertype (USNM P5813) from the Matthews Landing marl member of the Porters Creek clay, Naheola Landing, Tombigbee River, SE 1/4, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr. Figured hypertype (USNM P56992) from the Coal Bluff marl member of the Naheola formation in creek bottom, just west of store at Caledonia, about ¾ mile south of center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stearns MacNeil. Figured hypertype (USNM P5693) from the Salt Mountain limestone, in a limestone sink, ¾ mile north of Salt Mountain, in the NW 1/4 NW 1/4, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr. Figured hypertype (USNM P5694) from the Ostrea thorsae beds of the Nanafalia formation, 56 feet above the Midway contact, in road cut 1.2 miles east of Kimbrough Station, and 0.2 mile east of the Turkey Creek bridge, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr. Figured hypertype (USNM P5695) from the Aquia formation, 42 feet above the base of the exposure, west bank of Potomac River, near mouth of Aquia Creek, S. 10° E. of Brent Point, on U. S. Geol. Survey Nanjemoy Md.-Va. quadrangle, 1:62,500, 1913, reprinted 1945. Collected by A. R. Loeblich, Jr., and Richard A. Page. Figured hypertype (USNM P5697) from the Horners town formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl. Figured hypertypes (USNM P5133a-e) from the Vincentown limesand, along north bluff of Rancocas Creek, 0.3 to 0.5 mile northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl. Figured hypertype (USNM P5882) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker. Globorotalia esaenas (Le Roy) Plates 57, Figures 7a-c(?); 61, Figures 1a-2c, 9a-c Globigerina esaenas Le Roy, Geol. Soc. Amer., Mem. 54, p. 31, pl. 6, figs. 8–10, 1953. Test free, small, trochospiral, inflated, spiral side flattened, umbilical side convex, umbilicus small, periphery broadly rounded, peripheral outline lobulate; chambers increasing rapidly in size as added, four in the final whorl with final chamber occupying about one-third of the umbilical side; sutures distinct, depressed, radial; wall calcareous, finely perforate, surface finely spinose; aperture an interiomarginal arch tending to extend somewhat to an extrumbilical position. Hypotypes range in diameter from 0.25 to 0.38 mm. Remarks: The specimens here figured are similar to the holotype of Globorotalia esaenas (Le Roy) in all respects, except that they are about half its size. As various other species also appear somewhat smaller in the strata here studied than elsewhere, the specimens are regarded as conspecific. The present species is also very similar to G. wilcoensis Cushman and Ponton, but the latter is almost truncate and the sutures are curved and oblique on the spiral side.
Because of the extrabasal position of the aperture, the species is here regarded as a *Globorotalia*.

The specimen here figured from the Aquria formation is somewhat questionably referred to this species, as the early spire is more elevated than is usual in this species. Other specimens from the Aquria are quite typical, however, and this specimen is regarded as atypical.

**Types and occurrence:** Figured hypotypes (USNM P5876a,b) from the Nanafalia formation, basal six feet of the formation, in road cut 0.2 miles east of Turkey Creek bridge and 1.2 miles east of Kimberly Station, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5877) from the upper 25 feet of the Nanafalia formation exposed in the road cut at the above locality.


**Globorotalia bispiculicostata** Loeblich and Tappan, new species

**PLATE 58, FIGURES 1a–c**

Test free, of medium size, trochospiral, spiral side gently convex, umbilical side inflated, periphery angularly truncate, peripheral outline gently lobulate; chambers increasing slowly in size, 5 per whorl in early stages, final whorl with 6 to 7 chambers; sutures distinct, slightly depressed, curved and oblique on the spiral side, more deeply depressed, straight and radial around the small umbilicus on the umbilical side; wall calcareous, finely perforate, surface spinose throughout, although final one or two chambers may be less prominently spinose, distinctly spinose at the peripheral angle, presenting a keel-like appearance; aperture a low interiomarginal, extrabasal-umbilical arch extending to the periphery.

Holotype 0.35 mm. in diameter.

Remarks: This species resembles *Globorotalia conico-truncate* Subbotina from the Russian Danian(?) in the numerous chambers per whorl, truncated spiral side, and the angular-truncate periphery. The present species is smaller and has a prominently spinose surface.

It differs from *Globigerina mckannai* White in being less thickened and more nearly keeled, in having more chambers per whorl, more oblique sutures on the spiral side, and a truncate rather than rounded periphery.

**Globorotalia apanthesmus**, new species, has fewer chambers per whorl, a less truncate periphery and the chambers slope gradually from the peripheral keel to the umbilical shoulder. The wall surface is also less prominently spinose.

The specific name is from the Latin *hispidus*, bristly, prickly, and *cidaris*, a diadem or tiara, referring to the general appearance of the species.


**Globorotalia imitata** Subbotina

**PLATE 44, FIGURES 3a–c; 45, FIGURES 6a–c; 54, FIGURES 8a–9e; 59, FIGURES 8a–c; 63, FIGURES 8a–c**


Test free, tiny, spiral side flattened to gently convex, peripheral margin rounded, peripheral outline lobulate; chambers moderately inflated, ovate, increasing gradually in size and arranged in a low trochospiral coil of about 2 volutions, 4 to 5 in the final whorl; sutures distinct, slightly depressed, gently curved; wall calcareous, finely perforate, surface smooth; aperture interiomarginal, extrabasal-umbilical, a low arch, bordered by a narrow, protruding lip.

Hypotypes range from 0.15 to 0.25 mm. in diameter, and from 0.09 to 0.13 mm. in thickness.

Remarks: Originally described from strata of Danian age in Russia, this species occurs in beds of equivalent age in Texas (Wills Point formation), but also ranges somewhat higher, occurring also in the Matthews Landing marl member of the Porters Creek clay of Alabama, in the Vincentown formation of New Jersey and the Aquria formation of Virginia.

It somewhat resembles *Globorotalia compressa* (Plummer) in general appearance, but has a less acute periphery which is rounded to almost truncate, an almost flattened spiral side, more curved sutures and lower chambers.

**Types and occurrence:** Figured hypotype (USNM P5688) from the Wills Point formation (Mexia clay member) in abandoned pit of the Mexia Brick Works at Mexia, Limestone County, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5689) from the Matthews Landing marl member of the Porters Creek clay, at Naheola Landing, Tombigbee River, SE%, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5131 a, b) from the Vincentown limesand, along north bluff of Rancocas Creek 0.3 to 0.5 mile northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.


Figured hypotype (USNM P5886) from the Velasco
formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker. The species also occurs in the Ostraea thraesa beds of the Nanafalia formation in a road cut 1.2 miles east of Kimbrough Station and 0.2 mile east of the Turkey Creek bridge, Wilcox County, Alabama.

Globorotalia irrourata Loeblich and Tappan, new species

Plates 46, Figures 2a–c; 61, Figures 5a–c

Test free, small, trochospiral, spiral surface somewhat flattened, umbilical surface inflated, umbilicus small and deep, periphery broadly rounded, peripheral outline gently lobulate; chambers increasing gradually in size, 4 to 5 per whorl; sutures depressed, oblique on the spiral side, radial on umbilical side; wall calcareous, finely perforate, surface covered with short blunt spines; aperture a low interiomarginal, extraumbilical-umbilical arch.

Holotype 0.26 mm. in diameter.

Remarks: Globorotalia irrourata, new species, differs from Acarinina intermedia Subbotina in having lower chambers, with less rapid increase in thickness. It differs from Globigerina soldadoensis Bronnimann in having a more flattened spiral side, lower chambers, radial instead of oblique sutures on the umbilical side, and a lower, and more extraumbilical aperture. Globorotalia convexa differs from the present species in having broader and lower chambers, more oblique sutures, and a less broadly rounded periphery.

The specific name is from the Latin, irrouratus, beaded, covered with granules, and refers to the hirsute surface.

Types and Occurrence: Holotype (USNM P5872) from the Nanafalia formation, south valley wall of Shoal Creek, 5.5 miles southeast of Camden, along the Camden-Patama road, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured paratype (USNM P5873) from the Coal Bluff marl member of the Naheoa formation, in creek bottom just west of store at Caledonia, about ¾ mile south of the center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stearns MacNeil.

Globorotalia oculata Loeblich and Tappan, new species

Plates 55, Figures 3a–c; 64, Figures 3a–c

Test free, of medium size, trochospiral, side flat, umbilical side convex, with a very small and deep umbilicus, periphery keeled, peripheral outline entire to slightly lobulate; chambers gradually increasing in size, 4 to 5, rarely 6, in the final whorl, of greatest thickness at the umbilical shoulder immediately adjacent to the narrow umbilicus, umbilical shoulder subacutely rounded; sutures distinct, curved and oblique, thickened and flush to slightly elevated on the spiral side, radial and moderately depressed on the umbilical side; wall calcareous, finely perforate, surface smooth except for the thickened sutures on the spiral side and the peripheral keel which may be marginally nodose to hirsute, umbilical side with a somewhat granular appearance, particularly in the early region of the final whorl; aperture an interiomarginal, extraumbilical-umbilical arch with a distinct lip above.

Greatest diameter of holotype 0.45 mm.

Remarks: Globorotalia oculata, new species, differs from G. velascoensis (Cushman) and G. acuta Toulmin in being smaller, of less thickness, and in having a small, almost closed umbilicus in place of the wide umbilicus and sharply angled, highly ornamented umbilical shoulder. It also differs from G. velascoensis in having fewer chambers per whorl and from G. acuta in having elevated sutures on the spiral side.

It differs from G. crater Finlay in having a more narrow umbilicus and a less elevated umbilical side.

The specific name is from the Latin oculatus, shut up, closed, and refers to the narrow umbilicus.

Types and Occurrence: Holotype (USNM P5874) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

Figured paratype (USNM P5866) from the Vincentown formation, north bluff of Rancocas Creek, 0.3 to 0.5 miles northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

This species also occurs in the Salt Mountain limestone of Alabama and the Aquia formation of Virginia.

Globorotalia perclara Loeblich and Tappan, new species

Plates 40, Figures 7a–c; 41, Figures 8a–c; 42, Figures 4a–c; 45, Figures 1a–c; 46, Figures 3a–c; 47, Figures 6a–c; 50, Figures 1a–c; 52, Figures 6a–7c; 57, Figures 5a–4c; 60, Figures 5a–c


Test free, trochospiral, sides flattened, umbilicus small, peripheral margin broadly rounded, peripheral outline lobulate; 5 to 6 chambers in the final whorl, increasing gradually in size as added, rounded to ovate in shape, or may somewhat overhang the preceding suture, of somewhat greater breadth than height on the spiral side, and commonly somewhat excavated near the spiral suture, elevated near the periphery; sutures distinct, depressed, curved back at the periphery on the spiral side, radial on the umbilical side; wall calcareous, finely perforate, surface smooth to finely hispid on the spiral side, distinctly spinose on the umbilical side; aperture a small, interiomarginal, extraumbilical-umbilical arch.

Holotype 0.26 mm. in diameter.

Remarks: The specimens from the Aquia formation of Aquia Creek, Virginia, referred by Shifflet (1948) to Globigerina cf. pseudo-bulloides Plummer, belong to the present species. It differs from G. pseudo-bulloides (which is here considered also a Globorotalia) in the much smaller size, lower chambers, which increase
more slowly in size, and the very prominently spinose umbilical side.

_Globorotalia reissi_, new species, is similar in size, but has a more convex spiral side, and a nearly smooth surface.

**Types and Occurrence:** Holotype (USNM P5356) from the Brightseat formation, 1 mile west-southwest of Brightseat and 0.2 mile south of Sheriff Road, Prince Georges County, Maryland. Collected by A. R. Loeblich, Jr., and Richard A. Page.

Figured paratype (USNM P5821) from the Pine Barren member of the Clayton formation, road cut opposite small country store, 0.8 mile west of the Alabama River Bridge on Alabama state highway 28, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured paratype (USNM P5822) from the McBryde limestone member of the Clayton formation, in bed of Rock Creek, 0.8 mile south of junction of Alabama state highways 28 and 10, on highway 10, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured paratype (USNM P5823) from the Matthews Landing marl member of the Porters Creek clay, Naheola Landing, Tombigbee River, SE¼, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jackin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.

Figured paratype (USNM P5824) from the Coal Bluff marl member of the Naheola formation in creek bottom, just west of store at Caledonia, about ¾ mile south of center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stearns MacNeil.

Figured paratype (USNM P5825) from the Horners-town formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured paratypes (USNM P5135a, b) from the Vincentown formation, along north bluff of Rancocas Creek 0.3 to 0.5 miles northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr. and Norman Sohl.

Figured paratypes (USNM P5826a, b) from the Aqua formation, 6 to 9 feet above the base of the exposed section, west bank of Potomac River, near mouth of Aqua Creek, S. 10° E. of Brent Point, on U. S. Geological Survey Nanjemoy, Md.-Va. Quadrangle, 1:62,500, 1913, reprinted 1945. Collected by A. R. Loeblich, Jr., and Richard A. Page.

Figured paratype (USNM P5827) from the Nanafalia formation, south valley wall of Shoal Creek, 5.5 miles southeast of Camden, along Camden-Fatama road, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured paratype (USNM P5828) from the Salt Mountain limestone, in a limestone sink, ¾ mile north of Salt Mountain, in the NW¾NW¼, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

**Globorotalia pseudobulloides** (Plummer)

_Plates 40, Figures 3a-c, 9a-c; 41, Figures 1a-c; 42, Figures 3a-c; 43, Figures 3a-4c; 44, Figures 4-6c; 45, Figures 1a-2c; 46, Figures 6a-c._

_Globigerina pseudo-bulloides_ PLUMMER, Univ. Texas Bull. 2644, p. 133, pl. 8, figs. 9a-c, 1926.

Test free, medium sized, low trochosphiral, coil of about 2½ volutions, umbilical side with small deep umbilicus; chambers subglobular and inflated, increasing rapidly in size, 5 to 7 in the final whorl, most commonly 5; sutures distinctly constricted; wall calcareous, distinctly perforate and very finely pitted, but not spinose; aperture extrumbilical-umbilical, interiromarginall, a rounded arch bordered above by a narrow lip.

Hypotypes range from 0.18 to 0.50 mm. in diameter. **Remarks:** _Globorotalia pseudobulloides_ differs from _G. varians_ (Subbotina) in having a more coarsely perforate and finely pitted wall which may give the appearance of being reticulate, but does not have the finely spinose surface of the associated _G. varians_.

**Types and Occurrence:** Figured hypotype (USNM P5720) from the lower Danian, zone of _Tyloedicaridae_ (Wilson) in underlying calciluite (Cerithium limestone with _Cerithium balteus_) Højørup, Stevns Klint, Denmark. Collected by J. C. Troelsen.

Figured hypotypes (USNM P5721a,b) from the Kincaid formation, in a small stream bank on the east side of the road to Lund, 3 miles northwest of Elgin on the Bastrop-Travis county line, 0.5 mile north of the junction with the Austin-Elgin highway, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotypes (USNM P5722a,b) from the Mexia clay member of the Wills Point formation, in abandoned pit of Mexia Brick Works at Mexia, Limestone County, Texas. Collected by A. R. Loeblich, Jr.

Figured topotype (USNM P5723) from the Wills Point formation, shallow ditch at road corner southeast of the new Corsicana Reservoir, on the road to Mildred, Navarro County, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5724) from the Pine Barren member of the Clayton formation, blue black micaceous clay exposed in road cut opposite small country store on Alabama highway 28, 0.8 mile west of the Alabama River bridge, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5725) from the McBryde limestone member of the Clayton formation, in bed of Rock Creek, 0.8 mile south of junction of Alabama highways 28 and 10, on highway 10, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotypes (USNM P5726a,b) from the Matthews Landing marl member of the Porters Creek clay, at Naheola Landing, Tombigbee River, SE¼, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jackin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.
Figured hypotype (USNM P5727) from the Coal Bluff marl member of the Naehola formation in creek bottom, just west of store at Caledonia, about ⅝ mile south of center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stearns MacNeil.

Figured hypotype (USNM P5728) from the type locality of the Brightseat formation, 1 mile west-southwest of Brightseat and 0.2 mile south of Sheriff Road, Prince Georges County, Maryland. Collected by A. R. Loeblich, Jr., and Richard A. Page.

**Globorotalia pseudomenardii Bolli**

Plates 45, Figures 10a–c; 47, Figures 4a–c; 49, Figures 6a–c; 54, Figures 10a–13c; 59, Figures 3a–c; 60, Figures 8a–c; 63, Figures 13a–c


**Globorotalia membranacea** (Ehrenberg)'Toulmin, Journ. Paleontol., vol. 15, No. 6, p. 606, pl. 52, figs. 4, 5, 1941.


Test free, biconvex but compressed, trochospirally coiled, periphery with a narrow but distinct keel; all chambers of the 2½ whors visible on the gently but regularly convex spiral side, low and broad and curved backwards at the periphery, only the 5 to 5½ chambers of the final whorl visible on the umbilical side, where they are of nearly equal height and breadth and more wedge-shaped in outline, although the final chamber is commonly relatively large and almost hemispherical in outline, occasional specimens may show only a gradual increase in size or even a final chamber smaller than the penultimate one, umbilicus small or nearly closed; sutures of the early whors somewhat obscure on the spiral side, those of final whorl strongly curved backward and somewhat thickened although flush with the surface, radial and slightly depressed on the umbilical side; wall calcareous, finely perforate, surface smooth; aperture interiomarginal, extrumbilical-umbilical with a narrow lip, and in specimens with nearly closed umbilicus the aperture tends to become completely extrumbilical and to extend to the peripheral keel.

Hypotypes range in greatest diameter from 0.19 to 0.48 mm. and in thickness from 0.10 to 0.22 mm.

**Remarks:** **Globorotalia pseudomenardii** Bolli differs from the somewhat similar *G. elongata* Glaessner in having a peripheral keel, thickened and flush, rather than incised, sutures, which are more strongly curved on the spiral side, and a more gradual increase in chamber size and less enlarged final chamber, resulting in a less elongate test. The spiral side is gently convex, with flush chambers and sutures in all whors, whereas in *G. elongata* the more incised radial and spiral sutures give a depressed appearance to the early whors.

**Globorotalia membranacea** (Ehrenberg) of Toulmin is identical with this species, the original figures showing well the characteristic peripheral keel and thickened and curved sutures on the spiral side. *Planulina membranacea* Ehrenberg was originally recorded from Cretaceous chalk and two specimens were figured by transmitted light. No description was given and no depository cited for the types. As keeled *Globorotalia* is not found in the Cretaceous, Ehrenberg's form is undoubtedly not identical with the present species, and the only available evidence (the original figures) could place the form in almost any coiled genus. It is therefore unrecognizable.

**Types and Occurrence:** Figured hypotype (USNM P5701) from the Matthews Landing marl member of the Porters Creek clay, Naehola Landing, Tombigbee River, SE¼, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5702) from the Salt Mountain limestone, in a limestone sink, ⅝ mile north of Salt Mountain, in the NW¼ NW¼, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.


Figured hypotype (USNM P5704) from the Horners-town formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotypes (USNM P5137a–d) from the Vincentown limesand, along north bluff of Rancocas Creek, 0.3 to 0.5 mile northwest of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5706) from the *Ostrea thirsae* beds of the Nanafalia formation, approximately 56 feet above contact with the Midway, in road cut 1.2 mile east of Kimbrough Station and 0.2 mile east of the Turkey Creek Bridge, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5887) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

**Globorotalia pseudoscutula** Glaessner

Plates 46, Figures 4a–c; 48, Figures 3a–c; 53, Figures 5a–c; 59, Figures 2a–c; 63, Figures 6a–c

**Globorotalia pseudoscutula** Glaessner, Studies in Micropaleontology, Univ. Moscow Lab. Paleontol., vol. 1, No. 1, pp. 32, 49, text figs. 3a–c, 1957.

Test free, trochospiral, biconvex. almost lenticular in form, umbilicus small to nearly closed, peripheral margin subacute, peripheral outline very slightly lobulate; chambers appearing lunate from the spiral side, inflated and broadly cuneate from the umbilical side, ovate to almost angular rhomboid in section, increasing gradually in size as added, 5, or more rarely 6 to 7, in the final whorl; sutures nearly flush, curved, oblique and
somewhat thickened on the spiral side, nearly straight and radial on the umbilical side; wall calcareous, finely perforate, surface smooth to lightly spinose; aperture interiomarginal, extraumbilical-umbilical, a low arch which may show a narrow bordering lip.

Hypotypes range in diameter from 0.20 to 0.38 mm. and in thickness from 0.11 to 0.23 mm.

Remarks: Globorotalia pusilla laevigata Bolli from the Paleocene of Trinidad is a very similar form and undoubtedly related to the present species.

Globorotalia pseudoscitula differs from G. convexa Subbotina in being more lenticular in section, with a more convex spiral side rather than a flatter one and a less inflated umbilical side, with nearly closed umbilicus.

Types and occurrence: Figured hypotype (USNM P5139) from the Vincentown formation, north bluff of Rancocas Creek, 0.3 to 0.5 miles north of Vincentown, Burlington County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured hypotype (USNM P5130) from the Aquia formation, 15 to 17 feet above the base of the section exposed, west bank of Potomac River near mouth of Aquia Creek, S. 10° E. of Brent Point on U. S. Geological Survey Naukemoy Md.-Va. Quadrangle, 1:63,500, 1913, reprinted 1945.

Figured hypotype (USNM P5140) from the Salt Mountain limestone, in a limestone sink ¼ mile north of Salt Mountain. in the NW 1/4 SW 1/4, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5895) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusías and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

Figured hypotype (USNM P5870) from the Coal Bluff marl member of the Naheola formation, in creek bottom just west of store at Caledonia, about ½ mile south of center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stormes MacNeil.

Globorotalia pseudotopilensis (Subbotina)

Plate 60, Figures 2a–c


Test free, trochospiral, inflated, periphery broad, subtruncate but not angular, peripheral outline lobulate, with final chamber broadest somewhat above its base and presenting a trapezoidal appearance, umbilicus small, umbilical shoulder rounded; chambers in about two whorls, 4 in the final whorl, final chamber comprising about one-third of the test; sutures distinct, nearly radial and constricted on both sides; wall calcareous, finely perforate, hispid in appearance, covered with prominent blunt spines, which are strongest in the peripheral area; aperture an arched interiomarginal extraumbilical opening.

Greatest diameter of figured hypotype 0.30 mm.

Remarks: This species was originally described from the Paleocene and lower Eocene of Russia. It occurs rarely in the Nanafalia formation (Ostrea thersae beds) of Alabama.

Globorotalia pseudotopilensis differs from G. angulata (White) in the rounded margins, instead of having a peripheral keel, in the much more strongly spinose surface, and more elevated chambers.

Types and occurrence: Figured hypotype (USNM P5889) from the Nanafalia formation, south valley wall of Shoal Creek, 5.5 miles southeast of Camden, along the Camden-Fatama road, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Globorotalia reissi Loeblich and Tappan, new species

Plates 50, Figures 3a–c; 58, Figures 3a–c; 60, Figures 7a–c

Test free, trochospiral, periphery subangular, peripheral outline lobulate, strongly convex on the spiral side where the 2½ whorls may be seen with the early whorls raised distinctly above the level of the 5 to 6 chambers in the final whorl; chambers of greater breadth than height, increasing gradually in size as added; sutures distinct, depressed, slightly curved on the spiral side, radial on the umbilical side; wall calcareous, finely perforate, surface smooth; aperture a low extraumbilical-umbilical arch, with a narrow bordering lip above.

Greatest diameter of holotype 0.16 mm.

Remarks: This species is closest in appearance to G. perola, new species, but differs in the more elevated spire, and smooth rather than spinose surface. It differs from G. imitata Subbotina in the more lenticular form, with subglobular periphery, and the more numerous chambers per whorl.

The specific name is in honor of Dr. Z. Reiss, micropaleontologist, Geological Survey of Israel.


Figured paratype (USNM P5836) from the Hornstown formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Figured paratype (USNM P5837) from the Nanafalia formation, south valley wall of Shoal Creek, 5.5 miles southeast of Camden, on the Camden-Fatama road, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

This species also occurs in the Coal Bluff marl member of the Naheola formation of Alabama and the Matthews Landing marl member of the Porters Creek clay of Alabama.
Globorotalia rex Martin

Plate 60, Figures 1a–c


Test free, planoconvex, spiral side flattened, umbilical side convex to subconical, umbilicus small, periphery keeled, peripheral outline slightly lobulate; chambers increasing rapidly in size, commonly with 4 chambers in the final whorl, final chamber comprising \( \frac{3}{4} \) to \( \frac{1}{3} \) of the umbilical side, chambers gently convex at the umbilical shoulder; sutures somewhat indistinct on the spiral side, very gently curved, thickened and may be flush or very moderately elevated, especially near the peripheral margin, sutures radial and depressed on the umbilical side; wall calcareous, finely perforate, surface smooth on spiral side, with a granulated appearance on the umbilical side, becoming rougher toward the peripheral margin to appear somewhat spinose, peripheral keel somewhat beaded; aperture a very low interiomarginal, extraumbilical-umbilical arch.

Greatest diameter of hypotypes 0.38 mm.

Remarks: Globorotalia rex differs from G. angulata (White) in the flat spiral side with flush sutures, rather than the uneven spiral side and depressed sutures. It has a less markedly lobulate periphery, more pronounced keel, less angular umbilical shoulder and smaller umbilicus.

Types and occurrence: Figured hypotype (USNM P5867) from the Nanafalia formation, top of exposure of Ostrea thirona beds, road cut 0.2 mile east of Turkey Creek bridge, 1.2 miles east of Kimbrough Station, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

This species was originally described from the Lodo formation of California.

Globorotalia strabocella Loeblich and Tappan, new species

Plate 61, Figures 6a–c

Test free, of medium size, trochospiral, sides moderately convex, umbilical shoulder rounded, umbilicus broad and open, periphery broadly rounded, peripheral outline lobulate; chambers increasing gradually in size as added, of greater breadth than height, 4 per whorl in the early stages, increasing to 5 or 6 per whorl in the adult, early whorls somewhat elevated above the level of the final whorl, each successive chamber on the spiral side added somewhat below the level of that preceding, resulting in an imbricated appearance; sutures distinct, depressed, curved and oblique on the spiral side, radial and nearly straight on the umbilical side; wall calcareous, finely perforate, surface finely spinose, especially on the umbilical side; aperture an interiomarginal, extraumbilical-umbilical opening extending to the periphery.

Holotype is 0.33 mm in greatest diameter.

Remarks: Globorotalia strabocella, new species, differs from G. apanthesma, new species, in the more elevated early whors and less truncate spiral side, broadly rounded instead of subacute periphery, more rounded chambers and less curved sutures on the spiral side.

It differs from Globigerina mckannai White in being somewhat more compressed, with less globular chambers and a more extraumbilical aperture. G. mckannai may have been ancestral to the present species.

The specific name is from the Latin strabos, oblique, and cella, chamber, referring to the oblique attachment of successive chambers on the spiral side.

Types and occurrence: Holotype (USNM P5879) from the Nanafalia formation, south valley wall of Shoal Creek, 5.5 miles southeast of Camden, along the Camden-Fatama road, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

The species also occurs rarely in the Vincentown formation.

Globorotalia tribulosa Loeblich and Tappan, new species

Plates 56, Figures 3a–c; 61, Figures 7a–c

Test free, trochospiral, biconvex, spire nearly flat, umbilicus small and deep, periphery rounded, peripheral outline lobulate; chambers globular, increasing rapidly in size, forming about 2½ whorls, commonly with 4 to 5 chambers in the final whorl; sutures distinct, constricted, gently curved to radial; wall calcareous, distinctly perforate throughout, surface finely but prominently hspd; aperture an interiomarginal, extraumbilical-umbilical, high, broad arch.

Greatest diameter of holotype 0.30 mm. Paratype 0.28 mm. in diameter.

Remarks: The species somewhat resembles Globorotalia pseudobulboideis (Plummer) in general appearance, differing in the spinose surface. It differs from Globigerina esnaensis LeRoy in being much smaller, and in having more globular chambers.

The specific name comes from the Latin tribulosus, thorny, and refers to the spinose wall.

Types and occurrence: Holotype (USNM P5850) from the Nanafalia formation, basal 6 feet of the formation, road cut 0.2 mile east of Turkey Creek bridge and 1.2 miles east of Kimbrough Station, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.


Globorotalia trichotrocha Loeblich and Tappan, new species

Plates 50, Figures 5a–c; 57, Figures 1a–2c

Test free, small, trochospiral, spiral side flattened, umbilical side strongly convex and highest at the umbilical shoulder around the small deep umbilicus, periphery subangular, peripheral outline only slightly lobulate; chambers low and relatively broad on the spiral side, with 6 or more rarely 7 in the final whorl, the chambers sloping sharply outward to the periphery from the umbilical shoulder at the small umbilicus,
giving the test a low conical appearance; sutures distinct, curved obliquely backwards on the spiral side, radial on the umbilical side; wall calcareous, finely perforate, entire surface may be hispid, but with early spire most prominently spinose, final one or two chambers may be somewhat more smooth; aperture a very small interiomarginal, extraumbilical-umbilical arch.

Holotype 0.23 mm. in diameter.

Remarks: Globorotalia trichotrecha, new species, is one of a closely related group of species, all of small size with flattened spiral side, rounded or subacute peripheral angle and spinose surface. It differs from G. conicostruncta Subbotina in its smaller size, fewer chambers per whorl and narrower umbilicus. Globorotalia pericarpa, new species, differs in having more lobulate periphery, and relatively high, subglobular chambers which are evenly convex on the umbilical side without a prominent umbilical shoulder, and in having a less hispid surface; G. reissi, new species, has a convex spiral side, a more lobulate periphery, chambers evenly rounded on the umbilical side, sutures nearly radial instead of oblique on the spiral side.

The specific name is from the Greek thris, trichos, hair, and trochos, wheel.


Figured paratype (USNM P5690) from the Horners-town formation, north bank of Shingle Run, a tributary to Crosswicks Creek, 1.0 mile north of New Egypt, Monmouth County, New Jersey. Collected by A. R. Loeblich, Jr., and Norman Sohl.

Globorotalia troclesi Loeblich and Tappan, new species

Plates 60, Figures 4a-c; 63, Figures 5a-c

Test free, medium sized, compressed trochospiral, 1½ to 2 whorls visible on the spiral side with the early spire somewhat depressed, umbilical side with an open umbilicus with portions of earlier whors visible within, due to the tendency of the final whorl to uncoil slightly and appear somewhat evolute, periphery subacute with a slight keel, peripheral margin lobulate; 5 to 6 chambers in the final whorl, moderately inflated, of nearly equal breadth and height, increasing gradually in size as added; sutures distinct, depressed, gently curved on the spiral side, nearly radial on the umbilical side; wall calcareous, distinctly perforate, surface smooth; aperture interiomarginal, extraumbilical-umbilical, a relatively high arch extending to the periphery, bordered above with a very narrow lip.

Holotype 0.26 mm. in greatest diameter.

Remarks: This species is characterized by its tendency to become evolute, so that the early whors are visible from both the spiral and umbilical sides. It is closest in appearance to Globorotalia pseudomenardii Bolli, differing in the evolute tendency, and more numerous chambers, which are more equally inflated on the two sides. It has been observed only in the Nanafalia and Velasco formations.

This species is named in honor of Dr. John C. Troelsen, University of Copenhagen, Denmark, in recognition of his work on the Paleocene and lower Eocene Foraminifera.

Types and occurrence: Holotype (USNM P5687) from the Nanafalia formation (Ostrea thysae beds), 56 feet above the Midway contact, in road cut 1.2 mile east of Kimbrough Station and 0.2 mile east of the Turkey Creek bridge, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Paratype (USNM P5896) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Riusas and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

Globorotalia varianta (Subbotina)

Plates 44, Figures 1a–2b; 45, Figures 4a–c


Test free, medium sized, low trochospiral coil of approximately 2½ whors, umbilical side with small and deep umbilicus; chambers subglobular and inflated, increasing rapidly in size, 5 to 6 in the final whorl; sutures distinct, constricted; wall calcareous, distinctly perforate, surface prominently spinose, especially in the early chambers, later chambers becoming less spinose; aperture extraumbilical-umbilical, a high open arch extending to the periphery and bordered above by a subtriangular lip which is widest at its midpoint and tapers toward the periphery and umbilicus.

Hypotypes range from 0.23 to 0.40 mm. in diameter.

Remarks: This species is similar in size and plan of growth to G. pseudobulloides (Plummer) and has probably been confused with that species in the past. It differs in having a prominently spinose surface and is less coarsely perforate.

Types and occurrence: Figured hypotypes (USNM P5707a,b) from the Mexia clay member of the Wills Point formation, in abandoned pit of the Mexia Brick Works at Mexia, Limestone County, Texas. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5708) from the Matthews Landing marl member of the Porters Creek clay at Naheola Landing on the Tombigbee River, SEX, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.

Globorotalia velascoensis (Cushman)

Plate 64, Figures 1a–2c


Test free, trochospiral, spiral side flattened, umbilical side with the chambers much elevated at the umbilical
shoulder around the broad and open umbilicus, the umbilical shoulder strongly thickened, highly spinose, and may even form an everted collar, chamber wall sloping sharply in both directions from this umbilical shoulder, periphery with a distinct, wide and spinose keel, peripheral outline lobulate; chambers increasing gradually in size, 7 to 9 in the final whorl; sutures distinct, thickened, elevated, oblique and beaded on the spiral side, radial, depressed and straight on the umbilical side; wall calcareous, finely perforate, ornamented with the beaded sutures, beaded or spinose peripheral keel, and thickened and spinose collar at the umbilical shoulder; aperture an interiomarginal, extra-umbilical-umbilical arch with a narrow lip.

Hypotypes range from 0.42 to 0.60 mm. in diameter.

Remarks: This species is characterized by the limbate and beaded sutures, wide umbilicus and highly ornate collar at the umbilical shoulder. *Globorotalia acuta* Toulmin differs in lacking the beaded sutures, and in having fewer chambers per whorl. *Globorotalia apanthesma*, new species, lacks the umbilical collar, and has depressed sutures on the spiral side. *Globorotalia oculus*, new species, has a very narrow umbilicus and no umbilical collar.

Types and occurrence: Figured hypotypes (USNM P5871a,b) from the Velasco formation, middle bed at road crossing of arroyo halfway between San José de las Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

**Globorotalia species**

*Plate 45, Figures 8a–c*

Test free, small, trochospiral, compressed, umbilicus tiny, peripheral outline slightly lobulate, peripheral angle subacute; chambers in about two whorls, 4½ broad low chambers in the final whorl, gently convex on the spiral side, more elevated on the umbilical side, with a rounded to subacute umbilical shoulder; sutures distinct, slightly depressed, curved and oblique on the spiral side, nearly straight and radial on the umbilical side; wall calcareous, finely perforate, surface smooth, except near the periphery where it becomes very finely hispid; aperture interiomarginal, extra-umbilical-umbilical, bordered above by a narrow lip.

Greatest diameter of figured specimen 0.20 mm.

Remarks: This species somewhat resembles *Globorotalia pseudocincta* Gaussener, but has somewhat higher chambers on the spiral side, is less prominently perforate or punctate, is more compressed and has fewer chambers per whorl. It differs from *G. pusilla* Bolli in being more compressed, with a more flattened spiral side and higher chambers, and a more gradual increase in chamber size. Because it is quite rare it is not here described as a new species.

Types and occurrence: Figured specimen (USNM P5880) from the Matthews Landing marl member of the Porters Creek clay, Naheola Landing, Tombigbee River, SE¼, Sec. 30, T. 15 N., R. 1 E., 11 miles east of Jachin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.

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Part II:

BENTHONIC FORAMINIFERA
New Cretaceous Index Foraminifera from Northern Alaska

By Helen Tappan

Introduction

Study of rock samples from Naval Petroleum Reserve No. 4, northern Alaska, over a period of about 8 years has shown that among the microfossils occurring in the Cretaceous strata are several new species which because of their stratigraphic importance should be described. Possibly because the strata here considered are of a facies distinct from that of the better known Cretaceous horizons (Tappan, 1951, pp. 3-4), certain of these new species do not fit into any previously described genera and hence new genera are here described to include them.

This paper describes 3 new genera and 34 new species, two-thirds of which are agglutinated forms. The calcareous species described are in large part Nodosariidae and rotaliform genera.

Some reports that are in press or in preparation by other members of the U. S. Geological Survey describe the stratigraphy and structure of northern Alaska as deduced from field study and from information derived by drilling in connection with the petroleum exploration in this region. Further information on the foraminiferal zonation in the surface and subsurface material, as well as foraminiferal range charts for the various wells, is presented in those reports.

The Foraminifera discussed in this paper have been obtained from rocks ranging from Neocomian to Campanian in age. A correlation chart (text-fig. 29) shows how these Alaskan rocks are interrelated and how they fit into the European time scale.

All type specimens of the species described in the present paper are deposited in the U. S. National Museum.

Acknowledgments

The writer is indebted to many of the geologists of the U. S. Geological Survey for collecting the samples from which these Foraminifera were obtained and for supplying the necessary geographic and stratigraphic data. The field geologists are acknowledged by name under the locality data in the descriptions of species.

Figure 29.—Cretaceous strata of Northern Alaska and correlation with European time scale (modified after Gryc and others, 1956, and Imlay and Reeside, 1954).
Family Rhizamininidae Cushman, 1927

Genus Bathysiphon Sars, 1872

Bathysiphon brosgei Tappan, new species

PLATE 65, FIGURES 1–5

Test free, elongate, consisting of an undivided tubular chamber, commonly straight but rarely somewhat irregularly bent or curved; wall finely agglutinated with considerable cement, rather smoothly finished, surface may have transverse growth wrinkles, irregularly spaced; aperture rounded at the open end of the tubular chamber.

Length of holotype 1.22 mm., greatest breadth 0.31 mm. Other specimens range from 0.34 to 1.56 mm. in length and from 0.10 to 0.32 mm. in breadth.

Remarks: Bathysiphon brosgei Tappan, new species, differs from the associated B. vita Nauss in being much narrower, about one-third to one-fifth as broad, and in having a somewhat more roughened surface. It is similar in appearance to the figures of B. alexander Cushman, but an examination of the type specimens of the latter shows them to be inorganic limonitic sticks, and not Foraminifera. B. brosgei occurs throughout the Nanushuk group and the underlying Fortress Mountain formation. It is named in honor of W. P. Brosge, geologist, U. S. Geological Survey.

Types and occurrence: Holotype (USNM P4216), figured paratypes (USNM P4217a,b) and unfigured paratypes (USNM P4218) from the Topagoruk formation in a core at 2,235–2,245 feet, unfigured paratypes (USNM P4219) from a core at 1,247–1,267 feet, unfigured paratype (USNM P4220) from a core at 1,197–1,207 feet, all from Simpson test well 1, at lat. 70°57′05″ N., long. 155°21′45″ W., west of Cape Simpson, northern Alaska.

Unfigured paratype (USNM P4221) from well cuttings at 3,650–3,660 feet and unfigured paratype (USNM P4222) from well cuttings at 3,920–3,940 feet, both in the Topagoruk formation in Umiat test well 1, at lat. 69°23′52″ N., long. 152°19′45″ W., west of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4223) from well cuttings at 2,640–2,650 feet and figured paratypes (USNM P4224a,b) from well cuttings at 2,670–2,680 feet, all in the Topagoruk formation in Umiat test well 2, at lat. 69°23′04″ N., long. 152°05′01″ W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4225) from the Fortress Mountain formation (field sample 49A Pa 125), and Florence Rucker, who determined lithologic types.

Illustrations for the present paper are shaded camera lucida drawings by the writer and by Patricia Isham, scientific illustrator, Smithsonian Institution.

Family Hyperamminidae Cushman, 1910

Genus Hyperamminoides Cushman and Waters, 1928

Hyperamminoides barksdalei Tappan, new species

PLATE 65, FIGURES 6–12

Test free, flattened, elongate, somewhat flaring, consisting of an undivided tubular chamber with occasional growth wrinkles or constriction but without internal partitions; wall finely arenaceous, smoothly finished; aperture a rounded opening at the somewhat constricted end of the chamber.

Length of holotype 0.55 mm., breadth 0.26 mm. Paratypes range from 0.26 to 1.12 mm. in length.

Remarks: Hyperamminoides barksdalei, Tappan, new species, differs from H. elegans (Cushman and Waters) in being less tapering and much smaller and in having less constricted transverse growth wrinkles. This species occurs in the Topagoruk and Grandstand formations. It is named in honor of W. L. Barksdale, geologist, formerly with the U. S. Geological Survey.

Types and occurrence: Holotype (USNM P4386) from a core at 196–201 feet and unfigured paratypes (USNM P4387) from a core at 438–443 feet in the Grandstand formation; and unfigured paratypes (USNM P4388) from a core at 1,302–1,312 feet in the Topagoruk formation; all from Simpson test well 1, at lat. 70°57′05″ N., long. 155°21′45″ W., west of Cape Simpson, northern Alaska.

Figured paratype (USNM P4389) from well cuttings at 2,110–2,120 feet in the Topagoruk formation, in South Barrow test well 1, at lat. 71°19′12″ N., long. 156°42′16″ W., southwest of Point Barrow, northern Alaska.

Figured paratype (USNM P4390) and unfigured paratypes (USNM P4391) from a core at 660–670 feet in the Topagoruk formation, in South Barrow test well 2, at lat. 71°15′49″ N., long. 156°38′03″ W., southwest of Point Barrow, northern Alaska.

Unfigured paratypes (USNM P4392) from a core at 950–960 feet in the Topagoruk formation, in Arcon Point Barrow core test 1, at lat. 71°20′ N., long. 156°40′ W., southwest of Point Barrow, northern Alaska.

Figured paratype (USNM P4226) from the Grandstand formation, 2,000 feet below the top (field sample 47A Dt 236), about 4½ miles airline upstream from
the mouth of Fossil Creek, a small north-flowing tributary to the Colville River, approximately at lat. 69°19'15" N., long. 152°28' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Dettman, 1947.

Figured paratype (USNM P4227) from the lower part of the Topagoruk formation, west fork of Birthday Creek, Awuna River area (field sample 47A Wh 541), lat. 69°11'30" N., long. 156°41' W., northern Alaska. Collected by C. L. Whittington, 1947.

Figured paratype (USNM P4228) from well cuttings at 1,370–1,380 feet, figured paratype (USNM P4229) from well cuttings at 3,300–3,310 feet, and unfigured paratypes (USNM P4230) from well cuttings at 1,290–1,300 feet, all in the Topagoruk formation, Umiat test well 2, latex 69°23'04" N., long. 152°05'01" W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4231) from the Grandstand formation (field sample 47A Tr 108), north limb of Awuna anticline, on Discovery Creek, lat. 69°14' N., long. 157°25' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by M. L. Troyer, 1947.

Family Tolypamminidae Cushman, 1929

Genus Involutina Terquem, 1862

Involutina mangusi Tappan, new species

Plate 65, Figures 13, 14

Test free, discoidal, consisting of protoconulus and long undivided, planispiral, evolute second chamber, which is relatively thick and forms only a few whorls; specimens commonly compressed in preservation, surface granular in appearance; wall finely to moderately coarsely agglutinated; aperture at the open end of the tubular chamber.

Greatest diameter of holotype 0.49 mm., thickness 0.06 mm. Paratypes range from 0.36 to 0.68 mm. in diameter.

Remarks: Involutina mangusi Tappan, new species, differs from Ammodiscus gaultinus Berthelin in being about one-half as large, in having a relatively thicker spiralling chamber, and in being more coarsely agglutinated. The present species is more evenly planispiral, rather than irregularly coiled in the early stages as in A. gaultinus. The species is found in the Topagoruk and Grandstand formations and marine tongues in the equivalent Chandler formation. It is named in honor of M. D. Mangus, geologist, U. S. Geological Survey.

Types and occurrence: Holotype (USNM P4232) and unfigured paratype (USNM P4233) from a core at 1,080–1,087 feet, unfigured paratype (USNM P4234) from a core at 1,187–1,197 feet, unfigured paratypes (USNM P4235) from a core at 1,247–1,267 feet, all in the Topagoruk formation; and unfigured paratype (USNM P4236) from a core at 673–683 feet in the Grandstand formation; all from Simpson test well 1, lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Unfigured paratypes (USNM P4237) from a core at 548–558 feet in the Topagoruk formation, in Aron Point Barrow core test 1, at lat. 71°20' N., long. 156°40' W., southwest of Point Barrow, northern Alaska.

Unfigured paratype (USNM P4238) from well cuttings at 1,130–1,140 feet and unfigured paratype (USNM P4239) from well cuttings at 1,140–1,150 feet in the Topagoruk formation, in South Barrow test well 1, at lat. 71°19'12" N., long. 156°42'15" W., southwest of Point Barrow, northern Alaska.

Paratype (fig. 14; USNM P4240) from field sample 47A Wh 623, residual soil of marine zone in Chandler formation, on the south flank of the Awuna anticline, lat. 69°03'18" N., long. 156°02'30" W., northern Alaska. Collected by C. L. Whittington, 1947.

Unfigured paratype (USNM P4241) from field sample 47A Wh 688, residual soil sample of the Grandstand formation on the south flank of the Awuna anticline, lat. 69°02'48" N., long. 155°59'30" W., northern Alaska. Collected by C. L. Whittington, 1947.

Family Lituolidae Reuss, 1861

Genus Haplophragmoides Cushman, 1910

Haplophragmoides topagorukensis Tappan, new species

Plate 65, Figures 15–25

Test free, planispiral and involute, occasional specimens partly evolute, biumbilicate, periphery rounded, 8 to 12 chambers in the final whorl, increasing gradually in size as added, and slightly inflated; sutures straight and radial, somewhat thickened, moderately depressed; wall finely agglutinated, with variable amount of cement, test apparently not extremely rigid in original character, as most tests are distorted in preservation, those laterally crushed having the appearance of a more sharply angled periphery; surface generally smoothly finished, but those specimens from sandy horizons commonly possessing a more roughened exterior; aperture an arch at the base of the final chamber face on the periphery.

Greatest diameter of holotype 0.62 mm., thickness 0.08 mm. Paratypes range from 0.31 to 1.87 mm. in greatest diameter.

Remarks: This is an extremely variable species in size; and because of the prevalence of distorted tests due to compression in preservation, it is variable in apparent relative thickness and angularity of periphery. However, as there are specimens crushed in different directions as well as some pyrite-filled tests which are
less distorted, it is possible to determine the true character. It is found in the Grandstand and Topagoruk formations, the upper part of the Torok of the surface sections, and in marine zones within the Chandler formation.

The species differs from Haplophragmoides colyra Nau{ss} in having more numerous chambers in the final whorl and a less lobulate periphery. It is distinguished from H. eggert Cushman in being about twice as large and in having about double the number of chambers in the final whorl.

It occurs at approximately the same stratigraphic position as does Haplophragmoides gigas Cushman in Canada, in beds of middle and upper Albian age. Although similar to H. gigas in size, and possibly related to it, the present species lacks the distinctly sinuate sutures and the raised umbilical margins which are characteristic of the Canadian form.

**Types and Occurrence:** Holotype (USNM P4242) and unfigured paratypes (USNM P4243) from a core at 1,322–1,330 feet in the Topagoruk formation; unfigured paratypes (USNM P4244) from a core at 303–308 feet, unfigured paratypes (USNM P4245) from a core at 443–444 feet, figured paratypes (USNM P4246a,b) and unfigured paratypes (USNM P4247) from a core at 533–543 feet, unfigured paratypes (USNM P4248) from a core at 565–575 feet, unfigured paratypes (USNM P4249) from a core at 578–588 feet, and unfigured paratypes (USNM P4250) from a core at 713–723 feet, all in the Grandstand formation; unfigured paratypes (USNM P4251) from a core at 1,227–1,237 feet, figured paratype (USNM P4252) and unfigured paratypes (USNM P4253) from a core at 1,247–1,267 feet, figured paratype (USNM P4254) and unfigured paratypes (USNM P4255) from well cuttings at 1,730–1,740 feet, unfigured paratypes (USNM P4256) from well cuttings at 1,830–1,840 feet, figured paratype (USNM P4257) and unfigured paratypes (USNM P4258) from a core at 2,235–2,245 feet, unfigured paratypes (USNM P4259) from a core at 2,739–2,749 feet, unfigured paratypes (USNM P4260) from well cuttings at 2,760–2,770 feet, and unfigured paratypes (USNM P4261) from well cuttings at 2,880–2,890 feet, all in the Topagoruk formation; all from Simpson test well 1, at lat. 70°57′05″ N., long. 155°21′45″ W., west of Cape Simpson, northern Alaska.

Unfigured paratypes (USNM P4262) from well cuttings at 1,180–1,190 feet and (USNM P4263) at 1,370–1,380 feet in the Topagoruk formation, from South Barrow test well 1, at lat. 71°19′12″ N., long. 156°42′15″ W., southwest of Point Barrow, northern Alaska.

Unfigured paratypes (USNM P4269) from a core at 264 feet in the Grandstand formation, in Skull Cliff core test 1, at lat. 70°55′ N., long. 157°38′ W., southwest of Point Barrow, and approximately midway between Point Barrow and Point Franklin, northern Alaska.

Figured paratype (USNM P4270) from a core at 3,776–3,786 feet in the Topagoruk formation, in Fish Creek test well 1, at lat. 70°18′36″ N., long. 151°52′40″ W., about 15 miles west of the mouth of the Colville River, northern Alaska.

Unfigured paratypes (USNM P4271) from a core at 1,615–1,625 feet and unfigured paratypes (USNM P4272) from a core at 1,625–1,635 feet, unfigured paratypes (USNM P4273) from a core at 2,347–2,357 feet, and unfigured paratypes (USNM P4274) from a core at 2,366–2,370 feet, all in the Grandstand formation; and figured paratype (USNM P4275) from well cuttings at 3,660–3,670 feet and unfigured paratypes (USNM P4276) from well cuttings at 4,110–4,120 feet, all in the Topagoruk formation; all in Umiat test well 1, west of Umiat, at lat. 69°23′52″ N., long. 152°19′45″ W., in the northern foothills of the Brooks Range, northern Alaska.

Figured paratype (USNM P4277) and unfigured paratypes (USNM P4278) from cuttings at 2,400–2,410 feet and figured paratype (USNM P4279) from cuttings at 2,950–2,960 feet, all in the Topagoruk formation, in Umiat test well 2, north of Umiat, at lat. 69°23′04″ N., long. 152°05′01″ W., in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4280) from the upper part of the Torok formation, equivalent of the upper part of the Topagoruk formation in the subsurface, about 2,960 feet below the top of the Grandstand formation (field sample 47A D4 223), 5 miles airborne upstream from the mouth of Fossil Creek, a small north-flowing tributary to the Colville River. Unfigured paratypes (USNM P4281) from the Grandstand formation, 2,390 feet below the top (field sample 47A D4 227), about ½ mile farther upstream; unfigured paratypes (USNM P4282) from the Grandstand formation, 2,000 feet below the top (field sample 47A D4 236), about ¾ mile farther upstream; and unfigured paratypes (USNM P4283) from the Grandstand formation, 1,450 feet below the top (field sample 47A D4 244), about 1¼ miles farther upstream, from approximately lat. 69°19′30″ N., to 69°18′40″ N., long. 152°28′ W., in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1947.

Unfigured paratypes (USNM P4284) from the Grandstand formation (field sample 48A D4 336) on Trouble Creek, Big Bend anticline, at lat. 69°06′30″ N., long. 151°38′ W., in the area of the Chandler River, northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1948.

Unfigured paratypes (USNM P4285) from the Grandstand formation, 140 feet below the base of the Ninulkuk formation (field sample 48A D4 268), Chandler River, Ninulkuk syncline to Big Bend anticline, lat. 69°04′ N., long. 161°52′ W., northern Alaska. Collected by R. L. Detterman, 1947.

Unfigured paratypes (USNM P4286) from a marine zone in the Chandler formation (field sample 47A Tr 241), north flank of Awuna anticline, lat. 69°12′18″ N., long. 155°47′ W., northern Alaska. Collected by M. L. Troyer, 1947.

Unfigured paratype (USNM P4287) from well cuttings at 250–260 feet in the Grandstand formation, in
Simpson core test 8, lat. $70°56'43''$ N., long. $155°17'16''$ W., northern Alaska.

Figured paratype (USNM P4288) and unfigured paratype (USNM P4289) from a core at 529–532 feet in the Grandstand formation, in Umiat test well 3, lat. $69°23'16''$ N., long. $152°05'14''$ W., north of Umiat, northern Alaska.

**Family Textulariidae d’Orbigny, 1846**

**Genus Spiroplectammina Cushman, 1927**

**Spiroplectammina koveri Tappan, new species**

**Plate 66, Figures 1, 2**

Test free, tiny, elongate, early chambers in a planispiral coil, later chambers biserially arranged, increasing gradually in breadth as added, but increasing more rapidly in relative height, from five to six pairs of biserial chambers; sutures distinct, depressed, slightly oblique; wall finely agglutinated, rather smoothly finished; aperture a low arch at the base of the final chamber.

Length of holotype $0.49$ mm., greatest breadth $0.18$ mm., greatest thickness $0.06$ mm. Paratype specimens range from $0.34$ to $0.57$ mm. in length.

**Remarks:** This species differs from *Spiroplectammina longa* Laceller in being smaller and less tapering, and in the more gradual increase in chamber size with development. It occurs in the Topagoruk formation.

It is named in honor of A. N. Kover, geologist, U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4290) and unfigured paratypes (USNM P4291) from a core in the Topagoruk formation at 459–469 feet, in South Barrow test well 2, at lat. $71°15'15''$ N., long. $156°37'55''$ W., south-southwest of Point Barrow, northern Alaska.

Figured paratype (USNM P4292) and unfigured paratypes (USNM P4293) from a core at 1,342–1,352 feet in the Topagoruk formation, in Arcon Point Barrow core test 1, at lat. $71°20'3''$ N., long. $156°40'9''$ W., southwest of Point Barrow, northern Alaska.

Unfigured paratypes (USNM P4294) from a core at 1,030–1,040 feet in the Topagoruk formation, in Simpson test well 1, at lat. $70°57'05''$ N., long. $155°21'45''$ W., west of Cape Simpson, northern Alaska.

Unfigured paratype (USNM P4295) from seismograph party 47, line 27–48, shot hole 8, at 190–200 feet, lat. $71°15'58''$ N., long. $156°37'27''$ W., northern Alaska.

**Spiroplectammina webberi Tappan, new species**

**Plate 66, Figures 3–5**

Test free, small, elongate, base rounded with early portion planispiral, later biserial with sides gradually flaring; chambers increasing gradually in size, about three or four pair of biserial chambers, of nearly equal height and breadth; sutures slightly depressed, nearly horizontal in the biserial portion; wall agglutinated, of fine to medium grains, roughly finished; aperture at the base of the inner margin of the chamber.

Length of holotype $0.44$ mm., breadth $0.21$ mm., thickness $0.08$ mm. Paratypes range from $0.26$ to $0.88$ mm. in length.

**Remarks:** This species differs from *S. mordenensis* Wickenden in being larger and more compressed, in having a relatively smaller coil, higher biserial chambers, and a more flaring test. It occurs throughout the Colville group, from the Seabee formation to the Sentinel Hill member of the Schrader Bluff formation.

The species is named in honor of E. J. Webber, geologist, formerly with the U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4348) and unfigured paratypes (USNM P4349) from the Seabee formation (field sample 47A Wb 150) and unfigured paratypes (USNM P4350) from the Seabee formation (field sample 47A Wb 153) both samples from an outcrop on the Nanushuk River, south-southeast of Umiat, at approximately lat. $69°03'9''$ N., long. $150°56'9''$ W., in northern Alaska. Collected by E. J. Webber, 1947.

Unfigured paratypes (USNM P4351) from 31 to 42 feet above the base of the Sentinel Hill member of the Schrader Bluff formation (field sample 47A St 25), on the north bank of the Colville River, about 7½ miles southwest of the confluence with the Chandler River, at approximately lat. $69°25'9''$ N., long. $151°45'9''$ W., northern Alaska. Collected by Karl Stefansson, 1947.

Figured paratypes (USNM P4352 a, b) and unfigured paratypes (USNM P4353) from a core at 1,110–1,120 feet in the Sentinel Hill member of the Schrader Bluff formation, in Sentinel Hill core test 1, at lat. $69°37'30''$ N., long. $151°27'9''$ W., on the west bank of the Colville River, northern Alaska.

Unfigured paratypes (USNM P4354) from a core at 490–499 feet in the Seabee formation, in Umiat test well 1, west of Umiat, at lat. $69°24'9''$ N., long. $154°20'9''$ W., in the northern foothills of the Brooks Range, northern Alaska.

**Genus Textularia Delfance, 1824**

**Textularia topagorukensis Tappan, new species**

**Plate 66, Figures 8, 9**

Test free, tiny, tapering, biserial throughout; chambers numerous, somewhat inflated, increasing gradually in size; wall finely agglutinated, commonly crushed and distorted in preservation; aperture at the base of the final chamber.

Length of holotype $0.46$ mm., breadth $0.17$ mm., thickness $0.07$ mm. Paratypes range from $0.23$ to $0.60$ mm. in length.

**Remarks:** *Textularia topagorukensis*, new species, differs from *T. rollaensis* Stelck and Wall in the lower and more numerous chambers, more horizontal sutures, and more nearly parallel sides. It is found in the Grandstand and Topagoruk formations.

**Types and occurrence:** Holotype (USNM P4296) and unfigured paratypes (USNM P4297) from a core...
at 459–469 feet and figured paratype (USNM P4302) from well cuttings at 1720–1730 feet, in the Topagoruk formation, in South Barrow test well 2, at lat. 71°15′15″ N., long. 156°37′55″ W., south-southwest of Point Barrow, northern Alaska.

Unfigured paratypes (USNM P4298) from a core at 2,235–2,245 feet, unfigured paratypes (USNM P4299) from a core at 2,930–2,949 feet, all in the Topagoruk formation, in Simpson test well 1, at lat. 70°57′05″ N., long. 155°21′45″ W., west of Cape Simpson, northern Alaska.

Unfigured paratypes (USNM P4300) from a core at 1,600–1,610 feet in the Topagoruk formation, in South Barrow test well 1, at lat. 71°19′12″ N., long. 156°42′15″ W., northern Alaska.

Unfigured paratypes (USNM P4303) from a core at 256–264 feet in the Grandstand formation, in Skull Cliff core test 1, at lat. 70°55′ N., long. 157°38′ W., midway between Point Barrow and Point Franklin, northern Alaska.

Genus Siphotextularia Finlay, 1939

Siphotextularia? rayi Tappan, new species

Plate 66, Figures 6, 7

Test free, biserial, somewhat flaring; chambers inflated, relatively high, and increasing rapidly in size; sutures distinct, depressed, horizontal; wall finely agglutinated, smoothly finished, white; aperture a slit in the terminal face of the final chamber, not extending to the base of the chamber.

Length of holotype 0.55 mm., breadth 0.31 mm., thickness 0.08 mm. Paratypes range from 0.44 to 0.60 mm. in length.

Remarks: Siphotextularia? rayi, new species, differs from S. washtenensis Loeblich and Tappan in being larger, with higher and more inflated chambers and more nearly horizontal sutures. It is not a typical Siphotextularia in that it is not quadrangular in section, but seems closest to that genus in the terminal apertural character, although the aperture is not produced on a neck. It occurs in the Grandstand and Topagoruk formations.


Types and occurrence: Holotype (USNM P4304) and unfigured paratypes (USNM P4305) from a core at 660–670 feet in the Topagoruk formation, in South Barrow test well 2, at lat. 71°15′15″ N., long. 156°37′55″ W., south-southwest of Point Barrow, northern Alaska.

Figured paratype (USNM P4306) from well cuttings at 857–867 feet and unfigured paratypes (USNM P4307) from well cuttings at 1,086–1,091 feet, all in the Topagoruk formation, in Arcon Point Barrow core test 1, at lat. 71°19′30″ N., long. 156°40′ W., north-northeast of Barrow Village, northern Alaska.

Unfigured paratypes (USNM P4308) from a core at 2,235–2,345 feet in the Topagoruk formation, in Simpson test well 1, at lat. 70°57′05″ N., long. 155°21′45″ W., west of Cape Simpson, northern Alaska.

Unfigured paratype (USNM P4309) from seismograph party 47, line 14 A–48, shot hole 35, at 110–120 feet in the Grandstand formation, at lat. 71°18′08″ N., long. 156°42′45″ W., northern Alaska.

Family Verneulinidae Cushman, 1911

Genus Verneulinoides Loeblich and Tappan, 1949

Verneulinoides borealis Tappan, new species

Plate 66, Figures 10–18

Test free, elongate, triserial, axis commonly slightly twisted, rounded in section, broadly flaring, rarely more elongate and less flaring in the later portion; chambers increasing rapidly in size, normally inflated, but in many specimens the tests are crushed in preservation; sutures distinct, depressed; wall commonly finely agglutinated, or may be relatively coarse grained, probably reflecting the character of the local depositional environment; aperture a low arch at the base of the final chamber.

Length of holotype 0.49 mm., breadth 0.18 mm. Paratypes range in length from 0.26 to 1.17 mm.

Remarks: This species is extremely variable in size, degree of flaring, coarseness of texture, and type of preservation. Commonly the specimens are crushed and distorted, but more rarely specimens are filled with pyrite, which preserves the original form and inflation of the chambers. It is one of the most abundant species in the northern Alaska strata. It differs from Veneulinoides perplexa var. gleddiei Steleck and Wall in being considerably larger and more flaring.

V. borealis occurs in the Grandstand and Topagoruk formations, in equivalent marine zones in the Chandler formation, and in the upper part of the surface Torok formation.

Types and occurrence: Holotype (USNM 106131), figured paratype (USNM 106132), and unfigured paratypes (USNM 106133) from a core at 1,810–1,816 feet, unfigured paratypes (USNM P4310) from a core at 1,635–1,645 feet, unfigured paratypes (USNM P4311) from a core at 1,693–1,703 feet, unfigured paratypes (USNM P4312) from a core at 2,365–2,370 feet, all in the Grandstand formation; and unfigured paratypes (USNM P4313) from well cuttings at 3,890–3,900 feet and unfigured paratypes (USNM P4314) from well cuttings at 4,860–4,870 feet in the Topagoruk formation; all in Umiat test well 1, at lat. 69°23′52″ N., long. 152°19′45″ W., west of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4315) from a core at 469 feet and unfigured paratypes (USNM 106135) from a core at 785–788 feet in the Grandstand formation, in Umiat test well 2, at lat. 69°23′04″ N., long. 152°05′01″ W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM 106134) from a core at 361–366 feet in the Grandstand formation, in Umiat test well 3, at lat. 69°23′16″ N., long. 152°05′14″ W.,
north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4316) from field sample 48A Dt 328, in a marine zone interfingered with the Chandler formation, Chandler River, Big Bend anticline, lat. 69°09'30" N., long. 151°45' W., northern Alaska. Collected by R. L. Detterman, 1948.

Figured paratype (USNM P4317) and unfigured paratypes (USNM P4318) from a core at 461–466 feet in the Grandstand formation, in Skull Cliff core test 1, at lat. 70°55' N., long. 157°38'00" W., between Point Barrow and Point Franklin, northern Alaska.

Figured paratype (USNM P4319) and unfigured paratypes (USNM P4320) from a core at 308–318 feet, and unfigured paratypes (USNM P4321) from a core at 533–543 feet, all in the Grandstand formation; and unfigured paratypes (USNM P4322) from a core at 2,275–2,285 feet in the Topagoruk formation; all from Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Unfigured paratype (USNM P4323) from a core at 231.5 to 233 feet in the Grandstand formation, in Simpson core test 3, at lat. 70°55'27" N., long. 155°16'55" W., northern Alaska.

Unfigured paratypes (USNM P4324) from a core at 342–352 feet in the Grandstand formation, in Simpson core test 8, at lat. 70°56'43" N., long. 155°17'16" W., northern Alaska.

Unfigured paratypes (USNM P4325) from well cuttings at 150–160 feet, figured paratype (USNM P4326) and unfigured paratypes (USNM P4327) from well cuttings at 170–180 feet, and unfigured paratypes (USNM P4328) from well cuttings at 180–190 feet, all from the Grandstand formation, in Umalik core test 2, at lat. 69°50'18" N., long. 155°59'24" W., northern Alaska.

Figured paratypes (USNM P4329a–d) and unfigured paratypes (USNM P4330) from the Grandstand formation (field sample 46A Th 165), on the Colville River, lat. 69°06' N., long. 154°24' W., northern Alaska. Collected by R. F. Thurrell, 1946.

Unfigured paratypes (USNM P4331) from the Grandstand formation (field sample 47A Dt 240), about 3½ miles airline upstream from the mouth of Fossil Creek, a north-flowing tributary to the Colville River, at approximately lat. 69°19'05" N., long. 152°28" W., in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1947.

Unfigured paratypes (USNM P4332) from field sample 48A Dt 2, upper part of the Torok formation (equivalent to the Topagoruk formation in the subsurface) at Tuktu Bluff on the Chandler River, lat. 68°43' N., long. 152°15' W., northern Alaska. Collected by R. L. Detterman, 1948.

Unfigured paratypes (USNM P4333) from the lower part of a 50-foot section on the west fork of Birthday Creek (field sample 47A Tr 167), 80 feet below the top of the Topagoruk formation, lat. 69°12'30" N., long. 156°47" W., northern Alaska. Collected by M. L. Troyer, 1947.


Unfigured paratypes (USNM P4335) from an outcrop 3,850 feet below the top of the Grandstand formation (field sample 47A Z 615 A), in a section on the north limb of the Kurupa anticline, from lat. 68°55' N., long. 155°05' W., to lat. 69° N., long. 155° W., along the Kurupa River, in the northern foothills of the Brooks Range, northern Alaska. Collected by J. H. Zumberge, 1947.


Unfigured paratypes (USNM P4337) from well cuttings at 450–460 feet in the Topagoruk formation, in South Barrow test well 2, at lat. 71°15'15" N., long. 156°37'55" W., south-southwest of Point Barrow, northern Alaska.

Verneulinoides fischeri Tappan, new species

PLATE 66, FIGURES 23–28

Test large, free, flaring at the base, but comparatively narrow and elongate, sides nearly parallel in the later portion; chambers numerous, inflated, triseriarily arranged, increasing in proportional height as added; sutures distinct, depressed; wall finely agglutinated, surface smoothly finished; aperture loop shaped, at the base of the inner face of the final chamber.

Length of holotype 1.30 mm., breadth 0.39 mm. Paratypes range from 0.36 to 1.77 mm. in length.

REMARKS: This species occurs in the Seabee and Schrader Bluff formations of Turonian to Campanian age, and their equivalent zones in the Ignek formation. VerneuUinoides fischeri, new species, differs from VerneuUinoides parallela Cushman from the Craie Blanche of France, in being longer, narrower and more tapering, in having relatively higher chambers, and in lacking the triangular section of true VerneuUina. V. bearpaawensis (Wickenden) has more inflated and higher chambers and a more twisted test.

The species is named in honor of W. A. Fischer, geologist, U. S. Geological Survey, who collected some of the material containing this species.

TYPES AND OCCURRENCE: Holotype (USNM P4356), figured paratypes (USNM P4357a,b), and unfigured paratypes (USNM P4358) from the Upper Cretaceous part of the Ignek formation (field sample 46A L 66), at the base of the section exposed at the forks of the Ivishak and Sagavanirktok Rivers, at approximately lat. 69°30' N., long. 148°30' W., northeastern Alaska. Collected by E. H. Latham, 1946.

Figured paratype (USNM P4359) from a core at 571–574 feet, unfigured paratype (USNM P4360) from a core at 500–510 feet, unfigured paratypes (USNM 4361) from a core at 589–602 feet, unfigured paratypes...
(USNM P4362) from a core at 602–604 feet, and unfigured paratypes (USNM P4363) from a core at 829–839 feet, all from the Sentinel Hill member of the Schrader Bluff formation, in Sentinel Hill core test 1, at lat. 69°35′48″ N., long. 151°28′09″ W., on the banks of the Colville River, northwest of Umiat, northern Alaska.

Unfigured paratypes (USNM P4364) from a core at 1,351 feet in a marine zone of the Prince Creek formation, in Gubik test well 2, at lat. 69°25′10″ N., long. 151°27′26″ W., near the confluence of the Chandler and Colville Rivers, northern Alaska.

Figured paratype (USNM P4340) and unfigured paratypes (USNM P4341) from field sample 46A Fi 80A, in the Seabee formation (Turonian), taken one mile east of Wolf Creek test well 2, in the area of the Wolf Creek anticline, at lat. 69°24′32″ N., long. 153°31′25″ W., northern Alaska. Collected by W. A. Fischer, 1946.

Figured paratype (USNM P4342) and unfigured paratypes (USNM P4343) from field sample 46A Gr 98, lower part of the Ignek formation, on the Ivishak River, at lat. 69°20′04″ N., long. 148°10′50″ W., northern Alaska. Collected by George Gryc, 1946.

Unfigured paratypes (USNM P4346) from field sample 47A St 25, from 2,570 feet below the top of the Sentinel Hill member of the Schrader Bluff formation, on the north bank of the Colville River, about 8 miles east-northeast of Umiat, at lat. 69°25′ N., long. 151°48′ W., about 7½ miles southwest of the junction of the Chandler and Colville Rivers, in the northern foothills of the Brooks Range, northern Alaska. Collected by Karl Stefansson, 1947.

Verneulinoides tailleuri Tappan, new species

**Plate 66, Figures 19–22**

Test free, relatively narrow, elongate, sides nearly parallel; chambers numerous, low, triseriably arranged, somewhat inflated; sutures distinct, depressed, horizontal; wall finely agglutinated; aperture a low arch at the base of the final chamber.

Length of holotype 0.58 mm., breadth 0.18 mm. Paratypes range from 0.34 to 0.55 mm. in length.

Remarks: *Verneulinoides tailleuri*, new species, differs from *V. boracita*, new species, in being smaller and narrower, with nearly parallel sides, and in having lower, more numerous, and more closely appressed chambers and nearly horizontal sutures. It differs from *Triazia spirifenis prolongata* Steck and Wall in lacking the terminal aperture and in having lower and more closely appressed chambers.

*V. tailleuri* is restricted to the Fortress Mountain formation. The specific name is in honor of I. L. Tailleur, geologist, U. S. Geological Survey, who collected some of the outcrop material containing this species.

Types and occurrence: Holotype (USNM P4367), figured paratype (USNM P4368), and unfigured paratypes (USNM P4369) from 5,500 to 6,000 feet above the base of the Fortress Mountain formation (field sample 49A Tr 565), on Castle Creek, southwest of Castle Mountain, at lat. 68°32′05″ N., long. 152°49′ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by I. L. Tailleur, 1949.

Unfigured paratype (USNM P4370) from the Fortress Mountain formation (field sample 49A Pa 84), along Fortress Creek, tributary to the Ayiyak River, northwest of Fortress Mountain, at lat. 68°35′20″ N., long. 153°11′30″ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

Figured paratype (USNM P4365) and unfigured paratypes (USNM P4366) from the Fortress Mountain formation (field sample 49A Tr 662), from a cut bank on the east side of a small tributary that enters Kirukttagiak River from the south, about 1,000 feet upstream from their confluence, at lat. 68°37′ N., long. 152°42′ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by I. L. Tailleur, 1949.

Unfigured paratype (USNM P4371) from the Fortress Mountain formation (field sample 49A Pa 436), on Castle Creek, 2.9 miles airline south-southwest of Castle Mountain, at lat. 68°32′30″ N., long. 152°51′30″ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

Unfigured paratype (USNM P4372) from the Fortress Mountain formation (field sample 49A Pa 571), on Castle Creek, about 2½ miles southwest of Castle Mountain, at lat. 68°32′45″ N., long. 152°51′30″ W., in southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

Figured paratype (USNM P4373) and unfigured paratypes (USNM P4374) from field sample 49A Pa 594, in a section from 1,150 to 1,750 feet above the base of the Fortress Mountain formation, on the Kirukttagiak River, west of Castle Mountain, at lat. 68°35′ N., long. 152°54′ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

Family Valvulinidae Cushman, 1927

Genus Arenobulimina Cushman, 1927

*Arenobulimina paynei* Tappan, new species

**Plate 67, Figures 1–4**

Test free, flaring, early portion triserial, later with four chambers to a whorl; chambers much inflated, although some specimens have been crushed in preservation, increasing rapidly in size; sutures distinct and much constricted; wall finely agglutinated, but some of the paratypes are represented only by pyritic casts, a common method of preservation in these strata; aperture a low arch at the inner margin of the final chamber.

Length of holotype 0.36 mm., breadth 0.21 mm. Paratypes range in length from 0.18 to 0.55 mm.

Remarks: This species differs from *Arenobulimina chapmani* Cushman from the Gault of England in being more flaring, about one-third as large, and with more
inflated and fewer chambers to each whorl. It occurs in the Grandstand and Topagoruk formations.

This species is named in honor of T. G. Payne, geologist formerly with the U. S. Geological Survey, in recognition of his work on the stratigraphy of the Cretaceous strata of Alaska.

**Types and occurrence:** Holotype (USNM P 4375) from well cuttings at 4,140-4,150 feet, unfigured paratype (USNM P4376) from well cuttings at 4,150-4,160 feet, unfigured paratypes (USNM P4377) from well cuttings at 3,160-3,170 feet, unfigured paratypes (USNM P4378) from well cuttings at 4,460-4,470 feet, all in the Topagoruk formation, in Umiat test well 1, west of Umiat, at lat. 69°23'52'' N., long. 152°19'45'' W., in the northern foothills of the Brooks Range, northern Alaska.

Figured paratype (USNM P4379) and unfigured paratypes (USNM P4380) from a core at 602-609 feet in the Grandstand formation; unfigured paratypes (USNM P4381) from well cuttings at 1,560-1,570 feet, unfigured paratype (USNM P4382) from well cuttings at 2,850-2,860 feet, unfigured paratype (USNM P4383) from well cuttings at 2,900-2,910 feet, figured paratypes (USNM P4384a,b) from well cuttings at 2,950-2,990 feet, and unfigured paratype (USNM P4385) from well cuttings at 4,580-4,590 feet, all in the Topagoruk formation; all in Umiat test well 2, at lat. 69°23'04'' N., long. 152°05'01'' W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

*Arenobulimina torula* Tappan, new species

**Plate 67, Figures 5-7**

Test free, elongate, flaring from the pointed base, rounded in section; chambers numerous, low and triserial in the early portion, later becoming higher and narrower with four chambers to a whorl, the chambers lying somewhat obliquely; sutures distinct, flush, oblique, somewhat darker in color than the remainder of the test; wall finely arenaceous, surface smoothly finished, specimens commonly crushed in various ways in preservation; aperture an arch at the base of the inner face of the final chamber.

Length of holotype 0.62 mm., breadth 0.36 mm. Paratypes range from 0.16 to 0.68 mm. in length.

**Remarks:** *Arenobulimina torula*, new species, differs from *A. chapmani* Cushman in being slightly larger, and in having broader, lower, and more inflated chambers, and in being more finely arenaceous with a more smoothly finished surface.

This species occurs in the Aiyik member of the Seabee formation and in the Ignek formation.

**Types and occurrence:** Holotype (USNM P4393) from the Ignek formation, on the Shaviovik anticline, seismograph party 144, line 4-53, shot hole 6, at 50-100 feet, at lat. 69°34'26'' N., long. 147°43'03'' W., at the eastern end of the northern foothills of the Brooks Range, northern Alaska.

Figured paratype (USNM P4394) from a depth of 50-100 feet and unfigured paratypes (USNM P4395) from a depth of 100-150 feet, all in the Ignek formation, seismograph party 144, line 8-53, shot hole 4, along the Shaviovik anticline, at lat. 69°34'26'' N., long. 147°43'03'' W., at the eastern end of the northern foothills of the Brooks Range, northern Alaska.

Figured paratypes (USNM P4396a,b) and unfigured paratypes (USNM P4397) from the Ignek formation (field sample 46A L 66), at the base of the section exposed at the confluence of the Ivishak and Sagavanirktok Rivers, at approximately lat. 69°30' N., long. 148°30' W., in northern Alaska. Collected by E. H. Latham, 1946.

Unfigured paratypes (USNM P4398) from the Aiyik member of the Seabee formation (field sample 47A Wb 35), on the Nanushuk River, at lat. 68°45' N., long. 150°43' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by E. J. Webber, 1947.

Unfigured paratypes (USNM P4399) from the Aiyik member of the Seabee formation, in Umiat seismograph shot point 13, at a depth of 25 feet, at lat. 69°24'29.4'' N., long. 152°05'19.8'' W., near Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4400) from the Seabee formation, at 561-571 feet, in Umiat test well 11, lat. 69°24'29'' N., long. 152°05'58'' W., north of Umiat, northern Alaska.

**Genus Dorothisia Plummer, 1931**

*Dorothisia chandlerensis* Tappan, new species

**Plate 66, Figures 29, 30**

Test free, narrow, elongate, sides nearly parallel; early chambers in a whorl at the base forming a somewhat inflated knob, followed by seven or eight pairs of biserially arranged, somewhat compressed chambers all of nearly equal size, relatively low and broad; sutures obscure in the early portion, distinct and depressed in the biserial portion; wall finely arenaceous, roughly finished; aperture a low arch at the base of the final chamber.

Length of holotype 0.62 mm., breadth 0.18 mm. Paratypes range from 0.39 to 0.99 mm. in length.

**Remarks:** *Dorothisia chandlerensis*, new species, differs from *D. filiformis* (Berthelin) in the more bulbous early portion, the broader parallel-sided biserial portion, and more roughly finished wall.

It occurs in the Torok and Umalik formations.

**Types and occurrence:** Holotype (USNM P4401) and unfigured paratypes (USNM P4402) from field sample 48A Dt 120, in the Torok formation, 4300 feet below the top of the section exposed in Tuktu Bluff, and unfigured paratypes (USNM P4403) from field sample 48A Dt 121, taken 80 feet lower, in the Tuktu Bluff on the Chandler River, at lat. 68°41' N., long. 152°15' W., in the southern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1948.

Figured paratype (USNM P4404) from well cuttings at 5,150-5,160 feet in the Umalik formation, in
Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.


Unfigured paratype (USNM P4406) from field sample 49A Tr 756, in the Torok formation, on Okok Creek, tributary to the Ophikruak River, at lat. 68°42'30" N., long. 153°35' W., in the Castle Mountain area in the southern foothills of the Brooks Range, northern Alaska. Collected by I. L. Tailleur, 1949.

Family Rzehakinidae Cushman, 1933

The genera here included were in part previously placed in the subfamily Rzehakininae, family Silicinidae. However, the type genus of the family, Silicina Bornemann 1874, is unrecognized as based on its type species, Involutina polymorpha Terquem, 1863. Of the three types specimens of Terquem in the Museum National d'Histoire Naturelle, Paris, examined by Alfred R. Loeblich, Jr., and the writer, one is a fragment of a Reophax and the other two are indeterminate fragments. Hence the species and the genus for which it serves as type species are unrecognized and are here suppressed. Of the three genera placed by Cushman in the subfamily Silicininae Cushman (1933, p. 143) (not Involutininae as proposed by Thalmann, 1935, p. 715) Silicina is thus unrecognized; Involutina Terquem, 1862, was shown (Loeblich and Tappan, 1954, p. 308) to be an agglutinated form (including species previously referred to Ammodiscus); and Problematica Bornemann is calcareous, not related to these siliceous genera.

Because Silicina is invalid, the family name has no validity, as families (and subfamilies) must be based on a valid genus included in them. For this reason the subfamily Silicininae of Earland (1933, p. 91) also was invalid, as he originally considered it a subfamily of the Lituolidae, including only Rzehakina, Silicosigmoilina and Miliammina, and not including Silicina, which must be included if the subfamily name be based on its name. Thalmann (1935, p. 715) was therefore in error in proposing the subfamily Involutininae for the subfamily Silicininae Cushman, 1933 (not Earland, 1933). Cushman included the genus Silicina Bornemann in his subfamily and therefore his usage was valid, whereas Earland did not include that genus and his usage was not valid.

The name Involutininae Thalmann, 1935 (not Cushman, 1940, as was erroneously cited by Loeblich and Tappan, 1954, p. 308), with the type genus Involutina Terquem, 1862, must therefore be removed to the family Tolypomaminidae (see Loeblich and Tappan, 1954, p. 308).

Sigal (1952, p. 159) restricted the Involutininae to include only Silicina, Problematica, and Involutina, and placed the family under the suborder Biloculinida. He then (1952, p. 208) named an “appendice-famille” Paramiliolidae to include the chambered genera, i. e., Rzehakina, Silicosigmoilina, Miliammina, and Spirolocammina, and placed this “family” in the suborder Pluriloculinidae, superfamily Miliolidae. However, the family “Paramiliolidae” is also invalid, as there is no genus “Paramiliola” upon which it can be based.

Therefore as the Involutininae is based on a genus belonging elsewhere, as the Silicinidae is based on a genus which is unrecognized, and as the “Paramiliolidae” is not based on any genus, the next family or subfamily name available (these are considered of equal rank for purposes of priority, according to the Rules of Nomenclature) would be the Rzehakininae Cushman, 1933, which is here elevated to family rank.

This family now includes Rzehakina Cushman, 1927, Silicosigmoilina Cushman and Church, 1929, Miliammina Heron-Allen and Earland, 1930, Spirolocammina Earland, 1934, Bramlettietia Israelsky, 1951, Trilocularena Loeblich and Tappan, 1955, and the new genus Psamminopella, here described.

The Rzehakininae includes siliceous or arenaceous genera, insoluble in acid, which are in large part isomorphs of the calcareous imperforate Miliolidae.

Genus Miliammina Heron-Allen and Earland, 1930

Miliammina awunensis Tappan, new species

PLATE 67, FIGURES 19-21

Test free, elongate, flattened, ovate in outline, quinqueculine in plan; chambers narrow, elongate, each a half coil in length, of equal diameter throughout length; sutures distinct, depressed; wall finely agglutinated, surface smoothly finished; aperture a simple opening at the end of the tubular chamber.

Length of holotype 0.44 mm., breadth 0.26 mm. Paratypes range from 0.23 to 0.65 mm. in length.

Remarks: Specimens of this species are commonly distorted in preservation and may be crushed at varying angles, so that the test may assume variable outlines.

Miliammina awunensis, new species, differs from M. valdensis Wickenden in having narrower chambers, of even diameter throughout, and in being more finely agglutinated and smoothly finished. It differs from M. valdensis Bartenstein and Brand in being somewhat larger with thicker chambers.

It occurs in the Grands tand and Topagoruk formations and in marine zones of the equivalent Chandler formation.

Types and occurrence: Holotype (USNM P4407) from residual soil of brackish or marine tongues in the Chandler formation, on the south flank of the Awuna syncline (field sample 47A Wh 623), at lat. 69°03'18" N., long. 156°02'30" W., in the northern foothills of the Brooks Range, northern Alaska. Collected by C. L. Whittington, 1947.
Unfigured paratypes (USNM P4408) from field sample 47A Wh 688, in residual soil of the Grandstand formation, on the south flank of the Awuna anticline, at lat. 69°02'48" N., long. 155°59'30" W., in the northern foothills of the Brooks Range, northern Alaska. Collected by C. L. Whittington, 1947.

Figured paratype (USNM P4409) and unfigured paratypes (USNM P4410) from field sample 47A Wh 655, in residual soil of marine or brackish tongues in the Chandler formation, on the south flank of the Awuna anticline, at lat. 69°06'48" N., long. 155°58' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by C. L. Whittington, 1947.

Unfigured paratypes (USNM P4411) from field sample 47A Wh 655, in residual soil of marine or brackish tongues in the Chandler formation, on the north flank of the Awuna anticline, at lat. 69°09'30" N., long. 155°59' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by C. L. Whittington, 1947.

Unfigured paratypes (USNM P4412) from field sample 47A Tm 13, bed 12, 60 feet below the top of exposed 100-foot section of the Cretaceous, probably equivalent to the lower part of the Nanushuk group of the eastern areas, on the south limb of a syncline, on the west bank of the Utukok River, at approximately lat. 69°13' N., long. 160°38' W., about 70 miles east-northeast of Cape Beaufort, in the northern foothills of the Brooks Range, northern Alaska. Collected by R. M. Thompson, 1947.

Unfigured paratypes (USNM P4413) from field sample 47A Z 604, in the Grandstand formation, on the north limb of the Kurupa anticline, in a section from lat. 68°55' N., long. 155°05' W., to lat. 69°00' N., long. 155° W., along the Kurupa River, west-southwest of Umiat, in the northern foothills of the Brooks Range, northern Alaska. Collected by J. H. Zumberge, 1947.

Unfigured paratype (USNM P4414) from a core at 432-439 feet in the Grandstand formation, in Umiat test well 3, at lat. 69°23'16" N., long. 152°05'14" W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Figured paratype (USNM P4415) and unfigured paratypes (USNM P4416) from a core at 256-264 feet, in the Grandstand formation in Skull Cliff core test 1, at lat. 70°55' N., long. 157°38' W., between Point Barrow and Point Franklin, northern Alaska.

Unfigured paratypes (USNM P4417) from a core at 443-444 feet in the Grandstand formation, in Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Unfigured paratypes (USNM P4418) from a core at 459-469 feet in the Topagoruk formation, in South Barrow test well 2, at lat. 71°16'15" N., long. 156°37'55" W., south-southwest of Point Barrow, northern Alaska.

**Miliammina ischnia Tappan, new species**

*Plate 67, Figures 25, 26*

Test free, small, narrow, elongate, sides subparallel, quinqueloculine in section; chambers narrow, elongate, a half coil in length; sutures distinct, depressed; wall finely agglutinated, surface smoothly finished; aperture at the open end of the final chamber.

Length of holotype 0.36 mm., breadth 0.10 mm.

**Remarks:** *Miliammina ischnia,* new species, differs from *M. manitobensis* Wickenden in being smaller and comparatively narrower and more elongate. It differs from *Miliammina awumensis,* new species, in being narrower with nearly parallel sides, rather than ovate in outline. *Miliolina gramen* Friedberg is similar in general appearance, but is two to three times at large.

This species is found in the Grandstand formation.

**Types and occurrence:** Holotype USNM P4419) and unfigured paratypes (USNM P4420) from a core at 1,910-1,920 feet and figured paratype (USNM P4421) and unfigured paratypes (USNM P4422) from a core at 1,693-1,703 feet, both in the Grandstand formation, in Umiat test well 1, at lat. 69°23'52" N., long. 16°19'45" W., west of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4423) from a core at 432-439 feet in the Grandstand formation, in Umiat test well 3, at lat. 69°23'16" N., long. 152°05'14" W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

**Genus Psamminopelta Tappan, new genus**

**Type species:** *Psamminopelta bowsheri* Tappan, new species. (Derivation: psammonis, Gr., of sand + pelta, Gr., f., small, light shield; gender, feminine.)

Test free, flattened, consisting of proloculus and tubular, planispirally coiled chambers, each a half coil in length, and only very slightly overlapping earlier whorls; wall agglutinated with siliceous cement, insoluble in hydrochloric acid; aperture at the open end of the tubular chamber, without a tooth.

**Remarks:** *Psamminopelta,* new genus, differs from *Rzezakina* Cushman in having chambers exactly half a coil in length, so that the test is symmetrical about the vertical axis rather than having a sigmoid vertical axis. It differs from *Spirolocammina* Earland in having a perfectly planispiral development, and lacking the slightly sigmoid plan of chamber arrangement, as seen in horizontal section.

*Miliammina* Heron-Allen and Earland has a quinqueloculine rather than planispiral development, and *Trilocularena* Loeblich and Tappan is triloculine in section.

**Psamminopelta bowsheri** Tappan, new species

*Plate 67, Figures 11-18, 22-24*

Test free, ovate in outline, flattened, consisting of long, narrow and tubular planispirally arranged chambers, each a half coil in length, and only very slightly overlapping earlier coils; sutures depressed; wall finely agglutinated, smoothly finished, with siliceous cement, insoluble in acid, commonly crushed and flattened in preservation; aperture at the open ends of the tubular chamber, commonly appearing elongate because of compression of the test, without a tooth.
Length of holotype 0.83 mm., breadth 0.57 mm., thickness 0.05 mm. Paratypes range from 0.29 to 0.91 mm. in length.

Remarks: *Psammominopetta bowsheri*, new species, differs from *Massilina texensis* Cushman in the narrower chambers, planispiral coiling, relatively broader test, and the agglutinated wall, which is insoluble in acid.

The species occurs in the Grandstand, Topagoruk, Tuktu, and upper part of the Torok formations and in marine zones of the equivalent Chandler formation. It is named in honor of A. L. Bowsher, geologist, U. S. Geological Survey.

Types and occurrence: Holotype (USNM P4424) from a core at 256–264 feet in the Grandstand formation, in Skull Cliff core test 1, at lat. 70°35’ N., long. 157°38’ W., between Point Barrow and Point Franklin, northern Alaska.

Unfigured paratypes (USNM P4425) from a core at 438–443 feet, in the Grandstand formation, figured paratype (USNM P4426) from a core at 1,020–1,030 feet and unfigured paratypes (USNM P4427) from a core at 1,247–1,267 feet in the Topagoruk formation, all in Simpson test well 1, at lat. 70°57’05” N., long. 155°21’45” W., west of Cape Simpson, northern Alaska.

Unfigured paratype (USNM P4428) from well cuttings at 470–480 feet in the Grandstand formation, in Simpson core test 10, at lat. 70°57’34” N., long. 155°17’27” W., near Cape Simpson, northern Alaska.

Unfigured paratypes (USNM P4468) from a core at 1,424–1,434 feet, figured paratype (USNM P4429) from a core at 1,615–1,620 feet, and figured paratypes (USNM P4430a–d) and unfigured paratypes (USNM P4431) from a core at 1,810–1,816 feet, all from the Grandstand formation; and unfigured paratypes (USNM P4432) from well cuttings at 3,970–3,980 feet and unfigured paratype (USNM P4433) from well cuttings at 4,790–4,800 feet in the Topagoruk formation; all in Umiat test well 1, at lat. 69°23’52” N., long. 152°19’45” W., west of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

FIGURED PARATYPE (USNM P4434) from residual soil of the Grandstand formation (field sample 47A Wh 688), at lat. 69°02’48” N., long. 155°59’30” W.; unfigured paratypes (USNM P4435) from residual soil of marine zone in the Chandler formation (field sample 47A Wh 648), at lat. 69°06’12” N., long. 155°57’ W.; figured paratype (USNM P4436) and unfigured paratype (USNM P4437) from field sample 47A Wh 654, a residual soil sample of marine tongues taken 610–650 feet above the base of the Chandler formation, at lat. 69°06’48” N., long. 155°58’ W.; and unfigured paratype (USNM P4438) from residual soil of marine zone in the Chandler formation (field sample 47A Wh 671), at lat. 69°07’18” N., long. 155°58’18” W.; all from the south flank of the Awuna anticline, in the northern foothills of the Brooks Range, northern Alaska. Collected by C. L. Whittington, 1947.

Unfigured paratypes (USNM P4439) from marine zone in the Chandler formation (field sample 48A Dt 249), from the Chandler River area, at lat. 68°55’ N., long. 151°50’ W., in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1948.

FIGURED PARATYPE (USNM P4462) and unfigured paratypes (USNM P4463) from field sample 47A Tr 253, in the Kukpovruk formation, on the north flank of the Awuna anticline, at lat. 69°09’30” N., long. 155°59’ W., in the northern foothills of the Brooks Range, northern Alaska. Collected by M. L. Troyer, 1947.

Unfigured paratypes (USNM P4464) from field sample 47A Wh 594, residual soil sample of the Grandstand formation, on the south flank of the Kigalik anticline, at lat. 69°17’48” N., long. 155°51’ W., in the northern foothills of the Brooks Range, northern Alaska. Collected by C. L. Whittington, 1947.

Unfigured paratype (USNM P4465), from seismograph party 47, line 14 A–48, shot hole 45, at 110–120 feet, in the Grandstand formation, at lat. 71°16’20” N., long. 156°45’07” W., in the Arctic Coastal Plain of northern Alaska.

Unfigured paratype (USNM P4466) from the Grandstand formation (field sample 47A Dt 227) from 4½ miles airline upstream from the mouth of Fossil Creek, tributary to the Colville River, at approximately lat. 69°19’20” N., long. 152°28’ W., in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1947.

Unfigured paratype (USNM P4467) from 81 feet below the top of the Tuktu formation (field sample 47A Z 604) and unfigured paratypes (USNM P4445) from 70 feet above the base of the Tuktu formation (field sample 47A Z 605), on the north limb of the Kurupa anticline, in a section from lat. 68°55” N., long. 155°05’ W., to lat. 69°N., long. 155° W., along the Kurupa River, in the northern foothills of the Brooks Range, northern Alaska. Collected by J. H. Zumbeerge, 1947.

FIGURED PARATYPE (USNM P4443) and unfigured paratypes (USNM P4444) from field sample 47A Wh 199, in the upper part of the Torok formation, equivalent to the Topagoruk formation of the subsurface, 75–100 feet above the base of the section exposed on Quartzite Creek, Awuna River region, at lat. 69°13” N., long. 157°02’18” W., in the northern foothills of the Brooks Range, northern Alaska. Collected by C. L. Whittington, 1947.

Unfigured paratypes (USNM P4447) from field sample 47A Ba 50, in a marine zone, in an unnamed, dominantly nonmarine upper unit of the Nanushuk group of the western area and equivalent to the Corwin formation of the Cape Lisburne Peninsula, 1,400 feet below the top of a 3,700-foot section of intermittent exposures along the north bank of the Utukok River, at approximately lat. 69°07’30” N., long. 160°54” W., about 70 miles east of Cape Beaufort, in the northern foothills of the Brooks Range, northern Alaska. Collected by W. L. Barksdale, 1947.
Unfigured paratypes (USNM P4448) from a core at 472–481 feet in the Grandstand formation, in Umiat test well 3, at lat. 69°23'16'' N., long. 152°05'14'' W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratype (USNM P4449) from well cuttings at 1,090–1,100 feet and unfigured paratype (USNM P4450) from well cuttings at 1,180–1,190 feet in the Topagoruk formation, in South Barrow test well 1, at lat. 71°19'12'' N., long. 156°42'15'' W., southwest of Point Barrow, northern Alaska.

Unfigured paratype (USNM P4451) from well cuttings at 750–760 feet in the Topagoruk formation, in South Barrow test well 2, at lat. 71°15'15'' N., long. 156°37'55'' W., south-southwest of Point Barrow, northern Alaska.

Psamminopelta subcircularis Tappan, new species

PLATE 67, FIGURES 8–10

Test free, discoidal, planispiral, each chamber a half coil in length, chambers very narrow and elongate, nearly circular in section; sutures distinct, depressed; wall finely agglutinated, smoothly finished; aperture at the end of the last tubular chamber, no tooth visible.

Length of holotype 0.31 mm., greatest breadth 0.26 mm., thickness 0.04 mm. Paratypes range from 0.18 to 0.34 mm. in length.

Remarks: Psamminopelta subcircularis, new species, differs from Miliammina mantobensis Wickenden in being much smaller, about one fourth as large, in being discoidal rather than fusuline in shape, and in lacking the quinqueloculine development of Miliammina. It somewhat resembles Massilina glutinosa Cushman and Cahill, but is about one-half as large, with narrower chambers and more nearly circular outline, planispiral development, and arenaceous wall, insoluble in acid.

The species occurs in the Grandstand and Topagoruk formations.

Types and Occurrence: Holotype (USNM P4452) and figured paratype (USNM P4453) from a core at 361–366 feet in the Grandstand formation, in Umiat test well 3, at lat. 69°23'16'' N., long. 152°05'14'' W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Figured paratype (USNM P4454) and unfigured paratype (USNM P4455) from a core at 499–509 feet, unfigured paratype (USNM P4456) from a core at 522–524 feet, unfigured paratypes (USNM P4457) from a core at 770–780 feet, all from the Grandstand formation; and unfigured paratype (USNM P4458) from well cuttings at 4,010–4,020 feet in the Topagoruk formation; all in Umiat test well 2, at lat. 69°23'04'' N., long. 152°05'01'' W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4459) from a core at 1,424–1,434 feet, unfigured paratypes (USNM P4460) from a core at 1,693–1,703 feet, and unfigured paratypes (USNM P4461) from a core at 1,713–1,723 feet, all from the Grandstand formation, in Umiat test well 1, at lat. 69°23'52'' N., long. 152°19'45'' W., west of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Family Trochamminidae Schwager, 1877

Genus Trochammina Parker and Jones, 1859

Trochammina eilete Tappan, new species

PLATE 68, FIGURES 1, 2

Test free, discoidal, trochoid but with a flattened spire, periphery rounded; chambers numerous, about 10 to 14 in the final whorl of adult specimens, of greater height than breadth and appearing cuneate in side view; sutures distinct, thickenened, somewhat depressed, radiate; wall finely agglutinated, with considerable cement, surface smoothly finished; aperture a low arch at the base of the final chamber face, against the periphery of the previous whorl.

Greatest diameter of holotype 0.52 mm., thickness 0.17 mm. Paratypes range from 0.21 to 0.68 mm. in diameter.

Remarks: Trochammina eilete, new species, differs from T. sablei Tappan from the Jurassic in being about twice as large, in having many more chambers per whorl, and in the chambers being wedge shaped rather than inflated and subglobular. This species is characteristic of the Torok formation and the equivalent Fortress Mountain formation.

Types and Occurrence: Holotype (USNM P4483) and unfigured paratypes (USNM P4484) from field sample 49A Ch 45 and unfigured paratypes (USNM P4485) from field sample 49A Ch 44, both taken 180 feet (approximate) below top of the Torok formation in Ravine Basin, Kuikpouwuk River area, at lat. 68°46'30'' N., long. 163°07' W., in northwestern Alaska. Collected by R. M. Chapman, 1949.

Figured paratype (USNM P4487) and unfigured paratype (USNM P4488) from the Fortress Mountain formation, in a section 1,150–1,750 feet above the base (field sample 49A Pa 593), on the Kaiuktak River, west of Castle Mountain, at lat. 68°35' N., long. 152°54' W., in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

Unfigured paratypes (USNM P4489) from 5,600 to 6,000 feet above the base of the Fortress Mountain formation (field sample 49A Tr 562), on Castle Creek, south-southwest of Castle Mountain, at lat. 68°32'05'' N., long. 152°49' W., in the southern foothills of the Brooks Range, north Alaska. Collected by I. L. Taillieu, 1949.

Unfigured paratypes (USNM P4482) from the Torok formation (field sample 49A Tr 698), on the south limb of the Aiyak anticlinorium, on the Kuiraktag River, due north of Castle Mountain, at lat. 68°38'40'' N., long. 152°34' W., in the southern foothills of the Brooks Range, northern Alaska. Collected by I. L. Taillieu, 1949.
Trochammina stefanssoni Tappan, new species

**PLATE 67, FIGURES 30–33**

Test free, trochoid, low spired, periphery rounded; all chambers of the approximately two whors visible dorsally, only the nine of the final whorl visible on the umbilicate ventral side, chambers increasing rapidly in size, early ones subglobular, later cuneate in side view; sutures distinct, depressed, radial; wall very finely arenaceous, with considerable cement and smoothly finished, all specimens crushed and distorted in preservation; aperture an arch at the base of the final chamber face, against the previous whorl on the periphery.

Greatest diameter of holotype 0.55 mm. Paratypes range from 0.31 to 0.62 mm in diameter.

**REMARKS:** *Trochammina stefanssoni,* new species, differs from *T. diagonis* (Carsey) in having more chambers to each whorl and in the chambers being cuneate rather than rounded and inflated. It is also more finely arenaceous and more smoothly finished.

This species has been found only in the Sentinel Hill member of the Schrader Bluff formation (Upper Cretaceous). The specific name is in honor of Karl Stefanson, geologist, formerly of the U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4490) and unfigured paratypes (USNM P4491) from a core at 475–476 feet, figured paratypes (USNM P4492a–c) and unfigured paratypes (USNM P4493) from a core at 478–480 feet, and unfigured paratypes (USNM P4494) from a core at 579–589 feet, all from the Sentinel Hill member of the Schrader Bluff formation, in Sentinel Hill core test 1, at lat. 69°35'48” N., long. 151°28'09” W., on the west bank of the Colville River, Arctic Coastal Plain, northern Alaska.

**Trochammina umiatensis** Tappan, new species

**PLATE 67, FIGURES 27–29**

Test free, trochoid, relatively high spired, periphery lobulate and rounded; chambers inflated and subglobular, few in number, increasing rapidly in size, only four or rarely five in each whorl; sutures distinct, depressed, radial; wall finely to coarsely agglutinated, roughly finished; aperture ventral, a slit at the base of the final chamber face.

Greatest diameter of holotype 0.68 mm., thickness 0.29 mm. Paratypes range from 0.29 to 0.81 mm in diameter.

**REMARKS:** *Trochammina umiatensis,* new species, differs from *T. globigeriniformis* (Parker and Jones) in having more chambers per whorl, commonly four instead of the three of *T. globigeriniformis,* in being nearly three times as large, and in having a better developed and higher spire and a greater increase in chamber size.

**Types and occurrence:** Holotype (USNM P4495) from well cuttings at 735–740 feet in the Grandstand formation, in Umiat test well 2, at lat. 69°23'04” N., long. 152°05'01” W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4500) from a core at 1,615–1,625 feet and unfigured paratype (USNM P4501) from a core at 1,625–1,635 feet, both in the Grandstand formation, in Umiat test well 1, at lat. 69°23'52” N., long. 152°19'45” W., west of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Figured paratypes (USNM P4502a–b) from a core at 1,130–1,133 feet, unfigured paratypes (USNM P4503) from a core at 1,183–1,186 feet, and unfigured paratypes (USNM P4504) from well cuttings at 1,190–1,195 feet, all in the Grandstand formation, in Umiat test well 8, at lat. 69°23'59” N., long. 152°06'56” W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

**Trochammina whittingtoni** Tappan, new species

**PLATE 68, FIGURES 3–6**

Test free, trochoid, much compressed; chambers numerous, increasing gradually in size, eight to nine in the final whorl; sutures slightly depressed, radial; wall finely agglutinated, probably with a "chitinous" base as all specimens are laterally crushed in preservation and of a brownish color, with chambers collapsed centrally; aperture obscured by the lateral compression of the test.

Greatest diameter of holotype 0.49 mm. Paratypes range from 0.26 to 0.73 mm in diameter.

**REMARKS:** This species differs from *T. diagonis* (Carsey) in having more chambers per whorl and having a characteristic brownish color and fine-grained wall, with its usual lateral compression.

The species occurs in the Seabee and Schrader Bluff formations of the Upper Cretaceous. It is named in honor of C. L. Whittington, geologist, U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4505), figured paratype (USNM P4506), and unfigured paratypes (USNM P4507), all from the Seabee formation (field sample 47A Wh 295), taken 541–545 feet below the top, on September Creek, Knifeblade area, between the Kigiklik and Awuna Rivers, at lat. 69°11’ N., long. 154°34’ W., in the northern foothills of the Brooks Range, northern Alaska. Collected by C. L. Whittington, 1947.

Figured paratype (USNM P4508) and unfigured paratype (USNM P4509) taken 20 feet above the base of the Seabee formation (field sample 47A Dt 80) and unfigured paratypes (USNM P4510) taken 210 feet above the base of the Seabee formation (field sample 47A Dt 125), all from the vicinity of the Colville River, west of Ninulkuk Creek, at lat. 69°13’ N., long. 153°15’ W., in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1947.

Unfigured paratypes (USNM P4511) taken 140–160 feet above the base of the Ayiyak member of the Seabee formation (field sample 48A Dt 377), at lat. 69°10’ N., long. 151°27’ W., and unfigured paratypes (USNM P4512) taken 990–1010 feet above the base of the Rogers Creek member of the Schrader Bluff formation (field sample 48A Dt 422), at lat. 69°14’ N., long.

Unfigured paratypes (USNM P4513) taken 2,460 feet below the top of the Sentinel Hill member of the Schrader Bluff formation (field sample 47A St 30), on the north bank of the Colville River, about 7½ miles southwest of the confluence of the Chandler and Colville Rivers at lat. 69°25' N., long. 151°48' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by Karl Stefansson, 1947.

Figured paratype (USNM P4514) and unfigured paratypes (USNM P4515) from a core at 609–615 feet, all from the Sentinel Hill member of the Schrader Bluff formation, in Sentinel Hill core test 1, at lat. 69°35'48'' N., long. 151°28'09'' W., on the west bank of the Colville River, Arctic Coastal Plain, northern Alaska.

Unfigured paratypes (USNM P4517) from a core at 499–509 feet and unfigured paratypes (USNM P4518) from a core at 519–529 feet, all from the Seabee formation, in Umiat test well 1, at lat. 69°23'32'' N., long. 152°19'45'' W., west of Umiat in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4519) from 1,290 feet below the top of the Seabee formation (field sample 47A Wb 172), along the Nanushuk River about 15 miles south of the confluence of the Nanushuk and Anaktuvuk Rivers, at approximately lat. 69°04' N., long. 150°55' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by E. J. Webber, 1947.

Family Nodosariidae Schultze, 1854
Genus Marginulina d'Orbigny, 1826
Marginulina gatesi Tappan, new species

Test free, robust, early portion with a curved axis, but not a distinct coil, later uncouled and rectilinear, rounded in section; chambers few in number, those of the curved early portion increasing very rapidly in size as added, later three or four chambers uncouled and of more nearly equal size, considerably overlapping, inflated, final chamber about twice the height of the penultimate one; sutures distinct, somewhat constricted, radial in the early portion, nearly horizontal in the uncoiled part of the test; wall calcareous, finely perforate, surface ornamented with about 12 low and widely spaced vertical ribs; aperture radiate, terminal on the final chamber, eccentric, somewhat closer to the dorsal angle and slightly produced.

Length of holotype 0.52 mm., breadth 0.26 mm. Paratypes range from 0.36 to 0.68 mm. in length.

Remarks: Marginulina gatesi, new species, differs from M. radiata Terquem in having fewer and wider spaced ribs and in these being vertical rather than crossing the chambers obliquely. The present species is also much more robust.

This species occurs in the Grandstand and Topagoruk formations. The specific name is in honor of G. L. Gates, chief of the Alaskan Geology Branch, U. S. Geological Survey.

Types and occurrence: Holotype (USNM P4522) and unfigured paratypes (USNM P4523) from a core at 273–283 feet, unfigured paratypes (USNM P4524) from a core at 238–256 feet, unfigured paratypes (USNM P4525) from a core at 293–303 feet, unfigured paratype (USNM P4526) from a core at 338–348 feet, figured paratype (USNM P4527) and unfigured paratypes (USNM P4528) from a core at 523–533 feet, unfigured paratypes (USNM P4529) from a core at 900–910 feet, all in the Grandstand formation; and unfigured paratype (USNM P4530) from a core at 1,080–1,087 feet in the Topagoruk formation; all from Simpson test well 1, at lat. 70°57'05'' N., long. 155°21'45'' W., west of Cape Simpson, northern Alaska.

Unfigured paratype (USNM P4531) from well cuttings at 410–420 feet in the Grandstand formation, in Simpson core test 10, at lat. 70°57'34'' N., long. 155°17'27'' W., in the vicinity of Cape Simpson, northern Alaska.

Unfigured paratype (USNM P4532) from the Grandstand formation (field sample 47A Dt 228) taken about 4½ miles airline upstream from the mouth of Fossil Creek, a small, north-flowing tributary to the Colville River, at lat. 69°19'20'' N., long. 152°28' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1947.

Genus Dentalina d'Orbigny, 1826
Dentalina? dettermani Tappan, new species

Plate 68, Figures 9–12

Test free, consisting of inflated somewhat elongate or ovate chambers, much constricted to a slender tubular neck at each end, and probably originally consisting of a number of these chambers uniseri ally arranged, but in an arcuate series as the chambers may be slightly asymmetrical, with the apertural neck eccentric; sutures consisting of greatly constricted neck, but chambers of all specimens observed have been broken apart at these constrictions; wall calcareous, finely perforate, hyaline, surface smooth or finely hispid; aperture at the end of the tubular neck, rounded.

Length of chamber of holotype 0.65 mm., breadth 0.34 mm. Paratypes range in chamber length from 0.29 to 0.55 mm.

Remarks: The generic placement of this species is questioned, as no complete tests have been found, undoubtedly because of the fragile nature of the connecting necks between the inflated chambers. The asymmetry of the single chambers, their size range, and the invariable presence of a broken neck at one or both ends strongly suggest that these chambers represent an elongate, fragile Dentalina, whose chambers were isolated in preservation.

Superficially D.† dettermani, new species, resembles Lagena haueriivana Bartenstein and Brand but differs in the presence of a connecting neck at both ends of
the inflated ovate chambers, their asymmetrical and more elongate outline, and the greater range in size, the smaller specimens possibly representing earlier formed chambers.

This species occurs in the Grandstand, Topagaruk, and Fortress Mountain formations. The specific name is in honor of R. L. Dettmerman, geologist, U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4556), figured paratype (USNM P4557), and unfigured paratypes (USNM P4558), all from a core at 543–545 feet in the Grandstand formation, in Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Figured paratype (USNM P4559) from well cuttings at 5,730–5,740 feet and unfigured paratypes (USNM P4560) from well cuttings at 4,310–4,320 feet, all from the Topagaruk formation, in Umiat test well 2, at lat. 69°23'04" N., long. 153°05'01" W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Figured paratype (USNM P4561) from the Fortress Mountain formation (field sample 49A Pa 94), on the north limb of Fortress Mountain syncline, along Fortress Creek, tributary to the Ayiyak River, southwest of Fortress Mountain, at lat. 68°35' N., long. 153°10' W., in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

**Genus Rectoglandulina Loeblich and Tappan, 1955**

*Rectoglandulina kirschneri* Tappan, new species

**Plate 68, Figures 17, 18**

Test free, elongate, rectilinear, circular in section, chambers increasing gradually in size from the conical proloculus, early chambers closely appressed and overlapping, later more inflated and with less overlap, final chamber turbinate in appearance; sutures distinct, depressed, horizontal; wall calcareous, hyaline, finely perforate, surface smooth; aperture terminal, radiate, slightly produced on a neck.

Length of holotype 0.52 mm., breadth 0.23 mm. Paratypes range from 0.34 to 0.94 mm. in length.

**Remarks:** This species somewhat resembles *Glandulina elongata* Reuss, 1860, from the Upper Cretaceous (not *G. elongata* Bornemann, 1865) in general appearance but is about one-third as large and has a conical instead of a rounded proloculus.

The species has been found in the Grandstand, Topagaruk, and Oumalik formations. It is named in honor of C. A. Kirschner, geologist, formerly with U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4546) from a core at 1,152–1,162 feet in the Topagaruk formation, in Point Barrow core test 1, at lat. 71°19'30" N., long. 156°40' W., southwest of Point Barrow, northern Alaska.

Unfigured paratype (USNM P4547) from a core at 555–565 feet in the Grandstand formation and figured paratype (USNM P4548) from well cuttings at 4,870–4,880 feet in the Oumalik formation, both in Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Unfigured paratype (USNM P4549) from a core at 1,625–1,630 feet in the Grandstand formation, in Umiat test well 1, at lat. 69°23'52" N., long. 153°19'45" W., in the northern foothills of the Brooks Range, northern Alaska.

**Genus Saracenaria Defrance, 1824**

*Saracenaria dutroi* Tappan, new species

**Plate 68, Figures 14–16**

Test free, early portion coiled, later uncoiling and rectilinear, triangular in section, periphery acute but without a keel; chambers increasing rapidly in size from the globular proloculus, becoming increasingly broader but enlarging very little in height, with considerable overlap, so that final chamber is about half again as high as the penultimate, sides of chambers flattened or slightly depressed centrally, apertural face flattened; sutures distinct, gently curved in the early portion, more nearly straight but oblique in the later portion, highest at the dorsal angle, wall calcareous, hyaline, finely perforate, surface smooth; aperture terminal at the dorsal angle, radiate, and slightly produced.

Length of holotype 0.78 mm., greatest breadth of side 0.31 mm., breadth of face 0.26 mm. Paratypes range from 0.26 to 0.73 mm. in length.

**Remarks:** *Saracenaria dutroi*, new species, differs from *S. saratogana* Howe and Wallace in being relatively narrower, with fewer and higher chambers, a more enrolled base, and more acutely angled margins.

This species occurs in the Grandstand and Topagaruk formations. The specific name is in honor of J. T. Dutro, Jr., geologist, U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4533) from well cuttings at 1940–1950 feet in the Topagaruk formation; unfigured paratypes (USNM P4534) from a core at 438–443 feet, unfigured paratype (USNM P4535) from a core at 493–503 feet, unfigured paratype (USNM P4536) from a core at 543–545 feet, all in the Grandstand formation; figured paratype (USNM P4537) from a core at 1,080–1,087 feet, unfigured paratype (USNM P4538) from well cuttings at 2,300–2,310 feet, and unfigured paratype (USNM P4539) from well cuttings at 2,460–2,470 feet, all in the Topagaruk formation; all in Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Figured paratype (USNM P4540) from well cuttings at 1,392–1,397 feet, in the Topagaruk formation, in Arcon Point Barrow core test 1, at lat. 71°19'30" N., long. 156°40' W., southwest of Point Barrow, northern Alaska.
Family Polymorphinidae d’Orbigny, 1846

Genus Pyrulinoides Marie, 1941
Pyrulinoides thurrelli Tappan, new species

**Plate 68, Figure 13**

Test free, elongate, fusiform in outline, circular in section; chambers added 180 degrees apart, in a biserial arrangement, much overlapping, increasing rapidly in size, final chamber extending back about three-fourths the distance to the base on one side, only about one-third the distance on the opposite side; sutures strongly oblique, flush; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate.

Length of holotype 0.94 mm., greatest breadth 0.42 mm. Paratypes range from 0.60 to 1.12 mm. in length.

**Remarks:** *Pyrulinoides thurrelli,* new species, differs from *P. osea* Marie in the larger size, more regularly fusiform outline, greater chamber overlap, more oblique sutures, and fewer, larger chambers. The species occurs in the Grandstand and Topagoruk formations. The specific name is in honor of R. F. Thurrell, geologist, formerly with U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4553) from a core at 466-476 feet in the Grandstand formation, in Skiff Cliff core test 1, lat. 70°55' N., long. 157°38' W., between Point Barrow and Point Franklin, northern Alaska.

Unfigured paratype (USNM P4554) from a core at 523-533 feet in the Grandstand formation and unfigured paratype (USNM P4555) from well cuttings at 3,160-3,170 feet in the Topagoruk formation, both from Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

**Family Buliminidae Jones, 1876**

Genus Praebulimina Hofker, 1951
Praebulimina seabeensis Tappan, new species

**Plate 69, Figures 14-16**

Test free, elongate, flaring, chambers in a high spiral, triserially arranged, low, somewhat inflated, increasing gradually in size, those of final whorl somewhat higher and subglobular; sutures distinct, depressed, horizontal; wall calcareous, finely perforate, surface smooth; aperture loop-shaped, at the inner margin of the final chamber, extending up into the chamber face.

Length of holotype 0.26 mm., breadth 0.18 mm. Paratypes range from 0.10 to 0.42 mm. in length.

**Remarks:** *Praebulimina seabeensis,* new species, differs from *P. venusae* (Naus) in the larger size, more bluntly rounded base, less flared test, and lower final whorl of chambers.

The specific name refers to the Seabee formation, in which this species is found.

**Types and occurrence:** Holotype (USNM P4564) and unfigured paratypes (USNM P4565) from a core at 591-601 feet, figured paratype (USNM P4566) and unfigured paratype (USNM P4567) from a core at 519-529 feet, and figured paratype (USNM P4568) and unfigured paratypes (USNM P4569) from a core at 584-591 feet, all in the Seabee formation, in Umiat test well 1, at lat. 69°23'52" N., long. 153°19'45" W., west of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

**Family Discorbidae Cushman, 1927**

Genus Eurycheilostoma Loeblich and Tappan, 1957
Eurycheilostoma grandstandensis Tappan, new species

**Plate 68, Figures 19-25**

Test free, trochoid, extremely high spired, all whorls visible dorsally, only the final whorl visible on the concave, widely umbilicate ventral side, triserial throughout, chambers increasing gradually in size in the early portion, forming a gradually enlarging spire, later chambers enlarging rapidly and becoming inflated, so that there may be a distinct change in the diameter of the test with the final whorl, the final chamber occupying one-half to two-thirds of the ventral side of the test; sutures distinct, flush in the early spire, depressed in the later portion; wall calcareous, finely but distinctly perforate, surface smooth, aperture an arch at the inner margin of the final chamber on the ventral side opening into the umbilicus, partly covered over by an extensive although narrow flap which has a serrate border in all well preserved specimens, an apertural reentrant occurring at both extremities of this flap.

Greatest diameter of holotype 0.16 mm., height of spire 0.31 mm. Paratypes range from 0.13 to 0.26 mm. in diameter.

**Remarks:** This species differs from *E. altispira* Loeblich and Tappan in being larger and extremely high spired and in having the conical early portion commonly followed by an abrupt flaring of the final whorl. It differs from *E. robinsonae,* new species, in being much higher spired, with a pointed apex and nearly flush sutures in the early development.

*Eurycheilostoma grandstandensis* occurs in the Grandstand and Topagoruk formations.

**Types and occurrence:** Holotype (USNM P4595), figured paratypes (USNM P4596 a,b), and unfigured paratype (USNM P4597) from a core at 555-565 feet, unfigured paratypes (USNM P4598) from a core at 433-438 feet, unfigured paratypes (USNM P4599) from a core at 534-545 feet, all from the Grandstand formation; unfigured paratypes (USNM P4600) from a core at 1,030-1,040 feet, unfigured paratypes (USNM P4601) from a core at 1,070-1,080 feet, unfigured paratypes (USNM P4602) from a core at 1,247-1,267 feet, figured paratype (USNM P4603) and unfigured paratypes (USNM P4604) from a core at 1,360-1,370 feet, figured paratype (USNM P4605) and unfigured paratypes (USNM P4606) from well cuttings at 1,580-1,590 feet, unfigured paratypes (USNM P4607) from well cuttings at 1,760-1,770 feet, unfigured paratypes (USNM P4608) from well cuttings at 1,870-1,880 feet, unfigured paratypes (USNM P4609) from a core at
1,967–1,977 feet, unfigured paratypes (USNM P4610) from a core at 3,024–3,026 feet, and figured paratypes (USNM P4611a,b) from well cuttings at 2,330–2,335 feet, all from the Topagoruk formation; all from Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Unfigured paratypes (USNM P4612) from well cuttings at 4,180–4,190 feet, unfigured paratypes (USNM P4613) from well cuttings at 4,220–4,230 feet, unfigured paratypes (USNM P4614) from well cuttings at 4,340–4,350 feet, all from the Topagoruk formation, in Umiat test well 2, at lat. 69°23'32" N., long. 152°19'45" W., west of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4615) from well cuttings at 4,140–4,150 feet and unfigured paratypes (USNM P4616) from a core at 5,585–5,595 feet in the Topagoruk formation in Umiat test well 2, at lat. 69°23'04" N., long. 152°05'01" W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1947.

Unfigured paratypes (USNM P4617) from 2,390 feet below the top of the Grandstand formation (field sample 47A Dt 227), about 4½ miles airline upstream from the mouth of Fossil Creek, a small north-flowing tributary to the Colville River, at approximately lat. 69°19'20" N., long. 152°28' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by M. L. Troyer, 1947.

Eurycheilostoma robinsonae Tappan, new species

PLATE 70, FIGURES 8-11

Test free, trochoid, conical, dorsal side in a much elevated spire of about four volutions, ventral side concave with open and extensive umbilicus, periphery rounded; chambers inflated, increasing rapidly in size, later ones becoming semilunar in dorsal view but relatively high as seen in edge view, final whorl with only three chambers, the last chamber occupying about three-fifths of the area of the ventral side; sutures distinct, slightly depressed; wall calcareous, finely but distinctly perforate, surface smooth; aperture ventral, an arch at the inner margin of the final chamber, opening into the umbilicus and partly covered by a ventral umbilical flap of the chamber, which has a serrated border, and an apertural reentrant into the chamber face at each extremity of the flap.

Greatest diameter of holotype 0.29 mm., height of spire 0.31 mm. Paratypes range from 0.13 to 0.29 mm. in diameter.

Remarks: Eurycheilostoma robinsonae, new species, differs from the associated E. grandstandensis in the much lower spire and more regular increase in chamber size. It differs from E. altispira Loebllich and Tappan in being about twice as large and higher spired.

This species is found in the Grandstand and Topagoruk formations. The specific name is given in honor of Florence Robinson, geologist, U. S. Geological Survey.

Types and occurrence: Holotype (USNM P4584) and unfigured paratypes (USNM P4585) from a core at 651–661 feet in the Topagoruk formation, in Arcon Point Barrow core test 1, at lat. 71°19'30" N., long. 156°40' W., southwest of Point Barrow, northern Alaska.

Figured paratype (USNM P4586) from a core at 264 feet in the Grandstand formation, in Skull Cliff core test 1, at lat. 70°55' N., long. 157°38' W., between Point Barrow and Point Franklin, northern Alaska.

Figured paratype (USNM P4587) and unfigured paratypes (USNM P4588) from a core at 2,024–2,026 feet, unfigured paratypes (USNM P4589) from well cuttings at 1,760–1,770 feet, and unfigured paratypes (USNM P4590) from well cuttings at 1,840–1,850 feet, all in the Topagoruk formation, in Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Figured paratype (USNM P4591) and unfigured paratypes (USNM P4592) from a marine zone at the base of a 640-foot section, in an unnamed, dominantly marine lower unit of the Nanushuk group found in the western area (field sample 47 A Ba 67), on the north limb of a syncline, just north of the Utikok River and southwest of a small tributary at approximately lat. 69°14' N., long. 160°37' W., about 70 miles east-northeast of Cape Beaufort, in the northern foothills of the Brooks Range, northern Alaska. Collected by W. L. Barksdale, 1947.

Genus Nanushukella Tappan, new genus

Type species: Nanushukella umiatensis Tappan, new species. (Derivation: Nanushuk, formational group in Alaska + ella, L., diminutive; gender, feminine.)

Test free, trochoid, planoconvex, low spired, ventrally umbilicate, periphery rounded; all chambers visible on the convex dorsal side, only the relatively few of the last whorl visible ventrally; sutures distinct, oblique dorsally, radiate ventrally; wall calcareous, relatively coarsely perforate, surface smooth; aperture ventral, a low arch along the broad umbilical margin of the final chamber and opening into the umbilicus, with a narrow fimbriate lip or flap extending its full length, the apertures of all earlier chambers of the final whorl remaining open beneath their flaps along the sutures from the umbilicus about one-half the distance to the periphery.

Remarks: Nanushukella, new genus, differs from Conorhinella Brotzen in having a more extensive umbilical aperture and an open umbilicus and in having all earlier apertures of the final whorl remaining open.
Nanushukella umiantensis Tappan, new species

Plate 69, Figures 1–10

Test free, trochoid, planoconvex, with a low rounded spire of about 2½ volutions, periphery rounded; chambers increasing rapidly in size, semilunate in dorsal view, about six in the early whorls and commonly only four in the final whorl, last chamber occupying about one-third of the ventral side; sutures distinct, flush dorsally and may be somewhat limbate, ventrally depressed and nearly radial, with a slight forward swing from the outer margin of the aperture to the periphery; wall calcareous, coarsely perforate, surface smooth; aperture ventral, a low arch at the umbilical margin of the final chamber extending over much of the length of its ventral margin, bordered above by a narrow apertural flap that has a fimbriate margin, apertures of earlier chambers of the final whorl all remaining open and visible, radiating from the open umbilicus.

Greatest diameter of holotype 0.29 mm., height 0.16 mm. Paratypes range from 0.18 to 0.34 mm. in diameter.

Remarks: This species differs from Conorhina conica Lozo in having higher and less arcuate chambers as seen dorsally, a lower, more rounded spire, less oblique sutures, the characteristic umbilical aperture with serrated lip, and the earlier apertures remaining open with later development.

It is found in the Grandstand, Topagoruk, and Fortress Mountain formations.

Types and occurrence: Holotype (USNM P4619), figured paratype (USNM P4620), and unfigured paratypes (USNM P4621) from a core at 565–578 feet, unfigured paratypes (USNM P4622) from a core at 206–211 feet, figured paratypes (USNM P4623a–c) and unfigured paratypes (USNM P4624) from a core at 238–256 feet, unfigured paratypes (USNM P4625) from a core at 338–348 feet, figured paratypes (USNM P4626a,b) and unfigured paratypes (USNM P4627) from a core at 348–358 feet, unfigured paratypes (USNM P4628) from a core at 438–443 feet, figured paratype (USNM P4629) and unfigured paratypes (USNM P4630) from a core at 513–523 feet, and unfigured paratypes (USNM P4631) from a core at 543–545 feet, all from the Grandstand formation, Nanushuk group; unfigured paratype (USNM P4632) from a core at 1,758–1,768 feet and unfigured paratype (USNM P4633) from well cuttings at 1,990–2,000 feet, both in the Topagoruk formation; all in Simpson test well 1, at lat. 70°57′05″ N., long. 155°21′45″ W., west of Cape Simpson, northern Alaska.

Unfigured paratype (USNM 106138) from well cuttings at 1,560–1,570 feet, unfigured paratypes (USNM 106137) from a core at 1,850–1,855 feet, unfigured paratypes (USNM 106136 and P4634) from well cuttings at 2,610–2,620 feet, from the Topagoruk formation, in Umiat test well 2, at lat. 69°23′04″ N., long. 153°05′01″ W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P4635) from the Fortress Mountain formation (field sample 49A Tr 611), east of Castle Mountain, on the east fork of Torok Creek, at lat. 68°33′35″ N., long. 152°38′30″ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by I. L. Tailleur, 1949.

Unfigured paratype (USNM P4636) from the middle part of the Fortress Mountain formation (field sample 49A Pa 468), 1½ miles southwest of Castle Mountain, along a tributary to Castle Creek, which flows north to join the Kurutagiak River, at lat. 68°33′40″ N., long. 151°51′ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

Unfigured paratype (USNM P4637) from seismograph party 47 test hole, line 14A-48, shot hole 37, at 190–200 feet, in the Grandstand formation, at lat. 71°17′54″ N., long. 156°43′21″ W., northern Alaska.

Figured paratypes (USNM P4570a,b) and unfigured paratypes (USNM P4571), all from the Cretaceous, probably equivalent to the lower part of the Nanushuk group of the eastern areas (field sample 47A Tm 10), in a section of intermittent exposures along the Utukok River, at lat. 69°07′30″ N., long. 160°54′ W., about 70 miles due east of Cape Beaufort in the northern foothills of the Brooks Range, northern Alaska. Collected by R. M. Thompson, 1947.

Unfigured paratype (USNM P4572) from the lower part of the Fortress Mountain formation (field sample 49A Pa 81), on Fortress Creek, north of Fortress Mountain, at lat. 69°35′25″ N., long. 153°11′ W., in the southern foothills of the Brooks Range, Northern Alaska. Collected by W. W. Patton, Jr., 1949.

Genus Eponides Montfort, 1808

Eponides morani Tappan, new species

Plate 70, Figures 1–7

Test free, trochoid, biconvex, periphery subacute, all chambers of the 1½ to 2½ whorls visible dorsally, only the 6 to 8 chambers of the final whorl visible on the umbilicate ventral side, chambers relatively narrow, extending backward at the periphery; sutures distinct, thickened, flush dorsally, ventrally nearly radial although slightly curved; wall calcareous, hyaline, relatively coarsely perforate, surface smooth; aperture broad and low, a ventral, interiomarginal slit, extending from the umbilical region almost to the peripheral margin.

Greatest diameter of holotype 0.47 mm., thickness 0.18 mm. Paratypes range in diameter from 0.26 to 0.49 mm.

Remarks: Eponides morani, new species, differs from E. repandus (Fichtel and Moll) in being much smaller, with a lower spire, in having 6 to 8 chambers rather than 5 or 6 in the final whorl, in lacking a keel, and in having a lower more slitlike aperture.

The specimen selected as holotype was obtained from well cuttings, but it was selected as type because it was the most complete and best preserved specimen.
found; its true stratigraphic age is inferred from the occurrence of other specimens in core samples.

This species is found in the Grandstand and Topagoruk formations; its appearance in older rocks is probably due to contamination of the well cuttings.

It is named for P. F. Moran, administrative assistant, U. S. Geological Survey.

**Types and occurrence:** Holotype (USNM P4638) from well cuttings at 5,670-5,680 feet, probably from the Topagoruk formation, found as contamination in the underlying Jurassic rocks; figured paratypes (USNM P4639a-c) and unfigured paratype (USNM P4640) from a core at 2,235-2,245 feet, unfigured paratype (USNM P4641) from a core at 2,275-2,285 feet, all from the Topagoruk formation; unfigured paratype (USNM P4644) from well cuttings at 3,760-3,770 feet, unfigured paratype (USNM P4642) from well cuttings at 4,180-4,190 feet, and figured paratype (USNM P4643) from well cuttings at 5,190-5,200 feet, all of Topagoruk age but found as contamination in older beds; all from Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Figured paratype (USNM P4645) and unfigured paratype (USNM P4646) from the upper part of the Torok formation (Topagoruk formation equivalent) (field sample 47A Wh 543), and figured paratype (USNM P4647) and unfigured paratype (USNM P4648) from the upper part of the Torok formation (Topagoruk formation equivalent) (field sample 47A Wh 541), all on the north flank of the Awuna anticline, along Birthday Creek, which flows south into the Awuna River, at lat. 69°11'30" N., long. 156°41' W., in the northern foothills of the Brooks Range, north-central Alaska. Collected by C. L. Whittington, 1947.

Unfigured paratypes (USNM P4659) from a core at 2,789-2,797 feet in the Grandstand formation, in Oumalik test well 1, at lat. 69°50'18" N., long. 155°59'24" W., approximately 125 miles airline south of Point Barrow, northern Alaska.

**Genus Globorotalites Brozten, 1942**

**Globorotalites alaskensis** Tappan, new species

**PLATE 69, FIGURES 11-13**

Test free, trochoid, dorsally flat to slightly convex, ventrally strongly convex and centrally umbilicate, periphery subacute; chambers increasing rapidly in size and becoming more oblique dorsally, extending back along the periphery, the six to eight chambers of the final whorl may be slightly less elevated than the peripheral keel, presenting an almost collapsed appearance; sutures distinct, dorsally oblique, those of final whorl somewhat thickened and elevated dorsally, radial and flush or slightly depressed ventrally; wall calcareous, finely perforate, surface smooth; aperture interiomarginal, ventral, a low slit extending from the umbilicus almost to the periphery.

Greatest diameter of holotype 0.31 mm., thickness 0.13 mm. Paratypes range from 0.16 to 0.36 mm. in diameter.

**Remarks:** *Globorotalites alaskensis*, new species, differs from *G. multisecta* (Brozen) in being one-third as large, in being less elevated ventrally, in having fewer chambers per whorl, and in the chambers being broader and the sutures less oblique.

It occurs in the Grandstand and Topagoruk formations.

**Types and occurrence:** Holotype (USNM P4649) and unfigured paratypes (USNM P4650) from a core at 680-690 feet in the Grandstand formation; unfigured paratypes (USNM P4651) from a core at 1,429-1,439 feet and figured paratype (USNM P4652) from well cuttings at 1,770-1,780 feet in the Topagoruk formation; all in Umiat test well 2, at lat. 69°23'04" N., long. 152°05'01" W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Figured paratype (USNM P4653) and unfigured paratype (USNM P4654) from a core at 206-211 feet, unfigured paratype (USNM P4655) from a core at 211-221 feet, and unfigured paratype (USNM P4656) from a core at 555-565 feet, all in the Grandstand formation, in Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Unfigured paratypes (USNM P4657) from well cuttings at 190-200 feet in the Grandstand formation, in Simpson core test 10, at lat. 70°57'34" N., long. 155°17'27" W., near Cape Simpson, northern Alaska.

Unfigured paratypes (USNM P4658) from a core at 874-885 feet in the Grandstand formation, in Simpson core test 25, at lat. 70°55'56" N., long. 184°43'52" W., near Cape Simpson, northern Alaska.

**Family Chilostomellidae Brady, 1881**

**Genus Pallaimorphina Tappan, new genus**

**Type species:** *Pallaimorphina ruckae* Tappan, new species. (Derivation: *pallai*, Gr., plural of *palla*, f., *bull* + *morphe*, Gr., form or shape + *ina*, diminutive suffix; gender feminine.)

Test free, small, subglobular, trochoid, with broadly rounded periphery; chambers increasing rapidly but evenly in size as added, early chambers subglobular, later tending to become crescentic in dorsal view, four to five in the final whorl; sutures oblique dorsally, radial ventrally; wall calcareous, finely perforate, granular in structure, surface smooth; aperture a low sutural slit, extending from the umbilical region about half the distance to the periphery, bordered above by a narrow lip.

**Remarks:** *Pallaimorphina*, new genus, is closest in character to *Quadrimorphina* Finlay and may have given rise to that genus. It differs in the gradual chamber enlargement, and does not have the extremely high final chamber characteristic of the genera *Allosmorina* and *Quadrimorphina*. The apertural flap of *Pallaimorphina* is also primitive, being extremely
narrow, and extending along the suture from the umbilicus toward the periphery rather than across the umbilical margin of the chamber as in the other genera mentioned above. Nevertheless the granular wall structure, trochoïd coiling, and apertural flaps definitely show the present genus to belong to the Chilostomellidae.

**Pallaimorphina ruckerae Tappan, new species**

**PLATE 71, FIGURES 1–9**

Test free, small, trochoid, rotund, and biconvex, periphery broadly rounded; four to five inflated chambers per whorl, increasing gradually in height and rapidly in length as added, so that chambers of final whorl are crescentic in dorsal view, about twice as long as high; sutures distinct, slightly depressed, curved and oblique dorsally, nearly straight and radial ventrally; wall calcareous, finely perforate, surface smooth; aperture a low suture slit, extending from the umbilicus about half the distance to the periphery, bordered above by a narrow lip.

Greatest diameter of holotype 0.21 mm., thickness 0.16 mm. Paratypes range from 0.13 to 0.36 mm. in diameter.

**Remarks:** *Pallaimorphina ruckerae*, new species, differs from *Quadririmorphina allomorphinoides* (Reuss) in lacking an extremely broad spatulate apertural flap, having instead only a very narrow one. It is also much smaller and the chambers are subglobular, increasing gradually in size, without developing the extremely radial elongate final chamber characteristic of *Q. allomorphinoides*. Very small young specimens of Reuss' species tend somewhat to resemble the present species, suggesting that this genus may be ancestral to *Quadririmorphina*.

The species occurs in the Grandstand, Topagoruk, and Fortress Mountain formations. It is named in honor of Florence Rucker, geologist, U. S. Geological Survey.

**Type and Occurrence:** Holotype (USNM P 4664) and figured paratype (USNM P 4665) from a core at 533–543 feet, figured paratypes (USNM P 4666a, b) and unfigured paratypes (USNM P 4667) from a core at 206–211 feet, unfigured paratypes (USNM P 4668) from a core at 238–256 feet, figured paratype (USNM P 4669) and unfigured paratypes (USNM P 4760) from a core at 256–266 feet, figured paratypes (USNM P 4671a, b) from a core at 273–283 feet, unfigured paratypes (USNM P 4672) from a core at 338–348 feet, figured paratype (USNM P 4673) from a core at 358–368 feet, unfigured paratypes (USNM P 4674) from a core at 438–443 feet, unfigured paratypes (USNM P 4675) from a core at 503–513 feet, unfigured paratypes (USNM P 4676) from a core at 533–543 feet, unfigured paratypes (USNM P 4677) from a core at 565–578 feet, unfigured paratypes (USNM P 4678) from a core at 663–673 feet, all in the Grandstand formation; and unfigured paratypes (USNM P 4679) from a core at 1,000–1,010 feet in the Topagoruk formation; all from Simpson test well 1, at lat. 70°57'05" N., long. 155°21'45" W., west of Cape Simpson, northern Alaska.

Figured paratype (USNM P 4680) from a core at 464½ feet in the Grandstand formation, in Umiat test well 2, at lat. 69°23'04" N., long. 152°05'01" W., north of Umiat, in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P 4681) from a core at 256–264 feet and unfigured paratypes (USNM P 4682) from a core at 461–466 feet all in the Grandstand formation, in Skull Cliff core test 1, at lat. 70°55' N., long. 157°38' W., between Point Barrow and Point Franklin, northern Alaska.

Unfigured paratypes (USNM P 4683) from a core at 558–568 feet in the Topagoruk formation, in Arcon Point Barrow core test 1, at lat. 71°19'30" N., long. 156°40' W., southwest of Point Barrow, northern Alaska.

Unfigured paratype (USNM P 4684) from well cuttings at 2,545–2,550 feet in the Grandstand formation and unfigured paratype (USNM P 4685) from well cuttings at 4,820–4,830 feet in the Topagoruk formation, all in Umiat test well 1, at lat. 69°23'52" N., long. 152°19'45" W., in the northern foothills of the Brooks Range, northern Alaska.

Unfigured paratypes (USNM P 4686) from the Cretaceous, probably equivalent to the lower part of the Nanushuk group of the eastern areas (field sample 47A Ba 83), 903–1,043 feet above the base, south and east of the Utukok River and 2½ miles west of the confluence of Disappointment Creek with the Utukok River, at lat. 69°15' N., long. 156°57' W., about 70 miles east of Cape Beaufort, in the northern foothills of the Brooks Range, northern Alaska. Collected by W. L. Barksdale, 1947.

Unfigured paratype (USNM P 4687) from the upper part of the Torok formation (Topagoruk formation equivalent) (field sample 47A Tr 161), on the north flank of the Awuna anticline, at lat. 69°11'42" N., long. 156°45' W., in the Awuna River region, northern foothills of the Brooks Range, northern Alaska. Collected by M. L. Troyer, 1947.

Unfigured paratypes (USNM P 4688) from the Topagoruk formation (field sample 48A Wb 24), at the confluence of Reynard Creek with the Colville River, northeast of Noluk Lake, at lat. 69°06'30" N., long. 159°27' W., in the northern foothills of the Brooks Range, northern Alaska. Collected by E. J. Webber, 1948.

Unfigured paratype (USNM P 4689) from the Fortress Mountain formation (field sample 49A Pa 90), on the north limb of the Fortress Mountain syncline on Fortress Creek, at lat. 68°35'10" N., long. 153°10'30" W., and unfigured paratype (USNM P 4690) from the Fortress Mountain formation (field sample 49A Pa 94), at lat. 68°35' N., long. 153°10' W., on the syncline along Fortress Creek, tributary to the Ayiyak River,

Unfigured paratypes (USNM P4691) from the Fortress Mountain formation (field sample 49A Pa 561), on Castle Creek, about 2½ miles southwest of Castle Mountain, at lat. 68°33′15″ N., long. 152°52′30″ W., and unfigured paratypes (USNM P4692) from the Fortress Mountain formation (field sample 49A Pa 564), about 2½ miles southwest of Castle Mountain on Castle Creek, at lat. 68°33′10″ N., long. 152°52′15″ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

Unfigured paratypes (USNM P4693) from the Fortress Mountain formation (field sample 49A Tr 611), on the east fork of Torok Creek, east of Castle Mountain, at lat. 68°33′35″ N., long. 152°38′30″ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by I. L. Tailleur, 1949.

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Tappan, H.

Thalmann, H. E.
Eleven New Genera of Foraminifera

By Alfred R. Loeblich, Jr., and Helen Tappan

Introduction

With the increased number of aids for identification of genera now in common use, such as X-ray and petrographic methods of determining wall structure and composition, thin-sectioning or dissections to show internal structures, and higher magnifications to study apertural characters, etc., a more refined classification is often possible, and species are occasionally found which do not fit into previously described genera without greatly expanding the generic limits. As too wide generic limits lessen their usefulness in stratigraphic work, and also may transgress natural relationships, it seems advisable to propose new generic names for these dissimilar species.

During a restudy of type species of foraminiferal genera, undertaken by the writers in connection with the preparation of the "Treatise on Invertebrate Paleontology," there were found a number of such species which did not fit well into any previously described genera. Some of these species had been described in the past and referred to other genera to which they can no longer be assigned. Seven new species are also described. Eleven new generic names are proposed and defined, and one previously described genus is emended on the basis of unsuspected characters discovered in the type species. The Foraminifera discussed in the present paper are of varying ages and localities, six being found in Recent dredgings, one from the Pleistocene, two from the Tertiary, five from the Cretaceous, and one from the Jurassic; and the species cover a geographic range from Europe to North America, and from the North Atlantic to the South Pacific.

The writers are grateful to the Smithsonian Institution for making it possible for Alfred R. Loeblich to visit the British Museum (Natural History) in London and to make collections in the field in England, France, and Spain; and to the John Simon Guggenheim Memorial Foundation for a fellowship grant to Helen Tappan Loeblich, which made possible the restudy and reillustration of the Jones, Parker and Brady, and the Barnard types in the British Museum.

Assistance in the field, in the collection of material used in the present paper, was graciously given by Mr. A. G. Davis, British Museum (Natural History), London, Mr. Raymond Casey, Geological Survey of Great Britain, London, Dr. J. R. Bataller, University of Barcelona, Spain, and M. Pierre Marie, Bureau des Recherches Géologiques et Géophysiques, Paris, France.

Dr. H. W. Parker, British Museum (Natural History), London, also aided the present study by allowing access to the types of Foraminifera under his care, and making possible the reillustration of the type specimens of Hemisphaerammina bradyi, Tentifrons barnardi, and Webbinella hemisphaerica. He also made possible the exchange of material, allowing us to obtain topotype specimens of Favosidulina favus.

All specimens studied in the present paper are deposited either in the U. S. National Museum, Washington, D. C. (hereafter abbreviated as USNM), or in the British Museum (Natural History), London, England (hereafter abbreviated as BMNH).

Systematic Descriptions

Family Saccamminidae Brady, 1884

Hemisphaerammina Loeblich and Tappan, new genus

Type species: Hemisphaerammina batalleri, new species. (Derivation: hemi, Gr., half; sphaira, Gr., ball; ammos, Gr., sand; gender feminine.)

Test attached, consisting of a single hemispherical chamber; wall agglutinated, with considerable cement; aperture not observed.

Remarks: Upon examination of the British Museum (Natural History) collections in London, the holotype of Webbina hemispherica Parker, Jones and Brady (type species of Webbinella Rhumbler) was found to be an attached polymorphinid, and the generic description has therefore been emended. This left nameless the attached hemispherical agglutinated forms previously placed in Webbinella and the present genus is described to fill that vacancy.

It differs from Webbinelloidea Stewart and Lampe, 1947, in consisting only of single chambers, whereas the type species of Webbinelloidea is two chambered, and other species have three or four chambers. Two species of Webbinelloidea have been described as single-
chambered forms, but as they occurred with other multilocular forms they may have represented young individuals not yet completely developed, or may have become separated in fossilization. The multilocular Webbinelloidea is more characteristic of the Paleozoic and the single-chambered Hemisphaerammina of the Mesozoic and Cenozoic.

Hemisphaerammina batalleri Loeblich and Tappan, new species

Plate 72, Figure 3

Test attached, consisting of a single, rounded to ovate, inflated chamber attached by the flattened side; wall agglutinated, of rather coarse grains with a ground mass of finer material; no aperture visible.

Greatest diameter of holotype 1.04 mm., least diameter 0.88 mm., greatest diameter of paratype 0.83 mm.

Remarks: This species differs from Webbinella rugosa ten Dam from the Albian of the Netherlands, in being of considerably larger size, nearly three times as large, and in lacking the narrow flattened border of W. rugosa.

The specific name is given in honor of Dr. J. R. Bataller of the University of Barcelona, Spain, in recognition of his outstanding work on the Cretaceous of Spain.

Types and occurrence: Holotype (USNM P3095) and unfigured paratype (USNM P3096) both from the upper Santonian, near Casa Canellas, northeast of Trago di Noguera, on the east bank of the Noguera River, 16.5 km west of the main route between Trago and Blanchaforte, Province Lerida, Spain. Collected by H. T. and A. R. Loeblich, Jr., with Dr. J. R. Bataller, April 3, 1954.

Hemisphaerammina bradyi Loeblich and Tappan, new species

Plate 72, Figure 2

Webbina hemispherica Brady (not Jones, Parker and Brady 1866).


Test attached, consisting of a single hemispherical chamber; wall agglutinated, consisting of large angular grains in a ground mass of finer particles, with much cement; no visible aperture.

Diameter of holotype 1.56 mm. According to Brady other specimens range from 0.5 to 1.4 mm. in diameter.

Remarks: As noted above, the holotype of Webbina hemispherica Jones, Parker and Brady from the Pliocene is an attached polymorphid and quite distinct from the agglutinated forms later referred to that species. The latter requires a distinct name and the present species is therefore described. It differs from Hemisphaerammina batalleri, new species, in being more circular in outline, more inflated, and the surface more smoothly finished. H. depressa (Heron-Allen and Earland) has a more irregular outline and is less inflated.

Types and occurrence: Holotype (BMNH ZF2626) is the specimen figured by Brady (pl. 41, fig. 11) and is from the Recent deposits off Redcliff, Durham at 30 fathoms.

A hypotype (USNM P3225) of Hemisphaerammina depressa (Heron-Allen and Earland) is here figured for comparison on plate 72, figure 1. It is from the Recent, at Albatross station D4900, Ose Saki Light, N. 10° E., 8 miles, lat. 32°28'50" N., long. 128°34'40" E., at a depth of 139 fathoms.

Family Textulariidae d’Orbigny, 1846

Zotheculifida Loeblich and Tappan, new genus

Type species: Textularia lirata Cushman and Jarvis, 1929. Derivation: zothecula, L., f., diminutive of zotheca, chamber or closet; + fid, L., suffix, denoting division into parts; gender feminine.

Test free, compressed, elongate or palmate, chambers numerous, biserially arranged with internal incomplete partitions extending obliquely downward from the septa, these partitions not visible externally on most well preserved specimens, but may be seen when the outer surface has either been dampened or somewhat abraded, and in occasional rare specimens the secondary partitions are visible externally as slightly darker than the intervening spaces; wall agglutinated, fine grained, rather smoothly finished; aperture a high narrow arch at the base of the final chamber.

Remarks: Zotheculifida, new genus, differs from Tavitavina Loeblich in the more numerous and regularly arranged internal partitions and in possessing a single textularian aperture rather than the terminal linear series of pores. It differs from Portitectularia Loeblich and Tappan in the presence of the internal partitions and in possessing only a single aperture. From Textularia Defrance it is differentiated by the internal secondary partitions.

Zotheculifida lirata (Cushman and Jarvis), emended

Plate 72, Figures 4–8

Textularia lirata Cushman and Jarvis, Contr. Cushman Lab. Foram. Res., vol. 5, p. 6, pl. 2, figs. a,b, 1929.

Test free, greatly compressed, margins subacute, palmate in outline; chambers numerous, biserially arranged, up to eight or nine pair, strongly recurved laterally with height about one-fourth their breadth, surface slightly excavated; sutures distinct, limbate and raised above the level of the chamber surface, strongly arched, internally the septa have numerous pendant partial secondary partitions which are radially arranged, being nearly vertical near the plane of biseriality and horizontal or even recurved at the outer margins; wall finely agglutinated, rather smoothly finished; aperture a high narrow arch about four times as high as broad, at the base of the last chamber.

Remarks: In describing this species, Cushman and Jarvis (1929, p. 6), on the basis of a single incomplete specimen, stated that the chambers were somewhat spinose at the periphery and that the surface showed oblique furrows in the outer portions of each chamber. The “spinose periphery” is not always present, occurring only in greatly compressed specimens and the “oblique furrows” are actually the surface reflection of
the internal secondary partitions and are present equally in the central portion of the test and not restricted to the outer margins.

Length of incomplete holotype (fig. 4) 1.27 mm., breadth 1.30 mm.; length of hypotype of figure 5, 1.20 mm., breadth 1.22 mm.; length of hypotype of figure 7, 0.52 mm., breadth 0.55 mm.; length of hypotype of figure 8, 1.22 mm., breadth 1.14 mm. Other specimens range up to 2.16 mm. in length.

**Types and Occurrence:** Cushman and Jarvis described this species as occurring in the Eocene "Sagrina" beds of Trinidad. At present these beds are considered to be Upper Oligocene in age.

Holotype (Cushman Coll. 10084) from the "Sagrina Beds," Trinidad Point, Oropouche Lagoon, Trinidad, B. W. I.

Figured hypotypes (USNM P3086a-c) and unfigured hypotypes (USNM P3085) from the Upper Oligocene Brasso formation, Tumpuna River, southeast of Boca Uno Hill, 3 miles south of Four Road, Central Range, Trinidad, B. W. I.

Figured sectioned hypotype (USNM P4884) and unfigured hypotypes (USNM P3087) from the Brasso formation, Carata Hill West, coal mine area, 3 miles north of Mount Harris, Central Range, Trinidad, B. W. I.

Family Nodosariidae Schultze, 1854

**Berthelina** Loeblich and Tappan, new genus

**Plate 72, Figures 9–13**

**Type species:** *Frondicularia paradoxa* Berthelin, 1879. (Derivation: patronymic, in honor of G. Berthelin + ella, L., diminutive suffix; gender, feminine.)

Test free, palmate, flattened; consisting of an elongate proloculus followed by a reduced biserial stage which may consist solely of an ovate second chamber, extending from a point near the aperture of the proloculus along one side nearly to the base, or may consist of two pairs of alternating chambers, biserial stage followed by low, broad and equitant chambers extending back on both sides of the aperture of the preceding chambers, although early equitant chambers may be slightly asymmetrical; sutures distinct, depressed to limbate, strongly arched over the center of the test; wall calcareous, finely perforate, surface smooth or faintly ribbed; aperture terminal and central, an elongate slit.

**Remarks:** Berthelina, new genus, differs from *Frondicularia* Defrance in having a reduced biserial early stage of one or two pairs of chambers preceding the uniserial development, and a slitlike rather than radiate aperture. *Palmita* Lea and *Neofabellina* Bartonstein differ in having a distinctly coiled early portion, *Citharina* Marie has an early *Citharina* -like stage, instead of a reduced biserial one. *Parafrondicularia* Asano has an elongate biserial portion and parallel sides.

Tappan (1951, p. 14), in a discussion of *Sagoplecta*, stated that "*Frondicularia paradoxa* Berthelin, from the Jurassic of France, also is biserial with later uniserial equitant chambers. The carinate margins, compressed ttes, and simple rounded aperture suggest that this species is a lagenid and it should probably be referred to *Parafrondicularia*. It has been placed in *Flabellina*, but seems to have a definite biserial early stage, and show no true coiling."

Some specimens of *Frondicularia didyma* Berthelin recorded from the Albian at Wissant on the west coast of France, and later also recorded from the Gault of Folkestone, England, as *Flabellina didyma* (Berthelin) and as *Palma tarrantensis* Loeblich and Tappan from the Lower Cretaceous (Upper Albian) Weno and Paw Paw formations of Texas, seem superficially to resemble the present genus. However, although the majority of specimens show only a single eccentric chamber at one side of the proloculus, followed by equitant chambers, as is also true of some specimens of *Frondicularia didyma*, a rare specimen of *F. tarrantensis* shows two or three chambers arranged as in *Citharina*, so that it does not have true biseriality as does the present genus. These species have been referred to *Frondicularia* by Berthelin, to *Flabellina* by Chapman and Eichenberg, to *Palma* by Loeblich and Tappan and to *Citharina* by ten Dam. Specimens of the common pseudobiserial form and the rare *Citharina* form of *C. tarrantensis* (Loeblich and Tappan) are here figured (pl. 72, figs. 14–16) for comparison with *Berthelina*, new genus. These Cretaceous species also differ from *Berthelina* in having a typical radiate aperture, as in *Citharina*.

**Types and Occurrence:** Topotypes (USNM P4473a–e) of *Berthelina paradoxa* (Berthelin) from the Lower Pliensbachian (Lias), below the *Ammonites margaritatus* zone, Lower Jurassic, in a quarry at Saint Vincent Sterlange, Dept. Vendée, France. Collected by H. T. and A. R. Loeblich, Jr., January 23, 1954.

Hypotype (USNM P4880) of *Citharina tarrantensis* (Loeblich and Tappan), from the Gault (Albian, Lower Cretaceous), bed 10, in sea cliffs at Folkestone, Kent, England. Collected by H. T. and A. R. Loeblich, Jr., September 4, 1953. Hypotype (USNM P4881) of *C. tarrantensis* (Loeblich and Tappan) from the Denton formation (Albian, Lower Cretaceous) at the Gainesville Brick pit, now unworked, southeast of Gainesville, Cooke County, Texas. Collected by H. T. and A. R. Loeblich, Jr., July 1940. Hypotype (USNM P4882) of *C. tarrantensis* (Loeblich and Tappan) from the Denton formation (Albian), on the west bank of the north fork of Nolands River, 100 feet south of bridge on the Godley-Joshua road, 1.4 miles NE of Godley, Johnson County, Texas. Collected by H. T. and A. R. Loeblich, Jr., June 1939.

**Tentifrons** Loeblich and Tappan, new genus

**Type species:** *Tentifrons barnardi*, new species. (Derivation: tentus, L., hold + frons, L., f., leaf; gender, feminine.)

Test free in early stages, with chambers in a citharine arrangement, loosely coiled and becoming uniserial, flattened and palmate with chevron-shaped chambers
which are smooth and centrally excavated, attached in the later stages, with the chambers slightly inflated, extremely papillose and fistulose although retaining somewhat the chevron-shaped character; sutures raised and thickened in the early portion, slightly depressed in the irregular attached portion; wall calcareous, perforate; aperture terminal like Citharinella in the early stages, with numerous apertures at the ends of the fistulose extensions in the later attached chambers.

Remarks: Tentifrons, new genus, differs from all palmate Nososariidae in being attached in its later stages, in developing the fistulose growth, and in having multiple apertures. These characters show again the close affinity between the families Nososariidae and Polymorphinidae.

Tentifrons barnardi Loeblich and Tappan, new species

Plate 72, Figures 17, 18


Test large, flattened, free in the early stage, later attached; chambers increase gradually in size from the globular proloculus, at first in a citharine arrangement, later uniserial with chevron-shaped chambers, and flattened or slightly depressed, the final chambers formed after the test becomes attached are irregular in outline, more inflated, and with a distinctly papillose surface and some develop numerous fistulose extensions along the chamber margins; sutures raised and thickened in the early stages, formed during the free development, but slightly depressed between the later fistulose attached chambers; wall calcareous, perforate, surface smooth in the early free portion, distinctly ornamented in the later portion; aperture terminal, as in Citharinella, at first at the dorsal angle, then terminal and central, but in the later attached portion there are numerous apertures at the ends of the fistulose extensions of the chambers along their margins.

Length of early free stage of holotype 1.4 mm., greatest breadth 0.84 mm., total length of test 8.9 mm., greatest breadth of fistulose chambers 2.99 mm.

Remarks: Barnard (1949, p. 285) described these specimens under the name Flabellina cf. angulosa d’Orbigny. Evidently this combination of names must be in error as d’Orbigny described no species F. angulosa so far as the authors have been able to determine. In addition no species of Cristellaria was termed angulosa by d’Orbigny. The species Frondicularia angulosa d’Orbigny is so different that it could not be this species. As no parentheses were placed around d’Orbigny’s name, the writers are in doubt as to what species Barnard referred these peculiar forms from the English Chalk. However, in the early stage of the present species compares favorably with that of Cristellaria gaudyana d’Orbigny, 1840.

Barnard considered these forms to be abnormal specimens, evidently “freaks”; but they seem to represent a trend in the development of the palmate Nososariidae, the end stage of one line of evolution. Certainly such forms, evidently not rare, which change from a free mode of existence to a fixed life, and develop a fistulose end stage with numerous apertures are worthy of recognition as a distinct genus.

Our illustration of the holotype (pl. 73, fig. 18), shows two more chambers than the illustration of this specimen published by Barnard (1949, pl. 12, fig. 6); however, these last two chambers are somewhat abraded, and are represented largely by a mere outline and some fragmentary portions of the test along the margins.

Tentifrons barnardi, new species, is similar to Cristellaria gaudyana d’Orbigny in size and shape of the early test, but C. gaudyana lacks any tendency to develop the fistulose growth in the later stage, and does not show the fistulose wall and inflated later chambers also typical of the present species.

Types and occurrence: Holotype (BMNH P40275), specimen figured by Barnard (1949), pl. 12, fig. 6 and paratype (BMNH P40274), specimen figured by Barnard (1949), pl. 12, fig. 5, both from the Belenlitella mucronata zone (Upper Senonian) of the Upper Chalk of Tharston, Norfolk County, England. Collected by A. W. Rowe.

Barnard (1949, pl. 12) also figured specimens similar to these from Councils Pit, Newmarket Road, Norwich, and from Stonehill Kiln, Norwich, both also from the Belenlitella mucronata zone of the Upper Chalk (BMNH P40272 and P40273).

Family Polymorphinidae d’Orbigny, 1846

Genus Webbinella Rhumbler, 1904, emended


Plate 72, Figure 19

Type species: Webbinia hemisphaerica Jones, Parker and Brady, 1865. Subsequent designation by Cushman (1918, p. 61).

Test attached, consisting of an initial polymorphine stage of three chambers, surrounded by a larger circular fourth chamber spreading on the surface of the substratum; wall calcareous, perforate; aperture not evident.

Remarks: The holotype of Jones, Parker and Brady, in the British Museum, is an attached hemispherical form, but is calcareous and not agglutinated. Furthermore, when dampened with glycerine the chamber divisions can be seen and the species is shown to be a polymorphinid, completely unlike the arenaceous forms usually placed under Webbinella. It is similar therefore to Bullopora Quenstedt, but differs in having an early multilocular polymorphine stage. It differs from Histopomphus Loeblich and Tappan in having a circular spreading attachment and not a branched and irregular one.
Type and occurrence: Holotype (BMNH P41659) here figured, from the Lower Crag (Pliocene) of Sutton, Suffolk, England.

? Family Virgulinidae Cushman, 1927

Aeolostreptis Loeblich and Tappan, new genus

Plate 72, Figure 20

Type species: Buliminella vitrea Cushman and Parker, 1936. Derivation: aeiolos, Gr., changeable + streptos, Gr., twisted; gender feminine.)

Test free, elongate, base bluntly rounded, the early portion in a low discorbinne coil with six chambers per whorl, later reduced in number to three chambers per whorl, and becoming high spired; chambers few in number, at first low, later about equal in breadth and height, but never extremely high and elongate; sutures distinct, depressed; wall calcareous, finely perforate, granular in structure, surface smooth; aperture a loop at the inner margin of the final chamber, at right angles to the sutures, with a narrow lip at the forward margin.

Remarks: Aeolostreptis, new genus, differs from Lacosteinae Marie in the early coil being trochoid as in Discorbis Lamarck, rather than planispiral, and in there being a gradual increase in the height of the spine instead of an abrupt change in the plane of coiling from the early coil to the later spine.

Buliminella Cushman differs in having a radial rather than granular wall structure and a tapered rather than bluntly rounded base, due to the type of chamber arrangement. Buliminella has an increasing number of chambers per whorl with later development, and has a complex internal toothplate, whereas Aeolostreptis has a decreasing number of chambers in later development.

The majority of species with few chambers in the last whorl, placed in Buliminella by Cushman and Parker (1947), are in reality species referable to Praebuliminina Hofker, since typical Buliminella apparently is not found below the Eocene. Aeolostreptis, new genus, differs from Praebuliminina in having the early many-chambered coil forming a bluntly rounded base, instead of being triserial throughout and increasing gradually in diameter.

It resembles Virgulinina in having a granular wall, unlike the radial-walled Buliminae, but has an early spire, rather than a twisted biserial development. It is therefore referred to the Virgulinidae questionably for the present.

Types and occurrence: Holotype of Buliminella vitrea Cushman and Parker (Cushman Coll. 22575), paratypes (Cushman Coll. 32550) from the Selma group, Dermpolis chalk (Campanian), 2 miles west of Guntown, Mississippi. Collected by G. M. Ponton.

Figured hypotype (Cushman Coll. 32549) from chalk of the Selma group, 11½ miles east of Blue Springs, Mississippi. Unfigured hypotypes (Cushman Coll. 32547) from chalk of the Selma group, 1 mile west of Tupelo, Mississippi. Unfigured hypotypes (Cushman Coll. 32548) from chalk of the Selma group, 1 mile east of Booneville, Mississippi. All hypotypes collected by G. M. Ponton.

Family Virgulinidae Cushman, 1927

Sigmasvirgulina Loeblich and Tappan, new genus

Plate 73, Figures 1, 2; Text-figure 30

Type species: Bolivina tortuosa Brady, 1881. (Derivation: sigma, Gr., letter S + Virgulina, genus of Foraminifera; gender feminine.)

Test free, biserial, with chambers added slightly more than 180° apart, forming a sigmoilne type of arrangement with two series of chambers at first forming a tight low spire, later developing a higher spire, and appearing almost regularly biserial although somewhat twisted throughout, periphery angled or with a distinct keel, chambers numerous, increasing regularly in height as added, increasing more rapidly in breadth so that the test is flaring; sutures distinct, thickened, depressed; wall calcareous, of calcite (by X-ray determination), coarsely perforate, granular in structure, surface smooth or with short spines, especially in the early portion; aperture at the inner margin of the final chamber, an elongate oval, surrounded by a lip which passes gradually into the peripheral keel, in some specimens the aperture may tend to become terminal, and is situated a short distance above the base of the chamber.

Remarks: Sigmasvirgulina, new genus, differs from Bolivina d'Orbigny in having a granular instead of a radial wall structure, in the early sigmoilne type of development, and the twisted adult test resulting from this process. Typical Bolivina may also have fingerlike extensions of the chambers extending back over the preceding sutures.

Sigmasvirgulina is thus much closer to Virgulina d'Orbigny in having a granular wall and a twisted biserial test. It differs in having a compressed rather than rounded test, broad low chambers rather than very high and elongate ones, and a coarsely perforate test.

Figure 30.—Outline camera lucida drawing of basal view of Sigmasvirgulina tortuosa (Brady) to show spiral biserial chamber arrangement and sigmoilne curve of plane of biseriality. P, proloculus, 1-7, and 1'-6' showing the two spiralling series of chambers. X 125.

Numerous references in the past have erroneously stated that Virgulina has a triserial base. Topotypes of the type species, V. squammosa d'Orbigny, from the Pilocene of Italy, when examined from the base show the same highly twisted biserial development as in Sigmasvirgulina. Those species with a true triserial
base must be referred to another genus. Many have radial walls and probably belong to the Buliminidae. The Recent species figured and discussed by Hofker (1951, p. 268) as Cassidella squammosa (d'Orbigny) is not conspecific and probably not congeneric with true V. squammosa, as he states that the walls are opaque. In typical V. squammosa the wall is hyaline, as was mentioned by d'Orbigny.

**Types and occurrence:** The type species, Bolivina tortuosa Brady, is a very common species in the Indo-Pacific area. Figured hypotypes (USNM P4857a,b) are from the Recent, near Nairai, Fiji.

**Family Spirillinidae Reuss, 1861**

Sejunctella Loebllich and Tappan, new genus

**Type species:** Sejunctella earlandi Loebllich and Tappan, new species. (Derivation: Sejugo, sejunctus, L., disunited, separated + ella, L., diminutive; gender feminine.)

Test free, planispiral, discoidal, and may have a peripheral keel; globular to ovate proloculus followed by loosely wound, spiral, undivided, tubular second chamber that does not lie in contact with the previous whorl but is separated from it by a solid platelike area; wall calcareous, finely perforate, chamber wall and peripheral keel, when present, formed of a single crystal of calcite, but the intercalary plate between coils of the tubular chamber is composed not of a single crystal but of secondary granular calcite; aperture a rounded opening at the end of the tubular chamber.

**Remarks:** Sejunctella differs from Spirillina Ehrenberg in the presence of the platelike intercalation between the planispiral whorls, a condition considered to be generically important, not only on external appearance but also because it differs in structure, being composed of granular calcite instead of a single crystal as is the remainder of the test. The type species has a peripheral keel on the final whorl, but this may be lacking in other species.

Spirillina late septata Terquem, 1875, from the Recent beach at Dunkerque, Dept. du Nord, France, and S. viipara var. carinata Halkyard, 1889, from Recent dredging at 3½ to 5 fathoms, St. Brelade's Bay, Jersey, Channel Islands, also belong to this genus.

Sejunctella earlandi Loebllich and Tappan, new species

**Plate 73, Figure 6**

Spirillina late septata Terquem Cushman (not Terquem, 1875), U. S. Nat. Mus. Bull. 104, pt. 8, p. 6, pl. 1, figs. 13a,b (not figs. 12a,b), pl. 2, fig. 1, 1931.

Test free, planispiral, discoidal, or sometimes more flattened on one side or even planoconceav, with finely fimbriate peripheral keel; globular to ovate proloculus, followed by loosely wound, spiral, undivided, tubular second chamber of about three to three and a half whorls separated from each other by a solid platelike area; wall calcareous, finely perforate, chamber walls and peripheral keel formed of a single crystal of calcite, but the intercalary plate between coils of the tubular chamber is composed of granular calcite; aperture a rounded opening at the end of the tubular chamber on the periphery.

Greatest diameter of holotype 0.23 mm, least diameter 0.18 mm. Paratypes range from 0.21 to 0.39 mm, in greatest diameter.

**Remarks:** This species was included by Cushman (1931, p. 6) in Spirillina late septata Terquem, but differs in being about one-half to one-third as large, and in the presence of a peripheral fimbriate keel, as S. late septata has a smoothly rounded periphery and only the intercalary plate between whorls. S. viipara var. carinata Halkyard is much larger than the present species.

The specific name is given in honor of Arthur Earland in recognition of his excellent works on the Recent Foraminifera.

**Types and occurrence:** Holotype (USNM P3294) and unfigured paratypes (USNM P3295) from F. C. Goldseeker Station 18, lat. 62° N., long. 6°12' W., off Faroe Islands at 128 meters. Unfigured paratypes (USNM P3297) from Porcupine Station 7, 3rd cruise 1870, lat. 48°18' N., long. 9°11' W., depth 93 fathoms, and unfigured paratype (USNM P3296) from Belgium station 1744, lat. 51°23' N., long. 3°15'E, depth 14.25 meters.

**Family Discorbidae Cushman, 1927**

Eurycheilostoma Loebllich and Tappan, new genus

**Type species:** Eurycheilostoma altispira, new species. (Derivation: eury, Gr., broad, wide + cheilos, Gr. lip + stoma, Gr., mouth; gender feminine.)

Test free, trochospiral, high spired, all chambers visible from the high conical spiral side, only the final whorl visible on the flattened to concave, deeply umbilicate, umbilical side, earliest whorl with four to six chambers and may be reduced in well developed specimens to three or four chambers per whorl, the last chamber occupying one-half or more of the ventral side, extending around both sides of the open umbilicus, the final whorl of chambers may abruptly attain a greater diameter, giving a flaring appearance to the test; sutures distinct, depressed; wall calcareous, finely perforate, surface smooth; aperture a broad arch at the inner margin of the last chamber, opening into the umbilicus, and partially covered by a broad lip, extending out over the umbilicus from the final chamber, which may have a serrate margin.

**Remarks:** Eurycheilostoma, new genus, differs from Discorbis Lamarck in the commonly high spired test, the large final chamber, which occupies one-half or more of the umbilical side, the absence of the alar chamber flaps of Discorbis and the presence of a broad serrate umbilical flap.

It is closest to Neoconorbina Hofker, differing in being high spired in character, rather than low and scalelike, and in having a rounded periphery and sub-
globular rather than semilunate chambers. The apertural characters are similar, each having a broad umbilical flap with apertural reentrants at its two extremities.

Superficially, high-spired species of this genus may resemble Bulimina d'Orbigny or Praebulimina Hofker, but the present genus has a completely different broad low aperture and open umbilicus, with the flap extending over the umbilicus, whereas the Buliminidae typically have loop-shaped apertures and an internal toothplate.

_Eurycheilostoma altispira_ Loeblich and Tappan, new species

**PLATE 73, FIGURES 3, 4**

Test free, tiny, trochospiral, high spired, umbilical side flattened to concave, deeply umbilicate, periphery rounded, chambers inflated and increasing rapidly in size, all of the two and a half whorls visible on spiral side, only the three chambers of the last whorl visible on umbilical side, with the final chamber occupying over half the periphery and the umbilical side; sutures distinct, umbilical side depressed, spiral side less depressed; wall calcareous, finely perforate, surface smooth; aperture a broad low arch at the inner margin of the final chamber on the ventral side, covered over by a narrow flap extending for a distance about half the diameter of the test, leaving a reentrant at its two extremities.

Greatest diameter of holotype 0.19 mm., height of spire 0.23 mm. Figured paratype 0.18 mm. in diameter, 0.17 mm. in height. Unfigured paratypes vary from 0.13 to 0.29 mm. in diameter and 0.10 to 0.29 mm. in height.

Remarks: _Eurycheilostoma altispira_, new species, differs from Discorbis scanica Broten in being higher spired, with less inflated chambers and having a broader apertural flap.

**TYPES AND OCCURRENCE:** Holotype (USNM P4882), figured paratype (USNM P4883), unfigured paratypes (USNM P4884 and P4885) from the Goodland formation (Albian), at Lake Worth Dam, 5.5 miles (airline) northwest of the courthouse in Fort Worth, Tarrant County, Texas. Collected by H. T. and A. R. Loeblich, Jr.

Unfigured paratypes (USNM P4886 and USNM P4887) from the Goodland formation, 3.8 miles west of Montgomery Street on Vickery Boulevard (Old Stove Foundry Road), at Cragin Knobs, Fort Worth, Tarrant County, Texas. Collected by H. T. and A. R. Loeblich, Jr.

_Sestrionophora_ Loeblich and Tappan, new genus

**TYPE SPECIES:** _Sestrionophora arnoldi_, new species. (Derivation: _sestron_, Gr., n., sieve + _phor_, Gr., suffix, to bear or carry; gender feminine.)

Test free, large, trochospiral, nearly planoconvex, periphery acute and with a keel; all whorls visible on the strongly convex spiral side where chambers are of greater breadth than height, somewhat oblique and overlapping at the periphery, only the chambers of the final whorl visible on the nearly flat, umbilicate side, the broad ventral umbilicus covered by a series of plates arising from the umbilical margin of each chamber and pierced by numerous very large openings leading through the plates to the open umbilical area beneath, which also opens laterally beneath the plate into the various chamber cavities; sutures distinct, somewhat thickened, gently curved and inclined back along the periphery and depressed on spiral side, nearly radial and more strongly depressed on umbilical side; wall calcareous, finely perforate, surface smooth; aperture a low slitlike opening on the umbilical side and at the margin of the final chamber extending from the umbilicus about half the distance to the periphery, with a few small accessory pores in the ventral face of the final chamber.

Remarks: _Sestrionophora_, new genus, is similar to _Eponides_ Montfort but differs in having the umbilical area covered by a series of plates pierced by pores and in having supplementary openings on the umbilical side of the final chamber. It is similar to _Poreoepides_ Cushman in having a few rounded openings on the umbilical side of the final chamber, but differs in possessing the complex perforated umbilical plates.

_Sestrionophora arnoldi_ Loeblich and Tappan, new species

**PLATE 73, FIGURE 5**

_Pulvinulina punctulata_ (d'Orbigny), BAGG (not Rotalia (Rotalie) punctulata d'Orbigny, 1826), U. S. Geol. Survey Bull. 513, p. 86, pl. 25, figs. 6-9, 1912.

Test free, large, trochospiral, strongly convex on spiral side, umbilical side flattened and broadly umbilicate, periphery acute, keeled; 2½ whorls visible on spiral side, with chambers of greater breadth than height and increasing in proportionate breadth as added; somewhat overlapping at the periphery, only the five to six chambers of the final whorl visible on the umbilical side, with the final chamber occupying about one-third of the area, umbilicus occupying about one-third the diameter of the test, and covered by a series of plates arising at the inner margin of each chamber and pierced by six or more relatively large openings, with additional openings left around the margins of the sieve plate, all openings connecting with the cavity beneath the plates and laterally into the chamber cavities also; sutures distinct, thickened, depressed, gently curved, strongly inclined backwards at the periphery on the spiral side, nearly radial and more strongly depressed on the umbilical side; wall calcareous, finely perforate, surface lightly sculptured in the early portion on the spiral side, smooth on the umbilical side; aperture a low slit-like interiomarginal opening extending from the umbilicus about ⅓ the distance to the periphery, with from five to eight small supplementary openings in the face of the final chamber.

Greatest diameter of holotype 2.05 mm., thickness 0.94 mm. Paratypes range from 1.72 to 2.39 mm. in diameter.
Remarks: This species was recorded by Bagg as Pulvinulina punctulata (d’Orbigny), but it differs from the latter in the less angular periphery, fewer chambers per whorl, in having the umbilical sieve plate over the large umbilicus, and in having the supplementary interioareal apertural openings, in addition to the pores in the sieve plate and the primary interiomarginal aperture.

Sestronophora arnoldi Loeblich and Tappan, new species, differs from Poroeponides lateralis (Terquem) in being about twice as large, in having a more gradual increase in chamber height, a less enlarged final chamber, a wider umbilicus and an umbilical sieve plate, and a more restricted series of supplementary apertural pores.

It differs from Eponides repandus (Fichtel and Moll) in being nearly twice as large, in having less thickened sutures and a broad umbilicus, umbilical sieve plate and supplementary apertures on the face of the final chamber.

The specific name is in honor of Zach Arnold, in recognition of his work on the life history of the Recent Foraminifera.

Types and occurrence: Holotype (USNM P3130) and unfigured paratypes (USNM P3131) from the lower Pleistocene, Santa Barbara formation, Pine Cone Hollow, Santa Barbara, California. Collected by F. C. Clark.

Family Cassidulinidae d’Orbigny, 1839

Favocassidulina Loeblich and Tappan, new genus

Plate 73, Figures 7-11

Type species: Pulvinulina favus Brady, 1877. (Derivation: favus from favus, L., m., honeycomb+cassid from cassida, L., helmet (cassidula), f., diminutive+fina, L., diminutive; gender feminine.)

Test free, planispiral, biumbilicate, both sides somewhat excavated centrally, periphery truncate; chambers laterally inflated, with their umbilical margins extending backward in a flap covering part of the previous suture and chamber, the flaps more rarely coalescing to obscure the commonly open umbilicus; sutures radial, depressed; wall calcareous, with clear imperforate wall on the sides and apertural face, coarsely perforate truncate periphery; aperture a broad low slit on the periphery bordered above by a narrow lip, at the base of the final chamber and against the preceding whorl, with supplementary openings beneath the umbilical chamber flaps on each side of the test.

Remarks: Paromalina, new genus, is similar to Discanomalina Asano in being planispiral, with broad periphery and depressed sides, but the present genus has the clear imperforate appearing shell wall on both sides of the test, and is coarsely perforate only on the truncate periphery. Discanomalina has the clear shell material and chamber flaps with secondary openings only on one side of the test, the entire opposite side being coarsely perforate, and lacking the umbilical flaps.

In addition to the type species, Anomalina coronata Parker and Jones, 1857, and A. coronata var. crassa Cushman, 1931, also belong to this genus. We believe the latter should be considered a distinct species, Paromalina crassa (Cushman), and not a variety of coronata.

Asano (1951, p. 13) had considered Anomalina coronata to belong to Discanomalina, but in describing that genus he stated “wall calcareous, coarsely perforate except for a large area of clear shell material in the umbilical region of ventral side.” However,
Parker and Jones' original description (1857, p. 294) stated that A. coronata "affects a bilateral symmetry, the two surfaces being often nearly equal," and this character is shown in their illustrations. Asano also placed Rotalina semipuncta Bailey, 1851, in Discano- malina, and this species is correctly assigned, having the clear shell material and chamber flaps only on one side, with the opposite side entirely coarsely perforate.

Paromalina bilateralis Loeblich and Tappan, new species

**Plate 73, Figures 12, 13**

Test, free, planispiral, biumbulate, very thick, with broad truncate periphery, early whorls obscured on both sides, seven to nine chambers in the final whorl, about equal in breadth and height, but with much greater thickness, truncate on the periphery and laterally inflated, chambers with an umbilical flap on each side that extends backward over the previous suture and toward the umbilicus to cover earlier whorls, rarely coalescing with those of other chambers to obscure the more commonly open umbilicus; sutures distinct, radial, depressed; wall calcareous, smooth, very coarsely perforate on the truncate peripheral portion of the chambers, but the sides and umbilical flaps and the apertural face are clear and apparently imperforate, and commonly a small imperforate area formed by the peripheral portion of the previous septal face is left exposed just behind the suture when the next chamber is added, giving an erroneous impression of thickened imperforate sutures, although the actual sutures are depressed; aperture a broad low slit at the base of the final chamber on the periphery and against the preceding whorl, bordered above by a slight lip, with supplementary openings beneath the umbilical and posterior margins of the umbilical chamber flaps on each side of the test.

Greatest diameter of holotype 0.78 mm., least diameter 0.68 mm., greatest thickness 0.65 mm. Paratypes range from 0.70 to 0.99 mm. in greatest diameter.

**Remarks:** This species is very similar to Anomalina coronata Parker and Jones, but neither their original illustration nor that of Brady (1884, pl. 97, figs. 1 and 2) show the large and distinctive flaps, covering the umbilical region and obscuring the earlier whorls, that are characteristic of the present species. Much smaller flaps are shown by Brady, but a portion of the previous whorl is left exposed on both sides. The figure given by Parker and Jones (1857, pl. 10, fig. 15) is too small to show these details clearly, but they also show the earlier whorls visible in the umbilical region.

**Types and Occurrence:** Holotype (USNM P4883) and unfigured paratypes (USNM P3216) from the Recent, Albatross Station D2262, lat. 39°54'45" N., long. 69°29'45" W., at 250 fathoms.

Figured paratype (USNM P3137), unfigured paratypes (USNM P3136 and P3138) from F. C. Goldseeker Station 16, Haul 89, lat. 62° N., long. 6°12' W., at 128 meters. Collected July 8, 1907.

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Tappan, H.

Wood, A.
The Foraminiferal Genus Cruciloculina d’Orbigny, 1839

By Alfred R. Loeblich, Jr., and Helen Tappan

Introduction

The genus *Cruciloculina* was described in 1839, and d’Orbigny (1839b) later recorded a single species, *C. triangularis*. Later workers did not recognize this genus, however, considering it a synonym of *Triloculina* d’Orbigny, in spite of the distinctive cruciform aperture. A century later Asano (1949, p. 479) made a detailed study of the apertural development of a second species, *Cruciloculina japonica*, and emended the generic diagnosis. The type species for the genus was from the Recent seas off the Falkland Islands, and the species described by Asano was from the Pliocene of Japan.

During the course of generic studies of Foraminifera for the "Treatise on Invertebrate Paleontology," the writers examined d’Orbigny’s types of *Cruciloculina* in the Museum National d’Histoire Naturelle in Paris. A lectotype for this species is here selected, refugited, and described. An additional topotype specimen of *C. triangularis* has also been illustrated.

A toptotype specimen of *C. japonica* Asano from the Japanese Pliocene is illustrated and a brief description given for comparison.

Three new Recent species of the genus are also here described, two occurring in the Caribbean and the other in the North Atlantic off southwestern Ireland.

Systematic Descriptions

Family Miliolidae d’Orbigny, 1839

Genus Cruciloculina d’Orbigny, 1839


Type species: *Cruciloculina triangularis* d’Orbigny, 1839. Fixed by subsequent monotypy by d’Orbigny (1839b, p. 72).

Test free, chambers coiled, with the longitudinal planes of successive chambers added 120 degrees apart as in the development of *Triloculina*, test rounded to triangular in section; sutures distinct, depressed; wall calcareous, imperforate, smooth or faintly striate; aperture complex, varying in shape from triradiate in the young to cruciform or denticrinite in the adult, bordered by a narrow lip, but without a distinct tooth.

*Cruciloculina* differs from *Triloculina* d’Orbigny in the apertural features, lacking the distinct tooth of *Triloculina* and developing from a simple linear, bifid or triradiate aperture in the young to a cruciform or denticrinite aperture in the adult.

This genus occurs in the Pliocene of Japan and in the Recent in the North and South Atlantic and Caribbean.

*Cruciloculina* asanoi Loeblich and Tappan, new species

Plate 74, Figures 8–11

Test free, triloculine in chamber development, ovate in side view, subtriangular in section, angles rounded; chambers with slight amount of overlap, so that those in the final whorl appear nearly equal in size; sutures distinct, slightly incised; wall calcareous, imperforate, surface smooth, aperture triradiate in young specimens, becoming cruciform in the adult.

Length of holotype 1.06 mm., thickness from center of final chamber to opposite angle 0.94 mm. Paratypes range from 0.51 to 1.10 mm. in length.

Remarks: This species is similar in appearance to *C. japonica* Asano, but differs in the very slight amount of chamber overlap, somewhat smaller size, and much less complex adult aperture, that of *C. asanoi* becoming only cruciform, whereas that of *C. japonica* may become highly denticrinite in appearance.

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The species is named in honor of Dr. K. Asano, in recognition of his work on this genus, as well as the other groups of Foraminifera.

**Types and occurrence:** Holotype (USNM P4880), figured paratypes (USNM P4267a–c), and unfigured paratypes (USNM P4268) from Challenger Station 24, lat. 18°38′30″ N., long. 65°05′30″ W., at 390 fathoms, in the Caribbean Sea.

**Cruciloculina ericsoni** Loeblich and Tappan, new species

**Plates 74, Figures 3–7**

Test free, ovate in section, nearly circular in side view, chambers trilocule in arrangement, final chamber with considerable overlap of earlier chambers, the margins of the chambers with a slight flange, which leaves a groove paralleling the suture at the contact with earlier chambers; sutures distinct, slightly incised; wall calcareous, imperforate, surface smooth; aperture triradiate in young specimens, becoming cruciform to dendritic in the adult, bordered by a distinct, slightly recurving lip.

Length of holotype 1.08 mm., breadth (from center of final chamber to opposite side) 1.05 mm.

**Remarks:** Cruciloculina ericsoni, new species, differs from *C. japonica* Asano in being smaller and more inflated, nearly circular in side view, and in lacking distinct angles; and in the slight chamber flange bordering the sutures. The apertural lip is also somewhat more prominent.

The species is named in honor of David Ericson in recognition of his work on deep sea cores.

**Types and occurrence:** Holotype (USNM P3140) and figured paratypes (USNM P4338a–d) from F. C. Helga Haul SR 331, southwest Ireland, lat. 51°12′ N., long. 11°55′ W., at a depth of 610 to 680 fathoms.

**Cruciloculina japonica** Asano, 1949

**Plate 74, Figure 12**

**Cruciloculina japonica** Asano. Journ. Palentol., vol. 23, no. 5, p. 480, pl. 80, figs. 1–2, 6–13, 1949.

Test free, trilocule in chamber development, sub-triangular in section with rounded angles, final chamber with considerable overlap of the earlier chambers, so that the final chamber covers nearly one-half the width when the test is viewed from the side showing the oldest of the three final chambers; sutures distinct, slightly incised; wall calcareous, imperforate, surface smooth; aperture triradiate in young specimens, then becoming cruciform and finally dendritic in adult specimens, with a narrow bordering lip.

Length of figured topotype 1.63 mm., greatest thickness, from center of last chamber to opposite angle, 1.43 mm., although the majority of specimens are somewhat smaller.

**Remarks:** Cruciloculina japonica Asano differs from *C. triangularis* d’Orbigny in being slightly smaller, and much less distinctly triangular, with more convex sides and rounded angles. The aperture of *C. japonica* also tends to become more complexly dendritic.

**Types and occurrence:** Figured topotype (USNM P4339) and unfigured topotypes (USNM P3221, P4864) from the Late Pliocene Sawane formation in a sea cliff facing Mano Bay, Sawane-Machi, Sado-Gun, Niigata Prefecture, lat. 37°59′47″ N., long. 138°16′43″ E., Japan. Collected by T. Uchio.

Unfigured topotypes (USNM P63) from the same locality. Collected by K. Asano.

**Cruciloculina striata** Loeblich and Tappan, new species

**Plate 74, Figures 13–16**

Test free, medium in size, robust, sides convex, subovate in section; chambers arranged as in *Triloculina*, inflated, with considerable overlap of earlier chambers; sutures distinct, flush to slightly incised; wall calcareous, imperforate, surface ornamented by numerous very fine longitudinal striae; aperture triradiate in young specimens, cruciform to dendritic in older specimens.

Length of holotype 1.04 mm., thickness from center of final chamber to opposite side 0.96 mm. Paratypes range from 0.73 to 1.09 mm. in length.

**Remarks:** Cruciloculina striata, new species, is closest to *C. ericsoni*, new species, in general form, but differs in the presence of the vertical striae which are characteristic of the present species.

**Types and occurrence:** Holotype (USNM P4264), figured paratypes (USNM P4265a–c), and unfigured paratypes (USNM P4266) all from Challenger Station 24, lat. 18°38′30″ N., long. 65°05′30″ W., in the Caribbean Sea at 390 fathoms.

**Cruciloculina triangularis** d’Orbigny, 1839

**Plate 74, Figures 1, 2**

**Cruciloculina triangularis** d’Orbigny, Voy. dans l’Amérique Mérid., Foraminifères, p. 72, 1839.

Test free, trilocule in chamber development, triangular in section, with sides equal in breadth and flat to very slightly convex and angles acute; chambers increasing regularly in size with final chamber only moderately overlapping earlier chambers; sutures distinct, very slightly incised; wall calcareous, imperforate, surface smooth; aperture typically cruciform, with the extremities tending to become dendritic in larger specimens, bordered with a narrow lip.

Length of lectotype 1.28 mm., greatest thickness (from center of final chamber to opposite angle) 1.13 mm. The topotype here figured is 1.9 mm. in length and the breadth of the final chamber is 1.68 mm.

**Remarks:** This species is characterized by the sharply triangular section, large size, and relatively simple cruciform aperture.

**Types and occurrence:** Lectotype (here designated and figured) of *C. triangularis* d’Orbigny in the Museum National d’Histoire Naturelle, Paris, France, from Recent dredgings near the Falkland Islands. Figured topotype (USNM P4520) and unfigured topotypes (USNM P4521) from R. R. S. Discovery Station 144, from lat. 54°04′ S., long. 36°27′ W., to lat. 53°58′ S., long. 36°26′ W., off the mouth of Stromness Harbor, depth 155–178 meters, South Georgia.
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Figures 1a, b. *Globigerinelloides algeriana* Cushman and ten Dam

1a, Side view of paratype (Cushman Coll. 56790), showing evolute coil, umbilical chamber extensions and sinuate sutures. 1b, Edge view, showing low arched equatorial aperture. From the Aptian (Lower Cretaceous) of Algeria. × 75.

Figures 2a–3b. *Planomalina apsidostroba* Loeblich and Tappan

2a, Side view of holotype (Cushman Coll. 45667), showing peripheral keel, limbate sutures and the lips of the lateral relict apertures. 2b, Edge view, showing equatorial primary aperture. × 110. 3a, Side view of hypotype (USNM P3934) with well preserved relict apertures in later chambers. 3b, Edge view, × 145. From the Lower Cretaceous (Albian) of Texas.

Figures 4a–5b. *Planomalina caseyi* Bolli, Loeblich, and Tappan, new species

4a, Side view of holotype (USNM P4869) showing planispiral test and relict apertures. 4b, Edge view, showing equatorial primary aperture, with the secondary relict apertures of earlier chambers remaining open. 5a, Side view of paratype (USNM P4870). 5b, Edge view of paratype. Both from the Gault (Albian), Lower Cretaceous, of England. × 180.

Figures 6a, b. *Hastigerinoides watersi* (Cushman)

6a, Side view of topotype (USNM P3934), showing well preserved relict supplementary apertures. 6b, Edge view, showing low arched primary aperture. From the Austin chalk (Upper Cretaceous) of Texas. × 130.

Figures 7a–10b. *Hastigerinoides alexanderi* (Cushman)

7a, Side view of holotype (Cushman Coll. 15750), showing radial elongate chambers. 7b, Edge view. 8a, 10a, Side views of topotypes (USNM P3920a, b), showing relict apertures around umbilical region, and variation in the shape of the radial elongate chambers. 8b, 10b, Edge views, showing low arched equatorial aperture. 9, Paratype (Cushman Coll. 15754). All from the Austin chalk (Upper Cretaceous) of Texas. × 95.

Figures 11–12b. *Biglobigerinella multispina* Lickler

11, Edge view of hypotype (USNM P3214a), showing lateral paired apertures. From the Upper Cretaceous Taylor marl (Campanian) of Texas. 12a, Side view of holotype (Cushman Coll. 51898), showing spherical chambers and deeply umbilicate test. 12b, Edge view, showing final paired chambers. From the Upper Cretaceous Maribrook marl (Campanian) of Arkansas. × 160.

Figures 13–18b. *Biglobigerinella barri* Bolli, Loeblich, and Tappan, new species

13, Side view of large paratype (USNM P4544a), showing well developed lateral relict supplementary apertures and somewhat sigmoid sutures of the larger specimens. 14–17, Edge views of paratypes (USNM P4544b–e), showing progressive apertural development, from a single equatorial arch to paired arched openings and finally paired chambers. 18a, Side view of holotype (USNM P4543), showing paired final chambers. 18b, Edge view, showing paired final chambers, each with separate aperture. All from the Lower Cretaceous Maridale formation of Trinidad, B.W.I. × 85.
HANTKENINIDAE: PLANOMALININAE
HANTKENINIDAE: HANTKENININAE
Plate 2. Hantkeninidae: Hantkenininae

Figures 1a–2. Schackoina cenomana (Schacko) 26
1a, b, Opposite sides of hypotype (USNM P464a), showing radially elongate chambers and basal portion of the tubulospines, which were broken in preservation. 1c, Edge view, showing low equatorial aperture. 2, Side view of smaller hypotype (USNM P464b). From the Cenomanian of Germany. × 230.

Figures 3a–4b. Hantkenina aragonensis Nuttall 26
3a, Side view of lectotype (Cushman Coll. 59476) of this species, which was designated as type species for the subgenus Aragonella Thalmann, with radially elongate chambers. 3b, Edge view, showing high arched aperture. 4a, Side view of paratype (Cushman Coll. 59477). 4b, Edge view. From the Eocene Aragon formation of Mexico. × 60.

Figures 5a–6. Hantkenina dumblei Weinzierl and Applin 26
This species was designated as type for the subgenus Applinella Thalmann. 5a, Side view of paratype (USNM P4790), showing how greater overlap of succeeding chambers changes the apparent position of the spines. 5b, Edge view showing high arched aperture. 6, Side view of lectotype (Cushman Coll. 12204) with elevated lips of previous apertures showing in the radial elevations paralleling the sutures. From the Eocene Yegua formation of Texas. × 65.

Figures 7a–b. Hantkenina alabamensis Cushman 26
var. primitiva Cushman and Jarvis
Designated as type species for the subgenus Hantkenella Bronnimann. 7a, Side view of holotype (Cushman Coll. 10067), showing the absence of spine on earlier chamber, which was the basis for the subgenus Hantkenella, but which is a variable character in this and other species. 7b, Edge view, showing high equatorial aperture, with lateral extensions beneath the apertural flanges, giving a triradiate appearance. From the Eocene San Fernando formation, Trinidad, B.W.I. × 35.

Figures 8a–b. Hantkenina alabamensis Cushman 26
8a, Side view of hypotype (USNM P4791), showing planispiral biumbilicate test, with spinate chambers. 8b, Edge view, showing triradiate aperture and lateral apertural flanges. From the Pachuta formation, Jackson Eocene of Alabama. × 35.

Figures 9a–11b. Cribrohantkenina bermudezi Thalmann 28
9a, 10a, 11a, Side views of hypotypes (USNM P4784a–c), showing typically robust appearance. 9b, Edge view, showing early development of supplementary areal aperture of only two openings, in addition to the low arched primary interiomarginal equatorial aperture. 10b, Edge view to show complete arched row of pores of the multiple aperture, with lateral remnants of the primary aperture. 11b, Edge view, showing multiple areal aperture of 2½ rows, with primary aperture completely closed, and supplementary openings also nearly completely obscured by a secondary deposit of shell material. Opening at top of illustration shows where large spine was broken. From the Pachuta formation, Jackson Eocene of Alabama. Fig. 9, × 35; figs. 10, 11, × 65.
Plate 3. HANTKENINIDAE : HASTIGERININAЕ, CASSIGERINELLINAЕ

Figures 1–3b. Hastigerina murrayi Thomson

1, 2, Hypotypes (BMNH ZF1562), mounted in balsam, were living specimens from tow net of the Challenger, and show the extremely elongate and delicate spines present in life. The protoplasm is also preserved within the shell, but the chamber arrangement can be seen. 1, Edge view; 2, side view of different specimens.

3, Dead shell of this species, from dredgings in the South Atlantic, showing how spines have been broken. 3a, Side view (BMNH ZF1563), showing planispiral test. 3b, Edge view, showing broad equatorial arched aperture. From the Recent of the South Atlantic. × 50.

Figures 4a, b. Hastigerina aequilateralis (Brady)

4a, Side view of topotype (USNM P3918) of the species designated as type for Globigerinella Cushman, showing the planispiral test and large equatorial aperture. 4b, Edge view. From the Recent of the Pacific. × 70.

Figures 5a, b. Clavigerinella akersi Bolli, Loeblich, and Tappan, new genus, new species

5a, Side view of holotype (USNM P4550), showing early spherical chambers and later clavate ones, and broad lateral apertural flanges. 5b, Edge view, showing high arched aperture. From the Eocene Navet formation of Trinidad, B.W.I. × 65.

Figures 6a–c. Cassigerinella boudecensis Pokorný

6a, b, Opposite sides of topotype (USNM P3389) with arched aperture visible in fig. 6b. 6c, Edge view, showing biserial enrolled test and arched aperture. From the middle Oligocene of Czechoslovakia. × 300.
HANTKENINIDAE: HASTIGERININAE, CASSIGERINELLINAE
ORBULINIDAE: GLOBIGERININAE
Plate 4. ORBULINIDAE: GLOBIGERININAE

Figures 1a–c. Globigerina bulloides d’Orbigny

1a, Spiral side of hypotype (USNM P3917).
1b, Umbilical side, showing broad arched umbilical aperture. 1c, Edge view. From Recent beach sand, Porto Corsini, Italy. × 115.

Figures 2a–c. Globigerinoides rubra d’Orbigny

2a, Spiral side of hypotype (USNM P3916), showing supplementary sutural apertures. 2b, Umbilical view, showing umbilical primary aperture. 2c, Edge view. From the Recent of the Atlantic. × 95.

Figures 3a–5. Pulleniatina obliqueloculata (Parker and Jones)

3a, Spiral view of paratype (USNM P4228).
3b, Apertural view, showing result of trochospiral coiling with earlier umbilicus covered by later whorls; broad arched aperture and thickened lip. 3c, Edge view. From the Recent of Abrolhos Bank, South Atlantic. × 110. 4a, Edge view of hypotype (USNM P4229a), showing variation in the streptospiral development. 4b, Apertural view. 5, View of dissected hypotype (USNM P4229b), showing neanic Globigerina stage, with typically umbilical aperture, and change in plane of coiling with later growth. Hypotypes from the Recent of the Pacific. × 75.
Plate 5. ORBULINIDAE: GLOBIGERININAE

Figures 1, 2. *Hastigerinella rhumbleri* Galloway
1, Umbilical view, showing clavate chambers and elongate spines. 2, Spiral view, showing spiroumbilical interiomarginal aperture. After Rhumbler’s original figures of *Hastigerina digitata* Rhumbler (not Brady) from the Recent of the Atlantic. × 10.

Figures 3a, b. *Hastigerinella digitata* (Brady)
3a, Spiral side of hypotype (USNM P3037), showing continuation of the spiroumbilical aperture, and radial elongate later chambers. 3b, Umbilical side, showing aperture. From the Recent of the South Atlantic. × 95.

Figures 4a–d. *Globoquadrina altispira* (Cushman and Jarvis)
4a, Spiral view of holotype (Cushman Coll. 22482). 4b, Umbilical view, showing the umbilical aperture and the umbilical teeth, formed by the triangular apertural flaps of the final whorl of chambers. 4c, Edge view. 4d, Oblique view to show the triangular apertural flaps. From the Miocene Bowden marl of Jamaica, B.W.I. × 70.

Figures 5a–c. *Globoquadrina dehiscens* (Chapman, Parr, and Collins)
5a, Spiral view of hypotype (USNM P3926). 5b, Umbilical view, showing less well developed umbilical teeth and more closed umbilicus. 5c, Edge view. From the Miocene (Balcombian) of Victoria, Australia. × 140.

Figure 6. *Globoquadrina sp.*
6, Umbilical view of specimen (USNM P4575) from the Miocene Lengua formation, Trinidad, B.W.I., showing angular chambers as in *G. dehiscens*, but with well developed apertural teeth as in *G. altispira*. × 100.
ORBULINIDAE: GLOBIGERININAE, ORBULININAE
Figures 1–5. Sphaeroidinella kuhlicens (Parker and Jones)

1, Dissected hypotype (USNM P4225a), showing neanic Globigerina stage with umbilical aperture and coarsely perforate wall. 2a, Side view of paratype (USNM P4224a), showing thickened heavy wall of ephebic stage, and solid chamber flanges extending over the apertural area. 2b, Edge view. 3a–4b, Views of paratypes (USNM P4224b, c). 5, Edge view of hypotype (USNM P4225b), showing rare development of a supplementary bulla across the apertural groove between chamber flanges. Figs. 1, 5 from the Recent of the Atlantic, figs 2–4 from the type locality in the Recent Pacific. All × 50.

Figures 6a–c. Globigerapsis kugleri Bolli, Loeblich, 34 and Tappan, new genus, new species

6a, Spiral view of holotype (USNM P4220), showing sutural secondary apertures around the margin of the final chamber. 6b, Umbilical side, showing enveloping final chamber which has completely covered the umbilical area and primary umbilical aperture. 6c, Edge view, showing secondary apertures at margin of final enveloping chamber. From the Eocene Navet formation, Trinidad, B.W.I. × 95.

Figures 7a–c. Globigerapsis semisquillata (Keijzer) 34

7a, Spiral side of hypotype (USNM P3937), showing large secondary apertures at margin of final chamber. 7b, Umbilical view. 7c, Edge view. From the Eocene Navet formation of Trinidad, B.W.I. × 95.

Figures 8–9b. Porticulasphaera mexicana (Cushman) 35

8, Dissected hypotype (USNM P3902), showing neanic Globigerina stage with coarsely perforate wall, and very fine elongate spines preserved on the interior, and suggesting that the living specimen was also spinose. 9a, Spiral view of hypotype (USNM P3901), showing supplementary sutural apertures in the early stage, as in Globigerinoides. 9b, Edge view, showing enveloping final chamber over umbilical region which obscures primary aperture of earlier neanic stage. Numerous sutural secondary apertures occur at lower margin of final chamber. From the Eocene Navet formation of Trinidad, B.W.I. × 60.

Figures 10a–11. Candeina niuida d’Orbigny 35

10a, Spiral view of hypotype (USNM P3924), showing multiple sutural secondary apertures as in Globigerinoides. 10b, Umbilical view, showing sutural secondary apertures and absence of primary umbilical aperture in the adult. 10c, Edge view. 11, Dissected hypotype (USNM P3923), showing neanic Globigerinoides stage with both primary umbilical apertures and secondary sutural apertures. From the Recent of the Atlantic. Figs. 10a–c, × 110; fig. 11, × 100.
Plate 7. Orbulinidae: Orbulininace, Catapsydracinae

Figures 1–5. Orbula universa d’Orbigny
1, Three-chambered hypotype (USNM P3911) from the Recent Atlantic, showing rarer multicellular development, but with typical areal aperture of large scattered pores. 2, Hypotype (USNM P3908), from the Miocene Choctawhatchee formation of Florida, showing early Globigerina stage incompletely enveloped by later spherical chamber, termed “Candorbulina” by Jedlitschka. 3, Typical spherical unilocular hypotype (USNM P3910). 4, Rare bilocular form (USNM P3909) of the type described as “Biorbulina” by Blow. Both from the Recent of the Atlantic. 5, Hypotype (USNM P3907), showing “Candorbulina” type of development, from the Miocene of Austria. Figs. 1, 3, 4, × 55. Figs. 2, 5, × 95.

Figures 6a–8c. Catapsydrax dissimilis (Cushman and Bermudez).
6a, Spiral side of holotype (Cushman Coll. 23430). 6b, Umbilical side, showing umbilical bulla covering primary aperture. 6c, Edge view, showing infralaminal accessory apertures beneath umbilical bulla. From the Eocene of Cuba. 7a, 8a, Spiral side of hypotypes (USNM P4218a, b). 7b, 8b, Umbilical side, showing slight variations in size of bullae. 8c, Edge view, showing infralaminal accessory apertures. From the Oligocene-Miocene Cipero formation of Trinidad, B.W.I. All × 60.

Figures 9a–c. Catapsydrax unicavus Bolli, Loeblich, and Tappan, new species
9a, Spiral side of holotype (USNM P4216). 9b, Umbilical side, showing single infralaminal accessory aperture. 9c, Edge view. From the Oligocene-Miocene Cipero formation of Trinidad, B.W.I. × 95.

Figures 10a–c. Catapsydrax parvulus Bolli, Loeblich, and Tappan, new species
10a, Spiral side of holotype (USNM P4219). 10b, Umbilical side, showing less depressed sutures and small umbilical bulla. 10c, Edge view. From the Miocene Lengua formation of Trinidad, B.W.I. × 265.

Figures 11a–c. Catapsydrax stainforthi Bolli, Loeblich, and Tappan, new species
11a, Spiral side of holotype (USNM P4840). 11b, Umbilical view, showing larger bulla with tendency to spread along sutures, with small infralaminal accessory apertures at the suture contacts. 11c, Edge view. From the Oligocene-Miocene Cipero formation of Trinidad, B.W.I. × 95.

Figures 12a–c. Globigerinatheka barri Bronnimann
12a, Spiral side of hypotype (USNM P3922). 12b, Umbilical side, showing enveloping final chamber obscuring primary aperture and earlier umbilical region. 12c, Edge view, showing Porticulosphaera stage with development of bullae over sutural openings, characteristic of Globigerinatheka. From the Eocene Navar formation of Trinidad, B.W.I. × 95.
Plate 8. ORBULINIDAE: CATAPSYDRACINAE

Figures 1a–2c. Globigerinita naparimaensis Bronnimann

1a, Spiral side of holotype (Cushman Coll. 64182). 1b, Umbilical side, showing two infralaminal accessory apertures at the edge of the transparent bulla, which is similar in appearance and position to a normal chamber, but overlaps the earlier umbilicus, covering the primary umbilical aperture of the neanic stage, which can be seen through the semitransparent bulla. 1c, Edge view, showing accessory apertures. From the Miocene Lengua formation of Trinidad, B.W.I.

2a, Spiral side of hypotype (USNM P3914), showing sutural extensions of bulla and infralaminal accessory apertures. 2b, Umbilical side, showing well developed umbilical-sutural bulla, with numerous infralaminal apertures along all margins of the bulla. 2c, Edge view. From the Recent Atlantic. Figs. 1a–c, ×190; figs. 2a–c, ×140.

Figures 3a–c. Globigerinoides morugaensis Bronnimann

3a, Spiral side of holotype (USNM P3913), showing spiral supplementary sutural apertures, as in Globigerinoides. 3b, Umbilical side, showing umbilical bulla as in Catapsydrax. 3c, d, Edge view, of opposite edges, showing bullae over the secondary sutural apertures, typical of Globigerinoides. From the Miocene Lengua formation of Trinidad, B.W.I. ×150.

Figures 4–7c. Globigerinatella insuecta Cushman and Stainforth

4, Dissected topotype (USNM P3932a), showing areal aperture as in Orbulina, covered by the bulla which has been partially removed, with infralaminal accessory openings visible at the lower margin of the remaining part of the bulla. 5a, Spiral side of paratype (Cushman Coll. 44043a), showing early trochospiral stage. 5b, Edge view, showing enveloping final chamber and areal and sutural bullae. 6, Umbilical view of topotype (USNM P3932b), showing sutural secondary apertures of Orbulina stage, and the sutural bullae with infralaminal apertures characteristic of Globigerinatella. 7a, Spiral side of paratype (Cushman Coll. 44043b). 7b, Umbilical side, showing embracing Orbulina-like final chamber, with small areal bullae at lower margin. 7c, Edge view, showing elongated sutural bullae and rounded areal bullae. From the Oligocene-Miocene Cipero formation, Trinidad, B.W.I. Figs. 4–6, ×110; fig. 7, ×105.
Plate 9. GLOBOROTALIIDAE

Figures 1a–c. Praeglobotruncana delrioensis (Plummer)

1a, Spiral side of topotype (USNM P4481), showing moderately developed early keel. 1b, Umbilical side, showing extraumbilical-umbilical aperture. 1c, Edge view. From the Cenomanian Del Rio clay of Texas. × 145.

Figures 2a–c. Praeglobotruncana stephani (Gandolfi)

2a, Spiral side of topotype (USNM P4848) of the type species of Rotundina Subbotina. 2b, Umbilical side, showing extraumbilical-umbilical aperture. 2c, Edge view. From the Cenomanian of Switzerland. × 95.

Figures 3a–d. Praeglobotruncana planispira (Tappan)

3a, Spiral side of hypotype (USNM P4875). 3b, Umbilical side, showing extraumbilical-umbilical aperture, and apertural flaps of final and preceding chambers projecting into the open umbilicus. 3c, Edge view, showing high arched aperture. 3d, Oblique edge view, showing apertures of earlier chambers all opening into the umbilicus beneath the apertural flaps. From the Gault (Albian) of England. × 265.

Figures 4a–c. Praeglobotruncana? seminolensis (Harlton)

4a, Spiral side of holotype (USNM 71380) of type species of Hedbergina Bronnimann and Brown, showing rounded chambers, smooth surface, and perforate wall. 4b, Umbilical view, showing extraneous material which fills the umbilicus and sutural depressions, obscuring the diagnostic umbilical and apertural features, and the rounded instead of elongated chambers. 4c, Edge view. From the Cretaceous? (reported originally as Pennsylvanian) of Oklahoma. × 80.

Figures 5a–c. Rotalipora cf. appenninica (Renz)

5a, Spiral side of hypotype (USNM P4873). 5b, Umbilical side, showing well developed extraumbilical-umbilical primary aperture and small rounded sutural secondary apertures. 5c, Edge view, showing high arched primary aperture. From the Cenomanian Del Rio formation of Texas. × 105.

Figures 6a–c. Rotalipora turonica Brotzen

6a, Spiral side of hypotype (USNM P50) of the type species of Rotalipora. 6b, Umbilical side, showing primary extraumbilical-umbilical aperture and secondary sutural apertures. 6c, Edge view. From the Turonian, Upper Cretaceous, of Sweden. × 85.

Figures 7a–c. Rotalipora brotseni (Sigal)

7a, Spiral side of topotype (USNM P3930) of the species designated as the type of Thalmannitella Sigal. 7b, Umbilical side showing sutural secondary apertures in addition to primary extraumbilical-umbilical aperture. 7c, Edge view. From the Cenomanian of Algeria. × 105.
GLOBOROTALIIDAE
GLOBOROTALIIDAE
Plate 10. GLOBOROTALIIDAE

Figures 1a–c. Rotalipora roberti (Gandolfi) 41

1a, Spiral side of hypotype (USNM P4829) of species selected as type of Ticinella Reichel. 1b, Umbilical side, showing extraumbilical-umbilical primary aperture and sutural secondary apertures. 1c, Edge view, showing open primary aperture. From the Cenomanian of Switzerland. × 150.

Figures 2a–c. Globorotalia tumida (Brady) 41

2a, Spiral side of syntype (USNM P3143) of type species of Globorotalia. 2b, Umbilical view, showing extraumbilical-umbilical primary aperture with broad apertural flap. 2c, Edge view, showing arched primary aperture. From the post-Tertiary of New Ireland. × 60.

Figures 3a–c. Globorotalia truncatulinoides (d’Orbigny) 41

3a, Spiral view of topotype (USNM P4542), showing flattened side. 3b, Edge view, showing extraumbilical-umbilical aperture. 3c, Edge view, showing umbilicoconvex test shape, considered typical of Truncorotalia Cushman and Bermudez, for which this species was type. The extraumbilical-umbilical aperture is covered by a broad apertural flap. From the Recent off the Canary Islands. × 95.

Figures 4a–c. Globorotalia centralis Cushman and Bermudez 41

4a, Spiral view of holotype (Cushman Coll. 23426) of type species of Turboartalia Cushman and Bermudez. 4b, Umbilical view, showing extraumbilical-umbilical aperture. 4c, Edge view, showing rounded to ovate chambers, and open arched primary aperture. From the Eocene of Cuba. × 110.

Figures 5a–c. Truncorotaloides rohri Bronnimann and Bermudez 42

5a, Spiral view of holotype (USNM P4233), showing sutural secondary apertures, similar to those of Globigerinoides. 5b, Umbilical view, showing extraumbilical-umbilical primary aperture. 5c, Edge view. From the Eocene of Trinidad, B.W.I. × 130.
Figure 1a–c. *Abathomphalus mayaroensis* (Bolli) 1a, Spiral side of hypotype (USNM P4833). 1b, Umbilical side, showing partially open primary extrumbilical-umbilical aperture and irregular continuous umbilical tegillum with accessory infralaminar apertures. 1c, Edge view. From the Maestrichtian Guayaguayare formation of Trinidad, B.W.I. × 90.

Figures 2a–c. *Rugoglobigerina rugosa* (Plummer) 2a, Spiral side of hypotype (USNM P3929), showing characteristic ornamentation. 2b, Umbilical side, showing well developed tegillum with both intralaminar and infralaminar accessory apertures. 2c, Edge view, showing meridional pattern of ornamentation. From the Navarro (Upper Cretaceous) of Texas. × 105.

Figures 3a–c. *Rugoglobigerina scotti* Bronnimann 3a, Spiral side of hypotype (USNM P4838). 3b, Umbilical view, showing development of tegilla from successive chambers, and extending across umbilicus. 3c, Edge view, showing infralaminar accessory apertures. From the Maestrichtian Navarro (Upper Cretaceous) of Texas. × 115; figs. 4a–c, × 120.

Figures 4a–c. *Rugoglobigerina hankeninoides* Bronnimann 4a, Spiral side of holotype (USNM P4856) of species described as type of *Trinitella* Bronnimann. 4b, Umbilical side, from which umbilical tegilla have been broken during course of preservation. 4c, Edge view. From the Maestrichtian Guayaguayare formation of Trinidad, B.W.I. × 105.

Figures 5a–c. *Rugoglobigerina hankeninoides* Bronnimann 5a, Spiral sides of holotype (USNM P4847), showing radially elongate early chambers considered basis for the subgenus *Plummerella* (= *Plummerita*, new name) Bronnimann, and the meridional pattern of ornamentation. 5b, Umbilical side, with tegilla somewhat obscurely preserved. 5c, Edge view. From the Maestrichtian Guayaguayare formation of Trinidad, B.W.I. × 150.

Figures 6–11c. *Globotruncanella arca* (Cushman) 6, Umbilical side of hypotype (USNM P4242a), showing well developed umbilical tegilla, and absence of open primary aperture. 7a, Spiral side of excellently preserved hypotype (USNM P4242b). 7b, Umbilical side, showing completely preserved tegilla, which cover entire umbilical region and obscure primary aperture. 7c, Edge view. × 150. 8, 9, Umbilical side of hypotypes (USNM P4242c–d) showing variation in development and preservation of tegilla. 10, Umbilical side of hypotype (USNM P4242e) showing tegilla broken out of center as is most common in the poorly preserved or prepared specimens of the genus. The primary umbilical aperture can be seen here, although in life it was always covered. Specimens such as this have led to the common misconceptions as to the distinctions between *Globorotalia* and *Globotruncana*. From the Navarro (Upper Cretaceous) of Texas. × 105. 11a, Spiral side of holotype (Cushman Coll. 5078). 11b, Umbilical side, showing poor preservation of the type with umbilical region obscured. 11c, Edge view. From the Mendez shale of Mexico. All × 80.
GLOBOTRUNCANIDAE
ROTA莉ORA, PRAEGLOBOGRUNCHANA
Plate 12. ROTALIPORA, PRAEGLOBOTRUNCANA

Figures 1a–c. Rotalipora ticinensis ticinensis (Gan-
dolfi)

1a, Spiral view of hypotype (USNM P4792).
1b, Side view. 1c, Umbilical view. From the
Rotalipora ticinensis ticinensis zone, Gautier for-
formation, Trinidad, B.W.I. × 200.

Figures 2a–3c. Praeglobotruncana coarctata Bolli, 55
new species

2a, Spiral view of holotype (USNM P4794).
2b, Side view. 2c, Umbilical view. 3a, Spiral
view of paratype (USNM P4795). 3b, Side
view. 3c, Umbilical view. Both from the Glo-
botruncana stuarti zone, Naparima Hill forma-
tion, Trinidad, B.W.I. × 110.

Figures 4a–c. Praeglobotruncana cf. delrioensis 55
(Plummer)

4a, Spiral view of specimen (USNM P4793).
4b, Side view. 4c, Umbilical view. From the
Globigerina wallisitensis zone, Gautier formation,
Trinidad, B.W.I. × 200.
Plate 13. GLOBOTRUNCANA

Figures 1a–c. *Globotruncana helvetica* Bolli 56

1a, Spiral view of hypotype (USNM P4796).

1b, Side view. 1c, Umbilical view. From the *Globotruncana inornata* zone, Naparima Hill formation, Trinidad, B.W.I. × 112.

Figures 2a–c. *Globotruncana repanda* Bolli, new species 56

2a, Spiral view of holotype (USNM P4797).

2b, Side view. 2c, Umbilical view. From the *Globotruncana stuarti* zone, Naparima Hill formation, Trinidad, B.W.I. × 120.

Figures 3a–c. *Globotruncana concavata* (Brotzen) 57

3a, Spiral view of hypotype (USNM P4798).

3b, Side view. 3c, Umbilical view. From the 250

Globotruncana concavata zone, Naparima Hill formation, Trinidad, B.W.I. × 73.

Figures 4a–c. *Globotruncana ventricosa* White 57

4a, Spiral view of hypotype (USNM P4799).

4b, Side view. 4c, Umbilical view. From the *Globotruncana stuarti* zone, Naparima Hill formation, Trinidad, B.W.I. × 73.

Figures 5a–6c. *Globotruncana inornata* Bolli, new species 57

5a, Spiral view of holotype (USNM P4800).

5b, Side view. 5c, Umbilical view. × 102.

6a, Spiral view of paratype (USNM P4801). 6b, Side view. 6c, Umbilical view. × 80. Both from the *Globotruncana inornata* zone, Naparima Hill formation, Trinidad, B.W.I.
Plate 14. GLOBOTRUNCANA

Figures 1a–c. Globotruncana schneegansi Sigal
1a, Spiral view of hypotype (USNM P4802).
1b, Side view. 1c, Umbilical view. From the Globotruncana inornata zone, Naparima Hill formation, Trinidad, B.W.I. $\times 80.$

Figures 2a–c. Globotruncana cf. lapparenti coronata Bolli
2a, Spiral view of specimen (USNM P4804).
2b, Side view. 2c, Umbilical view. From the Globotruncana renzi zone, Naparima Hill formation, Trinidad, B.W.I. $\times 85.$

Figures 3a–c. Globotruncana renzi Gandolfi
3a, Spiral view of hypotype (USNM P4803).
3b, Side view. 3c, Umbilical view. From the Globotruncana renzi zone, Naparima Hill formation, Trinidad, B.W.I. $\times 80.$

Figures 4a–c. Globotruncana wilsoni Bolli, new species
4a, Spiral view of holotype (USNM P4805).
4b, Side view. 4c, Umbilical view. From the Globotruncana concavata zone, Naparima Hill formation, Trinidad, B.W.I. $\times 73.$

Figures 5a–c. Globotruncana gagnebini Tilev
5a, Spiral view of hypotype (USNM P4806).
5b, Side view. 5c, Umbilical view. From the Abathomphalus mayaroensis zone, Guayaguayare formation, Trinidad, B.W.I. $\times 97.$

Figures 6a–c. Globotruncana andori de Klasz
6a, Spiral view of hypotype (USNM P4807).
6b, Side view. 6c, Umbilical view. From the Globotruncana lapparenti tricarinata zone, Guayaguayare formation, Trinidad, B.W.I. $\times 73.$
Figures 1, 2. *Globigerina taroubaensis* Bronnimann 1, Spiral view of topotype (USNM P5041). 2, Umbilical view. From the *Globorotalia aragonensis* zone, upper Lizard Springs formation, Trinidad, B.W.I. × 100.


Figures 6–8. *Globigerina primitiva* Finlay 6, Spiral view of hypotype (USNM P5035). 7, Side view. 8, Umbilical view. From the *Globorotalia rex* zone, upper Lizard Springs formation, Trinidad, B.W.I. × 100.

Figures 9–11. *Globigerina velascoensis* Cushman 9, Spiral view of hypotype (USNM P5034). 10, Side view. 11, Umbilical view. From the *Globorotalia pseudomenardii* zone, lower Lizard Springs formation, Trinidad, B.W.I. × 100.


Globorotalia pseudomenardii zone, lower Lizard Springs formation, Trinidad, B.W.I. × 100.


Figures 21–23. *Globigerina collactea* (Finlay) 21, Spiral view of hypotype (USNM P5039). 22, Side view. 23, Umbilical view. From the *Globorotalia rex* zone, upper Lizard Springs formation, Trinidad, B.W.I. × 100.

GLOBIGERINA, GLOBOROTALIA
Plate 16. GLOBIGERINA, GLOBOROTALIA
(All figures × 100)

Figures 1–3. Globigerina gravelli Bronnimann
1. Spiral view of topotype (USNM P5038).
2. Side view. 3. Umbilical view. From the
Globorotalia formosa formosa zone, upper Lizard
Springs formation, Trinidad, B.W.I.

Figures 4–6. Globigerina soldadoensis angulosa Bolli, new subspecies
4. Spiral view of holotype (USNM P5037).
5. Side view. 6. Umbilical view. From the
Globorotalia formosa formosa zone, upper Lizard
Springs formation, Trinidad, B.W.I.

Figures 7–9. Globigerina soldadoensis Bronnimann
7. Spiral view of hypotype (USNM P5036).
8. Side view. 9. Umbilical view. From the
Globorotalia formosa formosa zone, upper Lizard
Springs formation, Trinidad, B.W.I.

Figures 10–12. Transitional form between Globi-
gerina soldadoensis Bronnimann and Globigerina
gravelli Bronnimann
10. Spiral view of specimen (USNM P5073).
11. Side view. 12. Umbilical view. From the
Globorotalia formosa formosa zone, upper Lizard
Springs formation, Trinidad, B.W.I.

Figures 13–15. Globigerina daubjergensis Bronni-
mann
14. Side view. 15. Umbilical view. From the
Globorotalia trinidadensis zone, lower Lizard
Springs formation, Trinidad, B. W. I.

Figures 16–18. Globigerina spiralis Bolli, new species
17. Side view. 18. Umbilical view. From the
Globorotalia uncinata zone, lower Lizard Springs
formation, Trinidad, B.W.I.

Figures 19–23. Globorotalia trinidadensis Bolli, new species
19. Spiral view of holotype (USNM P5044).
view of paratype (USNM P5045). 23. Spiral view
of another paratype (USNM P5046). From the
Globorotalia trinidadensis zone, lower Lizard
Springs formation, Trinidad, B. W. I.
Plate 17. GLOBOROTALIA, GLOBIGERINA
(All figures × 100)

Figures 1–3. Globorotalia aequa Cushman and Renz

1, Spiral view of hypotype (USNM P5051).
2, Side view. 3, Umbilical view. From the Globorotalia velascoensis zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 4–6. Globorotalia angulata abundocamerata Bolli, new subspecies

4, Spiral view of holotype (USNM P5050).
5, Side view. 6, Umbilical view. From the Globorotalia pusilla pusilla zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 7–9. Globorotalia angulata (White)

7, Spiral view of hypotype (USNM P5049).
8, Side view. 9, Umbilical view. From the Globorotalia pusilla pusilla zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 10–12. Transitional form between Globorotalia uncinata Bolli, new species and Globorotalia angulata (White)

10, Spiral view of specimen (USNM P5074).
11, Side view. 12, Umbilical view. From the Globorotalia pusilla pusilla zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 13–15. Globorotalia uncinata Bolli, new species

13, Spiral view of holotype (USNM P5048).
14, Side view. 15, Umbilical view. From the

Globorotalia uncinata zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 16–18. Transitional form between Globorotalia pseudobulloides (Plummer) and Globorotalia uncinata Bolli, new species

16, Spiral view of specimen (USNM P5075).
17, Side view. 18, Umbilical view. From the Globorotalia uncinata zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 19–21. Globorotalia pseudobulloides (Plummer)

19, Spiral view of hypotype (USNM P5043).
20, Side view. 21, Umbilical view. From the Globorotalia pusilla pusilla zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 22–24. Globorotalia quadrata (White)

22, Spiral view of hypotype (USNM P5047).
23, Side view. 24, Umbilical view. From the Globorotalia pusilla pusilla zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 25–26. Globigerina triloculinoides Plummer

25, Spiral view of hypotype (USNM P5076) showing Globorotalia-like apertural character.
26, Umbilical view. From the Globorotalia pusilla pusilla zone, lower Lizard Springs formation, Trinidad, B.W.I.
Plate 18. GLOBOROTALIA

(All figures × 100)

Figures 1-3. Globorotalia formosa formosa Bolli, new species, new subspecies

1, Spiral view of holotype (USNM P5056).
2, Side view. 3, Umbilical view. From the Globorotalia formosa formosa zone, upper Lizard Springs formation, Trinidad, B.W.I.

Figures 4-6. Globorotalia formosa gracilis Bolli, new species, new subspecies

4, Spiral view of holotype (USNM P5055).
5, Side view. 6, Umbilical view. From the Globorotalia rex zone, upper Lizard Springs formation, Trinidad, B.W.I.

Figures 7-9. Globorotalia aragonensis Nuttall

7, Spiral view of hypotype (USNM P5054).

8, Side view. 9, Umbilical view. From the Globorotalia aragonensis zone, upper Lizard Springs formation, Trinidad, B.W.I.

Figures 10-12. Globorotalia rex Martin

10, Spiral view of hypotype (USNM P5053).
11, Side view. 12, Umbilical view. From the Globorotalia rex zone, upper Lizard Springs formation, Trinidad, B.W.I.

Figures 13-15. Globorotalia aqua Cushman and Renz

13, Spiral view of hypotype (USNM P5052).
14, Side view. 15, Umbilical view. From the Globorotalia velascoensis zone, lower Lizard Springs formation, Trinidad, B.W.I.
Plates 19. GLOBOROTALIA

(All figures × 100)

Figures 1–6. Globorotalia quita Bolli, new species
1, Spiral view of holotype (USNM P5070).
2, Side view. 3, Umbilical view. 4, Spiral view of paratype (USNM P5071). 5, Side view. 6, Umbilical view. Both from the Globorotalia formosa formosa zone, upper Lizard Springs formation, Trinidad, B.W.I.

Figures 7–9. Globorotalia wilcoxensis Cushman and Ponton
7, Spiral view of hypotype (USNM P5069).
8, Side view. 9, Umbilical view. From the Globorotalia rex zone, upper Lizard Springs formation, Trinidad, B.W.I.

Figures 10–12. Globorotalia whitei Weiss
10, Spiral view of hypotype (USNM P5068).
11, Side view. 12, Umbilical view. From the Globorotalia pseudomenardii zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 13–15. Globorotalia broedermanni Cushman and Bermudez
13, Spiral view of hypotype (USNM P5072).
14, Side view. 15, Umbilical view. From the Globorotalia formosa formosa zone, upper Lizard Springs formation, Trinidad, B.W.I.

Figures 16–18. Globorotalia mckannai (White)
16, Spiral view of hypotype (USNM P5067).
17, Side view. 18, Umbilical view. From the Globorotalia pseudomenardii zone, lower Lizard Springs formation, Trinidad, B.W.I.

Figures 19–21. Globorotalia tortiva Bolli, new name
19, Spiral view of hypotype (USNM P5066).
20, Side view. 21, Umbilical view. From the Globorotalia pseudomenardii zone, lower Lizard Springs formation, Trinidad, B.W.I.
GLOBOROTALIA
Plate 20. GLOBOROTALIA

(All figures × 100)

Figures 1-4. *Globorotalia velascoensis* (Cushman) 76


Figures 5-7. *Globorotalia pusilla laevigata* Bolli, 78 new species, new subspecies


Figures 8-10. *Globorotalia pusilla pusilla* Bolli, 78 new species, new subspecies


Figures 11-13. *Globorotalia elongata* Glaessner 77


Figures 14-17. *Globorotalia pseudomenardii* Bolli, new species


Figures 18-20. *Globorotalia ehrenbergi* Bolli, new species


Figures 21-23. *Globorotalia compressa* (Plummer) 77

Plate 21. CHILOGUENBELINA, ZEAUVIGERINA, GUEMBELITRIA

(All figures ×122; a list of the sample localities is given on p. 88)

Figures 1a, b. Chiloguembelina midwayensis midwayensis (Cushman)

1a, Side view of hypotype (USNM P5768), from sample 232705. 1b, Edge view.

Figures 2a–3. Chiloguembelina subtriangularis subcylindrica Beckmann, new subspecies

2a, Side view of holotype (USNM P5774), from sample 102301. 2b, Edge view. 3, Side view of paratype (USNM P5775) from sample 102301, showing small end chamber.

Figures 4a, b. Chiloguembelina crinita (Glassner)

4a, Side view of hypotype (USNM P5753a), from sample 228674. 4b, Edge view.

Figures 5a, b. Chiloguembelina subtriangularis Beckmann, new species

5a, Side view of holotype (USNM P5783), from sample 232706. 5b, Side view.

Figures 6a–c. Chiloguembelina midwayensis strombiiformis Beckmann, new subspecies

6a, Side view of holotype (USNM P5771), from sample 223472. 6b, Edge view. 6c, Side view (opposite side to 6a).

Figures 7a, b. Chiloguembelina trinitatensis (Cushman and Renz)

7a, Side view of hypotype (USNM P5786), from sample 50315. 7b, Edge view.

Figures 8a, b. Chiloguembelina parallela Beckmann, new species

8a, Side view of holotype (USNM P5780), from sample 228484. 8b, Edge view.

Figures 9a, b. Zeauvigerina aegyptiaca Said and Kenawy

9a, Side view of hypotype (USNM P5803), from sample 228674, specimen without terminal end chamber. 9b, Edge view, showing eccentric position of aperture. 11, Side view of hypotype (USNM P5804) from sample 228674, a complete specimen, showing end chamber with tubular neck.

Figures 10a, b, 12a–13. Chiloguembelina wilcoxensis (Cushman and Ponton)

10a, Side view of hypotype (USNM P5793), from sample 50315, showing the small variety occurring in the lower Lizard Springs formation. 10b, Edge view. 12a, Side view of hypotype (USNM P5794) from sample 102301, showing the large variety occurring in the upper Lizard Springs formation. 12b, Edge view. 13, Side view of hypotype (USNM P 5795,) from sample 228484, showing small subterminal end chamber.

Figures 14a, b. Chiloguembelina martini (Pijpers)

14a, Side view of hypotype (USNM P5759), from sample 221009. 14b, Edge view.

Figures 15a, b. Chiloguembelina cf. mauriciana (Howe and Roberts)

15a, Side view of hypotype (USNM P5764), from sample 177760. 15b, Edge view.

Figure 16. Guembelitria columbiana Howe

Side view of hypotype (USNM P5801), from sample 217995.

Figures 17a, b. Chiloguembelina cf. multicellularis (Hussey)

17a, Side view of hypotype (USNM P5778), from sample 177760. 17b, Edge view.

Figures 18a, b. Chiloguembelina sp.

18a, Side view of hypotype (USNM P5800), from sample 178162. 18b, Edge view.

Figures 19a–20b. Chiloguembelina victoriana Beckmann, new species

19a, Side view of holotype (USNM P5789), from sample 240966. 19b, Edge view. 20a, Side view of paratype (USNM P5790), from sample 193785. 20b, Edge view.

Figure 21. Chiloguembelina cubensis (Palmer)

21a, Side view of hypotype (USNM P5756), from sample 193785. 21b, Edge view.
CHILOGUEMBELINA, ZEAUWIGERINA, GUEMBELITRIA
Plate 22. HASTIGERINA, CASSIGERINELLA, GLOBIGERINA

Figures 1a–2b. *Hastigerina* cf. *acquilateralis* (Brady) 108

1a, Spiral view of specimen (USNM P5601a).
1b, Umbilical view. 1c, Side view. 2a, Equatorial view of hypotype (USNM P5601b). 2b, Side view. All from the *Globorotalia menardii* zone, Lenga formation, Trinidad, × 68.

Figures 3a–c. *Cassigcrinella chipolensis* (Cushman and Ponton) 108

3a, 3b, Opposite sides of hypotype (USNM P5602). 3c, Side view. From the *Globorotalia opina opima* zone, Cipero formation, Trinidad, × 210.

Figures 4a–7b. *Globigerina ampliapertura* Bolli, 108 new species

6a, Spiral view of holotype (USNM P5603).
6b, Umbilical view. 6c, Side view. 4a, Spiral view of paratype (USNM P5604).
4b, Umbilical view. 4c, Side view. 5a, Spiral view of paratype (USNM P5605a).
5b, Umbilical view. 7a, Spiral view of small paratype (USNM P5605b).
7b, Umbilical view. All from the *Globigerina ampliapertura* zone, Cipero formation, Trinidad, × 68.

Figures 8a–9c. *Globigerina* cf. *trilocularis* d'Orbigny 110

8a, Spiral view of specimen (USNM P5616a).
8b, Umbilical view. 8c, Side view. 9a, Spiral view of specimen (USNM P5616b).
9b, Umbilical view. 9c, Side view. All from the *Globigerina ciperoensis ciperoensis* zone, Cipero formation, Trinidad, × 68.

Figures 10a,b. *Globigerina ciperoensis ciperoensis* Bolli 109

10a, Spiral view of large paratype (USNM P5607).
10b, Umbilical view. From the *Globigerina ciperoensis ciperoensis* zone, Cipero formation, Trinidad, × 150.

Figures 11a-c. *Globigerina ciperoensis angulisatum* Bolli, new subspecies

11a, Spiral view of holotype (USNM P5608).
11b, Umbilical view. 11c, Side view. From the *Globorotalia opina opima* zone, Cipero formation, Trinidad, × 150.

Figures 12a–13c. *Globigerina ciperoensis angusti-umbilicata* Bolli, new subspecies

12a, Spiral view of paratype (USNM P5610).
12b, Umbilical view. 12c, Side view. 13a, Spiral view of holotype (USNM P5609).
13b, Umbilical view. 13c, Side view. Both from the *Globigerina ciperoensis ciperoensis* zone, Cipero formation, Trinidad, × 150.

Figures 14a–c. *Globigerina parae* Bolli, new species 108

14a, Spiral view of holotype (USNM P5606).
14b, Umbilical view. 14c, Side view. From the *Globigerina ampliapertura* zone, Cipero formation, Trinidad, × 68.
Plate 23. GLOBIGERINA

Figures 1a–4b. Globigerina rohri Bolli, new species
1a, Spiral view of holotype (USNM P5611). 1b, Umbilical view. 1c, Side view. 2a, Spiral view of paratype (USNM P5612a). 2b, Umbilical view. 3a, Spiral view of paratype (USNM P5612b). 3b, Side view. 4a, Spiral view of small paratype (USNM P5612c). 4b, Umbilical view. All from the Globorotalia opima opima zone, Cipero formation, Trinidad, × 68.

Figures 5a–c. Globigerina bradyi Wiesner
5a, Spiral view of hypotype (USNM P5619). 5b, Umbilical view. 5c, Side view. From the Globorotalia menardii zone, Lengua formation, Trinidad, × 210.

Figures 6a–8b. Globigerina venezuelana Hedberg
6a, Spiral view of large hypotype (USNM P5613). 6b, Umbilical view. 6c, Side view. From the Globorotalia fohsi robusta zone, Cipero formation, Trinidad. 7a, Spiral view of hypotype (USNM P5615). 7b, Umbilical view showing rudimentary ultimate chamber. From the Globorotalia fohsi lobata zone, Cipero formation, Trinidad. 8a, Spiral view of hypotype (USNM P5614). 8b, Umbilical view showing rudimentary ultimate chamber. From the Globorotalia menardii zone, Lengua formation, Trinidad. All × 68.
Plate 24. GLOBIGERINA, GLOBOQUADRINA

Figures 1a–c. Globigerina foliata Bolli, new species 111
   1a, Spiral view of holotype (USNM P5620).
   1b, Umbilical view. 1c, Side view. From the Globorotalia fohsi robusta zone, Cipero formation, Trinidad, × 68.

Figures 2a–c. Globigerina nepenthes Todd 111
   2a, Spiral view of hypotype (USNM P5621).
   2b, Umbilical view. 2c, Side view. From the Globorotalia mayeri zone, Lenga formation, Trinidad, × 68.

Figures 3a–4c. Globoquadrina dehiscens (Chapman, Parr, and Collins) 111
   3a, Spiral view of hypotype (USNM P5623) with last chamber broken. 3b, Umbilical view.
   3c, Side view. 4a, Spiral view of hypotype (USNM P5622). 4b, Umbilical view, showing a rudimentary ultimate chamber (the umbilical teeth are concealed). 4c, Side view. Both from the Globorotalia fohsi lobata zone, Cipero formation, Trinidad, × 68.

Figures 5a–6. Globigerina juvenilis Bolli, new species 110
   5a, Spiral view of holotype (USNM P5617).
   5b, Umbilical view. 5c, Side view. From the Globorotalia fohsi robusta zone. Cipero formation, Trinidad, × 120. 6, Spiral view of small paratype (USNM P5618) from the Globorotalia fohsi lobata zone, Cipero formation, Trinidad, × 380.

Figures 7a–8b. Globoquadrina altispira altispira 111 (Cushman and Jarvis)
   7a, Spiral view of hypotype (USNM P5624).
   7b, Umbilical view, (umbilical teeth are concealed by matrix). 7c, Side view. From the Globorotalia fohsi lobata zone, Cipero formation, Trinidad.
   8a, Umbilical view of small hypotype (USNM P5625). 8b, Side view. From the Globorotalia fohsi robusta zone, Cipero formation, Trinidad. Both × 68.

Figures 9a–10c. Globoquadrina altispira globosa 111 Bolli, new subspecies
   9a, Spiral view of holotype (USNM P5626).
   9b, Umbilical view showing umbilical teeth. 9c, Side view. 10a, Spiral view of small paratype (USNM P5627). 10b, Umbilical view.
   10c, Side view. Both from the Catapsydrax dissimilis zone, Cipero formation, Trinidad, × 68.
Plate 25. HASTIGERINELLA, GLOBIGERINOIDES

Page

Figures 1a–c. Hastigerinella bermudezi Bolli, new species

1a, Spiral view of holotype (USNM P5628);
1b, Umbilical view; 1c, Side view. From the Globorotalia fohsi barisanensis zone, Cipero formation, Trinidad.

Figures 2a–c. Globigerinoides triloba triloba (Reuss)

2a, Spiral view of hypotype (USNM P5629).
2b, Umbilical view. 2c, Side view. From the Globorotalia fohsi barisanensis zone, Cipero formation, Trinidad.

Figures 3a–c. Globigerinoides triloba immatura Le Roy

3a, Spiral view of hypotype (USNM P5630a).
3b, Umbilical view. 4a, Spiral view of hypotype (USNM P5630b). 4b, Umbilical view. 4c, Side view. Both from the Globorotalia fohsi robusta zone, Cipero formation, Trinidad.

Figures 5a–6. Globigerinoides triloba sacculifera (Brady)

5a, Spiral view of hypotype (USNM P5631a).
5b, Umbilical view. 5c, Side view. 6, Spiral view of small hypotype (USNM P5631b). Both from the Globorotalia fohsi lobata zone, Cipero formation, Trinidad.

Figures 7a–8. Globigerinoides triloba altiapertura Bolli, new subspecies

7a, Spiral view of holotype (USNM P5632).
7b, Umbilical view. 7c, Side view. 8, Umbilical view of paratype (USNM P5633). Both from the Catapsydrax dissimilis zone, Cipero formation, Trinidad.

Figures 9a–10c. Globigerinoides obliqua Bolli, new species

9a, Spiral view of paratype (USNM P5635).
9b, Umbilical view. 9c, Side view. 10a, Spiral view of holotype (USNM P5634). 10b, Umbilical view. 10c, Side view. Both from the Globorotalia mayeri zone, Lengua formation, Trinidad.

Figures 11a–c. Globigerinoides diminuta Bolli, new species

11a, Spiral view of holotype (USNM P5638).
11b, Umbilical view. 11c, Side view. From the Globigerinatella insueta zone, Cipero formation, Trinidad.

Figures 12a–13b. Globigerinoides rubra (d'Orbigny)

12a, Spiral view of hypotype (USNM P5636).
12b, Umbilical view. 12c, Side view. From the Globorotalia fohsi robusta zone, Cipero formation, Trinidad. 13a, Spiral view of small hypotype (USNM P5637). 13b, Umbilical view. From the Globigerinatella insueta zone, Cipero formation, Trinidad.
GLOBIKERINOIDES, SPHAEROIDINELLA
Plate 26. GLOBINGERINOIDES, SPHAEROIDINELLA

Figures 1a–4. Globigerinoides mitra Todd
1a, b, Side views of hypotype (USNM P5640) from the Globorotalia fohsi fohsi zone, Cipero formation, Trinidad. 2a, b, Side views of hypotype (USNM P5639a). 3a, b, Side views of hypotype (USNM P5639b). 4, Side view of hypotype (USNM P5639c). All from the Globorotalia menardii zone, Lengua formation, Trinidad, × 68.

Figures 5a–c. Globigerinoides species
5a, Spiral view (USNM P5641). 5b, Umbilical view. 5c, Side view. From the Globorotalia kugleri zone, Cipero formation, Trinidad, × 68.

Figures 6a–7b. Sphaeroidinella rutschi Cushman and Renz
6a, Spiral view of small hypotype (USNM P5645a). 6b, Umbilical view. 7a, Spiral view of hypotype (USNM P5645b). 7b, Umbilical view. Both from the Globorotalia menardii zone, Lengua formation, Trinidad, × 68.

Figures 8–12c. Sphaeroidinella grimsdalei (Keijzer)
8, Umbilical view of very small hypotype (USNM P5643a). 10a, Spiral view of small hypotype (USNM P5643b). 10b, Umbilical view. 11, Umbilical view of hypotype (USNM P5643c). All from the Globorotalia fohsi fohsi zone, Cipero formation, Trinidad. 9, Umbilical view of hypotype (USNM P5644a). 12a, Spiral view of large hypotype (USNM P5644b). 12b, Umbilical view. 12c, Side view. Both from the Globorotalia menardii zone, Lengua formation, Trinidad. All × 68.

Figures 13a–b. Sphaeroidinella cf. grimsdalei (Keijzer)
13a, Spiral view of specimen (USNM P5646). 13b, Umbilical view. From the Globorotalia menardii zone, Lengua formation, Trinidad, × 68.
Plate 27. GLOBIGERINOIDES, PORTICULASPHAERA, ORBULINA, GLOBOROTALOIDES

(All figures × 68)

Figures 1a, b. Globigerinoides bisperforata Todd 114
1a, Spiral view of hypotype (USNM P5642).
1b, Umbilical view. From the Globigerinatella insueta zone, Cipero formation, Trinidad.

Figure 2. Porticulasphaera glomerosa circularis 115
(Blow)
2, Hypotype (USNM P5649). From the Globigerinatella insueta zone, Cipero formation, Trinidad.

Figure 3. Porticulasphaera transitoria (Blow) 115
3, Hypotype (USNM P5650), same locality data as fig. 2.

Figure 4. Orbula suturalis Bronnemann 115
4, Hypotype (USNM P5651). From the Globorotalia menardii zone, Lengua formation, Trinidad.

Figure 5. Orbula universa d'Orbigny 115
5, Hypotype (USNM P5652). From the Globorotalia mayeri zone, Lengua formation, Trinidad.

Figure 6. Orbula bilobata (d'Orbigny) 116
6, Hypotype (USNM P5653). From the Globorotalia foehsi barisanensis zone, Cipero formation, Trinidad.

Figure 7. Porticulasphaera glomerosa curva (Blow) 115
7, Hypotype (USNM P5647), same locality data as fig. 2.

Figure 8. Porticulasphaera glomerosa glomerosa 115
(Blow)
8, Hypotype (USNM P5648), same locality data as fig. 2.

Figures 9a–13b. Globorotaloides sutera Bolli, new 117 species
9a, Spiral view of medium sized paratype (USNM P5655a).
9b, Umbilical view, showing
a "Globigerina" stage. 9c, Side view. 10a, Spiral view of small paratype (USNM P5655b).
10b, Umbilical view, showing "Globorotalia" stage. 11a, Spiral view of small paratype (USNM P5655c).
11b, Umbilical view, showing "Globigerina" stage. 12a, Spiral view of small paratype (USNM P5655d).
12b, Umbilical view. 13a, Spiral view of holotype (USNM P5654).
13b, Umbilical view. From the Globigerina ampliapertura zone, Cipero formation, Trinidad.

Figures 14a–c. Globorotaloides cf. sutera Bolli, new 117 species
14a, Spiral view (USNM P5656).
14b, Umbilical view. 14c, Side view. From the Globigerina ampliapertura zone, Cipero formation, Trinidad.

Figures 15a–20c. Globorotaloides variabilis Bolli, 117 new genus, new species
15a, Spiral view of small paratype (USNM P5658a). 15b, Umbilical view showing "Globorotalia" stage. 16a, Spiral view of small paratype (USNM P5658b).
16b, Umbilical view. 17a, Spiral view of medium sized paratype (USNM P5658c).
17b, Umbilical view, showing "Globorotalia" stage. 18a, Spiral view of medium sized paratype (USNM P5658d).
18b, Umbilical view. 19a, Spiral view of large paratype (USNM P5658e).
19b, Umbilical view, showing "Globigerina" stage. 19c, Side view. 20a, Spiral view of holotype (USNM P5657).
20b, Umbilical view. 20c, Side view. All from the Globorotalia menardii zone, Lengua formation, Trinidad.
GLOBIGERINOIDES, PORTICULASPHEERA, ORBULINA, GLOBOROTALOIDES
Plate 28. Globorotalia

(All figures × 68)

Figures 1a-2. Globorotalia opima opima Bolli, new species, new subspecies.

1a, Spiral view of holotype (USNM P5659).
1b, Umbilical view.
2, View of paratype (USNM P5660). Both from the Globorotalia opima opima zone, Cipero formation, Trinidad.

Figures 3a-c. Globorotalia opima nana Bolli, new species, new subspecies.

3a, Spiral view of holotype (USNM P5661).
3b, Umbilical view.
3c, Side view. From the Globorotalia opima opima zone, Cipero formation, Trinidad.

Figures 4a-c. Globorotalia mayeri Cushman and Ellisor

4a, Spiral view of hypotype (USNM P5662).
4b, Umbilical view.
4c, Side view. From the Catapsydrax dissimilis zone, Cipero formation, Trinidad.

Figures 5a-6. Globorotalia kugleri Bolli, new species

5a, Spiral view of holotype (USNM P5663).
5b, Umbilical view.
5c, Side view. From the Globorotalia kugleri zone, Cipero formation, Trinidad.

Figures 7a-c. Globorotalia cf. kugleri Bolli

7a, Spiral view of figured specimen (USNM P5665) with chambers more globular than in typical specimens.
7b, Umbilical view.
7c, Side view. From the Globorotalia kugleri zone, Cipero formation, Trinidad.

Figures 8a-c. Globorotalia fohsi barisanensis Le Roy

8a, Spiral view of hypotype (USNM P5666).
8b, Umbilical view.
8c, Side view. From the Globorotalia fohsi barisanensis zone, Cipero formation, Trinidad.

Figures 9a-10c. Globorotalia fohsi fohsi Cushman and Ellisor

9a, Spiral view of hypotype (USNM P5667).
9b, Umbilical view.
10a, Spiral view of hypotype (USNM P5668).
10b, Umbilical view.
10c, Side view. Both from the Globorotalia fohsi fohsi zone, Cipero formation, Trinidad.

Figures 11a-c. Globorotalia archeomenardii Bolli, new species

11a, Spiral view of holotype (USNM P5676).
11b, Umbilical view.
11c, Side view. From the Globorotalia fohsi barisanensis zone, Cipero formation, Trinidad.

Figures 12a-b. Transitional specimen of Globorotalia fohsi fohsi Cushman and Ellisor and Globorotalia fohsi lobata Bermudez

12a, Spiral view (USNM P5670).
12b, Umbilical view. From the Globorotalia fohsi fohsi zone, Cipero formation, Trinidad.

Figures 13a-14b. Globorotalia fohsi lobata Bermudez

13a, Spiral view of hypotype (USNM P5669a).
13b, Umbilical view.
13c, Side view. Spiral view of hypotype (USNM P5669b).
14a, Umbilical view.
14b, Side view. Both from the Globorotalia fohsi fohsi lobata zone, Cipero formation, Trinidad.

Figures 15a-b. Transitional specimen of Globorotalia fohsi lobata Bermudez to Globorotalia fohsi robusta Bolli

15a, Spiral view (USNM P5672).
15b, Umbilical view. From the Globorotalia fohsi fohsi robusta zone, Cipero formation, Trinidad.

Figures 16a-c. Globorotalia fohsi robusta Bolli

16a, Spiral view of paratype (USNM P5671).
16b, Umbilical view.
16c, Side view. From the Globorotalia fohsi robusta zone, Cipero formation, Trinidad.
Plate 29. GLOBOROTALIA

Figures 1a–c. Globorotalia minutissima Bolli, new species
  1a, Spiral view of holotype (USNM P5675).
  1b, Umbilical view. 1c, Side view. From the Globorotalia fohsi fohsi zone, Cipero formation, Trinidad, × 210.

Figures 2a–3. Globorotalia obesa Bolli, new species
  2a, Spiral view of holotype (USNM P5673).
  2b, Umbilical view. 2c, Side view. From the Globorotalia fohsi robusta zone, Cipero formation, Trinidad. 3, Spiral view of paratype (USNM P5674). From the Globorotalia fohsi fohsi zone, Cipero formation, Trinidad. Both × 68.

Figures 4a–c. Globorotalia praemenardii Cushman and Stainforth
  4a, Spiral view of hypotype (USNM P5677).
  4b, Umbilical view. 4c, Side view. From the Globorotalia fohsi fohsi zone, Cipero formation, Trinidad, × 68.

Figures 5a–c. Globorotalia lenguaensis Bolli, new species
  5a, Spiral view of holotype (USNM P5681).
  5b, Umbilical view. 5c, Side view. From the Lengua formation, Trinidad, × 68.

Figures 6a–10b. Globorotalia menardii (d’Orbigny)
  6a, Spiral view of hypotype (USNM P5678a).
  6b, Umbilical view. 6c, Side view. 7a, Spiral view of hypotype (USNM P5678b). 7b, Umbilical view. 8a, Spiral view of large hypotype (USNM P5678c). 8b, Umbilical view. 8c, Side view. 9a, Spiral view of hypotype (USNM P5678d). 9b, Umbilical view. 10a, Spiral view of small hypotype (USNM P5678e). 10b, Umbilical view. All from the Globorotalia menardii zone, Lengua formation, Trinidad, × 68.

Figures 11a–12c. Globorotalia scitula (Brady)
  11a, Spiral view of hypotype (USNM P5679).
  11b, Umbilical view. 11c, Side view. From the Globorotalia fohsi robusta zone, Cipero formation, Trinidad. 12a, Spiral view of hypotype (USNM P5680). 12b, Umbilical view. 12c, Side view. From the Globorotalia mayeri zone, Lengua formation, Trinidad. Both × 68.
Plate 30. GLOBIGERINA

(All figures × 135)

Figures 1a–2c. Globigerina daubjergensis Bronnimann

1a, Spiral view of hypotype (USNM P5573) from sample 2, Tylocidaris vexilifera zone, Östra Torp. 1b, Peripheral view. 1c, Umbilical view.

2a, Spiral view of hypotype (USNM P5574) from calcarenite, Tylocidaris vexilifera zone, Torp. 2b, Peripheral view. 2c, Umbilical view.

Figures 3a–4c. Globigerina triloculinoides Plummer

3a, Spiral view of hypotype (USNM P5575) from sample 3 (see text-fig. 24), Tylocidaris brünichii zone, Fakse. 3b, Peripheral view. 3c, Umbilical view.

4a, Spiral view of hypotype (USNM P5580) from calcarenite, Tylocidaris ödumi zone, Hjerm (western quarry). 4b, Peripheral view. 4c, Umbilical view.

Figures 5a–c. Globigerina compressa Plummer

5a, Spiral view of hypotype (USNM P5576) from Tylocidaris vexilifera zone, exact level unknown, Östra Torp. 5b, Peripheral view. 5c, Umbilical view.

Figures 6a–8c. Globigerina pseudobulloides Plummer

6a, Spiral view of hypotype (USNM P5577) from bryozoan limestone filling cavities in underlying hardened calcilutite, Tylocidaris ödumi zone, Höjerup, Stevns Klint. 6b, Peripheral view. 6c, Umbilical view. 7a, Spiral view of hypotype (USNM P5578) from calcilutite (the dark spots are accidental fractures), basal Danian Bögelund. 7b, Peripheral view. 7c, Umbilical view. 8a, Spiral view of gerontic hypotype (USNM P5579) from calcilutite, Tylocidaris ödumi zone, Hjerm (western quarry). 8b, Peripheral view. 8c, Umbilical view.
Figures 1a,b. *Guembelitria cretacea* Cushman

1a, Side view of holotype (Cushman Coll. 19022) from the Navarro formation, Upper Cretaceous, Guadalupe County, Texas. 1b, Top view. × 310.

**Figure 2.** *Guembelitria* vivans Cushman

2, Holotype (Cushman Coll. 21515), showing buliminoid aperture, proving this form not to be related to the Heterohelicidae; from the Recent, Challenger Station 192 A, off Little Ki Island, New Guinea, at 129 fathoms. × 290.

**Figures 3–4c.** *Guembelitriella graysonensis* Tappan

3, Paratype (Cushman Coll. 4713), showing multiple apertures in the final chamber. 4a, Holotype (Cushman Coll. 25098). 4b, Opposite side. 4c, Top view. Both from the Cretaceous Grayson formation (Cenomanian), on Denton Creek, 3 1/2 miles northeast of Roanoke, Denton County, Texas. Coll. by A. R. Loeblich, Jr., and Helen Tappan Loeblich. × 175.

**Figures 5a–11.** *Heterohelix navarroensis* Loeblich

5a, Side view of holotype (USNM P33). 5b, Edge view, showing low arched aperture. × 145. 6–11, Paratypes (USNM P37a–f), showing gradation from a large coil of typical *Heterohelix* type, to a relatively small coil, found in species formerly referred to *Guembelina*. × 120. All are from the Upper Cretaceous, Navarro group, Kemp clay, (Maestrichtian), pit of Seguin Brick and Tile Co., McQueeney, Guadalupe County, Texas. Coll. by A. R. Loeblich, Jr. × 105.

12, 13, Hypotypes (USNM P34a, b), showing microspheric and megalospheric forms of the type species of *Guembelina*. From the Upper Cretaceous, Navarro group, Kemp clay (Maestrichtian), in pit of the Seguin Brick and Tile Co., McQueeney, Guadalupe County, Texas. Coll. by A. R. Loeblich, Jr. × 105.

14, Hypotype (USNM 104332) from the Upper Cretaceous, Arkadelphia marl, on Arkansas Highway No. 4, 5 miles northwest of Hope, 100 yards east of the airport beacon, Hempstead County, Arkansas. Coll. by W. H. Deaderick. × 90. 15, Hypotype (Cushman Coll. 31517) from the Upper Cretaceous, Arkadelphia clay, 7 miles N. by W. of Hope, Hempstead County, Arkansas. Alignment of pores suggests the development of striae. × 90.

**Figure 16.** *Heterohelix carinata* (Cushman)

16, Hypotype (Cushman Coll. 31493), showing a microspheric form with early coil, from the Upper Cretaceous, Lower Taylor marl, in a ditch on the north side of the road to Farmersville, 9.5 miles east of the McKinney courthouse, Collin County, Texas. Coll. by J. A. Cushman and James Waters. × 145.

**Figure 17.** *Heterohelix globocarinata* (Cushman)

17, Hypotype (Cushman Coll. 31641) from the Upper Cretaceous, upper part of the Taylor marl, on the Paris highway 1.8 miles east of Deport, Red River Co., Texas. Coll. by L. W. Stephenson. Microspheric specimen showing the early coil. × 100.

**Figure 18.** *Heterohelix renisi* (Cushman)

18, Hypotype (Cushman Coll. 24463) from the Upper Cretaceous, middle Brownstown, in ditch east of the Commerce-Paris highway, 2.9 miles south of Paris, Lamar County, Texas. Microspheric specimen with early coil. × 115.

**Figure 19.** *Heterohelix lata* (Egger)

19, Hypotype (Cushman Coll. 31513) from the Upper Cretaceous, Hopflinger Mühl, Upper Bavaria, showing small early coil, and somewhat elongated chambers. × 125.

**Figure 20.** *Heterohelix pulchra* (Brotzen)

20, Hypotype (Cushman Coll. 24417) of *Guembelina pseudouessera* Cushman (= II. pulchra) from the Upper Cretaceous, upper Taylor marl, in road cut near crest of hill, 14.4 miles south of Paris, 0.9 mile north of Lake City, Delta County, Texas. Coll. by C. I. Alexander. Early coil is shown, and the much broadened later chambers, which appear reniform. × 135.

**Figures 21, 22.** *Pseudoguembelina costulata* (Cushman)

21, Hypotype (Cushman Coll. 31706), from the Upper Cretaceous, Navarro group, Corsicana marl, from pit near Corsicana, Navarro County, Texas. Megalospheric form, with biserial base, and well developed chamber extensions, and accessory apertures. × 125. 22, Hypotype (Cushman Coll. 31705), from the Upper Cretaceous, upper Taylor, in a road cut 14.4 miles S. of Paris, 0.9 mile north of Lake City, Delta County, Texas. Coll. by C. I. Alexander. Edge view, showing lateral extensions of the arched aperture. × 125.

**Figure 23.** *Pseudoguembelina excelata* (Cushman)

23, Hypotype (Cushman Coll. 31769) from the Upper Cretaceous, Navarro group, Corsicana marl, from clay pit near Corsicana, Navarro County, Texas, showing the early coil in the microspheric generation. The final chamber of the specimen is broken, obscuring the apertural characters. × 155.

Figures 5, 12, and 13 prepared by Helen Tappan Loeblich; others by Lawrence and Patricia Isham.
HETEROHELICIDAE: GUEMBELITRIINAE, HETEROHELICINAE
HETEROHELICIDAE: HETEROHELICINAE
Figures 1–6b. *Gublerina ornatissima* (Cushman and Church)  
1, Topotype (USNM P5446) of *Gublerina cuvillieri* Kikoïne (=*G. ornatissima*) the type species of *Gublerina*, from the Upper Cretaceous, Maestrichtian, between Gan and Rebecançq, Dept. Basses Pyrenees, France.  
2–4, Hypotypes of *G. cuvillieri* (USNM P5447a–c), from the Upper Cretaceous (Maestrichtian), 2 miles south of Salies de Béarn, Dept. Basses Pyrenees, France.  
2, Acid-treated specimen, with surface removed to show interior, the two diverging series of chambers, and wide non-camrate central area; 3, specimen showing ornamented basal portion, diverging chambers, and surface horizontal grooves suggesting septa across the central non-camrate area, with final chamber proliferation at the top; 4, specimen with beaded horizontal ornamentation across the non-septate central area, later bubbled appearance, and finally the chamber proliferation.  
5b, Top view, showing compressed form, but with upper surface broken and aperture not visible. Figs. 1–5, all × 75.  
6a, Paratype (Cushman Coll. 10038) of *Ventilabrella ornatissima* Cushman and Church (=*Gublerina*), from the Upper Cretaceous, at 1,000 to 1,135 feet, in “Calif. No. Petr. Co. well No. 19,” sec. 2, T. 21 S., R. 14 E., near Coalinga, California. Surface etched to show chamber arrangement.  
6b, Unacidized surface of opposite side, showing obscure appearance of septa at surface.  
× 100.  
Figure 7. *Gublerina glaesneri* Bronnimann and Brown  
7, Holotype (USNM P5442), from the Upper Cretaceous, Maestrichtian, in construction pit of Gran Templo Nacional Masonico, NW corner of Paseo Carlos III and Calzado de Belascoain (Padre Varela), Havana, Cuba, showing better preserved surface.  
× 100.  
Figure 8. *Gublerina decoratissima* (deKlasz)  
8, Paratype (USNM P5445) from the Upper Cretaceous, Santonian, from 500 m. South of Horgering, near Eisenärzt, Upper Bavaria. Coll. by I. de Klasz.  
× 80.  
Figure 9. *Gublerina acuta robusta* de Klasz  
9, Paratype (USNM P5441) of *Gublerina hedbergii* Bronnimann and Brown, 1953, text fig. 12, (=*G. acuta robusta*), from the Upper Cretaceous, Maestrichtian, in construction pit of Gran Templo Nacional Masonico, NW corner of Paseo Carlos III and Calzado de Belascoain (Padre Varela), Habana, Cuba.  
× 130.  
Figures 10–12. *Planoglobulina glabrata* (Cushman)  
10, Large specimen, paratype of *Ventilabrella eggeri* var. *glabrata* Cushman (Cushman Coll. 24408), from the Upper Cretaceous, Taylor clay pit at Palmer, Ellis County, Texas, showing striate surface, globular chambers and extreme chamber proliferation. Coll. by J. A. Cushman and James Waters.  
11, Smaller paratype from same locality, etched to show early *Heterohelix globulosa*-like stage, although the initial portion of the test is broken.  
12, Paratype (Cushman Coll. 24407) from the same locality, showing early *Heterohelix*-like stage.  
All × 100.  
Figure 13. *Planoglobulina caseyae* (Plummer)  
13, Megalospheric hypotype (USNM P35b) from the Upper Cretaceous, Navarro group, Kemp clay, 6 to 8 feet above the base of the pit of the Seguin Tile and Brick Co., McQueeny, Guadalupe County, Texas. Coll. by A. R. Loeblich, Jr.  
× 105.  
Figures 14a–15b. *Racemiguembelina fructicosa* (Egger)  
14a, 15a, Side views of the flaring conical and striate tests of hypotypes (USNM P5451) from the Upper Cretaceous, Navarro group, Corsicana marl, in branch of Mustang Creek, 1 mile WSW of Noack, 900 feet downstream from the road, and 0.2 mile southwest of Christ Evangelical Lutheran church, Williamson County, Texas. Coll. by A. R. Loeblich, Jr.  
14b, 15b, Top views, showing nearly circular form, primary and accessory apertures of the unusually well preserved specimens.  
× 115.  
Figures 13 prepared by Helen Tappan Loeblich, others by Lawrence and Patricia Isham.
PLATE 33. HETEROHELICIDAE, PLECTOFRONDICULARIIDAE, BULIMINIDAE

HETEROHELICIDAE

Figure 1. Tubitextularia bohemica (Sulc) 143
    1, Topotype (USNM P5437) from the Upper Cretaceous, Senonian, of Vinice, Czechoslovakia. Coll. by J. Sulc. × 150.

Figures 2, 3. Tubitextularia texana (Cushman) 143
    2, 3, Hypotypes (Cushman Coll. 31834) from the Upper Cretaceous, Eagle Ford formation, 1 mile north of Lovelace, Texas. Coll. by L. W. Stephenson. × 150.

Figures 4, 5. Tubitextularia cretacea (Cushman) 143
    4, 5, Topotypes (USNM P5436) of the type species of Rectoguembelina Cushman, from the Upper Cretaceous, Arkadelphia clay, at the SW corner of the NW¼, sec. 6, T. 12 S., R. 23 W., on the Hope-Prescott road, near Hope, Arkansas. × 150.

Figures 6a–c. Pseudotextularia elegans (Rzchak) 138
    6a, Side view of hypotype (Cushman Coll. 24384) from the Upper Cretaceous, Upper Taylor, in road cut 0.9 mile N. of Lake City, Delta County, Texas. 6b, Edge view. 6c, Apertural view. × 100.

PLECTOFRONDICULARIIDAE

Figures 7a–9. Amphimorphina hauerina Neugeboren 144
    7a, Side view of hypotype (Cushman Coll. 17212) from the Miocene of Kostej, Banat, Hungary. 7b, Basal view, showing early quadrilateral outline, with gradual growth to circular section in the adult. Both × 50. 8, 9, Hypotypes (USNM P5450a,b) from the Lower Miocene, La Sablaine, Saubriques, Dept. Landes, France. 8a, Side view of megaspherical form; 8b, top view, showing aperture. 9, Side view of microspherical form, showing biserial early stage. All × 75.

Figure 10. Plectofrondicularia floridaná Cushman 144
    10a, Side view of hypotype (Cushman Coll. 62866) from the upper Oligocene, in a core at 96 to 106 feet, Trinchera formation, Bravo well No. 2, Yaguate area, Trujillo Province, Dominican Republic. 10b, Apertural view. × 65.

Figure 11. Plectofrondicularia garzaensis Cushman 144
    and Siegfuß

BULIMINIDAE

Figure 11. Hypotype (USNM P5438), showing enveloping biserial early chambers. From the Oligocene Tumey formation, at 4,143 to 4,152 feet, in Seaboard Oil Co. Welch No. 1 well, Fresno County, California. × 65.

Figures 12a, 13b. Bolivinella folia (Parker and Jones) 143
    12a, Side view of hypotype (USNM P5449) from the Recent, at 12 fathoms, off Levuke, Fiji. 12b, Apertural view. 13a, Side view of hypotype (Cushman Coll. 17284) from the Recent, near Nairai, Fiji. 13b, Apertural view. All × 130.

Figures 14–16c. Bolivinoides draco (Marsson) 145
    14, 16, Topotypes (Cushman Coll. 12108; USNM P5435), from Upper Cretaceous, Campanian, at Sassnitz, Island of Rugen, Germany. Coll. by R. S. Bassler. 14, Showing interior of acid-treated specimen, with smooth, gently curved septa and internally tuberculate wall; 16a, side view, showing surface ornamentation; 16b, edge view; 16c, apertural view. 15, Oblique edge view of hypotype (Cushman Coll. 9383), from Upper Cretaceous, Pattenuer Stölken, Germany, with specimen tilted to show apertural opening. All × 100.

Figures 17a–20. Bolivinida quadrilatera (Schwager) 146
    17a, 18a, Side views of hypotypes (USNM P5439a–d) from the Recent at 383 fathoms, Albatross Station D5445, Atalaya Point, Batag Island, Philippines, S. 56° E., 5.3 mi. at lat. 12° 44′ 42″ N., long. 124° 59′ 50″ E. 17b, 18b, Edge views to show variation in shape in microspheric and megaspherical generations. 19, 20, Edge views of acid-dissected specimens to show internal tooth. All × 65.

Figures 21a, b. Tappanina selmers (Cushman) 147
    21a, Side view of holotype (Cushman Coll. 19043) from the Upper Cretaceous, Selma chalk, on New Corinth Highway, 13.5 miles south of Selmer, McNairy County, Tennessee. 21b, Apertural view. × 190.
HETEROHELICIDAE, PLECTOFRONDICULARIIDAE, BULIMINIDAE
Plate 34. BULIMINIDAE, UVIGERINIDAE

Eouvgigerininae

Figures 1–5. Eouvgigerina americana Cushman 148

1, Hypotype (USNM P5452), showing variability in shape and less closely appressed chambers, from the Upper Cretaceous, Taylor group, 7.7 miles east of McKinney, on the road to Farmersville, Collin County, Texas. 2, Hypotype (Cushman Coll. 32201) from the Upper Cretaceous, Taylor group, Wolfe City sand, 2.5 miles south of Gober, Fannin County, Texas. Coll. by L. W. Stephenson. Acid-dissected specimen, showing internal tube in the final chamber, not previously known in this genus. 3, 5, Hypotypes (Cushman Coll. 32208) from the Upper Cretaceous, Taylor group, Wolfe City sand, in a roadside ditch north of the McKinney-Farmersville road, 13.85 miles east of the T. C. railroad tracks in McKinney, Texas. Coll. by C. I. Alexander. These specimens show more rounded chambers than is typical of the species. 4a, Side view, showing carinate chambers and completely biserial test of holotype (Cushman Coll. 4986), from the Upper Cretaceous Taylor marl, in clay pit of the Dallas Brick Co., ½ mile west of Mesquite, Texas. 4b, Top view, showing terminal aperture. All × 160.

Figures 6, 7. Eouvgigerina plummerae Cushman 148

6, 7, Hypotypes (Cushman Coll. 32246) from the Austin chalk, in a road cut between two railroad underpasses at the north edge of Howe, Grayson County, Texas. Coll. by C. I. Alexander. × 160.

Figures 8a–10b. Siphogenerinoides plummeri (Cushman) 148

8a, 9, Side view of topotypes (USNM P5453) from the Upper Cretaceous, Navarro group, in the bank of Walker Creek, 6 miles N. 15° E. of Cameron, 1 mile upstream from the intersection of Walker Creek and the Cameron-Clarkson road, Milam County, Texas. Coll. by H. J. Plummer. 8b, Top view. × 65. 10a, Sectioned topotype (USNM P5455), showing internal tube. × 65. 10b, Upper part of same specimen, enlarged to show detail of internal tube, which is only hemicylindrical, and segments of adjoining chambers alternate in orientation, suggesting a reflection of the early biserial development in the interior of the otherwise uniserial and symmetrical chambers. × 130.

Figures 11a–12b. Zeauvgigerina zelandica Finlay 149

11a, Side view of paratype (Cushman Coll. 26775) from the type Wanstead (upper middle Eocene), Dannevirke area, Motuoaria S. D., 1 mile south of Wonstead Hotel, New Zealand. Coll. by H. J. Finlay. 11b, Top view, showing terminal aperture. 12a, Paratype (Cushman Coll. 26776) from the upper-middle Eocene, Moeraki S. D., 1 mile at 29° from Triq E., marly clay of Mackay, New Zealand. Coll. by H. J. Finlay. 12b, Top view, showing terminal aperture. All × 180.

Figures 13a–c. Trachelinella waversi (Cushman) 150

13a, Side view of hypotype (USNM P4480a) from the Upper Cretaceous, upper Navarro, Maestrichtian, in pit of Seguin Tile and Brick Co., at McQueeney, Guadalupe County, Texas. Coll. by A. R. Loeblich, Jr. 13b, Edge view. 13c, Top view, showing terminal aperture, × 190.

Figures 14–17. Bolivinella elegi (Cushman) 150

14a, Side view of holotype (Cushman Coll. 5552) from the Upper Cretaceous Brownstown marl, Hollywood road, 8.1 miles west of Arkadelphia, Clark County, Arkansas. Coll. by L. W. Stephenson. 14b, Edge view. 14c, Apertural view. × 105. 15, 16, Hypotypes (Cushman Coll. 62189) from the Upper Cretaceous in Ohio Oil Co. Larry G. Hammond well No 1, at 1,410 to 1,420 feet, Salisbury, Maryland. 17, Hypotype (Cushman Coll. 17662) from type locality of the Annona Chalk, Upper Cretaceous, at Annona, Texas. Coll. by N. L. Thomas. Figs. 15–17 × 100.

Bulimidiae

Figures 18a–c. Tosaia kanzawai Takayanagi 151

18a, Side view of paratype (USNM P5454), from the Pliocene, Nobori formation, in cliff 100 miles east of Nobori, Hane-muri, Aki-gun, Kochi prefecture, Japan. Coll. by Y. Takayanagi. 18b, Top view, showing low arched aperture. 18c, Basal view, showing trochoid early stage, later triserial, and finally biserial. × 100.

Uvigerinidae

Figures 19a–22. Pseudouvgigerina cristata (Mars-151

19a, Side view of topotype (Cushman Coll. 39651), from the Campanian, Upper Cretaceous, Island of Rügen, Germany. 19b, Top view. × 150. 20–22, Hypotypes (USNM P4858a–c), from the Upper Cretaceous, Maestrichtian, Gerhardsreuter Schichten, Starzmühl, near Teisendorf, Upper Bavaria. Coll. by H. Hagn. 20a, View of side; 20b, view from opposite angle; 20c, top view; 21, 22, acid-dissected specimens showing, respectively, internal tooth in final and penultimate chamber. × 140.

(Continued on page 272)
Plate 34. BULIMINIDAE, UVIGERINIDAE  
(Continued)

<table>
<thead>
<tr>
<th>Figures</th>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>23-24, Holotype (LSU 2563), from the Eocene, Cane River formation, in core from Louisiana Oil and Refining Co. Tremont well 2, 2,312 feet east and 345 feet north of the southwest corner, SW 1/4, Sec. 24, T. 10 N., R. 2 E., La Salle Parish, Louisiana. × 100. Figured to show characters of this probable arthropod appendage.</td>
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Plate 35. HASTIGERINA, CLAVIGERINELLA, GLOBIGERINA  
( Figures 1-2 × 144, all others × 73)
HASTIGERINA, CLAVIGERINELLA, GLOBIGERINA
Plate 36. GLOBIGERINA, “GLOBIGERINOIDES”, GLOBIGERAPSIS

(All figures × 73)

Figures 1a–2b. Globigerina boxeri Bolli, new species
1a, Spiral view of holotype (USNM P5711).
1b, Umbilical view. 1c, Side view. 2a, Spiral view of large paratype (USNM P5712). 2b, Umbilical view. Both from the Hantkenina aragonensis zone, Navet formation, Trinidad.

Figures 3a, b. Globigerina cf. trilocularis d’Orbigny 163
3a, Spiral view of figured specimen (USNM P5713). 3b, Umbilical view. From the Globorotalia cocoensis zone, San Fernando formation, Trinidad.

Figures 4a, b. Globigerina rohri Bolli 164
4a, Spiral view of hypotype (USNM P5714). 4b, Umbilical view, showing a rudimentary final chamber. From the Globorotalia cocoensis zone, San Fernando formation, Trinidad.

Figures 5a, b. Globigerina linaperta Finlay 163
5a, Spiral view of small hypotype (USNM P5715). 5b, Umbilical view. From the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 6a, b. Globigerina eiperoniensis angustium-bilicata Bolli 164
6a, Spiral view of hypotype (USNM P5716). 6b, Umbilical view. From the Globorotalia cocoensis zone, San Fernando formation, Trinidad.

Figures 7a–c. Globigerina parca Bolli 164
7a, Spiral view of hypotype (USNM P5717). 7b, Umbilical view. 7c, Side view. From the Globigerapsis semiinvoluta zone, Navet formation, Trinidad.

Figures 8a–c. Globigerina ampliapertura Bolli 164
8a, Spiral view of hypotype (USNM P5718). 8b, Umbilical view. 8c, Side view. From the Globorotalia cocoensis zone, San Fernando formation, Trinidad.

Figures 9, 10. Specimens transitional between Globorotalia centralis Cushman and Bermudez and Globigerina ampliapertura Bolli 164
9, Umbilical view of figured specimen (USNM P5719a). 10, Umbilical view of figured specimen (USNM P5719b). Both from the Globorotalia cocoensis zone, San Fernando formation, Trinidad.

Figures 11a–13b. “Globigerinoides” higginsi Bolli, new species

Figures 14a–18b. Globigerapsis index (Finlay) 165
14a, Spiral view of hypotype (USNM P5722a). 14b, Umbilical view. 15, Umbilical view of hypotype (USNM P5722b). Both from the Globigerapsis kugleri zone, Navet formation, Trinidad. 16, Side view of hypotype (USNM P5723). 17, Umbilical view of hypotype (USNM P5724), with final chamber removed to show the open umbilicus of the early globigerinid stage. 18a, Spiral view of juvenile specimen (USNM P5725), showing early Globigerina stage. 18b, Umbilical view. All from the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 19, 20. Globigerapsis semiinvoluta (Keijzer) 165
19, Side view of hypotype (USNM P5726a). 20, Side view of hypotype (USNM P5726b). Both from the Globigerapsis semiinvoluta zone, Navet formation, Trinidad.

Figures 21a, b. Globigerapsis kugleri Bolli, Loeblich, and Tappan 165
21a, Spiral view of hypotype (USNM P5727). 21b, Side view. From the Globorotalia lehneri zone, Navet formation, Trinidad.
Plate 37. Porticulasphaera, Catapsydrax, Globigerinatheka, Globorotaloides, Globorotalia

(All figures × 73)

Figures 1a, b. Porticulasphaera mexicana (Cushman) 165
1a, Spiral view of hypotype (USNM P5728).
1b, Side view. From the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 2a–5b. Catapsydrax echinatus Bolli, new 165 species
2a, Spiral view of holotype (USNM P5729).
2b, Umbilical view. 2c, Side view. 3a, Spiral view of paratype (USNM P5730a).
3b, Umbilical view. 3c, Side view. 4, Side view of small paratype (USNM P5730b).
5a, Spiral view of paratype (USNM P5730c). 5b, Umbilical view, showing thin-walled bulla without spines. All from the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 6a, b. Catapsydrax cf. dissimilis (Cushman and Bermudez)
6a, Spiral view (USNM P5731); 6b, Umbilical view. From the Globigerapsis semiinvoluta zone, Navet formation, Trinidad.

Figures 7a, b. Catapsydrax unicus Bolli, Loeblich, 166 and Tappan
7a, Spiral view of hypotype (USNM P5732).
7b, Umbilical view. From the Truncorotaloides rohri zone, Navet formation, Trinidad.

Figures 8, 9. Globigerinatheka barri Bronnimann 166
8, Hypotype (USNM P5733a), with only one of the 3 sutureal apertures visible in the figure, covered by a small sutureal bulla. 9, Hypotype USNM P5733b), with all sutureal apertures covered by large sutureal bullae. Both from the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 10a–12. Globorotaloides suturi Bolli 166
10a, Spiral view of hypotype (USNM P5734a).
10b, Umbilical view, showing much reduced final chamber which covers only small area of the umbilicus. 10c, Side view. 11, Umbilical view of hypotype (USNM P5734b). 12, Umbilical view of hypotype (USNM P5734c). All from the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 13a–c. Globorotalia broedermanni Cushman 167 and Bermudez
13a, Spiral view of hypotype (USNM P5735).
13b, Umbilical view. 13c, Side view. From the Globorotalia palmerae zone, Navet formation, Trinidad.

Figures 14a–16. Globorotalia bolivariana (Petters) 169
14a, Spiral view of hypotype (USNM P5736a).
14b, Umbilical view. 14c, Side view. 15a, Spiral view of hypotype (USNM P5736b).
15b, Umbilical view. 15c, Side view. 16, Umbilical view of hypotype (USNM P5736c). All from the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 17a–c. Globorotalia pseudomayeri Bolli, new 167 species
17a, Spiral view of holotype (USNM P5737).
17b, Umbilical view. 17c, Side view. From the Hankenina aragonensis zone, Navet formation, Trinidad.

Figures 18a–c. Globorotalia arvensis (Colom) 166
18a, Spiral view of hypotype (USNM P5738).
18b, Umbilical view. 18c, Side view. From the Globorotalia palmerae zone, Navet formation, Trinidad.
PORTICULASPHAERA, CATAPSYDRAX, GLOBIGERINATHEKA, GLOBOROTALOIDES, GLOBOROTALIA
Plate 38. Globorotalia

(Figures 3a–c, × 144; all others × 73)

Figures 1a–c. Globorotalia aragonensis Nuttall 167
   1a, Spiral view of hypotype (USNM P5739).
   1b, Umbilical view. 1c, Side view. From the Hantkenina aragonensis zone, Navet formation, Trinidad.

Figures 2a–c. Globorotalia palmerae Cushman and Bermudez 166
   2a, Spiral view of a worn hypotype (USNM P5740). 2b, Umbilical view. 2c, Side view. From the Globorotalia palmerae zone, Navet formation, Trinidad.

Figures 3a–c. Globorotalia renzi Bolli, new species 168
   3a, Spiral view of holotype (USNM P5741).
   3b, Umbilical view. 3c, Side view. From the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 4a–5c. Globorotalia bullbrooki Bolli, new 167 species
   4a, Spiral view of small paratype (USNM P5743). 4b, Umbilical view. 4c, Side view.
   5a, Spiral view of holotype (USNM P5742).
   5b, Umbilical view. 5c, Side view. Both from the Hantkenina aragonensis zone, Navet formation, Trinidad.

Figures 6a–7c. Globorotalia spinulosa Cushman 168
   6a, Spiral view of well preserved hypotype (USNM P5744a).
   6b, Umbilical view. 6c, Side view. 7a, Spiral view of hypotype with spines partially worn away (USNM P5744b).
   7b, Umbilical view. 7c, Side view. Both from the Hantkenina aragonensis zone, Navet formation, Trinidad.

Figures 8a–c. Globorotalia spinuloinflata (Bandy) 168
   8a, Spiral view of hypotype (USNM P5745).
   8b, Umbilical view. 8c, Side view. From the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 9a–13. Globorotalia lehneri Cushman and Jarvis 169
   9a, Spiral view of hypotype (USNM P5746a).
   9b, Umbilical view. 9c, Side view. 10a, Spiral view of small hypotype (USNM P5746b).
   10b, Umbilical view, showing rudimentary final chamber. 11a, Spiral view of large hypotype (USNM P5747).
   11b, Umbilical view. 12, Spiral view of hypotype (USNM P5746c).
   13, Spiral view of hypotype with broken rudimentary final chamber (USNM P5746d). All from the Porticulasphaera mexicana zone, Navet formation, Trinidad.
Plate 39. GLOBOROTALIA, TRUNCOROTALOIDES
(Figures 3a-c, × 144; all others × 73)

Figures 1a–4. Globorotalia centralis Cushman and 169 Bermudez
   1a, Spiral view of large hypotype (USNM P5748a). 1b, Umbilical view. 1c, Side view. 2a, Spiral view of high spired hypotype (USNM P5748b). 2b, Side view. 3a, Spiral view of small hypotype (USNM P5748c). 3b, Umbilical view. 3c, Side view. All from the Porticulasphaera mexicana zone, Navet formation, Trinidad.
   4, Side view of typical hypotype (USNM P5749). From the Globorotalia cocoaensis zone, San Fernando formation, Trinidad.

Figures 5a–7b. Globorotalia cocoaensis Cushman 169
   5a, Spiral view of the distinctly umbilico-convex hypotype (USNM P5750a). 5b, Side view. 6a, Spiral view of hypotype (USNM P5750b). 6b, Umbilical view. 6c, Side view. 7a, Spiral view of hypotype (USNM P5750c). 7b, Side view. All from the Globorotalia cocoaensis zone, San Fernando formation, Trinidad.

Figures 8–12c. Truncorotaloides rohri Bronnimann 170 and Bermudez
   8, Spiral view of juvenile hypotype which has not yet developed sutural supplementary apertures (USNM P5751a). 9, Spiral view of slightly larger hypotype (USNM P5751b), showing sutural supplementary apertures. 10a, Spiral view of hypotype (USNM P5751c) with sutural supplementary aperture on rudimentary final chamber. 10b, Umbilical view. 11, Spiral view of hypotype (USNM P5751d) showing several sutural supplementary apertures in the last two chambers. 12a, Spiral view of characteristic hypotype (USNM P5751e). 12b, Umbilical view. 12c, Side view. All from the Porticulasphaera mexicana zone, Navet formation, Trinidad.

Figures 13–16b. Truncorotaloides topilensis (Cushman 170 man)
   13, Spiral view of small hypotype which has not developed sutural supplementary apertures (USNM P5752a). 14, Spiral view of small hypotype showing two small sutural supplementary apertures (USNM P5752b). 15, Spiral view of large hypotype (USNM P5752c). 16a, Spiral view of very angular, spinose hypotype (USNM P5752d). 16b, Umbilical view. 16c, Side view. All from the Porticulasphaera mexicana zone, Navet formation, Trinidad.
GLOBOROTALIA, TRUNCOROTALOIDES
DANIAN AND PINE BARREN PLANKTONIC SPECIES
PLATE 40. DANIAN AND PINE BARREN PLANKTONIC SPECIES

(Figures 1-5 from type Danian, figures 6-9 from Pine Barren; figures 6-8, × 290; all others × 145)

Figures 1a-c. Globigerinoides daubjergensis (Bronnimann)

1a, Spiral view of hypotype (USNM P5709), showing supplementary apertures in final chamber. 1b, Umbilical view. 1c, Edge view.

Figures 2a-b. Chiloguembelina morsei (Kline)

2a, Side view of hypotype (USNM P5854) showing narrow test, and aperture directed toward the broad side. 2b, Edge view.

Figures 3a-c. Globorotalia pseudobulloides (Plummer)

3a, Spiral view of hypotype (USNM P5720). 3b, Umbilical view, showing extraumbilical aperture. 3c, Edge view.

Figures 4a-c. Globigerina triloculinoides Plummer

4a, Spiral view of hypotype (USNM P5814) showing coarsely pitted surface. 4b, Umbilical view, showing umbilical aperture with narrow lip. 4c, Edge view.

Figures 5a-c. Globorotalia compressa (Plummer)

5a, Spiral view of hypotype (USNM P5716). 5b, Umbilical view showing broad simple apertural lip. 5c, Edge view, showing slightly compressed chambers.

Figure 6. Woodringina claytonensis Loeblich and Tappan

6, Side view of holotype (USNM P5685), showing early triserial stage of a single whorl, and later biserial chambers.

Figures 7a-c. Globorotalia perclara Loeblich and Tappan, new species

7a, Spiral view of paratype (USNM P5821), showing distinctly hispid surface. 7b, Umbilical view. 7c, Edge view.

Figures 8a-c. Globigerinoides daubjergensis (Bronnimann)

8a, Spiral view of hypotype (USNM P5713). 8b, Umbilical view. 8c, Edge view.

Figures 9a-c. Globorotalia pseudobulloides (Plummer)

9a, Spiral view of hypotype (USNM P5724). 9b, Umbilical view showing prominent lip. 9c, Edge view.

277
Plate 41. McBRYDE PLANKTONIC SPECIES

(All figures × 145)

Figures 1a–c. Globorotalia pseudobulloides (Plummer)
   1a, Spiral view of hypotype (USNM P5725).
   1b, Umbilical view. 1c, Edge view.

Figures 2a–c. Globigerina triloculinoides Plummer 183
   2a, Spiral view of hypotype (USNM P5818), showing coarsely pitted surface.
   2b, Umbilical view, showing prominent apertural lip. 2c, Edge view.

Figure 3. Chiloguembelina midwayensis (Cushman) 179
   3, Side view of hypotype (USNM P5829), showing aperture directed toward broad side of test, and fine spines on later part of test.

Figure 4. Chiloguembelina morsei (Kline) 179
   4, Side view of hypotype (USNM P5855), showing narrower test than in C. midwayensis.

Figures 5a–c. Globorotalia compacta (Plummer) 188
   5a, Spiral view of hypotype (USNM P5718).
   5b, Umbilical view, showing prominent apertural lip. 5c, Edge view.

Figure 6. Tubitextularia laevigata Loeblich and Tappan, new species
   6, Side view of holotype (USNM P5820), showing early biserial part followed by uniserial stage, and the characteristic smooth surface of the test.

Figure 7. Tubitextularia alabamensis (Cushman) 180
   7, Side view of hypotype (USNM P5686), showing early biserial part and later cuneate chambers tending to become uniserial, and finely hispid surface.

Figures 8a–c. Globorotalia perclara Loeblich and Tappan, new species
   8a, Spiral view of paratype (USNM P5822).
   8b, Umbilical view, showing spinose surface.
   8c, Edge view, showing small aperture.

Figures 9a–c. Globigerinoids daubjergensis (Bronnimann) 184
   9a, Spiral view of hypotype (USNM P5714) showing prominently spinose wall surface, characteristic of this species. 9b, Umbilical view. 9c, Edge view.
McBRYDE PLANKTONIC SPECIES
BRIGHTSEAT PLANKTONIC SPECIES
Plate 42. BRIGHTSEAT PLANKTONIC SPECIES

(All figures × 145)

Figures 1a, b. *Chilogucinbelina morsei* (Kline) 179

1a, Side view of hypotype (USNM P5858), showing narrow test and asymmetrical aperture. 1b, Edge view.

Figures 2a–c. *Globigerina triloculinoides* Plummer 183

2a, Spiral view of hypotype (USNM P5699) showing reticulate surface. 2b, Umbilical view, showing distinct lip. 2c, Edge view.

Figures 3a–c. *Globorotalia pseudobulloides* (Plummer) 192

3a, Spiral view of hypotype (USNM P5728). 3b, Umbilical view, showing prominent apertural lip. 3c, Edge view.

Figures 4a–c. *Globorotalia perclara* Loeblich and Tappan, new species

4a, Spiral view of holotype (USNM P5356), showing depressed spire and elevated peripheral region, numerous whorls and low chambers. 4b, Umbilical view, showing somewhat spinose surface. 4c, Edge view.

Figures 5a–c. *Globorotalia compressa* (Plummer) 188

5a, Spiral view of hypotype (USNM P5719). 5b, Umbilical view. 5c, Edge view, showing compression and subacute periphery.

Figures 6a–7c. *Globigerinoides daubjergensis* (Brons-184

6a, 7a, Spiral views of hypotypes (USNM P5715a,b), showing well developed supplementary apertures and characteristic spinose surface. 6b, 7b, Umbilical views. 6c, 7c, Edge views, showing variation in height of spire.

279
Plate 43. KINCAID AND WILLS POINT PLANKTONIC SPECIES

(Figures 1–5 from Kincaid, figures 6–9 from Wills Point; all figures × 145)

**Figures 1a–c.** Globigerinoides daubjergensis (Bronnimann)

1a, Spiral view of hypotype (USNM P5710).
1b, Umbilical view.
1c, Edge view.

**Figure 2.** Chiloguembelina morsei (Kline)  
2, Side view of hypotype (USNM P5856), showing aperture directed toward broad side of test.

**Figures 3a–4c.** Globorotalia pseudobulloides (Plummer)

3a, Spiral view of hypotype (USNM P5721a).
3b, Umbilical view, showing simple apertural lip.
3c, Edge view, showing broad extraumbilical aperture.
4a, Spiral view of small hypotype (USNM P5721b).
4b, Umbilical view, showing bulla-like chamber covering the umbilical area.
4c, Edge view, showing bulla-like chamber.

**Figures 5a–c.** Globigerina triloculinoides Plummer

5a, Spiral view of hypotype (USNM P5815) showing coarsely punctate surface.
5b, Umbilical view, showing small apertural lip.
5c, Edge view.

**Figures 6a, b.** Chiloguembelina morsei (Kline)  
6a, Side view of hypotype (USNM P5857) showing narrow test, thin apertural lips and hispid wall surface.
6b, Edge view, showing the delicate apertural lip.

**Figures 7a–b.** Chiloguembelina midwayensis (Cushman)

7a, Side view of hypotype (USNM P5831), showing broad test and asymmetrical aperture.
7b, Edge view, showing aperture.

**Figures 8a–9c.** Globigerina triloculinoides Plummer

8a, Spiral view of hypotype (USNM P5817) showing coarsely punctate test and four chambers in the final whorl.
8b, Umbilical view.
9a, Spiral view of topotype (USNM P5816) showing three chambers in the final whorl.
9b, Umbilical view, showing prominent apertural lip.
9c, Edge view.
WILLS POINT GLOBOROTALIA AND GLOBIGERINOIDES
Plate 44. Wills Point Globorotalia and Globigerinoides

(All figures × 145)

Figures 1a–2b. Globorotalia varianta (Subbotina) 196

1a, Spiral view of hypotype (USNM P5707a), showing similarity to G. pseudobulloides, but with distinctly spinose early chambers. 1b, Umbilical view, showing distinct apertural lip. 1c, Edge view. 2a, Spiral view of hypotype (USNM P5707b), with final chamber of reduced size. 2b, Umbilical view.

Figures 3a–c. Globorotalia imitata Subbotina 190

3a, Spiral view of hypotype (USNM P5688), showing small size and low chambers. 3b, Umbilical view, showing distinct lip. 3c, Edge view.

Figures 4–6c. Globorotalia pseudobulloides (Plummer) 192

4, 5, Umbilical views of hypotypes (USNM P5722a, b) with aberrant final chamber extending, bulla-like, to cover the umbilicus. 6a, Spiral view of hypotype (USNM P5723). 6b, Umbilical view. 6c, Edge view.

Figures 7–8c. Globigerinoides daubjergensis (Bronnimann) 184

7, Umbilical view of hypotype (USNM P5711) with aberrant and somewhat elongate final chamber. 8a, Spiral view of hypotype (USNM P5712) showing supplementary apertures and spinose wall. 8b, Umbilical view. 8c, Edge view, showing relatively high spire.

Figures 9a–10c. Globorotalia compressa (Plummer) 188

9a, 10a, Spiral views of hypotypes (USNM P5717a, b). 9b, 10b, Umbilical views. 9c, 10c, Edge views, showing variation in degree of compression.
Plate 45. MATTHEWS LANDING GLOBIGERINA, GLOBOROTALIA, AND CHILOGUEMBELINA

(Figure 9 × 220; all others × 145)

Figures 1a–2c. Globorotalia pseudobulloides (Plummer)

1a, 2a, Spiral views of hypotypes (USNM P5726a,b). 1b, 2b, Umbilical views, showing prominent lip of final and earlier chambers remaining visible in the umbilical area. 2c, Edge view.

Figures 3a–c. Globigerina triloculinoides Plummer

3a, Spiral view of hypotype (USNM P5819). 3b, Umbilical view. 3c, Edge view.

Figures 4a–c. Globorotalia varianta (Subbotina)

4a, Spiral view of hypotype (USNM P5708) showing spinose surface. 4b, Umbilical view. 4c, Edge view.

Figures 5a–c. Globorotalia elongata Glaessner

5a, Spiral view of small hypotype (USNM P5813). 5b, Umbilical view. 5c, Edge view.

Figures 6a–c. Globorotalia imitata Subbotina

6a, Spiral view of hypotype (USNM P5689), showing similarity to G. compressa. 6b, Umbilical view. 6c, Edge view, showing broadly rounded periphery and inflated chambers, in contrast with G. compressa.

Figures 7a–c. Globorotalia angulata (White)

7a, Spiral view of hypotype (USNM P5892) showing keeled periphery and strongly curved sutures. 7b, Umbilical view, with elevated umbilical shoulder, small umbilicus and narrow apertural lip. 7c, Edge view, showing angular and keeled periphery and acutely angled umbilical shoulder.

Figures 8a–c. Globorotalia species

8a, Side view of specimen (USNM P5880), showing low chambers and curved sutures. 8b, Umbilical view. 8c, Edge view.

Figures 9a, b. Chiloguembelina midwayensis (Cushman)

9a, Side view of hypotype (USNM P5830) with asymmetrical aperture directed toward flat side of test. 9b, Edge view.

Figures 10a–c. Globorotalia pseudomenardii Bolli

10a, Spiral view of hypotype (USNM P5701), showing peripheral keel and rapid increase in chamber size. 10b, Umbilical view, showing small apertural lip. 10c, Edge view.

Figures 11a–c. Globorotalia perclara Loeblich and Tappan, new species

11a, Spiral view of paratype (USNM P5823), showing small size, globular chambers and spinose wall. 11b, Umbilical view, showing relatively wide umbilicus. 11c, Edge view.
MATTHEWS LANDING GLOBIGERINA, GLOBOROTALIA, AND CHILOGUEMBELINA
COAL BLUFF GLOBIGERINA AND GLOBOROTALIA
Plate 46. COAL BLUFF GLOBIGERINA AND GLOBOROTALIA

(All figures × 145)

Figures 1a–c. Globigerina triloculinosoides Plummer 183
1a, Spiral view of hypotype (USNM P5697).
1b, Umbilical view, with prominent apertural lip.
1c, Edge view.

Figures 2a–c. Globorotalia irrorata Loeblich and 191 Tappan, new species
2a, Spiral view of paratype (USNM P5873) showing spinose wall. 2b, Umbilical view, showing nearly closed small umbilicus. 2c, Edge view, showing small extraumbilical aperture.

Figures 3a–c. Globorotalia perclara Loeblich and 191 Tappan, new species
3a, Spiral view of paratype (USNM P5824) showing spinose early chambers and nearly smooth later chambers. 3b, Umbilical view, showing umbilicus and small apertural lip.
3c, Edge view, showing small aperture.

Figures 4a–c. Globorotalia pseudoscutula Glaessner 193
4a, Spiral view of hypotype (USNM P5870), showing low chambers and limbate, curved sutures. 4b, Umbilical view, showing small umbilicus and apertural lip. 4c, Edge view, showing sharply angled periphery.

Figures 5a–c. Globorotalia elongata Glaessner 189
5a, Spiral view of hypotype (USNM P5692) showing curved and slightly depressed sutures.
5b, Umbilical view, showing nearly radial sutures, small umbilicus and narrow apertural lip.
5c, Edge view.

Figures 6a–c. Globorotalia pseudobullosaides (Plummer) 192
6a, Spiral view of hypotype (USNM P5727).
6b, Umbilical view, showing narrow apertural lip. 6c, Edge view.

Figures 7a–8c. Globorotalia aequa Cushman and 186 Renz
7a, Spiral view of hypotype (USNM P5864a), showing spinose surface and curved and slightly limbate sutures. 7b, Umbilical view, showing apertural lip and umbilicus. 7c, Edge view, showing keeled periphery. 8a, Spiral view of hypotype (USNM P5864b), showing abnormal fourth chamber in final whorl, overlapping the third chamber and part of the early whorls. 8b, Umbilical view, showing surface ornamentation and prominent apertural lip. 8c, Edge view, showing “supplementary” aperture developed on abnormal chamber in final whorl.

Page 283
Plate 47. SALT MOUNTAIN CHILOGUEMBELINA, GLOBIGERINA, AND GLOBOROTALIA

(Figure 1 × 220; all others × 145)

Figure 1. Chiloguembelina species
1, Side view of specimen (USNM P5832), showing aperture directed toward broad side of test.

Figures 2a–c. Globigerina triloculinoides Plummer
2a, Spiral view of 4 chambered hypotype (USNM P5698), showing coarsely punctate surface. 2b, Umbilical view, with small lip covering the nearly umbilical aperture. 2c, Edge view.

Figures 3a–c. Globigerina spiralis Bolli
3a, Spiral view of hypotype (USNM P5122). 3b, Umbilical view, showing umbilical aperture and spinose character of wall in apertural region. 3c, Edge view, showing elevated spire.

Figure 4a–c. Globorotalia pseudomenardii Bolli
4a, Spiral view of hypotype (USNM P5702), showing rapid increase in chamber height and curved and slightly limbate sutures. 4b, Umbilical view, showing more nearly radial sutures. 4c, Edge view, showing keeled periphery.

Figures 5a–c. Globorotalia acuta Toulmin
5a, Spiral view of hypotype (USNM P5142), showing low chambers, curved sutures and keeled periphery. 5b, Umbilical view, showing ornate umbilical shoulder. 5c, Edge view, showing nearly flat spiral side and open aperture, with slight lip.

Figures 6a–c. Globorotalia perclara Loeblich and Tappan, new species
6a, Spiral view of paratype (USNM P5828). 6b, Umbilical view, showing small apertural lip. 6c, Edge view, showing low aperture.

Figures 7a–c. Globigerina mckannai White
7a, Spiral view of hypotype (USNM P5833), showing abnormal gap in the final pair of chambers in the last whorl. 7b, Umbilical view, showing completely umbilical aperture. 7c, Edge view.
SALT MOUNTAIN CHILOGUEMBELINA, GLOBIGERINA, AND GLOBOROTALIA
SALT MOUNTAIN GLOBOROTALIA
Plate 48. SALT MOUNTAIN GLOBOROTALIA

(All figures × 145)

Figures 1a–c. Globorotalia apanthesma Loeblich and Tappan, new species
1a, Spiral view of paratype (USNM P5862), showing low chambers and curved sutures. 1b, Umbilical view, showing small umbilicus, nearly radial sutures and extraumbilical-umbilical aperture. 1c, Edge view, showing aperture.

Figures 2a–c. Globorotalia angulata (White)
2a, Spiral view of hypotype (USNM P5126). 2b, Umbilical view, showing nearly closed small umbilicus. 2c, Edge view.

Figures 3a–c. Globorotalia pseudoscitula Glaessner
3a, Spiral view of hypotype (USNM P5140), showing low chambers, and curved and limbate sutures. 3b, Umbilical view. 3c, Edge view.

Figures 4a–c. Globorotalia convexa Subbotina
4a, Spiral view of hypotype (USNM P5847), showing low chambers and sutures with little curvature. 4b, Umbilical view. 4c, Edge view.

Figures 5a–c. Globorotalia elongata Glaessner
5a, Spiral view of hypotype (USNM P5693) showing chambers of nearly equal breadth and height. 5b, Umbilical view, showing relatively small umbilicus. 5c, Edge view.
Plate 49. HORNERSTOWN CHILOGUEMBELINA, GLOBIGERINA, AND GLOBOROTALIA

(All figures × 145)

Figure 1. Chilocuembelina crinita (Glaessner) 178
   1, Side view of hypotype (USNM P5853), showing aperture directed toward broad side of test, and the finely spinose wall.

Figure 2a–c. Globigerina inaequispira Subbotina 181
   2a, Spiral view of hypotype (USNM P5732).
   2b, Umbilical view, showing small apertural lip.
   2c, Edge view, showing spinose wall.

Figure 3a–c. Globigerina spiralis Bolli 182
   3a, Spiral view of hypotype (USNM P5838), showing low chambers, and slight curvature of sutures.
   3b, Umbilical view, showing successive umbilical apertures and prominent spines in apertural region.
   3c, Edge view, showing relatively high spired test.

Figures 4–5c. Globigerina chascanona Loeblich and 180
   Tappan, new species
   4, Paratype (USNM P5843).
   5, Holotype (USNM P5842).
   4a, 5a, Spiral views, showing inflated chambers, numerous whorls and hirsute surface.
   4b, 5b, Umbilical views, showing small umbilical aperture.
   4c, 5c, Edge views, showing globular chambers and variation in height of spire.

Figures 6a–c. Globorotalia pseudomenardii Bolli 193
   6a, Spiral view of hypotype (USNM P5704), showing strongly curved sutures.
   6b, Umbilical view, showing peripheral keel and low aperture.
   6c, Edge view, showing subacute, keeled periphery, and angular umbilical shoulder.

Figures 7a–c. Globorotalia elongata Glaessner 189
   7a, Spiral view of hypotype (USNM P5697), showing gently curved sutures, and rapidly enlarging chambers.
   7b, Umbilical view, with rounded chambers, small umbilicus and narrow apertural lip.
   7c, Edge view, showing rounded periphery and arched aperture.
HORNERSTOWN CHILOGUENBELINA, GLOBIGERNA, AND GLOBOROTALIA
HORNERSTOWN GLOBIGERINA AND GLOBOROTALIA
PLATE 50. HORNERSTOWN GLOBIGERINA AND GLOBOROTALIA

(All figures: a, spiral view; b, umbilical view; c, edge view; all × 145)

**Figure 1.** *Globorotalia perclara* Loeblich and Tappan, new species
Paratype (USNM P5825), showing small size, gradually enlarging chambers of equal breadth and height, subtruncate periphery, large and open umbilicus, small aperture and spiny surface.

**Figure 2.** *Globigerina* species
Small specimen (USNM P5849) with four chambers in final whorl, spiny surface and broadly rounded periphery.

**Figure 3.** *Globorotalia reissi* Loeblich and Tappan, new species
Paratype (USNM P5836) showing small size, rounded chambers, rounded periphery and smooth wall.

**Figure 4.** *Globorotalia angulata* (White)
Hypotype (USNM P5893), showing lunate appearing chambers and curved, elevated and beaded sutures on the spiral side, subacute and angled umbilical shoulder and radial sutures on the umbilical side, and the keeled periphery.

**Figure 5.** *Globorotalia trichotrocha* Loeblich and Tappan, new species
Paratype (USNM P5690), showing lenticular test, spiny surface, low aperture, depressed sutures which are curved backwards on the spiral side and are radial around the small open umbilicus on the umbilical side.

**Figure 6.** *Globorotalia aequa* Cushman and Renz
Hypotype (USNM P5889), showing few chambers per whorl, rapid increase in chamber size, spiny surface, peripheral keel, and elevated and angled umbilical shoulder.

**Figure 7.** *Globorotalia convexa* Subbotina
Hypotype (USNM P5845), showing sub-globose test, broad low chambers on the spiral side and strongly curved sutures, with elevated spire, radial sutures on umbilical side and low, extraumbilical-umbilical aperture.
Plate 51. VINCENTOWN CHILOGUEMBELINA AND GLOBIGERINA
(All figures × 145)

Figures 1a–3. Chiloguembelina crinita (Glaessner) 178
1a, 2a, 3, Side views of hypotypes (USNM P5115a–c), showing slightly twisted biserial test. 1b, 2b, Edge views, with slightly asymmetrical aperture bordered by an apertural flange, instead of the symmetrical and open arched aperture typical of true Heterohelix. 1c, 2c, Top views, showing how the bordering flange directs the apertural opening toward the side rather than the edge of the test.

Figures 4a–5c. Globigerina aquiensis Loeblich and 180
Tappan, new species
4a, 5a, Spiral views of paratypes (USNM P5841a, b), showing few chambers rapidly increasing in size. 4b, 5b, Umbilical views, showing small umbilical aperture. 4c, 5c, Edge views, showing inflated tests, and variation in height of spire.

Figures 6a–9c. Globigerina spiralis Bolli 182
Hypotypes (USNM P5121a–d); all figures a, spiral side; b, umbilical side; c, edge view. 6, Large hypotype with four chambers in final whorl and a bulla-like final chamber, showing a tendency to obscure the umbilical region. 7, 8, Typical hypotypes showing variation from 4 to 5½ chambers in the final whorl, characteristic many-whorled spire, spinose surface and open umbilical aperture. 9, Hypotype with small final chamber that has an almost extraumbilical aperture.
VINCENTOWN GLOBIGERINA
Plate 52. VINCENTOWN GLOBIGERINA

(All figures × 145)

Figures 1a–2c. Globigerina inaequispira Subbotina 181

1a, 2a, Spiral view of hypotypes (USNM P5117a,b), showing similarity to G. triloculinoides in test form, but with small pores instead of prominent surface reticulation. 1b, 2b, Umbilical side, showing rapid increase in chamber size, spiny surface of umbilical region, and broad flange-like apertural lip. 1c, 2c, Edge views, showing low spire and spiny surface.

Figures 3–7. Globigerina triloculinoides Plummer

Hypotypes (USNM P5123a–e). 4a, 6a, Spiral views, showing characteristic test form and prominent surface reticulation. 3, 4b, 5, 6b, 7, Umbilical views, showing rapid increase in chamber size, broad flange-like apertural lip and coarsely reticulate surface. 4c, 6c, Edge views, showing low spire.
PLATE 53. VINCENTOWN GLOBIGERINA AND GLOBOROTALIA

(All figures: a, spiral view; b, umbilical view, c, edge view; all × 110)

Figures 1, 2. Globigerina mckannai White
Hypotypes (USNM P5119a,b). 1, Large
typical specimen with 5½ chambers in final
whorl, open umbilicus and spiny surface, es-
pecially in the umbilical region. 2, Small hypot-
type with tendency to develop an extraumbilical
aperture.

Figure 3. Globigerina spiralis Bolli
Small hypotype (USNM P5121e), showing very
rare occurrence of an umbilical bulla. The
opening shown in edge view is not that beneath
the bulla, but an accidental break in the wall, the
ture opening being on the opposite side of the
bulla, facing the umbilicus.

290

Figure 4. Globigerina cf. G. soldadoensis Bronni-
mann
Small specimen (USNM P5130) with rounded
chambers.

Figure 5. Globorotalia pseudoscitula Glaessner
Hypotype (USNM P5139) showing typical
lenticular test, subacute periphery, gradually
enlarging chambers, nearly closed umbilicus and
extraumbilical-umbilical aperture.

Figures 6–8. Globorotalia convexa Subbotina
Hypotypes (USNM P5129a–c), showing small
size, gradually enlarging chambers, broadly
rounded periphery, flattened spiral side and
nearly closed umbilicus.
VINCENTOWN GLOBIGERINA AND GLOBOROTALIA
VINCENTOWN GLOBOROTALIA
Plate 54. VINCENTOWN GLOBOROTALIA

(All figures × 110)

Figures 1a–5c. Globorotalia elongata Glaessner

Hypotypes (USNM P5133a–e). 1a, 2, 3, 4a, 5a, Spiral views, showing rapid increase in chamber size and elongate test due to the relatively high chambers. 1b, 4b, 5b, Umbilical views, showing open umbilicus, and apertural lip. 1c, 4c, 5c, Edge views, showing compressed form, rounded to subacute periphery and flattened spire.

Figures 6a–7c. Globorotalia perclara Loeblich and Tappan, new species

Paratypes (USNM P5135a, b), showing small size, low spire, gradually enlarging rounded chambers, open umbilicus, spinose umbilical side and extrumbilical-umbilical aperture. a, Spiral side; b, umbilical side; c, edge.

Figures 8a–9c. Globorotalia imitata Subbotina

Hypotypes (USNM P5131a, b), showing small size, relatively closed umbilicus, slightly flattened and compressed chambers on the spiral side, and low aperture. a, Spiral side; b, umbilical side; c, edge.

Figures 10a–13c. Globorotalia pseudomenardii Bolli

Hypotypes (USNM P5137a–d). a, Spiral views, showing rapid increase in chamber size, broad and low chambers with semicircular outline, and peripheral keel. b, Umbilical views, showing open umbilicus and narrow apertural lip. c, Edge view, showing compressed form, acutely angled and keeled periphery and low but extensive aperture.
PLATE 55. VINCENTOWN GLOBOROTALIA

(All figures: a, spiral view; b, umbilical view; c, edge view; all \( \times 110 \))

Figure 1. *Globorotalia apanthesma* Loeblich and Tappan, new species
Paratype (USNM P5861), showing relatively large size, gently convex spiral side, keeled periphery, angular conical to angular truncate chambers, open umbilicus and angled umbilical shoulder.

Figures 2, 6, 7. *Globorotalia angulata* (White) 187
Hypotypes (USNM P5127a–c), showing medium size, flattened spiral side, strongly lobulate peripheral outline, subacute to rounded periphery and spinose surface, especially in the umbilical region, narrow umbilicus and rounded umbilical shoulder.

Figure 3. *Globorotalia occlusa* Loeblich and Tappan, new species
Paratype (USNM P5866), showing flat spiral side, low convexity of umbilical side, few chambers and small umbilicus.

Figures 4, 5. *Globorotalia acuta* Toulmin 185
Hypotypes (USNM P5141a, b), showing flat spiral side, with crescentic appearing chambers, strongly inflated umbilical side, with limbate and rugose umbilical shoulder, broad and open umbilicus, and broad, low aperture with nearly triangular apertural flaps. Chambers are strongly angular truncate in edge view, and the limbate umbilical shoulder gives the appearance of a doubly keeled test.

Figure 8. *Globorotalia aquea* (?) Cushman and Renz 186
Atypical hypotype (USNM P5888), with more rounded chambers than is usual in the species, and with a bulla-like final chamber.
VINCENTOWN GLOBOROTALIA
AQUIA CHILOGUEMBELINA, HETEROHELIX, AND GLOBIGERINA
Plate 56. AQUIA CHILOGUEMBELINA, HETEROHELIX, AND GLOBIGERINA

(All figures x 145)

Figures 1a, b. Chiloguembelina crinita (Glaessner) 178
1a, Side view of hypotype (USNM P5852), showing flaring test and asymmetrical aperture.
1b, Edge view.

Figures 2a, b. Heterohelix wilcoxensis (Cushman and Ponton)
2a, Hypotype (USNM P5834) showing striate surface, and globular chambers. 2b, Edge view, showing low, symmetrical arched aperture.

Figures 3a, c. Globorotalia trilobosa Loeblich and Tappan, new species
3a, Spiral view of paratype (USNM P5851), showing gradually enlarging chambers, with four in final whorl, and spinose surface. 3b, Umbilical view. 3c, Edge view.

Figures 4a−6c. Globigerina aquiensis Loeblich and Tappan, new species
4, 5, Paratypes (USNM P5840a, b). 6, Holotype (USNM P5839). a, Spiral views, which show gradually enlarging globular chambers. b, Umbilical views, showing spiny wall, open umbilicus and large umbilical aperture. c, Edge views, showing variation in height of spire.

Figures 7a−c. Globigerina inaequispira Subbotina 181
7a, Spiral view of hypotype (USNM P5731). showing resemblance to G. triloculinoides, but with spiny rather than pitted surface. 7b, Umbilical view. 7c, Edge view.

Figures 8a−c. Globigerina triloculinoides Plummer 183
8a, Spiral view of hypotype (USNM P5700). 8b, Umbilical view. 8c, Edge view.

Page 178

Page 180

Page 181

Page 183

Page 203
Plate 57. AQUIA GLOBIERINA AND GLOBOROTALIA

(All figures: a, spiral view; b, umbilical view; c, edge view; all × 145)

Figures 1, 2. *Globorotalia trichotrocha* Loeblich and Tappan, new species

1, Holotype (USNM P5355). 2, Paratype (USNM P5705). Specimens show the small size, relatively small, subangular-truncate chambers, of nearly equal breadth and height, spinose surface, subangular periphery, and small umbilicus.

Figures 3, 4. *Globorotalia perclara* Loeblich and Tappan, new species

Paratypes (USNM P5826a, b), showing robust test, with chambers flattened on the spiral side, but elevated near the periphery.

Figures 5, 6. *Globorotalia convexa* Subbotina Hypotypes (USNM P5846a, b), showing gently rounded spiral side and inflated umbilical side, curved sutures, spinose surface, and low aperture with narrow bordering lip.

Figure 7. *Globorotalia esnensis (?) (Le Roy)*

Hypotype (USNM P5878), which is relatively high spired for this species, but otherwise similar.

Figure 8. *Globigerina mckannai* White

Hypotype (USNM P5120), showing numerous chambers and whorls, flattened spiral side and inflated and broadly umbilicate umbilical side, and, in this specimen a tiny and bulla-like final chamber.
AQUIA GLOBOROTALIA
PLATE 58. AQUIA GLOBOROTALIA

(All figures: a, spiral view; b, umbilical view; c, edge view; figure 3 × 280; all others × 145)

Figure 1. *Globorotalia hispidicidaris* Loeblich and Tappan, new species
   Holotype (USNM P5875), showing flattened spiral side, angular truncate chambers with sharply angled umbilical shoulder, and spinose surface.

Figure 2. *Globorotalia angulata* (White) 187
   Hypotype (USNM P5859), showing angular truncate chambers, few per whorl, large final chamber, flat spiral side, and angular umbilical shoulder.

Figure 3. *Globorotalia reissi* Loeblich and Tappan, 194 new species
   Holotype (USNM P5835), showing small size, rounded chambers in spiral view, rounded umbilical shoulder, and subacute periphery.

Figure 4. *Globorotalia apantesma* Loeblich and Tappan, new species
   Paratype (USNM P5868), showing strongly curved and beaded sutures on the flat spiral side, and radial depressed sutures on the elevated umbilical side, keeled periphery and open umbilicus.

Figure 5. *Globorotalia acuta* Toulmin 185
   Hypotype (USNM P5865), showing flat spiral side, with depressed and gently curved sutures, peripheral keel, angular truncate chambers, acutely angular umbilical shoulder, and broad open umbilicus.
Plate 59. AQUIA GLOBOROTALIA

(All figures: a, spiral view; b, umbilical view; c, edge view; all × 145)

Figure 1. Globorotalia apanthesma Loeblich and Tappan, new species
   Holotype (USNM P5860), showing flat spiral side with strongly curved sutures, somewhat imbricated chambers, angled periphery, and spinose and broadly umbilicate, umbilical side.

Figure 2. Globorotalia pseudoscitula Glaessner
   Hypotype (USNM P5130), showing lenticular form, strongly curved sutures and broad and low, crescentic chambers of the spiral side, and the radial sutures, small umbilicus and low aperture on the umbilical side.

Figure 3. Globorotalia pseudomenardii Bolli
   Hypotype (USNM P5703), showing peripheral keel, strongly curved and limbate sutures on the flattened spiral side, and depressed, gently curved sutures on the convex umbilical side, the rapid increase in chamber size, and smooth surface.

Figure 4. Globorotalia elongata Glaessner
   Hypotype (USNM P5695), showing rounded chambers, gradually increasing in size, with gently curved and depressed sutures on both sides.

Figure 5. Globorotalia imitata Subbotina
   Hypotype (USNM P5691), showing small size, robust test, broadly rounded periphery, small umbilicus, and few chambers per whorl.

Figure 6. Globorotalia aequa Cushman and Renz
   Hypotype (USNM P5125), showing angular truncate chambers, few per whorl, flattened spiral side, and elevated umbilical side with subacute umbilical shoulder.
Plate 60. Nanafalia Chiloguembelina and Globorotalia

(All figures: a, spiral view; b, umbilical view; c, edge view; all $\times 145$)

Figure 1. Globorotalia rex Martin
Hypotype (USNM P5867), showing flattened spiral side with raised and curved sutures, peripheral keel, inflated and spinose umbilical side and subangular umbilical shoulder.

Figure 2. Globorotalia pseudotopilensis (Subbotina)
Hypotype (USNM P5869), showing few chambers per whorl, and cuneate shape of final, somewhat discrete, chamber, smooth spiral side and spinose umbilical side and low arched aperture.

Figure 3. Globorotalia aequa Cushman and Renz
Hypotype (USNM P5863), showing less discrete and cuneate final chamber and sharper keeled periphery than in G. pseudotopilensis.

Figure 4. Globorotalia troelseni Loeblich and Tappan
Holotype (USNM P5687), showing nearly evolute test, with tendency to uncoil, nearly bilaterally symmetrical chambers and peripheral keel.

Figure 5. Globorotalia perclara Loeblich and Tappan
Paratype (USNM P5827), showing small size, globular chambers, depressed spire and spinose surface.

Figure 6. Chiloguembelina crinita (Glaessner)
Side view of hypotype (USNM P5116), showing flared test, asymmetrical aperture and spinose upper surface.

Figure 7. Globorotalia reissi Loeblich and Tappan
new species
Paratype (USNM P5837), showing smooth surface, numerous chambers and somewhat elevated spire.

Figure 8. Globorotalia pseudomrnardii Bolli
Hypotype (USNM P5706), showing peripheral keel, curved and limbate sutures on the flattened spiral side and depressed sutures on the convex umbilical side.

Figure 9. Globorotalia elongata Glaessner
Hypotype (USNM P5694), showing depressed sutures on both sides, and subacute, but not keeled, periphery.
Plate 61. NANAFALIA GLOBIGERINA AND GLOBOROTALIA

(All figures: a, spiral view; b, umbilical view; c, edge view; all ×145)

Figures 1, 2, 9. Globorotalia esnaensis (Le Roy) 189
   1, 2, Hypotypes (USNM P5876 a, b), showing spinose surface, rapid increase in chamber size, flattened spiral side and few chambers per whorl.
   9, Small hypotype (USNM P5877), with relatively high aperture which is largely extraumbilical in position. 181

Figure 3. Globigerina inaequispira Subbotina
   Hypotype (USNM P5730), showing spinose surface and inflated chambers.

Figure 4. Globorotalia convexa Subbotina 188
   Hypotype (USNM P5848), showing low crescentic chambers and backward curving sutures on the spiral side, subacute periphery and radial sutures, small umbilicus, and low aperture on the umbilical side.

Figure 5. Globorotalia irrorata Loeblich and Tappan, 191 new species 288
   Holotype (USNM P5872), showing inflated chambers, spinose wall, open umbilicus and slightly flattened spiral side.

Figure 6. Globorotalia strabocella Loeblich and Tappan, new species 195
   Holotype (USNM P5879), showing numerous chambers, open umbilicus and flattened spiral side.

Figure 7. Globorotalia tribulosa Loeblich and Tappan, new species 195
   Holotype (USNM P5850), showing rapidly enlarging globular chambers, spinose surface and extraumbilical-umbilical aperture.

Figure 8. Globorotalia chascanona Loeblich and Tappan, new species 180
   Paratype (USNM P5844), showing numerous chambers, increasing gradually in size, spinose surface and wide umbilicus.
NANAFALIA GLOBIGERINA AND GLOBOROTALIA
VELASCO CHILOGUEMBELINA AND GLOBIGERINA
Plate 62. VELASCO CHILOGUEMBELINA AND GLOBIGERINA

(All figures: a, spiral view; b, umbilical view; c, edge view; all × 110)

Figure 1. *Chiloguembelina crinita* (Glaessner) 178
Side view of hypotype (USNM P5890), showing flaring test, spinose upper surface and asymmetrical aperture.

Figure 2. *Globigerina inaequispira* Subbotina 181
Hypotype (USNM P5881), showing globular chambers, tripartite test as seen in umbilical view, and spinose surface.

Figures 3, 4. *Globigerina triloculinoides* Plummer 183
3, Lectotype, here designated, of *Globigerina velascoensis* var. *compressa* White (not *G. compressa* Plummer), Columbia Univ. No. 19882, showing this species to be identical with *G. triloculinoides* Plummer of the Texas Midway group. 4, Hypotype (USNM P5883), showing characteristic pitted surface.

Figures 5–7. *Globigerina mckannai* White 181
5, 6, Hypotypes (USNM P5884a,b), showing variation in size, inflated test with wide umbilicus, and relatively numerous chambers per whorl. 7, Lectotype, here designated, of *G. mckannai* (Columbia Univ. No. 19878) in which the umbilical region is partially obscured by extraneous material.
PLATE 63. VELASCO GLOBOROTALIA

(All figures: a, spiral view; b, umbilical view; c, edge view; all × 145)

Figure 1. Globorotalia pseudomenardii Bolli 193
   Hypotype (USNM P5887), showing limbate sutures on spiral side, and peripheral keel.
Figure 2. Globorotalia elongata Glaessner 189
   Hypotype (USNM P5882), showing depressed sutures and subacute periphery, which is not keeled.
Figure 3. Globorotalia imitata Subbotina 190
   Hypotype (USNM P5886), showing globose chambers and small robust test.
Figure 4. Globorotalia convexa Subbotina 188
   Hypotype (USNM P5885), showing biconvex test, spiny surface, low and curved chambers on spiral side, and low arched aperture and closed umbilicus on the umbilical side.
Figure 5. Globorotalia troelseni Loeblich and Tap- 196
   pan, new species
   Paratype (USNM P5896), showing nearly bilaterally symmetrical test, uncoiling and evolute spiral and umbilical sides, and extraumbilical aperture.
Figure 6. Globorotalia pseudoscitula Glaessner 193
   Hypotype (USNM P5895), showing lenticular, spinose, keeled test and limbate sutures on the spiral side.
VELASCO GLOBOROTALIA
VELASCO GLOBOROTALIA
Plate 64. Velasco Globorotalia

(All figures: a, spiral side; b, umbilical side; c, edge; all \( \times 110 \))

**Figures 1, 2.** *Globorotalia velascoensis* (Cushman) 196

Hypotypes (USNM P5871a,b), showing the extremely ornate test, with raised and beaded sutures and keel on the spiral side, and angular and everted, keeled and beaded umbilical shoulder and wide open umbilicus on the umbilical side.

**Figure 3.** *Globorotalia occlusa* Loeblich and Tappan, 191

New species

Holotype (USNM P5874), showing few chambers per whorl, small umbilicus and angular but not keeled or everted umbilical shoulder.

**Figure 4.** *Globorotalia acqua* Cushman and Renz 186

Hypotype (USNM P5894), showing small test, flat spiral side and elevated umbilical side, few chambers per whorl and relatively large final chamber.

**Figure 5.** *Globorotalia angulata* (White) 187

Hypotype (USNM P5891), showing angular truncate chambers, depressed sutures, acutely angled periphery and more sharply angled umbilical shoulder.
Plate 65. Bathysiphon, Hyperamminoides, Involutina, Haplophragmoides

Figures 1–5. Bathysiphon brassei Tappan, new species

1, 5, Side views of paratypes (USNM P4224a,b).
2, Holotype (USNM P4216).
3, 4, Paratypes (USNM P4217a,b). These specimens show the irregularity of growth and surface wrinkles.

All from the Topagoruk formation, × 31.

Figures 6–12. Hyperamminoides barksdalei Tappan, new species

6, Large paratype (USNM P4229) from the Topagoruk formation, showing collapsed wall.
7, Paratype (USNM P4226) from the Grandstand formation.
8a, Side view of paratype (USNM P4228) from the Topagoruk formation.
8b, Edge view.
9, Paratype (USNM P4227) from the Topagoruk formation, showing wide aperture.
10, Paratype (USNM P4390) from the Topagoruk formation.
11, Holotype (USNM P4386) from the Grandstand formation.
12, Large paratype (USNM P4389) from the Topagoruk formation. Figs. 6–9, × 54; figs. 10–12, × 71.

Figures 13, 14. Involutina mangusi Tappan, new species

13, Holotype (USNM P4232) from the Topagoruk formation.
14, Paratype (USNM P4240) from the Chandler formation, × 71.

Figures 15–25. Haplophragmoides topagorukensis Tappan, new species

15, Holotype (USNM P4242).
16, Paratype (USNM P4246b).
17, Paratype (USNM P4252).
18, Paratype (USNM P4257).
19, Paratype (USNM P4270).
20, Paratype (USNM P4254).
21, Obliquely crushed paratype (USNM P4246a).
22, Edge view of crushed paratype (USNM P4277).
23, Paratype (USNM P4275).
24, Paratype (USNM P4288).
25, Paratype (USNM P4279).

Figs. 15, 17–20, 22, 23, 25, from the Topagoruk formation; figs. 16, 21, 24, from the Grandstand formation; these specimens show the variable appearance of the species, due to crushing in different planes with the resultant distortion. Figs. 15, 16, 21, 23–25, × 71; figs. 17–20, 22, × 31.

All figures are camera lucida drawings by Helen Tappan Loeblich.
BATHYSIPHON. HYPERAMMINOIDES, INVOLUTINA, HAPLOPHRAGMOIDES
SPIROPECTAMMINA, SIPHOTEXTULARIA, TEXTULARIA, VERNEUILINOIDES, DOROTHIA
Plate 66. SPIROPLECTAMMINA, SIPHOTEXTULARIA, TEXTULARIA, VERNEUILINOIDES, DOROTHIA

Figures 1a–2. Spiroplectammina koveri Tappan, 205 new species
1a, Side view of holotype (USNM P4290).
1b, Edge view.
2, Side view of small paratype (USNM P4292). Both from the Topogoruk formation. \( \times 71 \)

Figures 3–5. Spiroplectammina webberi Tappan, 205 new species
3, 4, Paratypes (USNM P4352 a, b), from the Sentinel Hill member of the Schrader Bluff formation.
5a, Side view of holotype (USNM P4348).
5b, Edge view. From the Seabee formation. \( \times 86 \).

Figures 6, 7. Siphotextularia ? rayi Tappan, new 206 species
6, Paratype (USNM P4306), an elongate specimen.
7a, Holotype (USNM P4304), showing almost terminal aperture. 7b, Edge view. Both from the Topogoruk formation. \( \times 71 \).

Figures 8a–9. Textularia topagorukensis Tappan, 205 new species
8a, Side view of holotype (USNM P4296).
8b, Top view.
9, Paratype (USNM P4302). Both from the Topogoruk formation. \( \times 71 \).

Figures 10–18. Verneuilinoides borealis Tappan, 206 new species
10, Paratype (USNM P4326). 11, Paratype (USNM P4317).
12, 13, 15, 17, Paratypes (USNM P4329 a–d) showing variation in size and outline.
14, Holotype (USNM 106131).
16, Small flaring paratype (USNM P4319).
18, Paratype (USNM 106132). All from the Grandstand formation. Figs. 10, 12, 17, \( \times 71 \); figs. 11, 14, 16, 18 \( \times 118 \); figs. 13, 15, \( \times 54 \).

Figures 19a–22. Verneuilinoides tailleuri Tappan, 208 new species
19a, Side view of holotype (USNM P4367).
19b, Top view.
20, Paratype (USNM P4365).
21, Paratype (USNM P4368).
22, Paratype (USNM P4373). All from the Fortress Mountain formation. \( \times 86 \).

Figures 23–28. Verneuilinoides fischeri Tappan, 207 new species
23, Paratype (USNM P4359) from the Sentinel Hill member of the Schrader Bluff formation.
24, 26, Paratypes (USNM P4357a, b).
25, Holotype (USNM P4356).
27, Paratype (USNM P4342). Figs. 24–27 from the Ignek formation.
28, Paratype (USNM P4340) from the Seabee formation. Figs. 23–26, \( \times 54 \); figs. 27–28, \( \times 71 \).

Figures 29–30b. Dorothia chandlerensis Tappan, 209 new species
29, Elongate paratype (USNM P4404) from the Oumalik formation.
30a, Side view of holotype (USNM P4401) from the Torok formation.
30b, Edge view. \( \times 71 \).

All figures are camera lucida drawings by Helen Tappan Loeblich.
Plate 67. ARENOBULIMINA, PSAMMINOPELTA, MILIAMMINA, TROCHAMMINA

Figures 1–4. Arenobulimina paynei Tappan, new species
1, Paratype, distorted by crushing (USNM P4379), from the Grandstand formation. 2, Holotype (USNM P4375) from the Topagoruk formation.

Figures 5–7. Arenobulimina torula Tappan, new species
5, Holotype (USNM P4393), a pyritic specimen preserving the original form. 6, 7, Crushed paratypes (USNM P4396a,b), one flattened longitudinally, the other crushed from above. All from the Ignek formation, × 71.

Figures 8–10. Psamminopelta subcircularis Tappan, new species
8, Paratype (USNM P4454). 9, Holotype (USNM P4452). 10, Paratype (USNM P4453). All specimens are pyritized, occurring in the Grandstand formation, × 71.

Figures 11–18, 22–24. Psamminopelta bowsheri Tappan, new genus, new species
11, 16, 22, 24, Paratypes (USNM P4430a–d). 12, Paratype (USNM P4434). 13, Paratype (USNM P4426), somewhat distorted in preservation. 14, Paratype (USNM P4429). 15, Holotype (USNM P4424). 17, Paratype (USNM P4462), a crushed specimen. 18, Paratype (USNM P4436) from the Chandler formation. 23, Paratype (USNM P4443) from the Torok formation.

Figures 19–21. Miliammina awunensis Tappan, new species
19, Paratype (USNM P4415) from the Grandstand formation. 20, Paratype (USNM P4409). 21, Holotype, (USNM P4407). Both from the Chandler formation. All × 71.

Figures 25, 26. Miliammina ischnia Tappan, new species
25, Paratype (USNM P4421). 26, Holotype (USNM P4419). Both from the Grandstand formation, × 71.

Figures 27a–29. Trochammina umiatensis Tappan, new species
27a, Dorsal view of holotype (USNM P4495). 27b, Ventral view. 27c, Edge view. × 71. 28, 29, Paratypes (USNM P4502a,b). × 54. All from the Grandstand formation.

Figures 30a–33. Trochammina stefanssoni Tappan, new species
30a, Dorsal view of holotype (USNM P4490). 30b, Edge view. 31–33, Paratypes (USNM P4492a–c), showing crushing and distortion in different planes. All from the Sentinel Hill member of the Schrader Bluff formation, × 71.

All figures are camera lucida drawings by Helen Tappan Loeblich.
TROCHAMMINA, MARGINULINA, DENTALINA, PYRULINOIDES, SARacenaria, RECTOGlandulina, EURycheiloSTOMa
Plate 68. Trochammina, Marginulina, Dentalina, Pyrulinoides, Saracenaria, Rectoglandulina, Eurycheilostoma

Figures 1a–2. Trochammina eilete Tappan, new 213 species
1a, Dorsal view of holotype (USNM P4483) from the Torok formation. 1b, Ventral view. 1c, Edge view. 2, Paratype (USNM P4487) from the Fortress Mountain formation. All × 71.

Figures 3–6b. Trochammina whittingtoni Tappan, new 214 species
3, Ventral side of larger paratype (USNM P4508) from the Seabee formation. 4, Paratype (USNM P4506) from the Seabee formation. 5, Dorsal view of small paratype (USNM P4514), from the Sentinel Hill member of the Schrader Bluff formation. 6a, Dorsal view of holotype (USNM P4505) from the Seabee formation. 6b, Edge view, showing the usual crushing of specimens of this species. All × 71.

Figures 7, 8. Marginulina gatesi Tappan, new 215 species
7, Holotype (USNM P4522). 8, Paratype (USNM P4527). Both from the Grandstand formation, × 71.

Figures 9–12. Dentalina? dettermani Tappan, new 215 species
9, Paratype (USNM P4561) from the Fortress Mountain formation. 10, Small paratype (USNM P4557), from the Grandstand formation. 11, Paratype (USNM P4559) from the Topagoruk formation. 12, Holotype (USNM P4556), a large isolated chamber showing terminal aperture and broken connecting neck; from the Grandstand formation. All × 71.

Figure 13. Pyrulinoides thurrelli Tappan, new 217 species
13, Holotype (USNM P4553) from the Grandstand formation. × 71.

Figures 14–16. Saracenaria dutroi Tappan, new 216 species
14, Paratype (USNM P4540). 15a, Side view of holotype (USNM P4533). 15b, Edge view. 16a, Side view of paratype (USNM P4537). 16b, Edge view. All from the Topagoruk formation, × 71.

Figures 17, 18b. Rectoglandulina kirschneri Tappan, new species
17, Paratype (USNM P4548) from the Oumalik formation, × 48. 18a, Side view of holotype (USNM P4546) from the Topagoruk formation. 18b, Top view, showing radiate aperture. × 63.

Figures 19a–25. Eurycheilostoma grandstandensis Tappan, new species
19a, 21a, Side view of paratypes (USNM P4611a, b) showing the extremely high-spired test. 19b, 21b, Top views showing the open umbilicus and fimbriate apertural flap. 20a, Side view of paratype (USNM P4605). 20b, Top view. 22a, Side view of paratype (USNM P4603). 22b, Top view. 23a, Side view of holotype (USNM P4595). 23b, Top view. 24, 25, Paratypes (USNM P4596a, b). Figs. 19–22 from the Topagoruk formation; Figs. 23–25 from the Grandstand formation; all × 105.

All figures are camera lucida drawings; figs. 1-13 by Helen Tappan Loeblich, figs. 14–25 by Patricia Isham.
Plate 69. NANUSHUKELLA, GLOBOROTALITES, PRAEBULIMINA

Figures 1–10. *Nanushukella umiatensis* Tappan, 219 new genus, new species

1, Holotype (USNM P4619). 2, 10, Paratypes (USNM P4570a–b). 3, Paratype (USNM P4629) with ventral side (3b) showing broad apertural flap of final chamber and earlier sutural slits remaining open. 4, 7, 9, Paratypes (USNM P4623a–c). 5, 6, Paratypes (USNM P4626a, b). 8, Paratype (USNM P4620). Figs. 2, 10 from an unnamed Cretaceous unit equivalent to the lower part of the Nanushuk group; figs. 1, 3–9 from the Grandstand formation; all × 112.

Figures 11a–13b. *Globorotalites alaskensis* Tappan, 220 new species

11, Holotype (USNM P4649) from the Grandstand formation. 12, Paratype (USNM P4652) from the Topagoruk formation. 13, Paratype (USNM P4653) from the Grandstand formation. All figures a, dorsal view; b, ventral view; c, edge view; × 118.

Figures 14–16b. *Praebulimina seabensis* Tappan, 217 new species

14, Paratype (USNM P4566). 15, Paratype (USNM P4568). 16a, Holotype (USNM P4564), side view. 16b, Top view, showing aperture. All from the Seabee formation, × 112.

All figures are camera lucida drawings; fig. 12a by Helen Tappan Loeblich, all others by Patricia Isham.
NANUSHUHELLA, GLOBOROTALITES, PRAEBULIMINA
EPONIDES, EURYCHEILOSTOMA
Plate 70. Eponides, Eurycheilostoma

Figures 1a–7c. Eponides morani Tappan, new species  
1, Holotype (USNM P4638). 2, 4, 7, Paratypes (USNM P4639a–c). 3, Paratype (USNM P4643) with center of dorsal side obscured by pyrite. 5, Paratype (USNM P4647). 6, Paratype (USNM P4645). Figs. 1–4, 7 from the Topagoruk formation; figs. 5, 6 from the Torok formation (Topagoruk equivalent). All figures a, dorsal view; b, ventral view; c, edge view. Figs. 1–4, 7, ×112; figs. 5, 6, ×75.

Figures 8a–11b. Eurycheilostoma robinsonae Tappan, new species  
8, Small paratype (USNM P4586) from the Grandstand formation. 9a, Edge view of paratype (USNM P4587) from the Topagoruk formation. 9b, Ventral view. 10a, Dorsal view of holotype (USNM P4584), from the Topagoruk formation. 10b, Ventral view, showing broad open umbilicus and ventral apertural flap. 10c, Edge view, showing high spire. 11, Paratype (USNM P4591) from an unnamed equivalent of the Corwin formation. Figs. 8a, 11a, dorsal views; 8b, 11b, edge views. All ×118.

All figures are camera lucida drawings by Patricia Isham.
Figures 1a–9c. *Pallaimorphina ruckerae* Tappan, 221
new species

1, Paratype (USNM P4669) showing gradual chamber enlargement, low aperture and narrow lip. 2, Holotype (USNM P4664). 3, Paratype (USNM P4665). 4, Small paratype (USNM P4680) 5, 6, Paratypes (USNM P4666a, b). 7, 8, 308

Paratypes (USNM P4671a, b). 9, Paratype (USNM P4673). All from the Grandstand formation; a, dorsal view; b, ventral view; c, edge view. Figs. 1, 4–9, × 150; figs. 2, 3, × 200.

All figures are camera lucida drawings by Patricia Isham.
HEMISPHERAMMINA, ZOTHECULIFIDA, BERTHELINELLA, CITHARINELLA, TENTIFRONS, WEBBINELLA, AEOLOSTREPTIS
Figure 1. Hemisphaerammina depressa (Heron-Allen and Earland)

1, Hypotype (USNM P3225), from the Recent, to show the low form and irregular border. × 25.

Figures 2a, b. Hemisphaerammina bradyi Loeblich and Tappan, new species

2a, Holotype (BMNH ZF2626) from Recent deposits off Durham, showing more elevated test and completely circular outline. × 30. 2b, Same, at less magnification, to show attachment. × 10.

Figure 3. Hemisphaerammina batalleri Loeblich and Tappan, new genus, new species

3, Holotype (USNM P5095) from the Santonian of Spain, showing ovate, coarsely agglutinated test. × 10.

Figures 4-8. Zotheculifida lirata (Cushman and Jarvis)

4, Holotype (Cushman Coll. 10084), showing test and chamber shape, and the surface reflection of the internal partitions. The base of this specimen is broken. 5, 7, 8a, Side views of hypotypes (USNM P3086a-c), showing variation in degree of recurving of chambers, the completely biserial early stage, and the surface reflection of the internal partitions. 8b, Top view, showing aperture, and narrow compressed form. 6, Sectioned hypotype (USNM P4884), showing the complex internal partitions which form an almost labyrinthic interior at the lateral extremities of the chambers. All specimens are from the Upper Oligocene, Brasso formation of Trinidad, B.W.I. All × 40.

Figures 9-13. Berthelinella paradoxa (Berthelin) 225

9, Topotype (USNM P4473a) showing ovate proloculus and two pair of alternating chambers. 10, Topotype (USNM P4473b), showing single pair of biserial chambers following the proloculus before the development of the equitant chambers. 11a, Topotype (USNM P4473c). 11b, Top view, showing simple, slitlike terminal aperture. 12, 13, Small topotypes (USNM P4473d, e), showing a single pair of biserial chambers. All from the Pliensbachian (Lias, Lower Jurassic) of France. × 175.

Figures 14-16. Citharinella tarrantensis (Loeblich 225 and Tappan)

14, Typical hypotype (USNM P4880) showing the usual 2-chambered neanic stage followed by equitant chambers. Such forms could be mistaken for the genus Berthelinella, except for the radial aperture. From the Gault (Albian, Lower Cretaceous) of England. 15, Hypotype (USNM P4881), showing very rare three-chambered Citharinella-like neanic stage, demonstrating the true generic relationships. From the Albian Denton formation of Texas. 16, Hypotype (USNM P4882), showing typical 2-chambered neanic stage and well developed adult equitant chambers. From the Albian Denton formation of Texas. All × 40.

Figures 17, 18. Tentifrons barnardi Loeblich and Tappan, new genus, new species

17, Paratype (BMNH P40274), showing typical free Citharinella stage, followed by attached fistulose adult stage. × 25. 18, Holotype (BMNH P40275), showing much elongated attached stage, with the early chambers equitant and sutures chevron-shaped, the later development increasingly more irregular, with numerous apertures at the ends of fistulose extensions. × 9. Both from the Senonian (Upper Cretaceous) of England.

Figure 19. Webbinella hemisphaerica (Jones, Parker 226 and Brady)

19, Holotype (BMNH P41659) from the Pliocene of England, showing the calcareous test, and polymorphine neanic stage, quite unlike the agglutinated species here placed in Hemisphaerammina, new genus. × 55.

Figures 20a-c. Aeolostreptis vitrea (Cushman and Parker)

20a, Side view of hypotype (Cushman Coll. 32549), showing spiral character and bluntly rounded base. 20b, Apertural view, showing the three chambers of the final whorl. 20c, Basal view, showing the tightly coiled early stage, with numerous chambers per whorl, decreasing in number per whorl in the later stage, and chambers arranged in a single spiralling series, not in the twisted biserial development of Virgulina. From the Dermopolis chalk, Selma Group (Campanian, Upper Cretaceous) of Mississippi. × 235.

All figures are camera lucida drawings; figs. 2b, 17–19, by Helen Tappan Loeblich, others by Lawrence and Patricia Isham.
Figures 1a–2. Sigmagirugulina tortuosa (Brady) 229

1a, Side view of hypotype (USNM P4857a), showing flaring test and inflated base, large pores, and marginal keel. 1b, Edge view, showing twisted test. 1c, Top view, showing slitlike aperture and compressed test. 2, Basal view of hypotype (USNM P4857b), from which outer wall has been etched to show early chamber development. Two series of chambers can be seen to diverge from the proloculus and spiral upwards, so that the early plane of biseriality assumes a sigmoid curve. From the Recent deposits of Fiji. All × 125.

Figures 3a–4c. Eurycheilostoma altispira Loeblich and Tappan, new genus, new species

3a, Spiral view of holotype (USNM P4882), showing discorbine appearance. 3b, Umbilical view, showing depressed center, broad low aperture and apertural flap of the much overlapping final chamber. 3c, Side view, showing extremely high spire, suggesting the family Buliminidae. 4a, Spiral view of paratype (USNM P4883). 4b, Umbilical view. 4c, Edge view, showing a somewhat lower spired form. From the Goodland formation (Albian), Lower Cretaceous of Texas. × 225.

Figures 5a–c. Sestronophora arnoldi Loeblich and Tappan, new genus, new species

5a, Spiral side of holotype (USNM P3130), showing faintly sculptured surface and limbate sutures. 5b, Umbilical view, showing perforated umbilical plate, interiomarginal aperture and small accessory pores in the umbilical side of the final chamber. 5c, Edge view. From the Pleistocene of California. × 25.

Figure 6. Sejunctella earlandi Loeblich and Tappan, new genus, new species

6, Side view of holotype (USNM P3294), showing limbate peripheral keel, and intercalary plate between the whorls, composed of the keels of earlier whorls with the addition of secondary granular calcite. Recent, Faroe Islands. × 225.

Figures 7–11. Favocassidulina favus (Brady) 230

7, 10, 11, Edge views of topotypes (USNM P3376a–c), showing honeycomblike surface, and the smooth area surrounding the elongate, slitlike aperture. 8, Sectioned hypotype (USNM P4469), showing the alternating chambers typical of the Cassidulinidae, beneath the secondary covering of the wall. 9a, Side view of topotype (USNM P3376d), showing exterior. 9b, Edge view, showing aperture and slight lip. Figs. 7, 9–11, from the Recent Pacific, off the coast of Chile, × 50; fig. 8, from the Recent Pacific, off the Caroline Islands, × 55.

Figures 12a–13. Paromalina bilateralis Loeblich and Tappan, new genus, new species

12a, b, Opposite sides of holotype (USNM P4883) from Albatross station D2262, showing coarsely perforate peripheral margin, and apparently imperforate sides, apertural face and umbilical flaps. Supplementary openings can be seen beneath the umbilical flaps. 12c, Edge view, showing truncate periphery and interiomarginal equatorial slitlike aperture. × 60.

13, Side view of paratype (USNM P3137) from Goldseeker station 16. × 55.

All figures are camera lucida drawings by Lawrence and Patricia Isham.
Plate 74. CRUCILOCULINA

Figures 1a–2c. Cruciloculina triangularis d'Orbigny 234

1a, Top view of lectotype (Mus. Hist. Nat. Paris) from Recent dredgings near the Falkland Islands, showing cruciform aperture, sharp angles, and flat to slightly convex sides. 1b, Side view, toward angle opposite last chamber, showing slightly ovate outline. × 31. 2a, Side view of topotype (USNM P4520) with last chamber at right. 2b, Side view with last chamber at left. 2c, Top view showing cruciform aperture. × 24.

Figures 3a–7. Cruciloculina eriesoni Loeblich and Tappan, new species

3a, Side view of holotype (USNM P3140) from Recent dredgings near Ireland, looking toward earliest chamber of final whorl, showing nearly circular outline and relatively strong chamber overlap. 3b, Opposite side view. 3c, Top view, showing broadly rounded chambers and slightly dendritic cruciform aperture with slight lip. 4–7, Top views of paratypes (USNM P4338a–d) showing increased complexity of aperture with increase in test size. × 40.

Figures 8–11c. Cruciloculina asanoi Loeblich and Tappan, new species

8, 9, Top views of paratypes (USNM P4267a, b) from Recent dredgings in the Caribbean, showing cruciform aperture, slightly rounded angles, and convex sides. 10a, 10b, Opposite views of juvenile paratype (USNM P4267c). 10c, Top view, showing triradiate aperture in the early stage. 11a, Side view of holotype (USNM P4880) showing ovate outline and slight amount of chamber overlap. 11b, Side view with final chamber at right. 11c, Top view, showing cruciform aperture. × 31.

Figures 12a–c. Cruciloculina japonica Asano 234

12a, Side view of topotype (USNM P4339) from the Pliocene of Japan showing ovate outline, rapid increase in chamber size and large degree of chamber overlap. 12b, Opposite view. 12c, Top view showing rounded angles and dendritic tendency of cruciform aperture. × 31.

Figures 13–16. Cruciloculina striata Loeblich and Tappan, new species

13, 14, 16, Top views of paratypes (USNM P4265a–c) from Recent dredgings in the Caribbean, showing ovate section, strong amount of chamber overlap, dendritic variation of cruciform aperture, and striate wall surface. 15a, b, Opposite sides of holotype (USNM P4264) showing ovate side view, striate surface, and rapid increase in chamber size. 15c, Top view. × 28.

All figures are camera lucida drawings; fig. 1 by Helen Tappan Loeblich, others by Patricia Isham.
Index

(Page numbers of principal entries in *italics*.)

Abathomphalus, n. gen., 19, 43, 45, 46, 51, 54
intermedia, 54
mayaroensis, 43, 44, 45, 54, 248
Abathomphalus sp., 52
abundocamerata, Globorotalia angulata, n. subsp., 74, 254
acarinata, Acrarinida, 41
Acrarinina, 41, 42
acarina, 41
intermedia, 191
pseudotopilensis, 194
aevulinoides, Guembelina, 141
Plano globulina, 142
Pseudotextularia elegans, 139
acuta, Globorotalia, 176, 185, 187, 197, 284, 292, 295
Globorotalia wilcoensis, 65, 68, 76
advena, Globoburdina quadraria, 111
aegyptica, Zeauvigerina, 85 (fig.), 92, 258
Aeolostreptis, n. gen., 227
vitrea, 227, 309
aqua, Globorotalia, 62, 64, 65, 66, 68, 74, 75, 76, 77, 170, 176, 186, 254, 255, 283, 287, 296, 297, 301
Globorotalia crassata, 74, 186
aequilateralis, Globigerina, 29
Globigerinella, 7, 30, 108
Hastigerina, 10, 29, 102, 108, 240, 259
Agathistèges, 17
akersi, Clavigerina, n. sp., 12, 30, 158, 161, 240, 272
alahamensis, Hantkenina, 26, 27, 239
Rectogenu belina, 180
Tubistriatulida, 180, 278
alaskensis, Globorotalites, n. sp., 220, 306
albeeri, Globorotalia, 78, 188
alexanderi, Bathysiphon, 202
Hastigerinella, 24, 25
Hastrigerinoides, 238
algeriana, Globigerinelloides, 21, 22, 23, 25
“Allomorphina,” 127
allomorphinaides, Quadrinemorphina, 221
altiapertura, Globigerinoides triloba, n. subsp., 112 (fig.), 113, 262
altripera, Eurychelostoma, n. sp. 217, 218, 228, 229, 310
Globigerina, 111
Globoquadrina, 32, 242
Globoquadrina altispera, 101, 102, 111, 112, 261
Alveovalvulinella pozoensis, 106
american, Eouvigerina, 138, 271
Heteroblastis, 133, 134
Spirulina, 137
Ammodiscus, 210
gaultinus, 202
Amphimorphina, 136, 144
Globigerina, n. sp., 100, 104, 105, 108, 109, 159, 250
andori, Globotruncana, 54, 59, 251
angulata, Globigerina, 74, 187
angularis, Globigerina, n. subsp., 109, 259, 273
Angulogenera, 136, 151
angulosa, Flabellina, 226
Frolundiculina, 226
Globigerina soldadoensis, n. subsp., 264, 67, 71, 192, 167, 253, 272
angustiarctica, Globotruncana, 54
angustiubvillulata, Globigerina, n. subsp., 109, 164, 259
Anomalina, 23
breggiensis, 23
corona, 230, 231
corona crassa, 230
roberti, 41
Anomalini, 14, 18, 230
apanthesis, Globorotalia, n. sp., 107, 190, 195, 197, 285, 292, 295, 296
apertura, Globigerina, 108
appendiculata, Globotruncana, 39, 46
Rotalipora, 41, 54, 246
appendiculata-lineata, Globotruncana, 58
Applinella, 26, 27
apsioldrota, Planolamina, 23, 24, 238
aquiesen, Globigerina, n. sp., 180, 181, 203, 289
Aragonella, 26, 27
aragonensis, Globorotalia, 64, 66, 67, 68, 75, 76, 158, 160, 167, 255, 275
Globorotalia (Truncorotalia), 167
Hantkenina, 15, 26, 30, 40, 136, 210, 239
Hantkenina mexicana, 28
Hastigerinella eocenea, 30, 162
arc, Globotruncana, 11, 15, 44, 248
Pulvinulina, 44, 45, 46
archaeomenardii, Globorotalia, n. sp., 119, 265
Arenobulimina, 208
champmani, 208, 209
paynei, n. sp., 208, 304
torula, n. sp., 208, 304
arnoldi, Sustronovaphora, n. sp., 229, 230, 310
asanoi, Crucioculina, n. sp., 233, 311
aspensis, Globorotalia, 156, 158, 162, 166, 274
asymetrica, Globorotalia, 57
awunensis, Milammina, n. sp., 210, 211, 304
barisanensis, Globorotalia, 109
Globorotalia fohi, 101, 103, 118, 118, 265
barksdalei, Hyperamminoides, n. sp., 202, 302
barnardi, Tentifrons, n. sp., 223, 225, 226, 309
barri, Biglobigerinella, n. sp., 24, 25, 238
barri, Globiginerina, 24, 38, 158, 159, 160, 166, 244, 274
batalleri, Hemisphaerammina, n. sp., 223, 224, 309
Bathysiphon, 202
alexanderi, 202
brosgei, n. sp., 201, 302
Beckman, J. P.: Chiloquemelia Loeblitch and Tappan and related Foraminifera from the lower Tertiary of Trinidad, B. W. I., 83
Benthonic Foraminifera, 199
ermucids, Cribrohantkenina, 27, 28, 29, 160, 161, 239
Hantkenina (Cribrohantkenina), 28
Hastigerinella, n. sp., 101, 113, 262
Berthelinitella, n. gen., 225
paradoxa, 225, 309
biformis, Spiroulepta, 45
Biglobaligerina, 15, 22, 23, 25, 29, 30
barri, n. sp., 24, 25, 238
multiapina, 25, 238
bilateralis, Parola, n. sp., 230, 231, 310
bilobata, Globigerina, 35, 116
Orbulina, 116, 264
Biorbulina, 35, 36
biaperta, Globigerinoids, 101, 114, 264
Biticinella, 28 (footnote), 41
bohemica, Pseudotextularia, 143
Tubitextularia, 143, 270
bolivariana, Globigerina, 109
Globorotalia, 169, 274
UNITED STATES NATIONAL MUSEUM BULLETIN 215

314
Bolivina, 86, 135, 145, 146, 227

draco, 145
tortuosa, 228
watersi, 146,150

US, 144

Bolivinella, 134, 135, 136,
folia,

chapmani, Arenobulimina, 208, 209
chascanona, Globigerina, n. sp., 180, 286,
298

Buliminella, 227

Bolivinita, 133, 134, 135, 136, 143, 144, 146,

227

vitrea,

145, 151,

Buliminidae, 26, 134, 136,

147, 148

217

227

147
costifera, 147
crawfordensis, 147

costerifera,

bulloides, Globigerina,

quadrilatera,

12,

7,

280, 282
midwayensis midwayensis, 84 (fig.),
89, 91, 258
midwayensis strombiformis, n. subsp.,
84 (fig.), 88, 89, 90, 258
midwayensis subcylindrica, n. subsp.,
84 (fig.), 86, 88, 90, 258
morsei, 176, 179, 277, 278, 279, 280

54,

59

Bullopora, 226
Calcarina, 26

271

BoUvinitinae, 136, 137, 143, 145

calciformis, Globotruncana, 54

Bolivinoides, 133, 134, 135, 136, lltS

californica, Plectofrondicularia,

draco draco, 145, 270
trinitatensis, 62
Bolivinopsis, 133, 137
Bolli, Hans M.: Planktonic Foraminifera
from the Eocene Navet and San
Fernando formations of Trinidad,
B.W.I., 155
Planktonic Foraminifera from the
Oligocene-Miocene Cipero and Lengua formations of Trinidad, B.W.I.,

Calpionella, 18

multicellaris, 91

canaliculata, Rosalina, 44

parallela, n. sp.

97

The genera Globigerina and Globorotalia in the Paleocene - lower
Eocene Lizard Springs formation of
61
The genera Praeglobotruncana, Rotalipora, Globotruncana, and Abathomphalus in the Upper Cretaceous of Trinidad, B.W.I., 51
Bolli, Hans M., Loeblich, Alfred R., Jr.,
and Tappan, Helen: Planktonic
Trinidad, B.W.I.

,

foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae,
and Globotruncanidae, 3
borealis, Verneuilinoides, n. sp., Z06, 208,

303

Rotalia, 120
14, 15, 17, SB,

nitida, 15, SB, 38,

91,

39

boweri, Globigerina, n.

sp., 158,

IBS, 273

bowsheri, Psamminopelta, n. sp., Sll, 304
bradyi, Globigerina, 110, 260

Hemisphaerammina,

n. sp., 223, 224,

309

Anomalina, 23

brevispina, Cribrohantkenina, 28

29
Hantkenina (Sporohantkenina), 28

Hantkenina,

26, 27, 28,

broedermanni, Globorotalia, 67, 68, 80, 158,
160, 167, 188, 256, 274
Bronnibrownia, 138

BronnimanneUa, 133, 138, 139
plummerae, 139
brosgei, Bathysiphon, n. sp., 201, 302

(fig.),

victoriana, n. sp., 85
92,

88,

(fig.),

86, 88, 91, 92,

(fig.),

87, 88, 91,

86, 88, 92,

sp., 92, 180, 258,

258

284

Chiloguembelinae, 155
Chilostomellidae, 220

Chilostomellina, 39
chipolensis,
160,

carseyi, VentilabreUa, 137

caseyi, Planomalina, n. sp., 24,

(fig.),

258

Chiloguembelina

carinata, Globotruncana ventricosa, 57
Guembelina, 137
Heterohelix, 137, 268
Spirillina vivipara, 228
carseyae, Planoglobulina, I4I, 269

Cassigerinella,

100,

105,

108,

259

Cibicidinae, 18

238

ciperoensis, Globigerina, 97, 105, 108, 109

squammosa, 228

Globigerina ciperoensis, 100, 107, 108,

Cassidulina, 17, 31, 230

109, 160, 259

favus, 230

Globigerinoides glomerosa, 115
Porticulasphaera glomerosa, IIB, 264

circularis,

Cassidulinidae, 11, 134, 230
Cassigerinella, 11, 17, SO, 108
chipolensis, 100, 105, 108, 160,

Catapsydracinae, n. subfam.,
n. gen., 13,

Globotruncana, 46, 51
Praeglobotruncana, 55

citae,

boudecensis, SO, 240

259

14,

6, 21,

S6, 116

16, S6,

101, 116, 166, 244,

274

244
unicavus, n. sp., S7, 116, 166, 244, 274
cenomana, Schackoina, 23, 239
Siderolina, 26
stainforthi, n. sp., 37, 101, 116,

Globorotalia, 41, 42, 100, 104,
158, 160, 161, 164, 169, 247, 276

Globorotalia (Turborotalia), 169

Citharinella, 225

tarrantensis, 225, 309

117, 165, 186

centralis,

Citharina, 225

116,

echinatus, n. sp., 16B, 274
parvulus, n. sp., 36, 37, 116, 244

Bramlettia, 210

85

wilcoxensis, 85

capdevilensis, Globorotalia, 78

dissimilis, 36, 37,

85

258

Candorbulina, 35, 36
universa, 35, 115

Catapsydrax,

86, 88, 91,

(fig.),

258

trinitatensis,

243

Candeininae, 17, 21

Cassidella

85

258
subtriangularis, n. sp.,

Cassigerinellinae, n. subfam., 21, 30, 108

boudecensis, Cassigerinella, SO, 240

breggiensis,

144

canariensis, Globorotalia, 7, 120

Candeina,

258

SI, 42, 102

calcarata, Globot uncana, 52, 59

148, ISO

86, 87, 89, 90,

mauriciana, 84 (fig.), 89, 258
midwayensis, 86, 89, 176, 179, 180, 278,

Globotruncana lapparenti,

selmensis, 147
Bolivinitella, 134, 135, 136, 143, 144, 147,

(fig.),

158, 160

sp.,

110, 114, 129, 182, 183, 241

US, 270

92

martini, 84

167, 170, 275

150

Chiloguembelina, 83, 86, 88, 89, 92, 165,
177, 178
crinita, 84 (fig.), 88, 89, 90, 92, 176,
178, 179, 258, 286, 288, 293, 297, 299
cubensis, 84, 87, 89, 91, 92, 258
garretti,

Buliminidea, 134, 137, 143
bullbrooki, Globorotalia, n.

exigua, 147

eleyi, 150,

chandlerensis, Dorothia, n. sp., 209, 303

Thalmanninella, 41
Bucherina, 18, 44, 45
sandidgei, 44, 45
Bulimina, 17, 229
iacksonensis, 100, 105, 160

US, 270

Bolivininae, 134, 136

eleyi,

brotzeni, Rotalipora, 11, 41, 246

Clavigerinella, n.gen., 13, SO, 112, 156, 158,

161, 167
akersi, n. sp., 12, SO, 158, 161, 240,
jarvisi, 162,

ClavuUna aspera

whitei, 62

claytonensis, Woodringina, 178, 277

coarctata, Praeglobotruncana, n. sp.,
BB,

52,

249

cocoaensis, Globorotalia, 100, 105, 160, 161,
169, 276
collactea, Globigerina, 67, 72, 162, 252,

GloborotaUa, 72, 162

Ceratobulimina perplexa, 127

coUyra, Haplophragmoides, 204

cerro-azulensis, Globigerina, 169

colombiana, Hastigerinella, 112, 162
Guembelitria, 92, 258

Globorotalia (Turborotalia), 169

272

272

272


INDEX

315
curva, Porticusaphaera glomerosa, 115, 264
cushmani, Rotallpora, 52, 54
cuvillieri, Globulina, 140, 141, 266
Cycloloculina, 18
Cymbalopora, 18
Cymbaloporid, 18
danica, Hercoglossa, 173
danvilensis, Hantkenina, 28
daubjergensis, Globulina, 62, 64, 67, 70, 127, 128, 129, 253, 267
Globigerinoides, 176, 184, 277, 278, 279, 280, 281
decorativissima, Globulina, 141, 269
Ventilabrella, 140, 141
deformis, Guembelina striata, 139
dehiscens, Globulina quadridina, 31, 101, 102, 111, 242, 261
Globorotalia, 31, 111
Sphaeroidina, 32, 33
Sphaeroidinella, 6, 7, 15, 38, 115, 243
delrioensis, Globorotalia, 39, 40, 51, 55
Praeglobotruncana, 39, 55, 246, 249
densa, Globorotalia crassata, 168
Dentalina, 215
dettermani, n. sp., 215, 305
depressa, Hemisphaerammina, 224, 307
dettermani, Dentalina, n. sp., 215, 305
diagonis, Trochammina, 214
didyma, Flabellina, 225
Priscocrioculina, 225
Didymotis, 51
digitata, Globulina, 32, 114
Hastigerina, 32
Hastigerinella, 32, 112, 242
digitifera, Hastigerina digitata, 32
diminuta, Globigerinoides, n. sp., 101, 114, 262
Discoanomalina, 230, 231
Discorbidae, 217, 228
Discorbis, v, 16, 44, 227, 228, 229
scania, 229
Disphoeridium, 18
dissimilitudinis, Catapsydrax, 36, 37, 101, 116, 166, 244, 274
Globigerina, 16, 36, 116
Dorothia, 209
chandlerensis, n. sp., 209, 303
filliformis, 209
draco, Bolivina, 145
Bolivinoides draco, 145, 270
dubia, Globulina, 7, 8
dumbel, Hantkenina, 26, 27, 28, 161, 239
Hantkenina (Applinella), 27
dutertrei, Globulina, 7, 9
dutroli, Saracenaria, n. sp., 216, 305
earlandi, Sejunctella, n. sp., 228, 310
echinatus, Catapsydrax, n. sp., 165, 274
eggeri, Globulina, 7, 102
Haplophragmoides, 204
Ventilabrella, 141, 142
ehrenbergi, Globorotalia, n. sp., 64, 67, 68, 77, 78, 188, 257
eilete, Trochammina, n. sp., 213, 305
elegans, Cuneolina, 138, 139, 142
Guembelina, 138
Pseudotextularia, 139, 142, 270
Hyperamminoides, 202
eleyi, Bolivinita, 150
Bolivinitella, 150, 271
dongata, Glandulina, 216
Globorotalia pseudosculpta, 77, 189
Nodosoplana, 151, 272
Elphidella prima, 127
Elphididae, 26, 137
Enclimatoceras ulrichi, 173
Entomostegus, 17
eocana, Hastigerinella, 112, 161
eoeana, Hastigerinella, 112
Eouvierina, 93, 134, 135, 136, 148, 149, 150
americana, 148, 271
excavata, 147, 271
fragilis, 148
plummerae, 147, 149, 271
serrata, 148
Eouvierininae, 130, 148, 150
epigona, Rzehakina, 62
Epistomina, 127
(Hoglundina) scalaris, 124
Epistomimidae, 18
Epistominoides midwaysensis, 127
Eponides, 219, 229
morani, n. sp., 219, 307
repandus, 219, 230
ericsoni, Cruciloculina, n. sp., 234, 311
esnaisis, Globulina, 189
Globorotalia, 189, 195, 294, 298
esenensis, Globulina cretacea, 181
Eurycheilostoma, n. gen., 217, 228
altispira, n. sp., 217, 228, 229, 310
grandstandensis, n. sp., 217, 218, 305
robinsonae, n. sp., 217, 218, 307
excavata, Eouvierina, 147, 145
exculata, Guembelina, 139
Pseudoguembelina, 140, 268
exigua, Bolivinita, 147
Favoecassidulinia, n. gen., 230
favus, 223, 289, 310
favus, Cassidulinia, 230
Favoecassidulinia, 223, 289, 310
Pulvinulina, 230
filliformis, Dorothia, 209
finlayi, Globigerina, 70, 183
fischeri, Verneullinoides, n. sp., 207, 303
Flabellina, 225
angulosa, 226
didyma, 225
floridana, Plectofrondicularia, 144, 270
fohsi, Globorotalia, 16 (fg.), 97, 102, 118, 119
Globorotalia fohsi, 101, 103, 104, 119, 265
folia, Bolivinella, 143, 270
foliata, Globigerina, 111, 261
folium, Textularia agglutinans, 143
formosa, Globorotalia formosa, n. sp., n. subsp., 64, 66, 67, 68, 76, 77, 255
forncala, Globotruncanca, 52, 54, 59
fragilis, Eouvigerina, 143
Frondicularia, 225
angulosa, 226
didyma, 225
paradoxa, 225
fructicosa, Guembelina, 142
Raceignemebelina, 126, 269
fructicosa, Guembelina, 142
gagnebini, Globotruncanca, 54, 69, 251
Gallitelli, see Montanaro Gallitelli, 133
gansseri, Globotruncanca, 54, 56
garreti, Clhoquebmelina, 92
garzena, Plecostrodoncularia, 133, 144, 270
gatesi, Marginulina, n. sp., 215, 305
gaudryana, Cristellaria, 226
Gaudryna pyramidata, 62
gautinus, Ammodiscus, 202
gautierensis, Globigerina, 51
igas, Haplophragmoides, 204
gibrans, Guembelina, 135, 137
glabrata, Planoglobulina eggeri, 141, 269
glasseaer, Guoberina, 141, 269
Glandulina elongata, 216
gledicci, Verneuellinoides perplexa, 206
Globozonalina, 41, 42
ovalis, 41, 42
Globigeropsis, n. gen., 33, 34, 38, 160, 165
index, 158, 159, 160, 165, 273
kugleri, n. sp., 33, 34, 158, 159, 160, 165, 243, 273
seminovoluta, 34, 159, 160, 161, 165, 243, 273
Globigerina, 13, 16, 17 (fig.), 20, 31, 32, 33, 35, 36, 37, 38, 39, 40, 42, 43, 45, 61, 62, 64, 68, 69, 70, 80, 88, 102, 127, 162, 174, 175, 176, 177, 180
eaquilateralis, 29
aldispira, 111
ampliapertura, n. sp., 100, 104, 108, 164, 259, 273
angulata, 74, 187
apertura, 108
aquisensis, n. sp., 180, 181, 288, 293
bilobata, 35, 116
bowski, n. sp., 180, 181, 288, 293
bradyi, 110, 260
bullioides, 7, 12, 31, 42, 102, 110, 114, 129, 182, 183, 241
cerno-azulensis, 169
chaseana, n. sp., 180, 286, 298
ciperoensis, 97, 105, 108, 109
ciperoensis angulilobulata, n. subsp., 109, 259, 273
ciperoensis anguilliformis, n. subsp., 109, 164, 259
ciperoensis ciperoensis, 100, 107, 108, 109, 160, 259
colactea, 67, 72, 169, 252, 272
compressa, 77, 126, 127, 189, 183, 184, 188, 267
condeina, 97, 109
Globigerina—Continued
conglobata, 114
conglomerata, 110, 164
crossiformis, 79
daubergensis, 62, 64, 67, 70, 127, 128, 129, 253, 267
digitata, 32, 114
dissimilis, 16, 36, 116
dubia, 7, 18
dutertrei, 7, 9
eggeri, 7, 102
esnagensis, 189
eretacea esnagensis, 181
finlayi, 70, 183
forniata, n. sp., 111, 261
gautierensis, 51
gravelii, 67, 72, 181, 182, 253
grimsdalei, 114
hornbrookii, 70, 71, 126, 183, 184
inaequispira, 181, 285, 295, 298, 299
inflata, 9
juvenilis, n. sp., 110, 111, 261
linaperta, 67, 70, 126, 165, 176, 181, 188, 222
meckmini, 70, 176, 181, 188, 190, 284, 295, 299
mexicana, 34, 34, 155
mcpenthes, 102, 111, 261
ouachitaensis, 164, 182
pachyderma, 5, 7
parva, n. sp., 100, 104, 108, 164, 259, 273
primitiva, 67, 71, 72, 252
prolapata, n. sp., 64, 67, 72, 73, 162, 252, 272
psuedobulbosides, 72, 73, 126, 127, 128
pseudotrilobata, 70, 183
quadra, 73
reticulata, 15
rubri, n. sp., 109, 164, 260, 273
rubra, 32, 43
saccularis, 113
semilunensis, 39, 40
senni, 154, 165, 272
soldadoensis, 67, 71, 72, 162, 167, 183, 191, 253, 272
soldadoensis angulosa, n. subsp., 64, 67, 71, 125, 167, 253, 272
spinningiflata, 168
spiralis, n. sp., 64, 67, 70, 176, 181, 182, 184, 253, 284, 286, 288, 295, 299
stainforthii, 70, 126, 183
tarouaensis, 78, 193, 252
topilensis, 170
triangularis, 67, 70, 71, 183, 252
triloba, 112
trilocularis, 110, 128, 135, 259, 273
triloculinoidea, 62, 67, 70, 126, 127, 129, 175, 176, 181, 188, 252, 254, 267, 277, 278, 279, 280, 282, 283, 289, 293, 299
trinidadensis, 62
trigida, 67, 75, 162, 252, 272
Globoquadrina, Guembelina, 135, 137, 138
Heterohelix, 137, 268
Globoquadrina, 13, 15, 16, 17 (fig.), 31, 111
talitira, 32, 242
altipira altipira, 101, 102, 111, 112, 261
altipira globosa, n. subsp., 111, 261
dehiscens, 31, 101, 102, 111, 242, 261
quadriaria, 111
quadriaria advena, 111
Globoquadrina sp., 32, 242
Globoquadrina, 9, 13, 15, 16, 17, 18, 31, 39, 40, 41, 42, 43, 45, 54, 55, 61, 62, 64, 68, 69, 70, 73, 88, 117, 126, 127, 161, 166, 174, 175, 177, 185
acute, 176, 183, 187, 197, 284, 292, 295
acqua, 62, 64, 65, 66, 68, 74, 75, 76, 77, 170, 176, 178, 254, 255, 283, 287, 296, 297, 301
albeart, 78, 188
angulata abundantecamata, n. subsp., 74, 254, 287
angulata hexacamera, n. subsp., 64
apanthesma, n. sp., 157, 190, 195, 197, 285, 292, 295, 296
aragonensis, 64, 66, 67, 68, 75, 76, 158, 160, 167, 255, 275
(Truncorotalia), aragonensis, 167
archeomenardii, n. sp., 119, 265
aspenis, 156, 158, 162, 166, 274
asymetrica, 57
barisanensis, 119
bolivariana, 169, 274
broedermanni, 67, 68, 80, 158, 160, 167, 188, 256, 274
bullbrooki, n. sp., 158, 160, 167, 170, 275
canariensis, 7, 120
canariensis minima, 120
capdeviensis, 78
centralis, 41, 42, 100, 104, 158, 160, 161, 164, 169, 247, 276
(Truncorotalia) centralis, 169
(Turborotalia) centralis, 169
cerro-azulensis, 169
cocoensis, 100, 105, 160, 161, 169, 276
collaeata, 72, 162
compressa, 42, 62, 67, 68, 77, 78, 176, 188, 189, 190, 237, 277, 278, 279, 281
conicotruncata, 190, 196
covea, 176, 184, 188, 191, 194, 235, 287, 290, 294, 298, 300
crasstata, 64, 75, 168
crasstata acqua, 74, 186
crasstata densa, 168
criosa, 7, 168
crester, 191
dehiscens, 31, 111
delrioensis, 39, 40, 51, 55
ehrenbergi, n. sp., 64, 67, 68, 77, 78, 188, 257
INDEX
Globorotalia, n. sp., 67, 68, 79, 170, 256
reissi, n. sp., 176, 192, 194, 196, 287, 295
renzi, n. sp., 160, 168, 275, 297
rex, 66, 68, 75, 176, 186, 187, 195, 255, 277
scitula, 7, 16, 101, 120, 266
simulautilus, 75
spinuloindifata, 158, 159, 161, 168, 275
spinulosa, 158, 159, 161, 168, 275
(Turcorotalia) spinulosa, 168
strabocella, n. sp., 195, 298
topilensis, 80
tortiva, n. name, 67, 78, 79, 183, 184, 256
tribulosa, n. sp., 195, 293, 298
trichotrocha, n. sp., 196, 287, 294
trinidadensis, n. sp., 66, 67, 68, 72, 73, 74, 253
troelseni, n. sp., 196, 297, 300
truncatulinoides, 7, 8, 11, 15, 16, 17
(Turcorotalia), 68, 102, 247
tumida, 7, 8, 11, 43, 102, 182, 247
uncinta, n. sp., 64, 66, 68, 74, 254
variata, 176, 196, 281, 282
velascoensis, 64, 65, 67, 68, 76, 176, 185, 186, 191, 257, 301
whitel, 65, 67, 68, 79, 256
wilcoxensis, 67, 68, 76, 79, 80, 170, 185, 187, 189, 256
wilcoxensis acuta, 65, 67, 76
Globorotalia sp., 197, 282
Globorotaliidae, 3, 15, 17, 18, 19, 21, 23, 26, 39, 40, 41, 45, 46, 52, 55, 73, 117, 137, 155, 166, 176, 185
Globorotaliinae, 18
Globorotalites, 15, 16, 220
alaskensis, n. sp., 220, 306
lobata, 126
multiseta, 220
Globorotaloides, n. gen., 117, 166
suteri, n. sp., 117, 159, 166, 264, 274
variabilis, n. sp., 117, 264
globosa, Globoquadrina altipira, n. subsp., 111, 261
Globotruncan, 13, 15, 16, 18, 19, 21, 39, 40, 41, 42, 43, 44, 51, 54, 55, 56, 126, 174
andori, 54, 59, 251
angustiatenaria, 54
appenninica, 39, 46
appenninica-linearis, 58
arca, 11, 15, 44, 248
calcarata, 52, 39
calpiformis, 54
canaliculata ventricosa, 57
citae, 46, 51
concavata, 52, 54, 56, 57, 250
costata, 11, 54
corona, 58
eretacea, 59
forncat, 52, 54, 59
gagnebini, 54, 59, 251
ganseri, 54, 56
globigerinoides, 46, 54
pseudotopilensis, Pseudouvigerina, Pullenia, Pulleniatina, 15, 141, 142
crystata, 140, 141, 142
puclora, Guembelina, Globorotalia, 135, 137, 138
pulverula, 33
Pulleniatina, 11, 15, 35
Pulleniatinae, 17, 21
Pullenoides, 39
Pulvinulina, 17, 44
arca, 44, 45, 46
favus, 230
menardii tumida, 41, 42
punetulata, 229, 230
scitula, 120
tricarina, 44
velascoensis, 76, 196
punetulata, Pseudouguerbelina, 140
Pulvinulina, 229, 230
Rotalia (Rotelle), 223, 230
pusilla, Globorotalia, 197
Globorotalia pusilla, n. sp., n. subsp., 64, 65, 67, 78, 257
pyrmiudata, Gaudryina, 62
Pyrulinoideae, 217
obesa, 217
thurareli, n. sp., 217, 305
quadraria, Globorochinida, 111
prolongata, Tritaxia spiritenis, 208
Psamminopecta, n. gen., 210, 211
bowsher, n. sp., 311, 304
subularellaris, n. sp., 318, 304
pseudoubollides, Globigerina, 72, 73, 126, 127, 128, 162, 183, 188, 191, 192, 267
Globorotalia, 42, 62, 66, 68, 72, 78, 74, 175, 176, 191, 182, 195, 196, 254, 277, 278, 279, 280, 281, 282, 283
Pseudogloborotalia, 41, 42
rasioktenis, 41, 42
Pseudouguerbelina, 135, 136, 137, 138, 139
costula, 139, 140, 268
exocola, 140, 268
palpebra, 140
punetulata, 140
striata, 140
pseudomayeri, Globorotalia, n. sp., 155, 167, 274
pseudomenardii, Globorotalia, n. sp., 67, 68, 77, 78, 176, 189, 193, 196, 257, 282, 284, 286, 291, 296, 297, 300
pseudocostula, Globorotalia, 77, 176, 193, 197, 283, 285, 290, 296, 300
pseudotessera, Guembelina, 135, 137
Heterohelix, 140, 141
Pseudotextularia, 51, 126, 133, 134, 135, 136, 141, 142
bohemica, 143
elegans, 135, 142, 270
elegans acervulinaoides, 139
elegans varians, 139
varians, 138, 139, 142
pseudotopilepia, Amarinina, 194
Globorotalia, 176, 194, 297
pseudotopiloida, Globigerina, 70, 183
Pseudouvigerina, 134, 135, 136, 151
cristata, 151, 271
Pulcira, Guembelina, 135, 137
Heterohelix, 140, 141
Pululla, 17
obliquoculata, 33
Pulleniatina, 11, 15, 35
obliquoculata, 6, 7, 8, 33, 241
Pulleniatininae, 17, 21
Pulvenulina, 17
obliquoculata, 33
Pulvulina, 17
obliquoculata, 33
Pulleniatinae, 17, 21
Pullenoides, 39
Pulvinulina, 17, 44
arca, 44, 45, 46
favus, 230
menardii tumida, 41, 42
punetulata, 229, 230
scitula, 120
tricarina, 44
velascoensis, 76, 196
punetulata, Pseudouguerbelina, 140
Pulvinulina, 229, 230
Rotalia (Rotelle), 223, 230
pusilla, Globorotalia, 197
Globorotalia pusilla, n. sp., n. subsp., 64, 65, 67, 78, 257
pyrmiudata, Gaudryina, 62
Pyrulinoideae, 217
obesa, 217
thurareli, n. sp., 217, 305
quadraria, Globorochinida, 111
INDEX

ventricosa, Globotruncanana, 46, 52, 54, 56, 67, 59, 250
Globotruncanana canaliculata, 57
Globotruncanana (Globotruncanana) ventricosa, 57
venusae, Praebulimina, 217
Verneuilinidae, 206
Verneuillinoides, 206
borealis, n. sp., 206, 208, 303
fischeri, n. sp., 207, 303
parallela, 207
perplexa gleddiei, 206
tailleuri, n. sp., 208, 303
victoriana, Chiloguembelina, n. sp., 85 (fig.), 87, 88, 91, 92, 258
Virgulina, 227
squammosa, 227, 228

Virgulinae, 227
vitrea, Aeolostreptis, 227, 309
Buliminella, 227
vivens, "Guembelitria," 136, 267
washitensis, Siphotextularia, 206
watersi, Bulivina, 146, 150
Hastigerinoides, 25, 238
Trachelinella, 150, 271
webberi, Spiroplectammina, n. sp., 205, 303
Webbina hemispherica, 223, 224, 226
Webbinella, 223, 226
hemisphaerica, 223, 226, 309
rugosa, 224
Webбинelloidea, 223, 224
whitei, Clavulina aspera, 62
Globorotalia, 65, 67, 68, 79, 256

whittingtoni, Trochammina, n. sp., 214, 305
wilcoxensis, Chiloguembelina, 85 (fig.), 86, 88, 92, 258
Globorotalia, 67, 68, 76, 79, 80, 170, 185, 187, 189, 256
Guembelina, 92, 137, 178
Heterohelix, 178, 180, 293
wilsoni, Globigerina, 169
Globotruncanana, n. sp., 52, 54, 68, 251
Woodringina, 177, 178
claytonensis, 178, 277
yeguaensis, Globigerina, 163, 272
Zeaувigerina, 83, 86, 88, 92, 135, 136, 149
aegyptiaca, 85 (fig.), 92, 258
teuria, 93
zelandica, 131, 271
zelandica, Zeaủvigerina, 149, 271
Zotheculifida, n. gen., 224
lirata, 224, 309