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STUDIES IN FORAMINIFERA

By ALFRED R. LOEBLICH, Jr., and COLLABORATORS:
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Publications of the United States National Museum

The scientific publications of the National Museum include two series, known, respectively, as *Proceedings* and *Bulletin.*

The *Proceedings* series, begun in 1878, is intended primarily as a medium for the publication of original papers, based on the collections of the National Museum, that set forth newly acquired facts in biology, anthropology, and geology, with descriptions of new forms and revisions of limited groups. Copies of each paper, in pamphlet form, are distributed as published to libraries and scientific organizations and to specialists and others interested in the different subjects. The dates at which these separate papers are published are recorded in the table of contents of each of the volumes.

The series of *Bulletins,* the first of which was issued in 1875, contains separate publications comprising monographs of large zoological groups and other general systematic treatises (occasionally in several volumes), faunal works, reports of expeditions, catalogs of type specimens, special collections, and other material of similar nature. The majority of the volumes are octavo in size, but a quarto size has been adopted in a few instances. In the *Bulletin* series appear volumes under the heading *Contributions from the United States National Herbarium,* in octavo form, published by the National Museum since 1902, which contain papers relating to the botanical collections of the Museum.

The present work forms No. 215 of the *Bulletin* series.

Remington Kellogg,
Director, United States National Museum.

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Contents

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 biformis* (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 Forammifera 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 faunules, 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, [1] 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 redescribed 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 nervetheless 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

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[1] Arrangement of names alphabetical, no seniority implied. Hans M. Bolli, Trinidad Oil Company, Ltd. (formerly Trinidad Leaseholds, Ltd.), Pointe-à-Pierre, Trinidad, B. 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, Jusepín, Venezuela; W. H. Blow, London, England; P. Bronnimann, Havana, Cuba; A. F. M. Mohsenul Haque, Quetta, Pakistan; C. G. Lalicker, McAllen, Texas; M. L. Natland, Rolling Hills, California; 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. Brotzen, Geological Survey of Sweden, Stockholm; Noel Brown, Cuban Gulf Oil Company, Havana, Cuba; A. C. Collins, Newtown, Geelong, Victoria, Australia; N. de B. Hornibrook, New Zealand Geological Survey, Wellington; V. Pokorný, Charles University, Prague, Czechoslovakia; M. Reichel, Basle, Switzerland; J. Sigal, Institut de Pétrole, Reuil-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 Muséum 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 1.28μ to 18μ, whereas specimens from the bottom have walls up to 24μ in thickness. The planktonic *Globigerinas* 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.

Emiliani (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 its increased size, and therefore decreased specific gravity, causes it to occupy in its later growth. Emiliani 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. Rhumblers' 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 accidental 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 *Pulleniatina 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 subfamily 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 psuedopodia, 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.

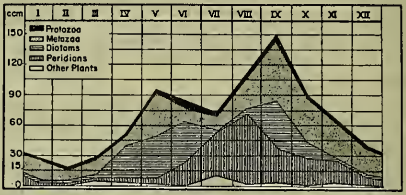


Figure 1.—Curves of volume of various groups of organisms in the total plankton at Laboe, in the Bay of Kiel, during the year. (From Hesse, Allee and Schmidt, 1937, after Lohmann).

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). Aggassiz (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 crassula* Cushman and Stewart, *G. canariensis* (d'Orbigny), *G. truncatulinoides* (d'Orbigny), and *G. hirsuta* (d'Orbigny). Warm and tropical forms: *Orbulina 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), *Sphaeroidinella 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), *Globigerinita glutinata* (Egger), *Globigerinoides conglobata* (Brady), *G. rubra* (d'Orbigny), and *Orbulina 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 (1935).

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 48th 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 noncirculating 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 (1897, 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 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.

Depth 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*, *Pulleniatina 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 pelagial, 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 is 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. Brotzen (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, exteriomarginal, 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 Brotzen. 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 Brotzen'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, turbospiral by Brotzen 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 whorls, 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

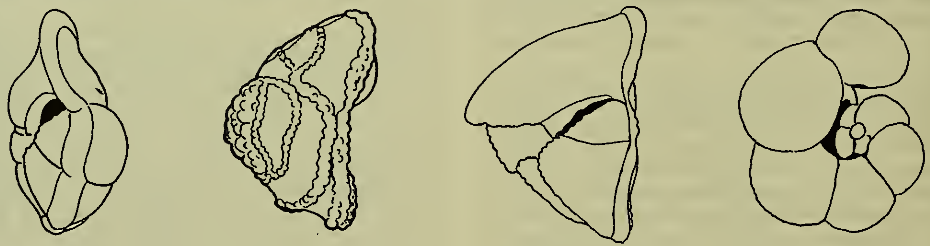
Umbilicate

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 BIUMBILICATE: 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.

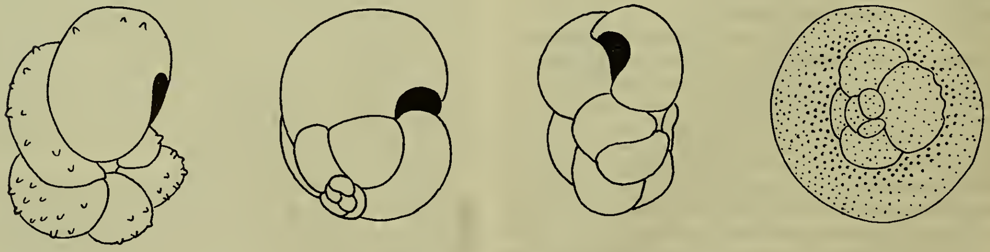


Biconvex Trochospiral

Spiroconvex Trochospiral

Umbilico-convex Trochospiral

Evolute Planispiral



Involute Planispiral

Streptospiral

Enrolled Biserial

Globular

FIGURE 2.—Test shapes in planktonic Foraminifera.

Biconvex. Both spiral and umbilical sides convex, or more or less inflated, e. g., *Globorotalia tumida* (Brady).

Spiroconvex. 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., *Globotruncana 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 *Globotruncana helvetica* Bolli.

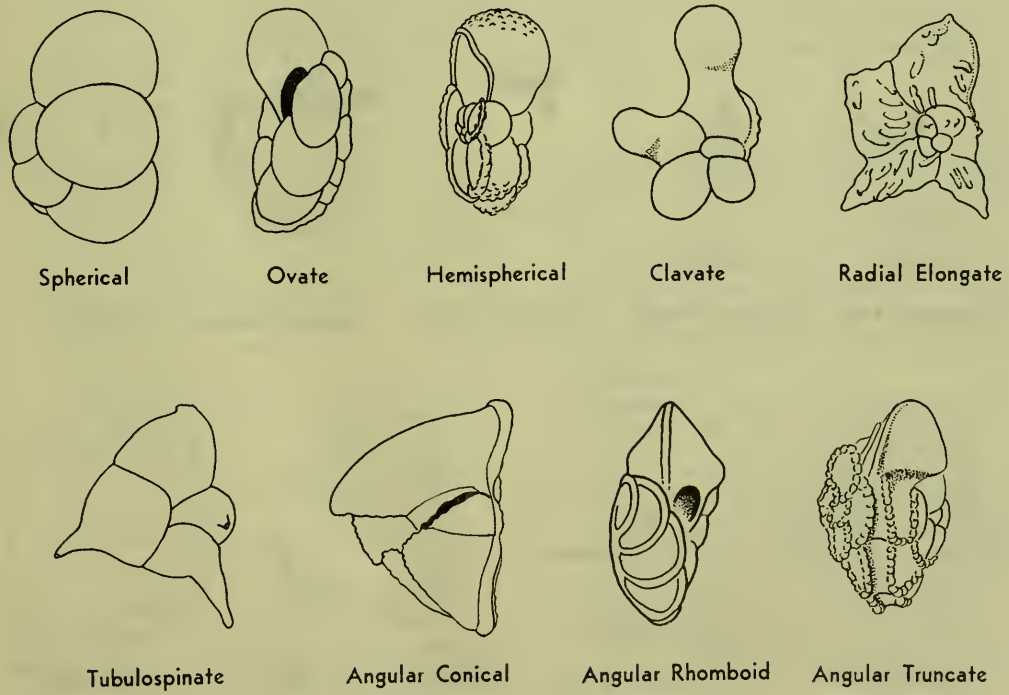


Figure 3.—Chamber shapes in planktonic Foraminifera.

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 akersi* 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.

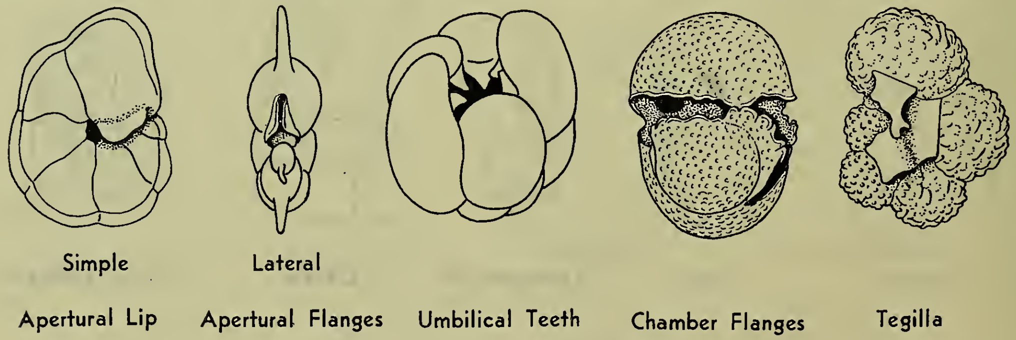
Accessory Structures

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



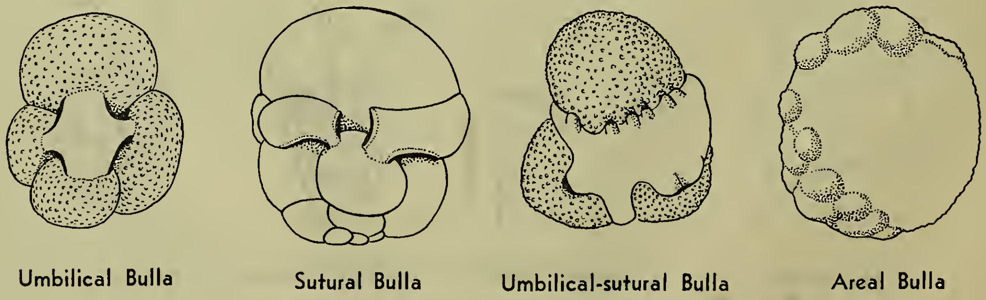


Figure 4.—Apertural modifications in planktonic Foraminifera.

and elongate, short and spatulate, or of various other shapes, e. g., *Globorotalia.*

LATERAL APERTURAL FLANGES: Similar to the apertural lip of trochospiral forms, but found on both sides of the commonly elevated peripheral aperture in *Hantkenina*, *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 *Globoquadrina.*

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 *tegulum*, 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 comonly 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 Forminifera of the family Orbulinidae, 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 bullae. 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 *Globigerinita.*
- Areal bullae. 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.*

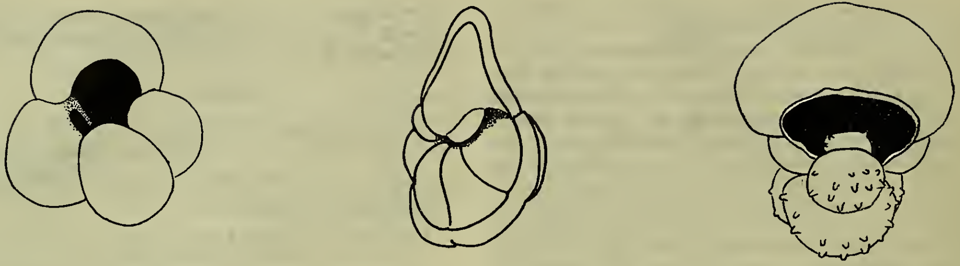
Secondary Apertures

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 Planomalininae 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.

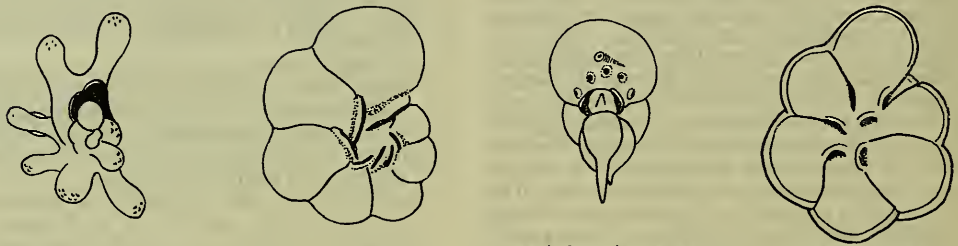
- Areal. Supplementary multiple areal apertures are developed in *Cribrohantkenina.* Specimens may be found in which both the primary equatorial aperture and the supplementary areal apertures occur, showing the latter to be of secondary rank.
- Sutural. Sutural supplementary apertures are in general relatively small. They may be single, or one per suture, as in *Rotalipora*, or multiple,



Umbilical Aperture

Extraumbilical-umbilical Aperture

Equatorial Aperture



Spiroumbilical Aperture

Relict Apertures

Areal Supplementary Apertures

Single Sutural Supplementary Apertures

Multiple Sutural Supplementary Apertures

Infralaminal Accessory Apertures

Intralaminal Accessory Apertures

Figure 5.—Apertural types in planktonic Foraminifera.

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*.

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

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 porcellanous 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.

SPINOSE: With very fine solid spines, generally elongate, e. g., *Hastigerinella rhumbleri* Galloway.

HISPID: Very fine, short, and hair-like "spines" as in *Globorotalia truncatulinoides* (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 *Globotruncana arca* (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:

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 *Globotruncana* or *Globigerinita*.

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., *Globoquadrina*). 2. Chamber extensions, e. g., the flanges of *Sphaeroidinella* and tegilla of *Globotruncana*. 3. Accessory structures or bullae, e. g., *Globigerinita*. 4. Enveloping final chambers, e. g., *Orbulina*. 5. Enfolding of chambers by development of streptospiral coiling, e. g., *Pulleniatina*.

Tendency to develop a spherical test: 1. By means of enveloping chambers, e. g., *Orbulina*. 2. By becoming streptospiral in development, e. g., *Pulleniatina*. 3. By much inflated chambers in planispiral genera, e. g., *Hastigerina*. 4. By becoming high spired in trochospiral genera, e. g., *Globigerinoides*.

Tendency to develop a radial form: 1. 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 fohsi* 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*, *Globoquadrina* 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.

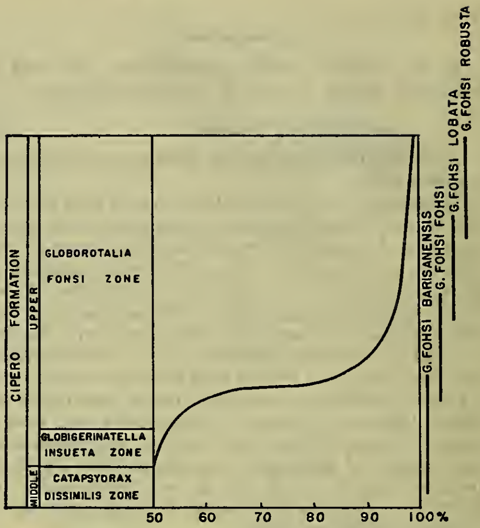


FIGURE 6.—Percentage of sinistral specimens of the *Globorotalia fohsi* group in the Miocene Cipero formation of Trinidad, showing evolution from random coiling to a sinistral dominance with time. (Modified after Bolli, 1950).

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.

Vašíček (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 Vašíček (p. 413) that the coiling might be related to the reproductive process of "plastogamy." Myers' work on life cycles showed the

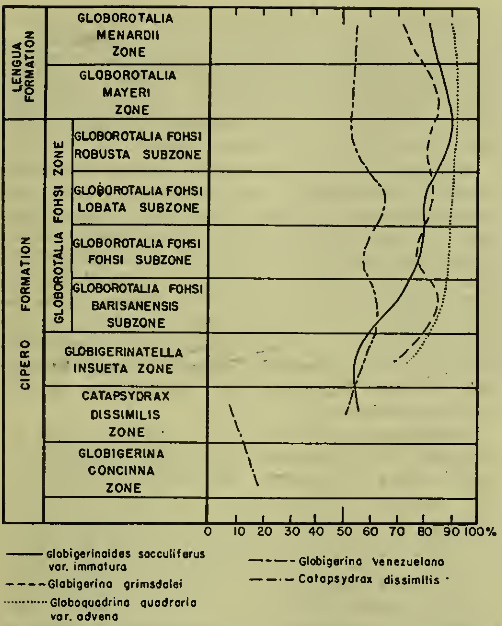


FIGURE 7.—Percentage of sinistral coiling of some Oligocene-Miocene Orbulinidae, showing dominantly sinistral coiling in later development of certain species of *Globigerina*, *Globigerinoides*, and *Globoquadrina*, and dominantly dextral coiling of *Catapsydrax*. (Modified after Bolli, 1951).

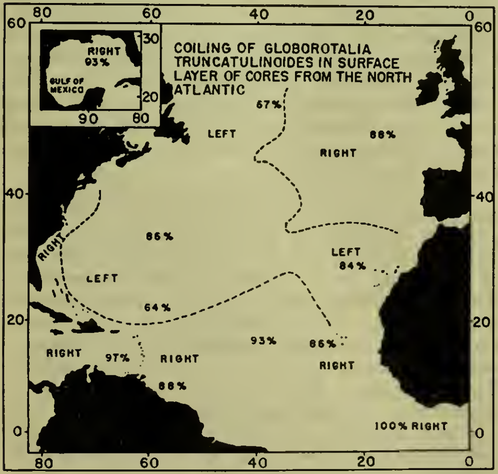


FIGURE 8.—Provinces of dominantly sinistral and dextral coiling of living *Globorotalia truncatulinoides* populations. (After Ericson, G. Wollin and J. Wollin, 1954).

syzygy of megalospheric individuals before the production of the gametes of the sexual generation. This syzygy in the case of *Patellina* 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 Monostègues, or single chambered forms. *Globigerina* and other trochospiral forms would belong to the Hélicostègues (or helically coiled forms), *Cassigerinella* (though then as yet unknown) would have been placed with *Cassidulina* in the Entomostègues and *Sphaeroidinella* in the Agathistègues.

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 Globigerinae the arenaceous Textularinae, 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*, *Sphaeroidina*, 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 *Cribrohantkenina* 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 in it 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 rotaliform Foraminifera into the Nonionidae (all planispiral 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 exteriomarginal aperture). He included within the Valvulineriidae the subfamilies Valvuleriinae, Cibicidinae, Globigerininae, and Globotruncaninae. However, the name Anomalinidae Cushman takes precedence over Cibicidinae, and the name Globorotaliinae has precedence over Globotruncaninae. Furthermore, Orbulinidae has priority over Globigerininae, and all of these names—Anomalinidae, Orbulinidae, and Globorotalidae—take precedence over the name Valvulineriidae.

Glaessner (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 planispiral 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 Valvulineriinae, 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 *Thalmanninella* (here considered a synonym of *Rotalipora*) were separated by Bermudez into the subfamily Globotruncaninae, 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 Brotzen had included *Rotalipora* and *Cymbalopora* in the Globotruncaninae.

Bronnimann and Brown (1956) recently elevated the subfamily Globotruncaninae 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 Globotruncanidae 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 extraumbilical-umbilical aperture like that of *Globorotalia*.

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

Hofker (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 Globotruncaninae of Brotzen, 1942), the "new" subfamily Globotruncaninae (which was proposed by Brotzen, 1942, and is not new with Hofker), which is comprised of four genera, *Thalmanninella* Sigal, 1948, *Rotalipora* Brotzen, 1942, *Globotruncana* Cushman, 1927, and a new genus, *Marginotruncana* Hofker. *Thalmanninella* is here shown to be a synonym of *Rotalipora*, which belongs to the family Globorotaliidae, and *Marginotruncana*, as based on the type species selected by Hofker, is a true *Globotruncana* (see below under the description of that genus), although Hofker also included other unrelated species in his proposed genus, including species of typical *Praeglobotruncana*, *Rotalipora*, and *Abathomphalus*.

A summary of the principal classifications is given below:

Galloway 1933

- Orbulinidae Schultze, 1854
    - Globigerina d'Orbigny
    - Neocribrella Cushman
    - Globotruncana Cushman
    - Pulleniatina Cushman
    - Candeina d'Orbigny
    - Hastigerina Thomson
    - Orbulina d'Orbigny
- Pegidiidae Heron-Allen and Earland, 1928
    - Sphaeroidinella Cushman
- Rotaliidae Reuss, 1860
    - Globorotalia Cushman
- Nonionidae Reuss, 1860
    - Hantkenina Cushman

Cushman 1948

- Globigerinidae
    - Globigerininae
        - Globigerina d'Orbigny
        - Globigerinoides Cushman
        - Globigerinatella Cushman and Stainforth
        - Globigerinelloides Cushman and ten Dam
        - Globigerinella Cushman
        - Hastigerina Thomson
        - Hastigerinella Cushman
    - Orbulininae
        - Orbulina d'Orbigny
    - Pulleniatininae
        - Pulleniatina Cushman
        - Sphaeroidinella Cushman
    - Candeininae
        - Candeina d'Orbigny
        - Candorbulina Jedlitschka
- Hantkeninidae
    - Schackoina Thalmann
    - Hantkenina Cushman
    - Cribrohantkenina Thalmann
- Globorotaliidae
    - Globotruncana Cushman
    - Globorotalia Cushman
    - Globorotalites Brotzen
    - Rotalipora Brotzen
    - Cribrogloborotalia Cushman and Bermudez
    - Cycloloculina Heron-Allen and Earland
    - Sherbornina Chapman

Bermudez 1952

- Rotaliidae
    - Valvulineriinae
        - Globorotalia Cushman
        - Globorotalites Brotzen
        - Turborotalia Cushman and Bermudez
        - Globoquadrina Finlay
        - Cribrogloborotalia Cushman and Bermudez
    - Globotruncaninae
        - Praeglobotruncana Burmudez
        - Thalmanninella Sigal
        - Globotruncana Cushman
        - Truncorotalia Cushman and Bermudez
- Cymbaloporidae
    - Rotalipora Brotzen
- Nonionidae
    - Hantkenininae
        - Schackoina Thalmann
        - Hantkenina Cushman
        - Sporohantkenina Bermudez
        - Applinella Thalmann
        - Aragonella Thalmann
- Globigerinidae
    - Globigerininae
        - Globigerina d'Orbigny
        - Globigerinoides Cushman
        - Hastigerinella Cushman
        - Hastigerinoides Bronnimann
        - Globigerinella Cushman
        - Biglobigerinella Lalicker
        - Trinitella Bronnimann
        - Hastigerina Thomson
        - Globigerinatheka Bronnimann
        - Globigerinelloides Cushman and ten Dam
        - Globigerinita Bronnimann
        - Globigerinoita Bronnimann
        - Rugoglobigerina Bronnimann
        - Plummerita Bronnimann
        - Ticinella Reichel
        - Globigerinatella Cushman and Stainforth
    - Orbulininae
        - Orbulina
    - Pulleniatininae
        - Pulleniatina Cushman
        - Sphaeroidinella Cushman
    - Candeininae
        - Candorbulina Jedlitschka
        - Candeina d'Orbigny

Bolli, Loeblich, and Tappan 1957

- Hantkeninidae Cushman, 1927
    - Planomalininae Bolli, Loeblich and Tappan, new subfamily
        - Globigerinelloides Cushman and ten Dam
        - Planomalina Loeblich and Tappan
        - Hastigerinoides Bronnimann
        - Biglobigerinella Lalicker
    - Hantkenininae Cushman, 1927
        - Schackoina Thalmann
        - Hantkenina Cushman
        - Cribrohantkenina Thalmann
    - Hastigerininae Bolli, Loeblich, and Tappan, new subfamily
        - Hastigerina Thomson
        - Clavigerinella Bolli, Loeblich, and Tappan
    - Cassigerinellinae Bolli, Loeblich, and Tappan, new subfamily
        - Cassigerinella Pokorný

- Globorotaliidae Cushman, 1927
    - Praeglobotruncana Bermudez
    - Rotalipora Brotzen
    - Globorotalia Cushman
    - Truncorotaloides Bronnimann and Bermudez
- Globotruncanidae Brotzen, 1942
    - Abathomphalus Bolli, Loeblich, and Tappan
    - Rugoglobigerina Bronnimann
    - Globotruncana Cushman
- Orbulinidae Schultze, 1854
    - Globigerininae Carpenter, 1862
        - Globigerina d'Orbigny
        - Globoquadrina Finlay
        - Hastigerinella Cushman
        - Globigerinoides Cushman
        - Sphaeroidinella Cushman
        - Pulleniatina Cushman
    - Orbulininae Schultze, 1854
        - Globigerapsis Bolli, Loeblich, and Tappan
        - Porticulasphaera Bolli, Loeblich, and Tappan
        - Candeina d'Orbigny
        - Orbulina d'Orbigny
    - Catapsydracinae Bolli, Loeblich, and Tappan, new subfamily
        - Catapsydrax Bolli, Loeblich, and Tappan
        - Globigerinita Bronnimann
        - Globigerinoita Bronnimann
        - Globigerinatheka 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 Hantkeninidae 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 *Globigerinoita* 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 *Globigerinoita*, 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 *Globotruncana* from the Globorotaliidae and *Rugoglobigerina* from the Globigerininae 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 Planomalininae, 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 Pulleniatininae—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 tubulospinate; wall calcareous, perforate, radial in structure; primary aperture symmetrical and equatorial, paired or multiple, may have relict or areal secondary apertures.

Planomalininae 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

Globigerinelloides CUSHMAN and TEN DAM, Contr. Cushman Lab. Foram. Res., vol. 24, p. 42, 1948.

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

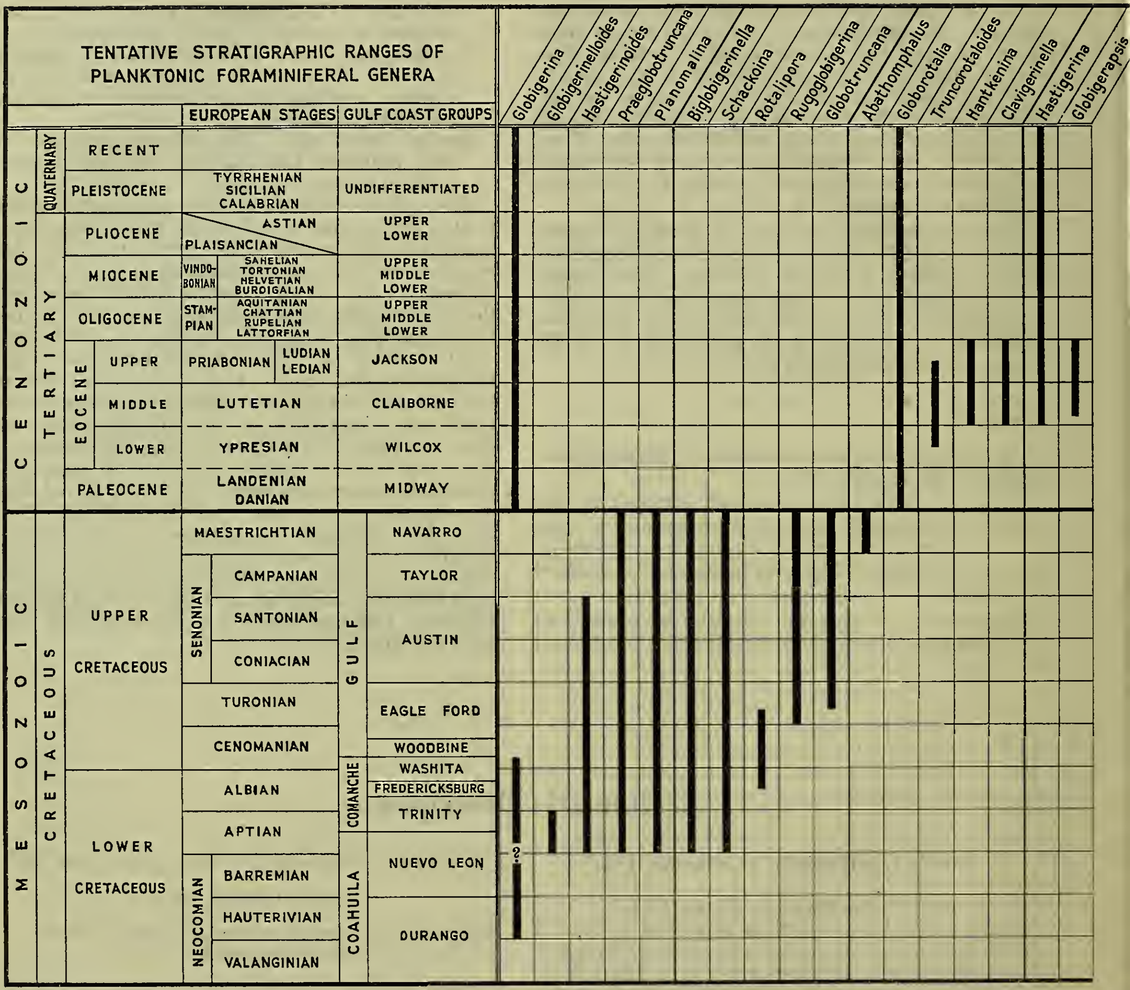
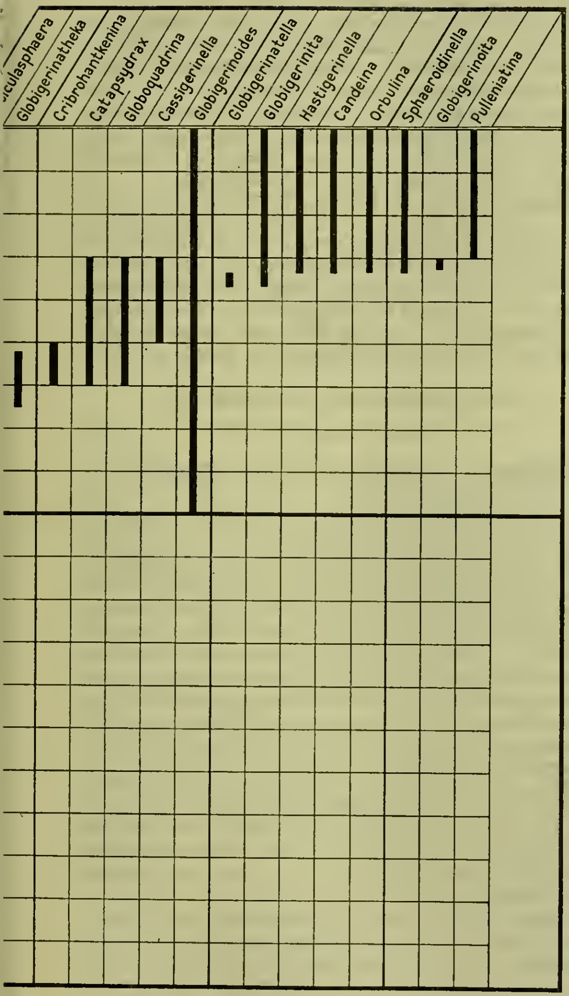


Figure 9.—Tentative stratigraphic ranges of planktonic foraminiferal genera.

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 Menaouer, between Relizane and Uzes-le-Duc, western Algeria. Collected by A. ten Dam.

RANGE: Aptian.

Genus Planomalina Loeblich and Tappan, 1946 [1]

PLATE 1, FIGURES 2a–3b

Planomalina LOEBLICH and TAPPAN, 1946, Journ. Paleontol., vol. 20, No. 3, p. 257, 1946.

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 Planomalininae.

Planomalina differs from *Biglobigerinella* Lalicker in having extremely prominent relict apertures, and in having only a single primary aperture, whereas *Biglobigerinella* 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 curved umbilical chamber extensions, and in possessing relict apertures.

TYPES AND OCCURRENCE: Holotype of *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 HTL–102, sample 418,

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[1] After the present paper had been sent to press, the genus *Biticinella* Sigal, 1956, was described, with *Anomalina breggiensis* Gandolfi as type species. *Biticinella*, superficially very similar to *Planomalina*, was defined as a "morphologic genus" related to the *Ticinella-Thalmanninella-Rotalipora* group in being slightly asymmetrical, 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 apertures in *Biticinella* should prove to be relict apertures, however, the genus *Biticinella* would probably become a synonym of *Planomalina*.

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, biumbilicate, 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.

TYPES AND OCCURRENCE: Holotype (USNM P4869), figured paratype (USNM P4870) and unfigured paratypes (USNM P4871 and P4872) from the Albian Gault clay, Brick pit of the London Brick Co., Arlesey, England. Collected 1953 by H. T. and A. R. Loeblich, Jr.

Unfigured paratypes (USNM P5396) from 5½ feet of section, alternating gray shale and marly limestone, 58 feet above the base of the Duck Creek formation, and 6½ feet below the fucoid-bearing basal limestone of the Fort Worth formation, Lower Cretaceous, Albian, on the west bank of the Red River, in the SW¼Sec.22,T.8-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

Hastigerinoides BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 140, p. 52, 1952.

TYPE SPECIES: *Hastigerinella alexanderi* Cushman, 1931. Fixed by original designation.

Test free, stellate in appearance, planispiral, biumbilicate, 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 extraumbilical-umbilical, in the later stages extending farther towards the periphery and even onto the spiral side, but is not a typically 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

Biglobigerinella Lalicker, Journ. Paleontol., vol. 22, p. 624, 1948.

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

Test free, planispiral, nearly or completely involute, biumbilicate, 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 extraumbilical 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), and 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, biumbilicate, 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 interiomarginal, 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 extraumbilical 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 trochospiral 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

Schackoina Thalmann, Eclog. Geol. Helvetiae, vol. 25, p. 289, 1932.

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, extraumbilical 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 *Hantkeinina* has a triradiate aperture with a high slit extending up the face of the final chamber.

It differs from *Hastigerinoides* Bronnimann 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 *Schloenbachia varians* zone; unfigured hypotypes (USNM P4562) from the Cenomanian *Inoceramus crippsi* zone; all from Ziegelei 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

Hantkenina Cushman, Proc. U. S. Nat. Mus., vol. 60, art. 30, p. 1, 1924.

Sporohantkenina Bermudez, Mem. Soc. Cubana Hist. Nat., vol. 11, p. 151, 1937. (Type species: *Hantkenina brevispina* Cushman, 1924. Fixed by original designation and monotypy.)

Aragonella Thalmann, Amer. Journ. Sci., vol. 240, pp. 811, 813, 818, 1942. (Type species: *Hantkenina mexicana* Cushman var. *aragonensis* Nuttall, 1930. Fixed by original designation.)

Applinella Thalmann, Amer. Journ. Sci., vol. 240, pp. 812, 813, 819, 1942. (Type species: *Hantkenina dumblei* Weinzierl and Applin, 1929. Fixed by original designation.)

Hantkeninella Bronnimann, Journ. Paleontol., vol. 24, No. 4, p. 399, 1950. (Type species: *Hantkenina alabamensis* Cushman var. *primitiva* Cushman and Jarvis, 1929. Fixed by original designation and monotypy.)

Type species: *Hantkenina alabamensis* 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 true *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 Hantkenininae, 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 Planomalininae 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 *Praeglobotruncana* 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 *Cribrohantkenina*. 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 *Cribrohantkenina*. 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 "*Cribrohantkenina bermudezi*" 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 *Cribrohantkenina* 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 *Cribrohantkenina bermudezi* 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 *Cribrohantkenina* 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 *Cribrohantkenina* 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 sutural 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 sutural 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 nonspinose 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.

Cribrohantkenina 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 dumblei* 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. 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

Cribrohantkenina Thalmann, Amer. Journ. Sci., vol. 240, pp 812, 815, 819, 1942.

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

Test free, planispiral, biumbilicate; chambers subglobular, with the prominent peripheral spine at the forward 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 "poreplate," 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 danvillensis* 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 Méxican 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 *Cribrohantkenina* 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, *Hantkenina brevispina* Cushman is the type species of *Sporohantkenina* by original designation and monotypy, and Thalmann was correct in suppressing the generic name as a synonym of *Hantkenina*, s. s.

Although originally described as a subgenus of *Hantkenina*, *Cribrohantkenina* was later elevated to generic rank (Cushman, 1948, p. 328). Barnard (1954, p. 384) showed the ontogenetic development of the aperture in *Cribrohantkenina*, although he considered it gradational with *Hantkenina*. It seems probable that he was dealing with more than one species, however, 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 *Cribrohantkenina bermudezi* Thalmann from the Jackson Eocene, Pachuta formation, Cushman's "Cocoa sand," 2.2 miles south of Melvin, Choctaw County, Aabama.

Range: Upper Eocene.

Hastigerininae Bolli, Loeblich, and Tappan, new subfamily

Type genus: *Hastigerina* Thomson, 1876.

Coiling of test planispiral; chambers spherical to clavate; primary aperture equatorial, no secondary apertures present.

Range: Eocene to Recent.

Genus Hastigerina Thomson, 1876

Plate 3, Figures 1–4b

Hastigerina Thomson, Proc. Roy. Soc. London, vol. 24, p. 534, 1876.

Globigerinella Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, p. 87, 1927. (Type species: *Globigerina aequilateralis* Brady, 1879. Fixed by original designation and monotypy.)

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 interiomarginal, 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 confounded is *Globigerina aequilateralis*," and it later became the type species of *Globigerinella*. He added that the latter was evolute. In the original description 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 *Planomalina* 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 aequilateralis* (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 trochospiral, 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 *Hantkenina aragonensis* Nuttall, but the present genus does not have tubulospines, and *Hantkenina* 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 5a, b

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* Nuttal from the Eocene of México, 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, extraumbilical and alternating in the adult.

Range: Oligocene to Miocene.

Genus Cassigerinella Pokorný, 1955

Plate 3, Figures 6a–c

Cassigerinella Pokorný, Věstník Ústředního Ústavu Geologického, vol. 30, p. 136, 1955.

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 extraumbilical 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: *Orbulina* 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 infralaminal 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

Globigerina d'Orbigny, Ann. Sci. Nat., ser. 1, vol. 7, p. 277, 1826.

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 extraumbilical 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, extraumbilical-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 extraumbilical-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 Cenomanian in the Lower and Middle Cretaceous which appear to be morphologically identical. The gap in the geologic record from the Cenomanian 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 Globoquadrina Finlay, 1947

Plate 5, Figures 4a–6

Globoquadrina Finlay, New Zealand Journ. Sci. Tech., vol. 28, No. 5 (sec. B), p. 290, 1947.

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

Types and occurrence: Figured hypotype (USNM P3926) and unfigured hypotype (USNM P3927) of *Globoquadrina 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 Barackpore and Princes Town, Trinidad, B. W. I.

RANGE: Upper Eocene to Miocene.

Genus Hastigerinella Cushman, 1927

PLATE 5, FIGURES 1–3b

Hastigerinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, p. 87, 1927.

TYPE SPECIES: *Hastigerina digitata* Rhumbler, 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* Rhumbler, Foram. Plankton Exped., Part 1, 1911, pl. 37, fig. 9a,b." The *digitata* of Rhumbler, 1911, is not conspecific with *Globigerina 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 Rhumbler'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 Rhumbler'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 Rhumbler (1911, pp. 202, 220) as being a new combination and not referring to *Globigerina digitata* Brady, 1879, for nowhere did Rhumbler (1911) use the name Brady in combination with *Hastigerina digitata.* The type thus should be cited as *Hastigerina digitata* Rhumbler, 1911, but this is a homonyn of *H. digitata* (Brady), 1879. Galloway in reality only renamed this homonyn 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 Rhumbler 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

Globigerinoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, p. 87, 1927.

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 specimen 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 Musuem 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

Sphaeroidinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, p. 90, 1927.

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 cancellated, in the later chambers a somewhat irregularly fimbriate or scalloped flange, 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 *Globigerinatheka* 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. 28° 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

Pulleniatina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, p. 90, 1927.

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 a broad umbilical arch, as in *Globigerina*, in the adult a broad low extraumbilical 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 extraumbilical peripheral aperture.

Pulleniatina resembles *Globigerapsis*, 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 *Globigerapsis* has in the final chamber multiple apertures which are against the sutures of the early coil.

TYPES AND OCCURRENCE: Lectotype (here designated) of *Pullenia obliqueloculata* Parker and Jones, 1865 (the type species of *Pulleniatina*), British Museum (Natural History) No. ZF 3583, and figured paratype (USNM P4228) from Abrohlos Bank, at 260 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 sutural 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 *Globigerinatheka* 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.

Bronnimann (1952a, p. 27, text-fig. 3d-f) included a single specimen of *Globigerapsis kugleri* with his *Globigerinatheka barri,* considering it to represent a stage prior to the development of the sutural 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 trochospiral 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 *Globigerinatheka barri* Bronnimann but may have a less embracing final chamber, and always lacks the small bullae which cover the secondary sutural apertures of *Globigerinatheka.*

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, *Globigerinatheka 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.

Porticulasphaera mexicana (Cushman), emended

Plate 6, Figures 8–9b

Globigerina mexicana Cushman, Contr. Cushman Lab. Foram. Res., vol. 1, No. 3, p. 6, pl. 1, figs. 8a-b, 1925.

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: *Porticulasphaera mexicana* was originally described from the upper Eocene Tantoyuca formation, Vera Cruz, México. 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 Chapapote") in Tierra Amarilla Well No. 25, at 1,200 feet, Vera Cruz, México. 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 Candeina d'Orbigny, 1839

Plate 6, Figures 10a–11

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

Type species: *Candeina 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: *Candeina* 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.

Candeina 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 *Candeina* 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 truc of *Globigerina*.

Types and occurrence: Figured hypotype (USNM P3924) of *Candenia 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 Orbulina d'Orbigny, 1839

Plate 7, Figures 1–5

Orbulina d'Orbigny, Foraminifères *in* de la Sagra, Histoire physique, politique et naturelle de l'Île de Cuba, p. 2, 1839.

Candorbulina Jedlitschka, Verh. Naturf. Ver. Brünn, vol. 65, p. 20, 1934. (Type species: *Candorbulina universa* Jedlitschka, 1934. Fixed by monotypy.)

Biorbulina Blow, Micropaleontology, vol. 2, No. 1, p. 69, 1956. (Type species: *Globigerina bilobata* d'Orbigny, 1846. Fixed by original desgination and monotypy.)

Type species: *Orbulina 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 *Orbulina*. 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 *Orbulina universa* d'Orbigny (USNM P3910) from *Albatross* Station D.2377, lat. 29°07′30″ N., long. 88°08′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 *Orbulina universa* d'Orbigny (USNM P3908) showing "*Candorbulina*" development of test from the Miocene Choctawhatchee formation (lower *Arca* 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 adult covered by bullae and with infralaminal accessory apertures.

Range: Middle Eocene to Recent.

Catapsydrax Bolli, Loeblich, and Tappan, new genus

Plate 7, Figures 6a–8c

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 *Globigerinita* Bronnimann in having a small umbilical bulla with relatively few infralaminal accessory apertures which are sutural in position. In *Globigerinita* 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, 1 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 10a–c

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 Lengua 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–c

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. unicavus*, 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 insueta* zone, Miocene), Ste. Croix quarry, near Broomage trigonometric station, south of Princes Town, Naparima region, Trinidad, B. W. I.

Catapsydrax unicavus Bolli, Loeblich, and Tappan, new species

[Plate 7, Figures 9a–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 unicavus*, 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 insueta* zone (Miocene) Cipero Coast section, Trinidad, B. W. I. Collected by Hans G. Kugler.

Genus Globigerinita Bronnimann, 1951

Plate 8, Figures 1a–2c

Globigerinita Bronnimann, Contr. Cushman Found. Foram. Res., vol. 2, pt. 1, p. 18, 1951.

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

Test free, trochospiral; chambers spherical to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface 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 *Globigerinoita* 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

(Cushman Coll. 64183, 64184, 64186, and 64187) from the Lengua formation, *Globorotalia menardii* zone, Naparima area; paratypes (Cushman Coll. 64185) from the Lengua formation, *Globorotalia mayeri* zone, Naparima area; and paratypes (Cushman Coll. 64188) from the Lengua formation, *Globorotalia* zone, Cats Hill area. All the above from Trinidad, B. W. I. Figured hypotype (USNM P3914) and unfigured hypotypes (USNM P3915) from the Recent, *Challenger* Station 8, lat. 28°03′15″ N., long. 17°27′ W., at a depth of 620 fathoms.

RANGE: Miocene to Recent.

Genus Globigerinoita Bronnimann, 1952

PLATE 8, FIGURES 3a–d

Globigerinoita BRONNIMANN, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1 p. 26, 1952.

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 infralaminal 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 *Globigerinatheka* Bronnimann in having a *Globigerinoides* stage, followed by the development of one or more bullae covering the primary and secondary apertures. In *Globigerinatheka* the primary aperture is covered by an enveloping final chamber as in *Orbulina*, and the bullae cover only the secondary apertures.

TYPES AND OCCURRENCE: Holotype (USNM P3913) and figured and unfigured paratypes (USNM P3212) from the Miocene Lengua formation, *Globorotalia menardii* zone, Moruga area, Trinidad, B. W. I.

RANGE: Miocene.

Genus Globigerinatheka Bronnimann, 1952

PLATE 7, FIGURES 12a–c

Globigerinatheka BRONNIMANN, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1, p. 27, 1952.

TYPE SPECIES: *Globigerinatheka 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 *Orbulina;* 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 infralaminal accessory apertures.

REMARKS: *Globigerinatheka* has a stage like *Globigerapsis*, new genus, preceding the development of bullae, whereas *Globigerinita* 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 bullae covering both the primary and secondary apertures.

TYPES AND OCCURRENCE: Holotype of *Globigerinatheka barri* Bronnimann (USNM P3919) and paratypes (USNM P3213) from the Eocene Mount Moriah formation, Harmony Hall Well 2, core 10, 11, 1,176–88 feet, 1,198–1,212 feet, Trinidad, B. W. I. Figured hypotype (USNM P3922) from the Eocene Navet formation (Penitence Hill marl), block in the Oligocene Nariva formation, Pointe-a-Pierre, Trinidad, B. W. I.

RANGE: Middle to upper Eocene.

Genus Globigerinatella Cushman and Stainforth, 1945

PLATE 8, FIGURES 4–7c

Globigerinatella CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 68, 1945.

TYPE SPECIES: *Globigerinatella 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 pustulelike bullae covering the areal secondary apertures, or more irregular spreading sutural bullae covering the secondary sutural apertures, all bullae may have infralaminal accessory apertures.

REMARKS: Bronnimann (1950b, p. 80) discussed and illustrated in considerable detail the ontogenetic development of *Globigerinatella,* 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 *Globigerinita* (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 *Globigerinatella:* "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 "*Quadrimorphina*, *Pullenoides*, *Candeina* and possibly also with *Chilostomellina*." As has been shown earlier (Loeblich and Tappan, 1953, p. 93), *Chilostomellina* has a granular wall structure, and a planispiral plan of coiling, 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 sutural 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 extraumbilical-umbilical, may have secondary sutural apertures on spiral or umbilical side.

RANGE: Cretaceous to Recent.

Genus Praeglobotruncana Bermudez, 1952

PLATE 9, FIGURES 1a–4c

Praeglobotruncana BERMUDEZ, Venezuela Minist. Minas, Bol. Geol., vol. 2, No. 4, p. 52, 1952.

Rotundina SUBBOTINA, Trudy Vses. Neft. Naukno-Issledov. Geol.-Razved. Inst., n. ser. 76, p. 165, 1953. (Type species: *Globotruncana stephani* Gandolfi, 1942. Fixed by original designation.)

?*Hedbergina* BRONNIMANN and BROWN, Eclog. Geol. Helvetiae, vol. 48 (1955), No. 2, p. 529, 1956. (Type species: *Globigerina seminolensis* Harlton, 1927. Fixed by original designation and monotypy.)

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 extra-umbilical-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 extra-umbilical-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 Pennsylvanian from the Ardmore basin of Oklahoma. As the type lacks the most important character of the Globotruncanidae (the tegilla) 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 Pennsylvanian 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 coiled 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 extraumbilical 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 extraumbilical 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 extraumbilical-umbilical to only umbilical, would give rise to *Rugoglobigerina* and *Globotruncana.*

Other species, such as *P. subcretacea* (Tappan) [=*Hastigerinella subcretacea* Tappan], show a tendency to develop radially elongate chambers, and may show a relationship to the Hantkeninidae. *Schackoina* does show a trochospiral coiling, differing only in the restriction of the aperture to a completely extraumbilical 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 *Globotruncana stephani* Gandolfi (USNM P4848), the type species of *Rotundina* Subbotina, and unfigured topotype (USNM P4832) from the Cenomanian, Breggia number 56, Canton Ticino, Switzerland. Received from Professor M. Reichel.

Figured hypotype of *Praeglobotruncana planispira* (Tappan) (USNM P4875), from the Albian Gault clay, brick pit of the London Brick Co., Arlesey, England. Collected by H. T. and A. R. Loeblich, Jr., 1953.

Figured holotype of *Globigerina seminolensis* Harlton (USNM 71380), a Cretaceous specimen erroneously reported to be from the Pennsylvanian (upper Glenn formation) from the SW¼, SE¼, NW¼ sec. 20, T. 5S., R. 1E., Carter County, Oklahoma.

RANGE: Aptian to Maestrichtian.

Genus Rotalipora Brotzen, 1942 [2]

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

Rotalipora BROTZEN, Sveriges Geol. Undersökning, Avh. ser. C, No. 451 (Årsbok. 36, No. 8), p. 32, 1942.

Thalmanninella SIGAL, Rev. de l'Inst. Français du Pétrole et Annales des Combustibles liquides, vol. 3, No. 4, p. 101, 1948. (Type species: *Thalmanninella brotzeni* Sigal, 1948. Fixed by original designation and monotypy.)

Ticinella REICHEL, Eclog. Geol. Helvetiae, vol. 42, No. 2, p. 600, 1950. (Type species: *Anomalina roberti* Gandolfi, 1942. Fixed by original designation and monotypy.)

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, extraumbilical-umbilical, and may be bordered above by a lip, secondary apertures sutural 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 *Globotruncana* Cushman in possessing an interiomarginal, extraumbilical-umbilical primary aperture, in having secondary sutural 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 sutural 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 sutural apertures open into the chambers themselves and not into the umbilicus. The topotype of *Thalmanninella brotzeni* Sigal, here figured, shows some of these secondary apertures which are as definitely sutural 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 commonly 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 topotype of *Thalmanninella brotzeni* Sigal (USNM P3930) from the middle Cenomanian, Sidi-Aïssa, Algeria.

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

Figured specimen of *Rotalipora* cf. *appenninica* (Renz) (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: Albian to Turonian.

Genus Globorotalia Cushman, 1927

PLATE 10, FIGURES 2a–4c

Globorotalia CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, pt. 1, p. 91, 1927.

Truncorotalia CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, p. 35, 1949. (Type species: *Rotalina truncatulinoides* d'Orbigny, 1839. Fixed by original designation.)

Turborotalia CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, p. 42, 1949. (Type species: *Globorotalia centralis* Cushman and Bermudez, 1937. Fixed by original designation.)

Acarinina SUBBOTINA, Trudy Vses. Neft. Naukno-Issledov. Geol.-Razved. Inst., n. ser. 76, p. 219, 1953. (Type species: *Acarinina acarinata* Subbotina, 1953. Fixed by original designation.)

Globanomalina HAQUE, Palaeontol. Pakistanica, vol. 1, p. 148, 1956. (Type species: *Globanomalina ovalis* Haque, 1956. Fixed by original designation.)

?*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 extraumbilical-umbilical arch bordered by a lip, varying from a narrow rim to a broad spatulate to triangular flap.

REMARKS: *Globorotalia* differs from *Globotruncana* Cushman in having an interiomarginal, extraumbilical-umbilical aperture and a simple umbilicus, and in lacking the umbilical tegilla and accessory intralaminal

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[2] The genus *Biticinella* Sigal was recently described from the Vraconnian as related to *Rotalipora*, in having accessory apertures at the posterior border of each chamber. As the present article was already in press and no specimens of *Biticinella* were available to the writers, the genus is not fully discussed herein. If there are true accessory apertures at the posterior border of the chambers and the test is asymmetrically coiled as described it would seem to be related to the Globorotaliidae, although no other genus of this family has accessory apertures on both sides. If however, the test is planispiral, the aperture equatorial as shown, and the "accessory apertures" should prove to be relict apertures instead, *Biticinella* would become a synonym of *Planomalina*. An examination of additional specimens is necessary to correctly place the genus.

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 *Globanomalina*, 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 extraumbilical-umbilical position of the aperture of *Globanomalina* prove it to be a synonym of *Globorotalia*. The type species, *Globanomalina 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 *Pseudogloborotalia*, 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 cancellated surface. Cushman (1927, p. 91) stated that *Globorotalia* has a "wall frequently roughened throughout," but did not state it to be cancellated, and the type species, *G. tumida*, has a smooth surface. Thus this basis for separation is invalid. *Pseudogloborotalia* 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* Brotzen, which is not a planktonic form, but a study of additional and better preserved material will be necessary to definitely place *Pseudogloborotalia*.

TYPES AND OCCURRENCE: Syntypes of *Pulvinulina 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 *Pseudogloborotalia ranikotensis* Haque (USNM P5398) from the Paleocene (Ranikot formation), Nammal Gorge, Salt Range, Pakistan. Sent by A. F. M. Mohsenul Haque.

Hypotypes of *Globanomalina ovalis* Haque (USNM P5399) 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

Truncorotaloides BRONNIMANN and BERMUDEZ, Journ. Paleontol., vol. 27, No. 6, p. 817, 1953.

TYPE SPECIES: *Truncorotaloides rohri* 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 rohri* 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: *Globotruncana* Cushman, 1927.

Coiling of test trochospiral; chambers spherical to angular, commonly truncate or keeled; wall calcareous, perforate, radial in structure; primary aperture umbilical in position but covered by a spiral system of tegilla, accessory intralaminal and infralaminal 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 concavoconvex, 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 infralaminal 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 infralaminal, not both infralaminal and intralaminal as in *Globotruncana*.

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

Rugoglobigerina BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 140, p. 16, 1952.

Plummerella BRONNIMANN (not *Plummerella* DeLong, 1942), Bull. Amer. Paleontol., vol. 34, No. 140, p. 37, 1952. (Type species: *Rugoglobigerina* (*Plummerella*) *hantkeninoides hantkeninoides* Bronnimann, 1952. Fixed by original designation.)

Plummerita BRONNIMANN, Contr. Cushman Found. Foram. Res., vol. 3, pts. 3, 4, p. 146, 1952 (new name for *Plummerella* Bronnimann, 1952).

Trinitella BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 140, p. 56, 1952. (Type species: *Trinitella scotti* Bronnimann, 1952. Fixed by original designation and monotypy.)

?*Kuglerina* BRONNIMANN and BROWN, Eclog. Geol. Helvetiae, vol. 48 (1955), No. 2, p. 557, 1956. (Type species: *Rugoglobigerina rugosa rotundata* Bronnimann, 1952. Fixed by original designation and monotypy.)

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, radial in structure, surface typically rugose with numerous large pustles which may coalesce into distinct ridges, radiating from the midpoint of each chamber on the periphery, or much produced peripherally into spinelike extensions, more rarely smooth; primary apertures interiomarginal, umbilical, in well preserved specimens covered by tegilla perforated by the accessory infralaminal and intralaminal 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 infralaminal and intralaminal 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*.

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

Plummerita 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 hantkeninoides inflata* show chambers as well rounded as those of typical *Rugoglobigerina* (Bronnimann, 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 specimens is completely obscured by matrix, and the actual presence or absence of tegilla 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 tegilla 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 assignation 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 P4838) 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, Milam 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

Globotruncana Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, p. 91, 1927.

Rosalinella Marie, Mém. Mus. Hist. Nat. Paris, new ser., vol. 12, p. 237, 1941. (Type species: *Rosalina linneiana* d'Orbigny, 1839. Fixed by original designation.)

Bucherina Bronnimann and Brown, Eclog. Geol. Helvetiae, vol. 48 (1955), No. 2, p. 557, 1956. (Type species: *Bucherina sandidgei* Bronnimann and Brown, 1956. Fixed by original designation and monotypy.)

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

Marginotruncana Hofker, Neues Jahrb. Geol. Paläontol., Abh., vol. 103, pt. 3, p. 319, 1956. (Type species: *Rosalina marginata* Reuss, 1845. Fixed by original designation.)

Type species: *Pulvinulina arca* Cushman, 1926. Fixed by original designation and monotypy.

Test free, trochospiral, biconvex, spiroconvex 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 infralaminal and intralaminal 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* Lamarck, 1804, and thus not related to the group of species under discussion here. *Globotruncana* is therefore the first valid name for the species originally described as *Pulvinulina arca*.

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, with *Rosalina* of de Lapparent (not d'Orbigny), etc., selecting as type species *Rosalina linneiana* d'Orbigny. As *Globotruncana* is a valid name and antedates *Rosalinella*, the latter becomes a junior synonym. The type species, *Rosalina 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, *Thalmanninella* 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), *Thalmanninella* 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. intermedia* 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 extraumbilical-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 sandidgei* 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 *Rosalina marginata* Reuss as type species. He considered *Globotruncana* to have a strongly reduced protoforamen (primary aperture), which is no longer an open slit, and *Marginotruncana* was said to have lost the protoforamen or to have it fused with a deuteroforamen (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 extra-umbilical 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 *Globotruncana* has an umbilical primary aperture. In well preserved specimens this is always covered by the umbilical 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 extraumbilical aperture, this specimen is probably a species of *Praeglobotruncana* or *Rotalipora*. The geologic occurrence supports this assumption, as true *Globotruncana* 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 Hofker identified as the species *marginata*, specimens which are actually *Praeglobotruncana*, although his citation of *Rosalina marginata* Reuss 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 paraventricosa* Hofker (which included *G. ventricosa of* Brotzen, not White) and *Marginotruncana pauperata* 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. ticinensis* Gandolfi (a *Rotalipora* previously placed in *Thalmanninella*, 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 *Thalmanninella* 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 Globotruncanidae. All but the last of these generic names preoccupy that of Hofker, if all were congeneric.

TYPES AND OCCURRENCE: Holotype of *Pulvinulina arca* 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 arca* 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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The Genera Praeglobotruncana, Rotalipora, Globotruncana, and Abathomphalus in the Upper Cretaceous of Trinidad, B. W. I.

By Hans M. Bolli[1]

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.[2] 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. Foraminifera 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 *Didymotis* 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 benthonic 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*. Benthonic and planktonic Foraminifera 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 gautierensis* 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-à-Pierre, Trinidad, B. W. I.

[2] Credit for this goes in the first place to Trinidad Oil Company, Ltd. (formerly Trinidad Leaseholds, 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 gansseri—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 foraminiferal 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 calcarata* 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 Albian to lower part of the Cenomanian. The formation is divided into the following zones (from top to bottom):

Rotalipora appenninica appenninica zone
Globigerina washitensis zone
Rotalipora ticinensis ticinensis zone

The *Rotalipora ticinensis ticinensis* and *Globigerina washitensis* 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, 1¼ 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 Planomalininae. 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 $CaCO_3$ 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,

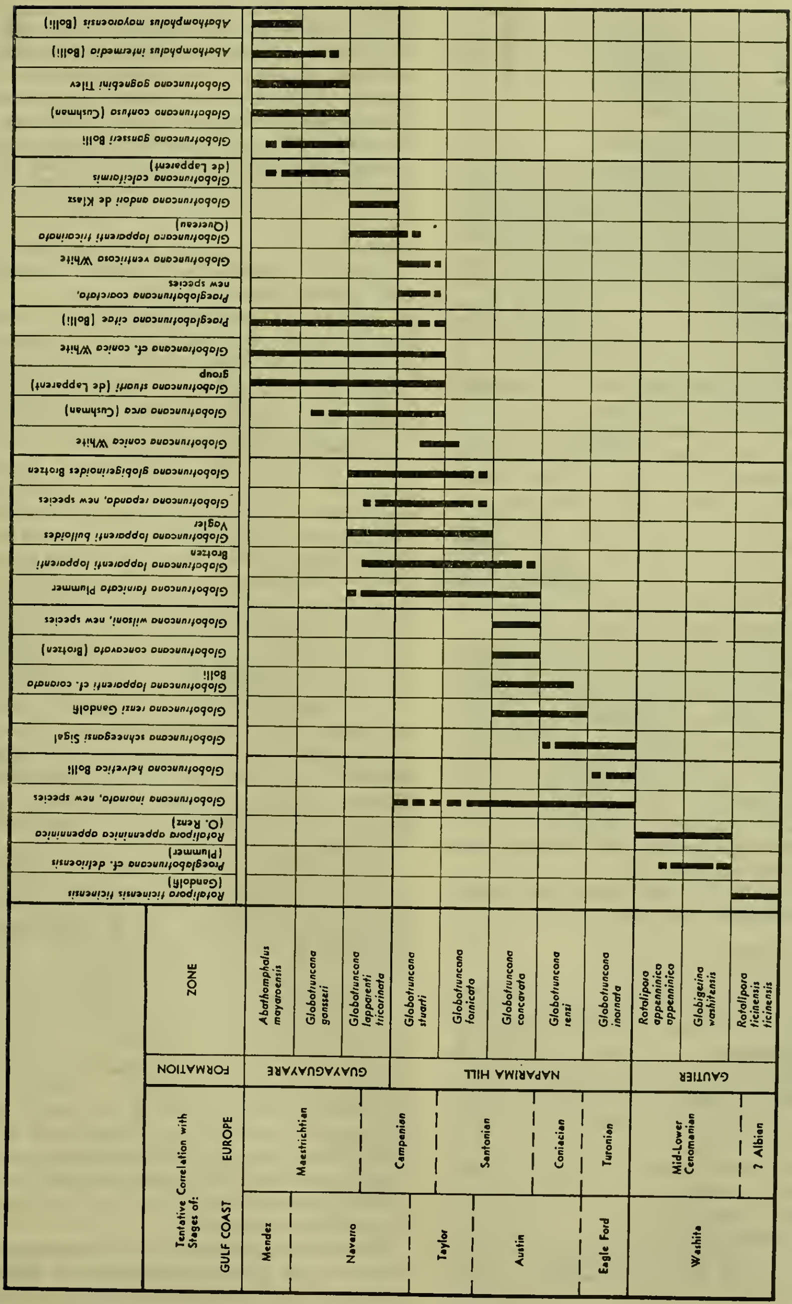

FIGURE 10.—Species distribution of *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus* in Trinidad, B. W. I.

1952). The formation is divided into the following zones (all established in the subsurface section of Trinidad Leaseholds well Guayaguayare 163, coordinates N:157646 links, E:572808 links):

Abathomphalus mayaroensis zone
Globotruncana gansseri zone
Globotruncana lapparenti tricarinata zone

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

The marker for the *Globotruncana gansseri* zone has also been recorded from Turkey (under the synonym of *Globotruncana lugeoni* Tilev) and from mid-Pacific sea mounts (Hamilton, 1953). The author has seen it in material from Cuba and in the Navarro formation. *Globotruncana calciformis* (de Lapparent), *G. contusa* (Cushman), *G. gagnebini* Tilev and *Abathomphalus intermedia* (Bolli) are other species occurring for the first time in the *Globotruncana 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 *Globotruncana 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 *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus*, the details are complex and little studied.

The evolutionary trend in *Rotalipora*, from a single inflated early form 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* Brotzen 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 *Globotruncana* species. This suggests a close generic relationship of at least a number of *Globotruncana* species with *Rugoglobigerina* species. It may be assumed that species of *Globotruncana* 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 *Globotruncana helvetica* Bolli which has no apparent direct descendants. The single-keeled *Globotruncana schneegansi* Sigal developed independently at approximately the same time from similar forms, possibly via *Globotruncana inornata*, new species. This seems to have been a more successful mutation, as it appears that the single-keeled *Globotruncana schneegansi* gave rise to the double-keeled *Globotruncana renzi* Gandolfi—*G. angusticarinata* Gandolfi—*G. concavata* (Brotzen)—*G. ventricosa* White suite. However, the possibility that the single keeled *Globotruncana schneegansi* might have developed from late representatives of *Praeglobotruncana stephani* (Gandolfi) should not be overlooked. A tendency is observed in late representatives of *Praeglobotruncana stephani* for the aperture to move from an interiomarginal, extraumbilical-umbilical position to an umbilical one.

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

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

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

Globotruncana gansseri Bolli, which is morphologically similar to the Turonian *Globotruncana 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 *Rotalipora* may be expected in Cenomanian ancestors.

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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: *Globigerina washitensis* zone and *Rotalipora appenninica appenninica* zone, Gautier formation.

Type and occurrence: Figured specimen (USNM P4793) from Trinidad Leaseholds well Marac 1, Trinidad (coordinates N:152141 links, E:424447 links), sample at 9,773 feet (TLL 177171).

Praeglobotruncana coarctata Bolli, new species

Plate 12, figures 2a–3c

Shape of test: very low trochospiral, biconvex; equatorial periphery lobate; a faint keel is often observed in last chambers; it may be ornamented with minute spines on peripheral edge. Wall: calcareous, perforate, surface smooth. Chambers: strongly compressed; 10–12, arranged in 2 whorls; the 5–6 chambers of the last whorl increase rapidly in size; the early whorl minute by comparison. Sutures: spiral side radial or slightly curved, depressed; umbilical side radial, depressed. Umbilicus: each chamber of last whorl extends towards the center, leaving only a small portion open. Aperture: a low arched, interiomarginal, extraumbilical-umbilical slit. Coiling: predominantly dextral; of 37 specimens counted, only 4 coiled sinistrally.

Dimensions of holotype: diameter 0.4 mm.; thickness 0.16 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.

Genus Rotalipora Brotzen, 1942

Rotalipora ticinensis ticinensis (Gandolfi)

Plate 12, Figures 1a–c

Globotruncana ticinensis Gandolfi, Riv. Italiana Paleontol. Stratigr., vol. 48, Suppl. Mem. 4, pp. 113–135, pl. 2, figs. 3, 4, 1942.

Thalmanninella ticinensis ticinensis (Gandolfi), Reichel, Eclog. 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 slit; 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 Marac 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

Globotruncana helvetica Bolli, Eclog. Geol. Helvetiae, vol. 26, No. 2, p. 226, pl. 9, figs. 6–8, figs. 9–12 of text-fig. 1, 1945.—Sigal, 19th Congr. Géol. Internat., Monogr. Rég., ser. 1, No. 26, p. 31, fig. 32 1952.—Hagn and Zeil, Eclog. Geol. Helvetiae, vol. 47, No. 1, p. 30, pl. 3 figs. 1a–c, 1954.

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; tegilla 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 P4796) 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; tegilla 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 tricarinata* 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. gansseri* 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. gansseri* 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

Rotalia concavata Brotzen, Zeitschr. Deutsch. Ver. Palaestinas, vol. 57, p. 66, pl. 3, fig. b, 1934.

Globorotalia asymetrica Sigal, 19th Congr. Géol. Internat., Monogr. Rég., ser. 1, No. 26, p. 35, fig. 35, 1952.

Globotruncana (*Globotruncana*) *ventricosa ventricosa* White, Dalbiez, Micropaleontology, vol. 1, No. 2, p. 168, figs. 7a–d, 1955.

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 3–3½ whorls; the 5–6 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side distinctly curved, depressed; umbilical side radial, depressed. Umbilicus· deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla 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. Paleontol. 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 2½–3 whorls; 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; tegilla 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 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: straight, depressed. Umbilicus: shallow, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla 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. stuarti* 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

Globotruncana schneegansi Sigal, 19th Congr. Géol. Internat., Monogr. Rég., ser. 1, No. 26, p. 33, fig. 34, 1952.

Shape of test: low trochospiral, 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 whorls; the 5 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side curved, raised, beaded; umbilical side radial, 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 0.6 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

Globotruncana appenninica-linnei O. Renz, Eclog. Geol. Helvetiae vol. 29, No. 1, pl. 6, figs. 16–19, 21, and pl. 8, figs. 2, 3, 5, 1936.

Globotruncana renzi Gandolfi, Riv. Italiana Paleontol., Stratigr., vol. 48, Suppl. Mem. 4, p. 124, pl. 3, figs. 1a–c, pl. 4, figs. 15, 16, 28, 29, 1942.—Hagn and Zeil, Eclog. Geol. Helvetiae, vol. 47, No. 1, p. 37, pl. 3, figs. 2a–c, 1954.

Shape of test: low trochospiral, biconvex; equatorial periphery slightly lobate, with closely spaced double keel in early chambers of last whorl; last and occasionally penultimate chambers with a single keel only. Wall: calcareous, perforate, surface smooth. Chambers: angular, strongly compressed; about 14, arranged in 2½–3 whorls; the 5 chambers of the last whorl increase rapidly in size, early whorls 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.

?*Globotruncana coronata* Bolli, Sigal, 19th Congr. Géol. Internat., Monogr. Rég., ser. 1, No. 26, p. 34, fig. 36, 1952.

Shape of test: low trochospiral, biconvex; equatorial periphery lobate, with closely spaced double keel. Wall: calcareous, perforate, surface smooth. Chambers: angular, strongly compressed; about 14, arranged in 2½–3 whorls; the 5 chambers of the last whorl increase rapidly in size; early whorls small by comparison. Sutures: spiral side curved, depressed or slightly raised in ultimate 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 specimen: 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 trochospiral, biconvex; equatorial periphery 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 apertures interiomarginal, umbilical; tegilla 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 P4805) from Trinidad Leaseholds 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 Tilev

Plate 14, igures 5a–c

Globotruncana gagnebini Tilev, Bull. Lab. Géol., Min., Géophys., Mus. Géol., Univ. Lausanne, No. 103, p. 50, pl. 3, figs. 2–5, and text figs. 14a–17d, 1952.

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; tegilla 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), 1¼ miles southeast of Mamon-Guaico-Tamana Road, eastern Central Range. Sample G. 3644A (TLL 226184).

Remarks: In its general shape, *Globotruncana gagnebini* Tilev 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 Klasz

Plate 14, Figures 6a–c

Globotruncana andori De Klasz, Geol. Bavarica, 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; tegilla 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 Leaseholds well Guayaguayare 163, Trinidad (coordinates N:157646 links, E:572808 links), sample from 5,961½ 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* Tilev. 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.

By Hans M. Bolli [1]

Introduction

Authors of previous papers on the foraminiferal fauna of the Lizard Springs formation restricted their observations entirely to surface sections. Because of complex tectonic conditions in Central and South Trinidad, most of the Lizard Springs outcrops are small isolated slipmasses that are often confined to a single zone and therefore are not suitable for comprehensive stratigraphic and evolutionary studies. The Lizard Springs formation as encountered in wells often consists of similar slipmasses. In a few boreholes, however, continuous and apparently undisturbed sections of over 1,000 feet in thickness have been penetrated. These sections, combined with surface information, now allow a much more complete and reliable study of the foraminiferal species and their stratigraphic ranges than was previously possible.

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 zoning 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 rank, 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 159. 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

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[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, *Trochammina 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 foraminiferal 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 foraminiferal 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 velascoensis* 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 compressa* (Plummer), *G. pseudobulloides* (Plummer), *G. trinidadensis* Bolli, new species, *Globigerina triloculinoides* Plummer and *G. daubjergensis* Bronnimann shows strong affinities to that described from Danian localities of Denmark (Bronnimann, 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.

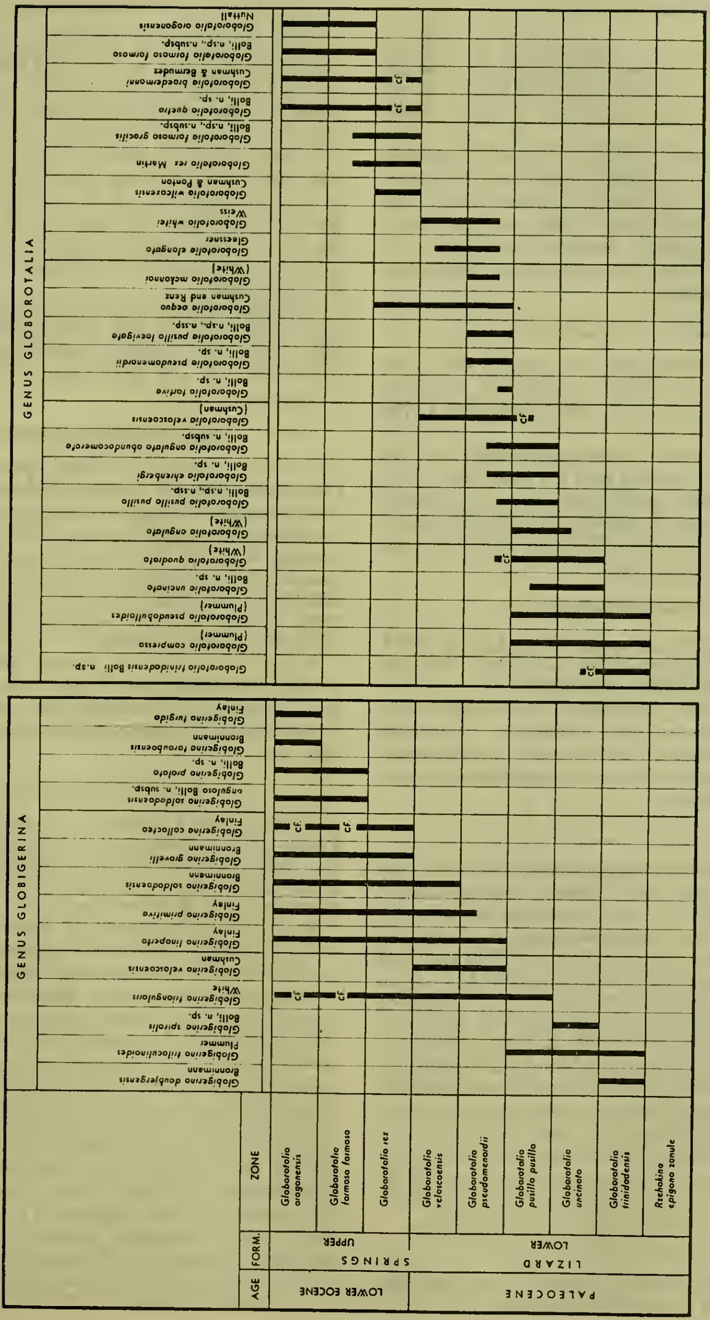

FIGURE 11.—Species distribution of *Globigerina* and *Globorotalia* in the Paleocene - lower Eocene Lizard Springs formation of Trinidad, B. W. I.

Globorotalia uncinata 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 uncinata* 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, new subspecies, extends into the basal part of the overlying *Globorotalia pseudomenardii* zone. *Globorotalia angulata* (White), *G. ehrenbergi* Bolli, new species, and *G. angulata hexacamerata* 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 1¼ 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:186454 links; E:556810 links), samples Rz. 282–291 (TLL 50315–16, 50503–10). For better accessibility the following cotype locality has been chosen: west side of railway track, south of the Pointe-a-Pierre Railway Station, about 650 feet from the level crossing of Station Road, Pointe-a-Pierre (coordinates N:259200 links; E:362900 links).

Remarks: *Globorotalia velascoensis* (Cushman) and *Globigerina velascoensis* Cushman become extinct at the top of the zone. Several species typical for the underlying *Globorotalia pseudomenardii* zone are absent.

Upper Lizard Springs Formation

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

Globorotalia rex Zone

Type Locality: In a left bank tributary of the Cascas River, 3,400 feet from its confluence with the Moriquite River, about 1½ miles west of the point where the Moriquite River crosses the Moruga Road (between the 14 and 14¼ M.P.). The ravine is some 650 feet in length, extending from northwest to southeast, and enters the Cascas River 250 feet downstream from the intersection of the latter with the Forest Reserve boundary. The type locality is an outcrop in the river bed of the ravine, 180 feet from its junction with the Cascas River (coordinates N:138700 links; E:435000 links).

Remarks: Eight species of *Globorotalia* and *Globigerina* occur for the first time in the *Globorotalia rex* zone. The long ranging characteristic *Globorotalia aequa* Cushman and Renz becomes extinct at the top of this zone.

Globorotalia formosa formosa Zone

Type locality: The original Lizard Springs locality is maintained for the *Globorotalia formosa formosa* zone: Ravine Ampelu, Lizard Springs area, about 1¼ 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, South East 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 soldadoensis 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 Bermudez, *G. crassata* (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. wilcoxensis* var. *acuta* Toulmin by Cushman and Renz, 1942, and Bolli, 1950), *G. aequa* Cushman and Renz, *G. whitei* Weiss and *G. elongata* Glaessner. 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 Río Querecual 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 "*Guembelina-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* zonule and the *Globorotalia trinidadensis*, *Globorotalia uncinata* and *Globorotolia 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; Toulmin, 1941) from the Wilcox group indicate that the planktonic Foraminifera correlate with the *Globorotalia rex* zone of the upper Lizard Spings and also with the uppermost part of the lower Lizard Springs.

Planktonic Foraminifera typical for the *Globorotalia uncinata* 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 Buffer 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 triloculinoides* 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 Danian localities of Jutland, Denmark (Bronnimann, 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* zonule. 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,

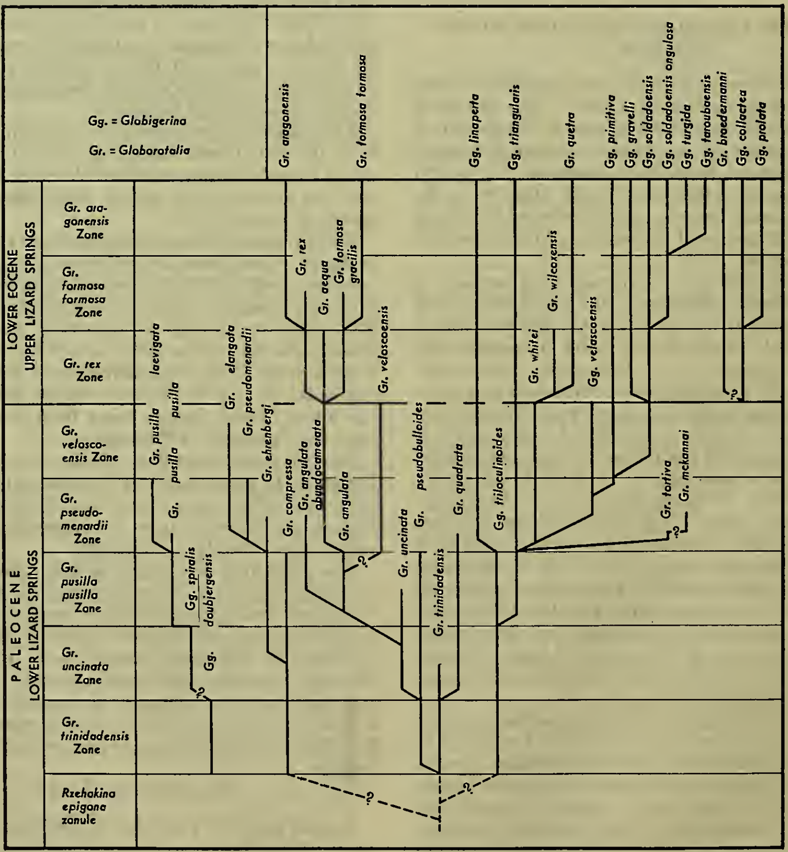

FIGURE 12.—Tentative evolution of *Globigerina* and *Globorotalia* species in the Paleocene - lower Eocene, Lizard Springs formation of Trinidad, B.W.I.

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. ehrenbergi* Bolli, new species—*G. pseudomenardii* Bolli, new species, and probably *G. elongata* Glaessner. *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. ehrenbergi* by increasing its size and becoming more compressed. *G. pseudomenardii*, the descendant of *G. ehrenbergi*, 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. ehrenbergi-G. pseudomenardii* at the base of the *Globorotalia pseudomenardii* zone continues into the *Globorotalia velascoensis* zone where the suite becomes extinct.

Globigerina daubjergensis Bronnimann 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 uncinata* 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 is another species likely to have developed from the *Globigerina triangularis-G. velascoensis* group. It is regarded as the ancestral form of *Globorotalia wilcoxensis* 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* Bronnimann 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* Bronnimann, which is regarded as related to *G. primitiva*; in order of first occurrence they are *G. gravelli* Bronnimann, *G. soldadoensis angulosa* Bolli, new subspecies, and *G. turgida* Finlay. *G. taroubaensis* Bronnimann 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 prolata* Bolli, new species, is likely to have developed from *G. collactea* at the base of the *Globorotalia formosa formosa* zone.

Globorotalia broedermanni 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 a 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* (d'Orbigny), *G. truncatulinoides* (d'Orbigny) (Bolli, 1950; Ericson, G. Wollin and J. Wollin, 1954). Changes in the environment probably cause such sudden changes.

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 trinidadensis* Bolli, new species, *G. pseudobulloides* (Plummer), *G. uncinata* 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, has been discussed in the previous section. When following the coiling ratios of these species we find that the stratigraphically older forms (*G. trinidadensis* 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. ehrenbergi* Bolli, new species, *G. pseudomenardii* Bolli, new species, and *G. elongata* Glaessner 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. quetra* would be expected to occur in the missing beds.

Globorotalia wilcoxensis Cushman and Ponton and *G. quetra* 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 Leaseholds, Ltd., Guayaguayare well 159). 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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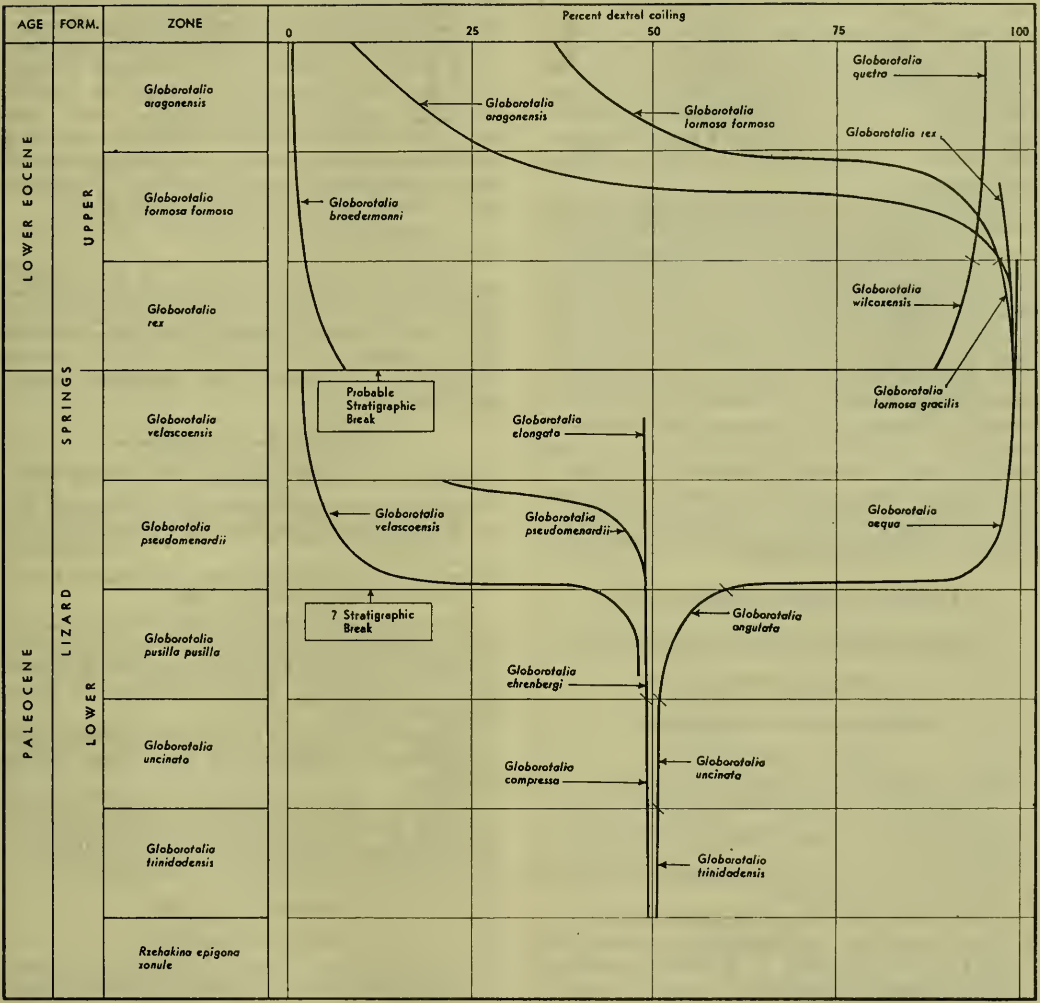

FIGURE 13.—Direction of coiling of some *Globigerina* and *Globorotalia* species in the Paleocene - lower Eocene Lizard Springs formation of Trinidad, B. W. I.

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—umbilical (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 *Globo-*

rotalia they vary from globular to strongly compressed and may have a peripheral keel. In a number of species with globular chambers, described in this paper, it became difficult to decide whether the position of the last aperture was truly umbilical or was to some degree extraumbilical—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. Cotypes 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 13–15

Globigerina daubjergensis BRONNIMANN, Eclog. Geol. Helvetiae, vol. 45 (1952), No. 2, pp. 340–341, fig. 1, 1953.

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:148191 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 uncinata* 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:259200 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 triloculinoides PLUMMER, Univ. Texas Bull. 2644, pp. 134–135, pl. 8, figs. 10a–c, 1926.—BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 24–25, pl. 3, figs. 13–18, 1952.

Globigerina pseudotriloba WHITE, Journ. Paleontol., vol. 2, No. 3, pp. 194–195, pl. 27, figs. 17a–b, 1928.

Coiling random in the *Globorotalia trinidadensis* and *Globorotalia uncinata* 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 232706).

Globigerina linaperta Finlay

PLATE 15, FIGURES 15–17

Globigerina linaperta FINLAY, Trans. Proc. Roy. Soc. New Zealand, vol. 69, p. 125, pl. 13, figs. 54–57, 1939.—BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 16–17, pl. 2, figs. 7–9, 1952.

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: *Globigerina linaperta* Finlay is probably a descendant of *G. triloculinoides* Plummer from which it is distinguished by its larger size and less distinct flaring lip protecting the aperture.

Globigerina triangularis White

Plate 15, Figures 12–14

Globigerina triangularis White, Journ. Paleontol., vol. 2, No. 3, pp. 195–196, pl. 28, figs. 1a–b, 1928.
Globigerina 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: *Globigerina triangularis* White apparently developed from *G. triloculinoides* Plummer, from which it is distinguished by the more trochospiral arrangement of its chambers and by the smaller relative size of the final chamber.

Globigerina velascoensis Cushman

Plate 15, Figures 9–11

Globigerina velascoensis Cushman, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, p. 19, pl. 3, fig. 6, 1925.—White, Journ. Paleontol., vol. 2, No. 3, p. 196, pl. 28, figs. 2a–b, 1928.

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 extraumbilical-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: *Globigerina velascoensis* Cushman apparently developed from *G. triangularis* 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).

Globigerina primitiva Finlay

Plate 15, Figures 6–8

Globigerina primitiva Finlay, New Zealand Journ. Sci. Tech., vol. 28, No. 5, p. 291, pl. 8, figs. 129–134, 1947.—Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 11–12, pl. 1, figs. 10–12, 1952.

Coiling random. Largest diameter of figured hypotype 0.37 mm.

Stratigraphic range: *Globorotalia pseudomenardii* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, continues 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: *Globigerina primitiva* Finlay probably developed from *G. velascoensis* Cushman, from which it is distinguished mainly by its spinose surface.

Globigerina soldadoensis Bronnimann

Plate 16, Figures 7–12

Globigerina soldadoensis Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 9–11, pl. 1, figs. 1–9, 1952.

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 1¼ 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: *Globigerina 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.

Globigerina 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 1¼ mile 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: *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

Globigerina gravelli Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 12–13, pl. 1, figs. 16–18, 1952.

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 1¼ 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: *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

Globorotalia collactea Finlay, Trans. Proc. Roy. Soc. New Zealand, vol. 69, p. 37, pl. 29, figs. 164–165, 1939.

Globigerina collactea (Finlay), Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 13–14, pl. 1, figs. 13–15, 1952.

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

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 extraumbilical-umbilical position is often noted.

Globigerina prolata Bolli, new species

Plate 15, Figures 24–26

Globigerina pseudobulloides Plummer, Bronnimann (not Plummer, 1926) Bull. Amer. Paleontol., vol. 34, No. 143, pp. 21–23, pl. 3, figs. 7–9, 1952.

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 1¼ mile 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. 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

Globigerina taroubaensis Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 18–19, pl. 2, figs. 16–18, 1952.

Largest diameter of figured hypotype 0.27 mm.

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

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

Globigerina turgida Finlay, Trans. Proc. Roy. Soc. New Zealand, vol. 69, p. 125, 1939.—Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 19–21, pl. 3, figs. 1–3, 1952.

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

Globigerina pseudobulloides Plummer, Univ. Texas Bull. 2644, pp. 133–134, pl. 8, figs. 9a–c, 1926.

Globigerina cretacea d'Orbigny, White, Journ. Paleontol., vol. 2, No. 3, pp. 193–194, pl. 27, figs. 15a–b, 1928.

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, extraumbilical-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 pusilla pusilla* zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5043) 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: 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, liplike flap in well preserved specimens; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameters of figured types 0.40–0.43 mm.

Stratigraphic range: *Globigerina 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:504382 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

Globigerina quadrata White, Journ. Paleontol, vol. 2, No. 3, p. 195, pl. 27, figs. 18a–b, 1928.

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, extraumbilical—umbilical. Coiling random. Largest diameter of figured hypotype 0.42 mm.

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

Locality: Figured hypotype (USNM P5047) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E554095 links), sample from core 4,524–36 feet (TLL 232705).

Remarks: Because of the interiomarginal, extraumbilical—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 2½ whorls, 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:362900 links), sample K.R. 23575 (TLL 178894).

Remarks: *Globorotalia uncinata* Bolli, new species, differs from the related *G. pseudobulloides* (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 ancester 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

Globigerina angulata White, Journ. Paleontol., vol. 2, No. 3, pp. 191–92, pl. 27, figs. 13a–c, 1928.

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 2½–3 whorls, 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 232705).

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 whorls, 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 232705).

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

Globorotalia crassata var. *aequa* Cushman and Renz, Contr. Cushman Lab. Foram. Res., vol. 18, p. 12, pl. 3, figs. 3a–c, 1942.

Globorotalia lacerti Cushman and Renz, Cushman Lab. Foram. Res., Spec. Publ. 18, p. 47, pl. 8, figs. 11, 12, 1946.

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 whorls; 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. lacerti* 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 rex Martin, Stanford Univ. Publ., Univ. Ser., Geol. Sci., vol. 3, No. 3, p. 117, pl. 8, fig. 2, 1943.

Globorotalia simulatilis (Schwager), Le Roy (not Schwager, 1893), Geol. Soc. Amer., Mem. 54, pp. 32–33, pl. 9, figs. 1–3, 1953.

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, extraumbilical-umbilical. Coiling between 90 and 100 percent dextral. Largest diameter of figured hypotype 0.56 mm.

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

Locality: Figured hypotype (USNM P5053) 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 rex* Martin differs from the related *G. aequa* Cushman and Renz in being more robust and in having a distinct thick peripheral keel. *G. rex* is regarded as the ancestor of *G. aragonensis* Nuttall.

Globorotalia aragonensis Nuttall

Plate 18, Figures 7–9

Globorotalia aragonensis Nuttall, Journ. Paleontol., vol. 4, No. 3, p. 288, pl. 24, figs. 6–8, 10, 11, 1930.—Cushman and Renz, Cushman Lab. Foram. Res., Spec. Publ. 24, p. 40, pl. 8, figs. 1, 2, 1948.—Cushman and Bermudez, Contr. Cushman Lab. Foram. Res., vol. 25, pt. 2, pp. 38, 39, pl. 7, figs. 13–15, 1949.

Shape of test very low trochospiral; spiral side almost flat or slightly convex, umbilical side strongly convex and slightly inflated; equatorial periphery nearly circular; axial periphery angular with keel, which is ornamented with small spines in well preserved specimens. Wall calcareous, perforate; surface, especially the umbilical side, rugose or with short, thick spines. Chambers angular, inflated; 15–18, arranged in about 3 whorls; the 6–7 chambers of the last whorl increasing slowly in size. Sutures on spiral side curved, often slightly raised and beaded; on umbilical side radial, slightly depressed. Umbilicus narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling preponderantly dextral in the lower part of the *Globorotalia formosa formosa* zone (over 90 percent); in its upper part reversing to a strongly predominant sinistral coiling in the *Globorotalia aragonensis* zone (about 90 percent). Largest diameter of figured hypotype 0.55 mm.

Stratigraphic range: *Globorotalia formosa formosa* zone to *Globorotalia aragonensis* zone; continuing into the Navet formation.

Locality: Figured hypotype (USNM P5054) from Ravine Ampelu, Lizard Springs area, about 1¼ mile 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 KWB 6972 (TLL 102301).

Remarks: *Globorotalia aragonensis* Nuttall differs from the ancestral *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, extraumbilical-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*

Cushman and Renz in possessing a more distinct but thinner peripheral keel and more chambers in the last whorl. *G. formosa gracilis* is regarded as the ancestor of *G. formosa formosa* Bolli, new species, new subspecies.

Globorotalia formosa formosa Bolli, new species, new subspecies

Plate 18, Figures 1–3

Globorotalia velascoensis (Cushman), Cushman and Renz (not Cushman, 1925), Cushman Lab. Foram. Res., Spec. Publ. 18, p. 47, pl. 8, figs. 13, 14, 1946.

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 sinistral 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 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 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 wilcoxensis Cushman and Ponton var. *acuta* Toulmin, 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 sinistral 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. wilcoxensis* 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. wilcoxensis* var. *acuta* is a synonym. This confirms Grimsdale (1951) who regards *G. wilcoxensis* 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. aequa* Cushman and Renz group. This is supported by the coiling ratios of the species under discussion. *G. velascoensis* coils almost exclusively sinistrally before its extinction at the end of the *Globorotalia velascoensis* zone. *G. aequa* 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.

Globorotalia compressa (Plummer), Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, p. 25, pl. 2, figs. 19–24, 1952.

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 hypotype 0.23 mm.

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

Locality: Figured hypotype (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

Globorotalia membranacea (Ehrenberg), White, Journ. Paleontol., vol. 2, p. 280, pl. 38, fig. 1, 1928.—Cushman and Bermudez, Contr. Cushman Lab. Foram. Res., vol. 25, No. 2, pp. 34, 35, pl. 6, figs. 16–18, 1949.

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 P5060) 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 membranacea* (Ehrenberg) has frequently occurred in the literature (see Cushman and Bermudez, 1949, p. 34). Ehrenberg (1854) figured under *Planulina membranacea* the spiral views of 2 rotalid Foraminifera from the Cretaceous that are at least specifically different. Of these, one (pl. 26, fig. 43) could be near to a form subsequently described on several occasions as *Globorotalia membranacea* (for example, from Trinidad by Cushman and Renz, 1946). No description or depository of a holotype was given by Ehrenberg however. It is for these reasons that a new name had to be chosen for these Paleocene specimens described as *Globorotalia membranacea*. *Globorotalia ehrenbergi* developed from *Globorotalia compressa* (Plummer) and is regarded as the ancestor of *Globorotalia pseudomenardii* Bolli, new species, and possibly of *Globorotalia elongata* Glaessner.

Globorotalia pseudomenardii Bolli, new species

Plate 20, Figures 14–17

?*Globorotalia pseudoscitula* Glaessner, Studies in Micropaleontol., Publ. Lab. Paleontol., Moscow Univ., vol. 1, pt. 1, pp. 32–33, figs. 3a–c, 1937.

Shape of test very low trochospiral, biconvex; equatorial periphery elongate, lobate, especially so in large specimens; axial periphery angular with distinct keel. Wall calcareous, perforate, surface smooth. Chambers strongly compressed; about 15, arranged in 3 whorls, the 5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side strongly curved, especially so between last chambers of large specimens, depressed; on umbilical side radial, depressed. Umbilicus shallow, open. Aperture a low arch with a lip; interiomarginal, extraumbilical-umbilical. Largest diameter of holotype 0.34 mm., of figured paratype 0.66 mm.

Stratigraphic range: *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 233000).

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

Globorotalia pseudoscitula var. *elongata* Glaessner, Studies in Micropaleontol., Publ. Lab. Paleontol., Moscow Univ., vol. 1, pt. 1, p. 33, figs. 3d–f, 1937.

Shape of test very low trochospiral, compressed, spiral side often slightly concave, umbilical side moderately convex; equatorial periphery slightly lobate, elongate; axial periphery subacute to acute but without keel. Wall calcareous, perforate, surface smooth. Chambers moderately to strongly compressed; about 12, arranged in 2–2½ whorls, 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, extraumbilical-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* Glaessner is probably closely related to the *G. ehrenbergi* Bolli, new species-*G. pseudomenardii* Bolli, new species, group. From *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 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 compressed; 12–16, arranged in 2½–3 whorls, the 5–6 chambers of the last whorl increasing moderately in size. Sutures on spiral side strongly curved, slightly depressed; on umbilical side radial, depressed. Umbilicus narrow, open. Aperture a low arch, with narrow lip; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of holotype 0.24 mm.

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

Locality: Holotype (USNM P5064) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,778–90 feet (TLL 233706).

Remarks: *Globorotalia pusilla pusilla* Bolli, new species, new subspecies, is distinguished from *G. capdevilensis* Cushman and Bermudez by its closer coiling, stronger curved sutures on the spiral side and slightly less compressed chambers. The new subspecies differs from *G. albeari* Cushman and Bermudez in having fewer chambers in the last whorl (about 5 instead of 8–10) and in being less trochospiral.

Globorotalia pusilla laevigata 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 whorls; 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, extraumbilical-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:256950 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 19–21

Globigerina velascoensis var. *compressa* White, Journ. Paleontol., vol. 2, No. 3, p. 196, pl. 28, 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 whorls, 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, extraumbilical-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, extraumbilical-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 mckannai (White)

PLATE 19, FIGURES 16–18

Globigerina mckannai WHITE, Journ. Paleontol., vol. 2, No. 3, p. 194, pl. 27, figs. 16a–c, 1928.

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, extraumbilical-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, extraumbilical-umbilical position of the aperture. *G. mckannai* (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

Globigerina crassaformis Galloway and Wissler, WHITE, Journ. Paleontol., vol. 2, No. 3, p. 193, pl. 27, figs. 14a–c, 1928.
Globorotalia whitei WEISS, Journ. Paleontol., vol. 29, No. 1, pp. 18, 19, pl. 6, figs. 1–3, 1955.

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, extraumbilical-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. wilcoxensis* 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

Globorotalia wilcoxensis CUSHMAN and PONTON, Contr. Cushman Lab. Foram. Res., vol. 8, pt. 3, p. 71, pl. 9, figs. 10a–c, 1932.

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 2-2¼ 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, extraumbilical-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, extraumbilical-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 1¼ mile 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 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 rohri* var. *mayoensis* Bronnimann and Bermudez or for *G. topilensis* Cushman (which probably is a *Truncorotaloides*). However, *G. quetra* lacks the sutural 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. wilcoxensis* 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

Globorotalia broedermanni CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, p. 40, pl. 7, figs. 22–24, 1949.

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 2½–3 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, extraumbilical—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 1¼ mile 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: 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 velascoensis* 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[1]

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 *Zeauvigerina* 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

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[1] Trinidad Oil Company, Ltd., Pointe-à-Pierre, Trinidad, B. W. I.

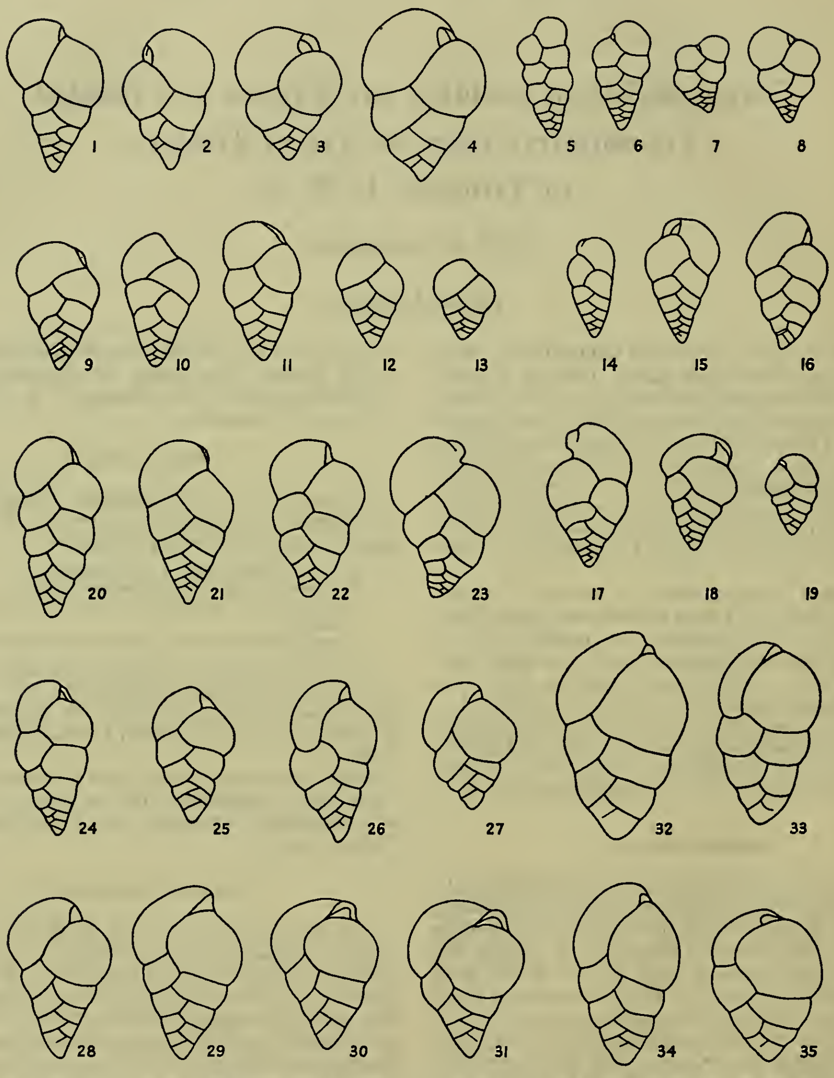


FIGURE 14.—Variability of species of *Chiloguembelina* (all figures approximately × 120; a list of the sample localities is given on p. 88).

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, *Globigerapsis 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 28–31. *Chiloguembelina midwayensis strombiformis* Beckmann, new subspecies (USNM P5772 a–d) from sample 228674.

Numbers 32–35. *Chiloguembelina midwayensis subcylindrica* Beckmann, new subspecies (USNM P5776a–d), from sample 228484.

FIGURE 15.—Variability of species of *Chiloguembelina* and *Zeauvigerina* (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 subtriangularis* Beckmann, new species (USNM P5784a–d), from sample 232706.

Numbers 43–45. *Chiloguembelina trinitatensis* (Cushman and Renz) (USNM P5787a–c), from sample 50315.

Numbers 46–48. *Chiloguembelina victoriana* Beckmann, new species (USNM P5791a–c), from sample 193785.

Numbers 49–58. *Chiloguembelina wilcoxensis* (Cushman and Ponton): 49–52 (USNM P5796a–d), from sample 223473, *Globorotalia pseudomenardii* zone. 53–55 (USNM P5797a–c), from sample 223470, *Globorotalia velascoensis* zone. 56–58 (USNM P5798a–c), from sample 102301, *Globorotalia formosa formosa* zone. Small subterminal end chamber visible in No. 56.

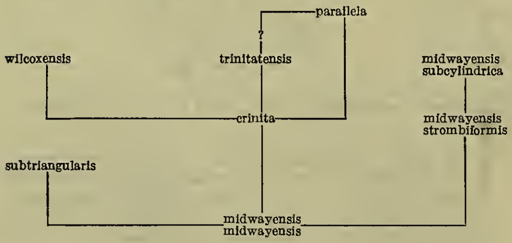
Numbers 59–62. *Zeauvigerina aegyptiaca* Said and Kenawy (USNM P5805a–d), from sample 228674. Small end chamber visible in Nos. 59–61, partly broken in Nos. 59 and 61.

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 *Chiloguembelina* group. Extremely asymmetrical apertures with a transparent flange occur in *Chiloguembelina midwayensis* (Cushman) and *Chiloguembelina martini* (Pijpers) (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, *Chiloguembelina wilcoxensis* (Cushman and Ponton) and *Chiloguembelina trinitatensis* (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 *Chiloguembelina 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 *Chiloguembelina midwayensis subcylindrica*, new subspecies, *C. parallela*, new species, and *C. wilcoxensis* (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 *Zeauvigerina* and suggests a close relationship between this genus and *Chiloguembelina*. The tubular neck characteristic of *Zeauvigerina* is, however, absent in *Chiloguembelina*.

It is interesting to note that *Chiloguembelina midwayensis subcylindrica*, new subspecies, *C. parallela*, new species, and *C. wilcoxensis* (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 *Chiloguembelina* is a gerontic 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 *Chiloguembelina* 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 *Chiloguembelina* within the Navet and Cipero formations.

The preceding discussion of morphological details indicates that the genus *Chiloguembelina* 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 *Chiloguembelina* 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 *Chiloguembelina* and *Bolivina* are similar in appearance. However, *Chiloguembelina* has inflated chambers, no ornamentation, but often a hispid wall surface. The aperture is rarely so high and narrow as in typical *Bolivina*. Further characteristics of *Chiloguembelina* 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 *Chiloguembelina* in *Globigerina* marls suggests a planktonic mode of life for this genus, whereas *Bolivina* is generally regarded as bottom-living.

The relationship between *Chiloguembelina* and *Zeauvigerina* has been mentioned above.

Stratigraphic Occurrence

The stratigraphic range (see text-fig. 16) of *Chiloguembelina* in Trinidad is from Paleocene to Oligocene. This is in agreement with the observations of most previous authors. None of the *Chiloguembelina* 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 *Chiloguembelina*, and it is possible that additional species will be found in these faunas.

The variety of species of *Chiloguembelina* reaches a first climax around the Paleocene-lower Eocene bound-

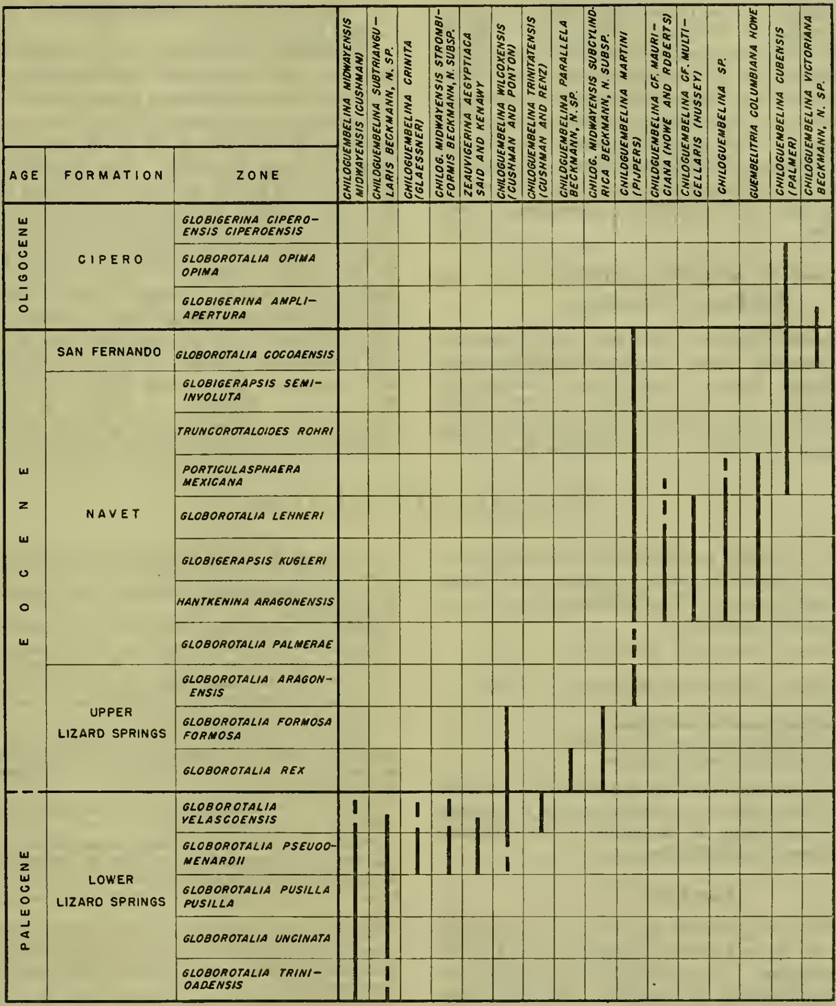


FIGURE 16.—Species distribution of *Chiloguembelina, Guembelitria,* and *Zeauvigerina* in the Tertiary of Trinidad, B. W. I.

ary, at a level which corresponds to the upper Midway and Wilcox groups of North America. A complete change of fauna takes place in the uppermost part of the Lizard Springs formation. After the extinction of all Paleocene-lower Eocene species, *Chiloguembelina martini* (Pijpers) appears in the *Globorotalia aragonensis* zone and becomes the dominant Eocene species in size and frequency. Some details of the distribution of other species in the lower to middle part of the Navet formation remain uncertain, owing to the insufficient number of samples from the *Globorotalia palmerae* zone and the poor preservation of the specimens from the *Globigerapsis 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 *Globigerina 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 floods 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, 1933) describe *Guembelina goodwini* from the Hospital Hill marl of Trinidad (upper Eocene, *Globigerapsis semiinvoluta* zone). Cushman and Renz (1948, p. 23) report *Guembelina goodwini* from all units of the Navet formation except the Ramdat marl. *Gümbelina 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 ultimatumida 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 *Zeauvigerina* are here recorded. The following new species and subspecies are described:

- *Chiloguembelina midwayensis strombiformis*, new subspecies
- *Chiloguembelina midwayensis subcylindrica*, new subspecies
- *Chiloguembelina parallela*, new species
- *Chiloguembelina subtriangularis*, 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 1¼ 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, 185 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 12½ of Brasso-Tamana Road (see Bolli, 1957b, text-fig. 25), collected by H. G. Kugler (8820).

178162: 4,570 feet south of milepost 9¾ 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 (9073).

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 (313B).

217995: 850 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).

223470–73: Trinidad Petroleum Development Co. well Moruga No. 15, south Trinidad (coordinates N:149878 links; E:497002 links); 223470 from core at 3,593–3,613 feet (upper part), 223472 from core at 3,720–3,740 feet, 223473 from core at 3,796–3,816 feet.

228484: Left bank tributary of Cascas River, 180 feet from its junction with the Cascas River, Moruga, south Trinidad (coordinates N:138700 links; E:435000 links), collected by L. W. Hawkins (1831).

228674: Northeastern bank of tank farm at the old club site, Pointe-a-Pierre, Trinidad (coordinates N:256950 links; E:380000 links), collected by H. G Kugler (10832).

232705–6, 232994: The Trinidad Oil Company well Guayaguayare No. 159, southeast Trinidad (coordinates N:151361 links; E:554095 links); 232705 from core at 4,524–4,536 feet, 232706 from core at 4,778–4,790 feet, 232994 from core at 3,707–3,713 feet.

238622: Hospital Hill, San Fernando, Trinidad, on eastern side of road leading from King's Wharf to Point Bontour (coordinates N:234850 links; E:355650 links), collected by H. M. Bolli (536).

240966: 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, collected by H. G. Kugler (9613).

Family Heterohelicidae Cushman, 1927

Genus Chiloguembelina Loeblich and Tappan, 1956

Chiloguembelina crinita (Glaessner)

Plate 21, Figure 4; Text-figure 14 (1–4)

Gümbelina 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 (USMN P5755).

Chiloguembelina cubensis (Palmer)

Plate 21, Figure 21; Text-figure 14 (5–8)

Gümbelina 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, B. W. I.).

Gümbelina 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 *Guembelina 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 topotypes 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, *Porticulasphaera 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 *Globigerapsis 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 martini (Pijpers)

Plate 21, Figure 14; Text-figure 14 (9–11, 14–18, 20–23)

Textularia martini Pijpers, 1933, p. 57, figs. 6–10 (upper Eocene, Bonaire, D. W. I.).

Gümbelina martini (Pijpers), Drooger, 1953, p. 100, pl. 1, fig. 2; text-fig. 4 (upper Eocene, Curacao and Bonaire).

Gümbelina goodwini 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.).

Gümbelina venezuelana Nuttall, 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 martini* 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)

?*Gümbelina mauriciana* Howe and Roberts, *in* Howe, 1939. p. 62, pl. 8, figs. 9–11 (Eocene, Louisiana, U. S. A.).

Gümbelina 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 *Guembelina 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 *Porticulasphaera mexicana* zone.

TYPES: Figured hypotypes (USNM P5764, 5765a, b, 5766) and unfigured hypotypes (USNM P5767).

Chiloguembelina midwayensis midwayensis (Cushman)

PLATE 21, FIGURE 1; TEXT-FIGURE 14 (24–27)

Gümbelina 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* (Glaessner) 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, biserially 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 links), core 3720–40 feet (TTOC 223472).

The variability of *Chiloguembelina midwayensis strombiformis* is illustrated by the text-figures 14, numbers 28–31. 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* (Glaessner) 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 biserially 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:187160 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

?*Gümbelina 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).

Chiloguemblina 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, symmetrical, bordered by two parallel lateral flanges, occasionally covered 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 Cascas River, 180 feet from its junction with the Cascas 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 subtriangularis 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 Guayaguayare 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 trinidadensis* zone have a more rounded periphery, slightly curved sutures and resemble compressed specimens of *C. midwayensis midwayensis.*

Length: 0.14–0.22 mm.; holotype, 0.21mm.

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)

Gümbelina 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 semicicular, 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 cocoaensis* 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 wilcoxensis (Cushman and Ponton)

PLATE 21, FIGURES 10, 12, 13; TEXT-FIGURE 15 (49–58)

Gümbelina wilcoxensis CUSHMAN and PONTON, 1932, p. 66, pl. 8, figs. 16, 17 (lower Eocene, Alabama, U. S. A.).—TOULMIN, 1941, p. 597, pl. 80, fig. 24 (lower Eocene, Alabama, U. S. A.).

With its globular chambers and its symmetrical, semicircular aperture, *Chiloguembelina wilcoxensis* 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. trinitatensis* Cushman and Renz, which has no twisted test or asymmetrical apertural flap either, it seems to develop from *C. crinita*, which is a typical *Chiloguembelina* (see p. 89). Therefore *C. trinitatensis* and *C. wilcoxensis* 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. wilcoxensis*, 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 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. Scarce and not typical specimens occur in the *Porticulasphaera mexicana* zone.

TYPES: Figured specimen (USNM P5800).

Genus Guembelitria Cushman, 1933

Guembelitria columbiana Howe

PLATE 21, FIGURE 16

Gümbelitria columbiana HOWE, 1939, p. 62, pl. 8, figs. 12–13 (Eocene, Louisiana, U. S. A.).—CUSHMAN and TODD, 1945a, p. 16, pl. 4, fig. 3 (Eocene, Alabama, U. S. A.).—HUSSEY, 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 *Porticulasphaera mexicana* zone.

TYPES: Figured hypotype (USNM P5801) and unfigured hypotypes (USNM P5802).

Genus Zeauvigerina Finlay, 1939

Zeauvigerina aegyptiaca Said and Kenawy

PLATE 21, FIGURES 9, 11; TEXT-FIGURE 15 (59–62)

Zeauvigerina aegyptiaca SAID and KENAWY, 1956, p. 141, pl. 4, fig. 1 (Maestrichtian 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, it 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 *Eouvigerina* 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 Eouvigerina,* 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[1]

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 independant 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 *Globorotalia 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 *Globorotalia fohsi* zone into four additional zones. This subdivision was based on evolutionary changes of *Globorotalia fohsi* (Bolli, 1951). In addition, the *Globigerina dissimilis* zone (now *Catapsydrax dissimilis* 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 *Globorotalia opima opima* zone from the *Globigerina ciperoensis ciperoensis* zone, a *Globorotalia kugleri* zone from the *Catapsydrax dissimilis* zone, and a *Catapsydrax stainforthi* 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 *Globorotalia mayeri* and an upper *Globorotalia menardii* zone (Bronnimann, 1951a).

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 *Globigerinita*, and *Globigerinoita* from the Lengua formation. Bronnimann (1951b) and Blow (1956) discussed the genus *Orbulina* and its evolutionary trends in the Cipero and Lengua formations. The present author followed his earlier investigations on coiling ratios of some Cipero-Lengua Globorotalias (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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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.

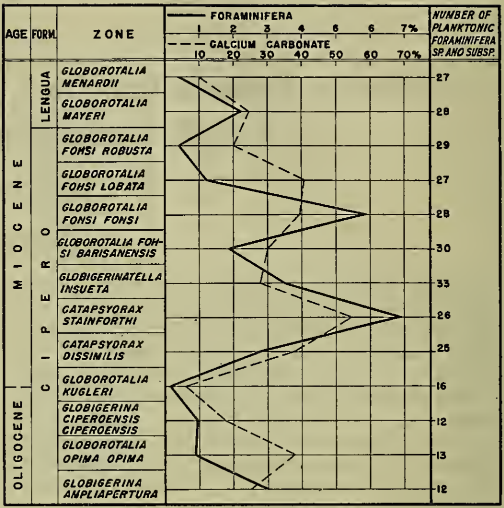

Figure 17.—Weight percentage of Foraminifera (>0.06 mm.), calcium carbonate content, and number of planktonic Foraminifera species and subspecies in samples from the type localities of the Cipero and Lengua formations.

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 Karamat 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 towards 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 northwards into the neritic facies of the Brasso formation.

Small reefal limestone developments with orbitoidal faunas are occasionally found in the Cipero formation (e. g., 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

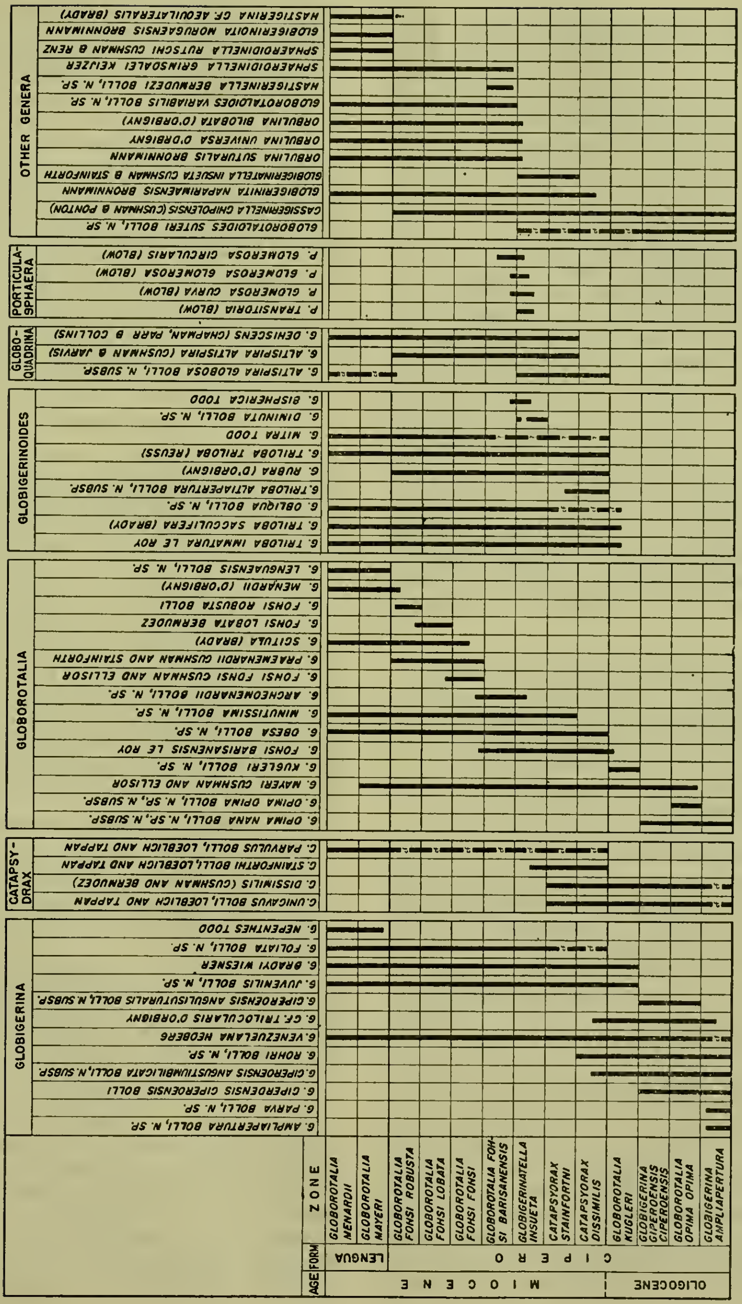

FIGURE 18.—Distribution of planktonic Foraminifera in the Oligocene - Miocene Cipero and Lengua formations of Trinidad, B. W. I.

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 nondeposition 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: In left side branch of a gully, 800 feet northeast of north end of San Fernando railway station, 250 feet southeast of railway bridge. Coordinates N:237850 links; E:357560 links (Coordinates are given according to the Government cadastral sheets of 12 chains to 1 inch, almost 1:10,000). Type sample SE 4668 (TTOC 246756).

Lithology: Massive, silty, impure, sepia colored marl.

Remarks: The *Globigerina ampliapertura* zone, formerly known as the *Globigerina apertura* zone (Suter, 1951) is characterized by the zonal marker and by *Globigerina parva* Bolli, new species. Both species occur also in the upper Eocene but such characteristic forms as *Hantkenina*, *Globorotalia centralis* Cushman and Burmudez, *Globorotalia cocoaensis* Cushman, *Bulimina jacksonensis* Cushman, became extinct at the close of the Eocene. Several planktonic species apparently originate in the *Globigerina ampliapertura* zone, e. g., *Cassigerinella chipolensis* (Cushman and Ponton), and *Globigerina ciperoensis ciperoensis* Bolli.

In the interval after the extinction of *Globigerina ampliapertura* and before the first occurrence of *Globorotalia opima opima* Bolli, new species, new subspecies (marker for the next younger zone), a comparatively monotonous planktonic fauna occurs, consisting predominantly of *Globigerina* cf. *venezuelana* Hedberg. A separate zone could be erected for this interval, but in order to avoid unnecessary complication this interval has here been included in the *Globigerina ampliapertura* zone and is referred to as its upper part. This upper part of the *Globigerina ampliapertura* zone is well exposed northeast of the type locality (in a gully 1,100 feet northeast of the north end of the San Fernando railway station, 200 feet southeast of the railway bridge, at the bottom of a small water fall (Coordinates N:238270 links; E:357940 links).

Globorotalia opima opima Zone

Type locality: Cipero type section, between 20 and 240 feet southwest from fixed point (see p. 103). Type sample JS 20 (TTOC 193265). Rz 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, gypsiferous; 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 southwest 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:361900 links. Type sample Bo 274 (TTOC 201223).

Lithology: Grey and yellow brown, mottled, calcareous clay, gypsiferous 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. *Globigerina juvenilis* Bolli, new species, and *Globigerina 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:362200 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 *Globigerinoides* are to 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). *Globoquadrina dehiscens* (Chapman, Parr, and Collins) and *Globoquadrina altispira altispira* (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:217296 links; E:371482 links.

Lithology: Massive, cream to yellow grey marl, fairly resistent 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). *Globigerinoides 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 *Globigerinoides bispherica* 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 foshi 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 *Globigerinoides bispherica* Todd to *Orbulina* disappear in the lower part of the zone. The characteristic *Hastigerinella bermudezi* Bolli, new species, has thus far been recorded only from this zone.

Globoratalia 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 insueta* 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 *Globigerinoides 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 lenguaensis* 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 Cruse 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, *Globoquadrina altispira altispira* (Cushman and Jarvis), *Globoquadrina 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 eggeri* 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, gypsiferous 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 lenguaensis* Bolli, new species, *Sphaeroidinella rutschi* Cushman and Renz, *Globigerinoita 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 178890).

Lithology: Buff to yellow grey, calcareous clay, gypsiferous 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 southernmost 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 235 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 triloba* (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 slip-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 845 ft. SW.: Large slip-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 components—*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 *Globigerinatella 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 robusta* zone.

This pebble bed is now regarded as the base of the large slump-mass extending from 848 feet to the northernmost 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 ciperoensis 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 ciperoensis 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 ampliapertura* 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).

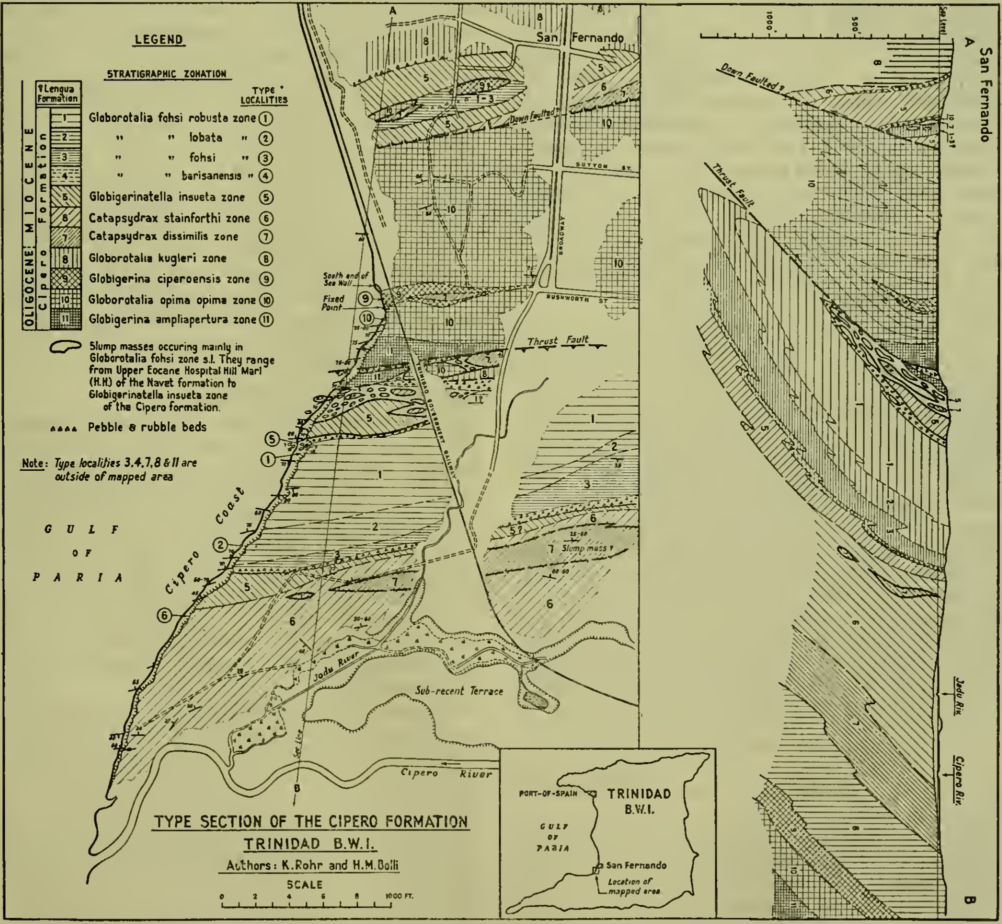

FIGURE 19.—Type section of the Cipero formation, Trinidad, B. W. I.

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 *Alveovalvulinella 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 interbedded 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* marls 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-

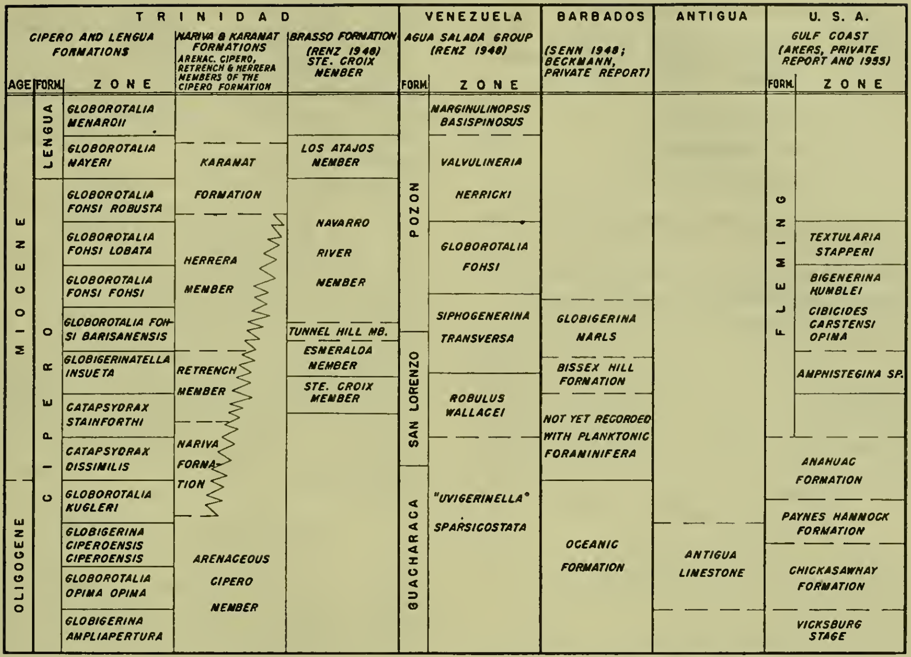

FIGURE 20.—Stratigraphic correlation of the Cipero and Lengua formations with other formations in Trinidad, the Caribbean, and the Gulf Coast region.

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. aequilateralis (Brady)

Plate 22, Figures 1a–2b

Globigerinella aequilateralis (Brady) Bermudez, Cushman. Lab. Foram. Res. Spec. Publ. 25, p. 280, pl. 21, fig. 51, 1949.

Stratigraphic range (in Lengua 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 Lengua 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

Cassidulina chipolensis Cushman and Ponton, Florida Geol. Surv. Bull. 9, p. 98, pl. 15, figs. 2a–c, 1932.—Cushman and Stainforth, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 64, pl. 12, fig. 5.

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 193265).

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 the 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-*

drax dissimilis zone. This form is here described as a new subspecies, *Globigerina ciperoensis angustiumbilicata.*

Another subspecies, *Globigerina ciperoensis angulisuturalis* 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 ciperoensis BOLLI, Contr. Cushman Found. Foram. Res., vol. 5, pt. 1, p. 1, 1954.

Globigerina concinna 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.

Globigerina cf. *concinna* Reuss, CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 67, pl. 13, figs. 1a–b, 1945.—BECKMANN, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 390, pl. 25, fig. 5, 1953.

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 *angulisuturalis.*

Globigerina ciperoensis angulisuturalis 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 angulisuturalis,* 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 *Globigerina 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

Globigerina venezuelana Hedberg, BECKMANN, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 392, pl. 10, figs. 12–13, 1953.

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.

Globigerina venezuelana Hedberg

PLATE 23, FIGURES 6a–8b

Globigerina venezuelana HEDBERG, Journ. Paleontol., vol. 11, No. 8, p. 681, pl. 92, figs. 7a–b, 1937.—CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 67, pl. 12, figs. 13a–b, 1945.—BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 280, pl. 21, figs. 39–40, 1949.

Globigerina conglomerata Schwager, BECKMANN, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 391, pl. 25, figs. 6–9, 1953.

STRATIGRAPHIC RANGE (in Cipero and Lengua formations): *Globigerina ampliapertura* zone to *Globorotalia menardii* zone.

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 *Catapsydrax 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 bulla.

Globigerina cf. trilocularis d'Orbigny

PLATE 22, FIGURES 8a–9c

Globigerina cf. *bulloides* d'Orbigny, CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 68, pl. 13, figs. 4a–b, 1945.

Globigerina trilocularis D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 277, 1826 (unpublished figures of d'Orbigny in Fornasini, Rend. Accad. Sci. Inst., Bologna, new ser. vol. 2, fasc. 1, pl. 1, figs. 6, 7–7a; p. 12, text-fig.).

STRATIGRAPHIC RANGE (in Cipero formation): *Globigerina ampliapertura* zone to *Catapsydrax dissimilis* zone.

LOCALITY: Figured specimens (USNM P5616a,b) from the *Catapsydrax dissimilis* zone, core at 4,543–48 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 triloba* (Reuss). Specimens of *Globigerina trilocularis* and *Globigerinoides triloba immatura* Le Roy were found to be indistinguishable in this zone, except that the latter showed a supplementary sutural 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; interiomarginal, umbilical. Coiling random. Largest diameter of holotype 0.29 mm.

STRATIGRAPHIC RANGE (in Cipero and Lengua formations): *Globorotalia kugleri* zone to *Globorotalia menardii* zone.

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* Wiesner, 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 *Globigerinita naparimaensis* Bronnimann, where the bulla is not yet developed (for comparison see Bolli, Loeblich and Tappan, 1957, pl. 8, figs. 1a–c).

Globigerina bradyi Wiesner

PLATE 23, FIGURES 5a–c

Globigerina sp., BRADY, Rep. Voy. *Challenger*, zool., vol. 9, p. 603, pl. 82, figs. 8, 9, 1884.

Globigerina bradyi WIESNER, Deutsche Südpolar-Expedition 1901–1903, vol. 20 (zool., vol. 12), p. 133 (for figs. see Brady op. cit.), 1901–1903.

STRATIGRAPHIC RANGE (in Cipero and Lengua formations): *Globorotalia kugleri* zone to *Globorotalia menardii* zone.

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 Wiesner as *G. bradyi*. Occasionally, specimens are seen that have one or several secondary sutural apertures on the last chamber. They should probably be placed in *Globigerinoides minuta* Natland. The two species seem to be synonymous, with the exception that *G. minuta* has sutural 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 naparimaensis* Bronnimann and between *Globigerinoides minuta* and *Globigerinoita 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 Lengua 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 nepenthes Todd

Plate 24, Figures 2a–c

Globigerina nepenthes Todd, U. S. Geol. Survey Prof. Paper 280–H, p. 301, pl. 78, fig. 7, 1957.

Stratigraphic range (in Lengua formation): *Globorotalia mayeri* zone to *Globorotalia menardii* zone.

Locality: Figured hypotype (USNM P5621) from the type locality of the *Globorotalia mayeri* zone, sample KR 23422 (TTOC 160634).

Remarks: *Globigerina nepenthes* 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 Lengua and Cruse formations and would under more favourable conditions probably have a longer range, it is here an excellent index fossil for the Lengua formation.

Genus Globoquadrina Finlay, 1947

Globoquadrina dehiscens (Chapman, Parr, and Collins)

Plate 24, Figures 3a–4c

Globorotalia dehiscens Chapman, Parr, and Collins, Linn. Soc. London, Journ. Zool., vol. 38, No. 262, p. 569, pl. 11, figs. 36a–c, 1934.

Stratigraphic range (in Cipero and Lengua formations): *Catapsydrax stainforthi* zone to *Globorotalia menardii* zone.

Locality: Figured hypotypes (USNM P5622) from the type section of the *Globorotalia fohsi lobata* zone, sample JS 32 (TTOC 193786); (USNM P5623) from the *Globorotalia fohsi robusta* zone, sample JS 46 (TTOC 194056).

Remarks: *Globoquadrina quadraria* (Cushman and Applin) and *G. quadraria* var. *advena* Bermudez are apparently closely related to *G. dehiscens*. Although some variation can be observed in the Cipero and Lengua specimens, they are here all placed in *G. dehiscens*.

Globoquadrina altispira altispira (Cushman and Jarvis)

Plate 24, Figures 7a–8b

Globigerina altispira Cushman and Jarvis, Contr. Cushman Lab. Foram. Res., vol. 12, pt. 1, p. 5, pl. 1, figs. 13a–c, 14, 1936.—Coryell and Rivero, Journ. Paleontol., vol. 14, No. 4, p. 339, pl. 42, fig. 32, 1940.—Bermudez, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 277, pl. 21, fig. 43, 1949.

Stratigraphic range (in Cipero and Lengua formations): *Catapsydrax stainforthi* zone to *Globorotalia fohsi robusta* zone.

Locality: Figured hypotypes (USNM P5624) from the type section of the *Globorotalia fohsi lobata* zone, sample JS 32 (TTOC 193786); (USNM P5625) from the *Globorotalia fohsi robusta* zone, sample JS 46 (TTOC 194056).

Remarks: *Globoquadrina altispira altispira* varies considerably, ranging from small to large specimens and from low to high trochospiral forms. The form described by Cushman and Jarvis is here given subspecies rank. It is distinguished from *G. altispira globosa*, new subspecies, by having somewhat elongate and laterally compressed chambers.

Globoquadrina altispira globosa Bolli, new subspecies

Plate 24, Figures 9a–10c

Shape of test medium to high trochospiral; equatorial periphery distinctly lobate. Wall calcareous, perforate, surface finely pitted, with short spines on well preserved specimens (figs. 10a–c). Chambers spherical to very slightly compressed laterally; 15–20, arranged in 3–4 whorls; the 5–6 chambers of the last whorl increase moderately in size. Sutures on spiral side radial, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, deep. Aperture high, covered above by an elongate, toothlike flap; interiomarginal, umbilical. Coiling random in the *Catapsydrax dissimilis* zone, later becoming predominantly sinistral (as is also *Globoquadrina altispira attispira* and *Globoquadrina dehiscens;* Bolli, 1951). Largest diameter of holotype 0.7 mm.

Stratigraphic range (in Cipero and Lengua formations): *Catapsydrax dissimilis* zone to *Globigerinatella insueta* zone and *Globorotalia fohsi robusta* zone to *Globorotalia menardii* zone.

Locality: Holotype (USNM P5626) and figured paratype (USNM P5627) from the type locality of the

Catapsydrax dissimilis zone, Trinidad, sample Bo 267 (TTOC 201216).

Remarks: *Globoquadrina 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–c

Hastigerinella eocanica Nuttall, Cushman and Stainforth, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 69, pl. 13, figs. 11a–b, 1945.—Bermudez, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 282, pl. 22, figs. 1–2, 1949.

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 fohsi barisanensis* zone.

Locality: Holotype (USNM P5628) from the type locality of the *Globorotalia fohsi 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. eocena* 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 species is named 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 altiapertura*, 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 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 altiapertura* differs from *G. triloba immatura* in having a high arched, primary aperture.

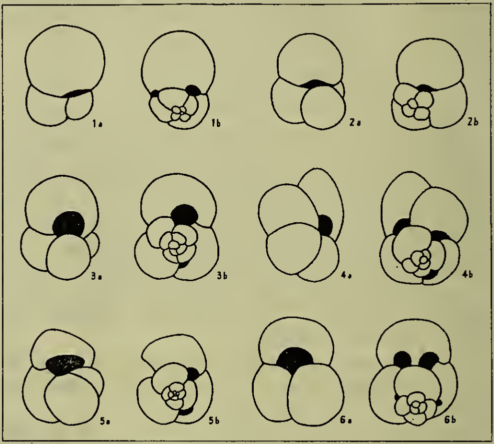

Figure 21.—Shape of test and position of apertures in some species and subspecies of *Globigerinoides* (a, umbilical view; b, spiral view): No. 1, *Globigerinoides triloba triloba* (Reuss); No. 2, *Globigerinoides triloba immatura* Le Roy; No. 3, *Globigerinoides triloba altiapertura* Bolli, new subspecies; No. 4, *Globigerinoides triloba sacculifera* (Brady); No. 5, *Globigerinoides obliqua* Bolli, new species; No. 6, *Globigerinoides rubra* (d'Orbigny).

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).

Globigerinoides triloba triloba (Reuss)

Plate 25, Figures 2a–c; Text-figure 21, No. 1

Globigerina triloba Reuss, Denkschr. Akad. Wiss. Wien, Math.-Nat. Classe, vol. 1, p. 374, pl. 47, figs. 11a–d, 1850.

Stratigraphic range (in Cipero and Lengua formations): *Catapsydrax dissimilis* zone to *Globorotalia menardii* zone.

LOCALITY: Figured hypotype (USNM P5629) from the type locality of the *Globorotalia fohsi barisanensis* zone, sample Bo 202 (TTOC 193125).

Globigerinoides triloba immatura Le Roy

PLATE 25, FIGURES 3a–4c; TEXT-FIGURE 21, No. 2

Globigerinoides sacculiferus (Brady) var. *immatura* LE ROY, Natuurk. Tijdschr. Nederl.-Indie, Batavia, vol. 99, pt. 6, p. 263, pl. 3, figs. 19–21, 1939.

Globigerinoides sacculifera (Brady), CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 68, pl. 13, fig. 3, 1945.—BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 278, pl. 21, fig. 49, 1949.

STRATIGRAPHIC RANGE (in Cipero and Lengua formations): *Globorotalia kugleri* zone to *Globorotalia menardii* zone.

LOCALITY: Figured hypotypes (USNM P5630a,b) from the *Globorotalia fohsi robusta* zone, sample JS 46 (TTOC 194056).

Globigerinoides triloba sacculifera (Brady)

PLATE 25, FIGURES 5a–6; TEXT-FIGURE 21, No. 4

Globigerina sacculifera BRADY, Geol. Mag., n. s., decade 2, vol. 4, No. 12, p. 535, 1877 (type figure in Rep. Voy. *Challenger*, Zool., vol. 9, pl. 80, figs. 15, 16, 1884).

Globigerinoides sacculifera (Brady), CORYELL and RIVERO, Journ. Paleontol., vol. 14, No. 4, p. 340, pl. 42, figs. 24, 25, 32, 1940.—BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 281, pl. 21, fig. 53, 1949.

STRATIGRAPHIC RANGE (in Cipero and Lengua 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, interiomarginal, 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 stainforthi* 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, interiomarginal, 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 Lengua 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

Globigerinoides rubra (d'Orbigny), BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 281, pl. 21, fig. 52, 1949.

Globigerinoides subquadrata BRONNIMANN, *in* Todd, Cloud, Low, and Schmidt, Amer. Journ. Sci., vol. 252, p. 680, pl. 1, fig. 5, 1954.

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 *Globigerinatella 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 *Globototalia fohsi robusta*, and is not found in the Lengua 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 Lengua formation might be found in assuming that the environmental conditions of the Lengua 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. Umbilicus 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 7,419–39 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–4

Globigerinoides mitra TODD, U. S. Geol. Surv., Prof. Paper 280-H, p. 302, pl. 78, figs. 3, 6, 1956.

STRATIGRAPHIC RANGE (in Cipero and Lengua 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 Lengua 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 bispherica Todd

PLATE 27, FIGURES 1a–b

Globigerinoides bispherica TODD, *in* Todd, Cloud, Low, and Schmidt. Amer. Journ. Sci., vol. 252, No. 11, p. 681, pl. 1, figs. 1a–c, 4, 1954.—BLOW, Micropaleontol., vol. 2, No. 1, p. 62, text-fig. 1, Nos. 4–8, text-fig. 2, Nos. 10–11, 1956.

Globigerina conglobata (H. B. Brady), CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 68, pl. 13, fig. 6, 1945.

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 bispherica* is regarded as the ancestor of the *Porticulasphaera glomerosa* (Blow) group and the genus *Orbulina*, (See Blow, 1956).

Genus Sphaeroidinella Cushman, 1927

Sphaeroidinella grimsdalei (Keijzer)

PLATE 26, FIGURES 8–12c

Globigerina grimsdalei KEIJZER, Univ. Utrecht, Geogr. Geol. Med., Phys. Geol. Reeks, ser. 2, No. 6, p. 205, tf. 33a–d, 1945.

Globigerina cf. *digitata* (Brady), CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 68, pl. 13, figs. 5a–b, 1945.

Globigerina digitata (Brady), BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 280, pl. 21, figs. 54–55, 1949.

Globigerinoides grimsdalei (Keijzer), BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 281, pl. 21, figs. 56–57, 1949.

STRATIGRAPHIC RANGE (in Cipero and Lengua 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. 25, pl. 4, fig. 5, 1941.—RENZ, Geol. Soc. Amer., Mem. 32, p. 167, pl. 10, figs. 1a–c.

Sphaeroidinella seminulina (Schwager), BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 283, pl. 21, fig. 59, 1949.

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 352 (TTOC 194771).

REMARKS: *Sphaeroidinella rutschi* has probably developed from the *Sphaeroidinella grimsdalei* Keijzer group and may be regarded as the ancestor of *Sphaeroidinella dehiscens* (Parker and Jones).

Subfamily Orbulininae Schultze, 1854

Genus Porticulasphaera Bolli, Loeblich, and Tappan, 1957

In a paper on the evolution of the genus *Orbulina* Blow (1956) described a number of forms under the genus *Globigerinoides* that are regarded as transitional between *Globigerinoides* and *Orbulina*. They resemble *Orbulina 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 *Porticulasphaera*. Although there is no genetic relation between the middle Eocene and the lower Miocene forms, Blow's transitional species are here placed in *Porticulasphaera*. 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).

Porticulasphaera 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).

Porticulasphaera 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).

Porticulasphaera glomerosa circularis (Blow)

PLATE 27, FIGURE 2

Globigerinoides glomerosa circularis BLOW, Micropaleontol., vol. 2, No. 1, p. 65, text-fig. 2, Nos. 3–4, 1956.

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).

Porticulasphaera transitoria (Blow)

PLATE 27, FIGURE 3

Globigerinoides transitoria BLOW, Micropaleontol., vol. 2, No. 1, p. 65, text-fig. 2, Nos. 12–15, 1956.

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 Orbulina d'Orbigny, 1839

Orbulina suturalis Bronnimann

PLATE 27, FIGURE 4

Orbulina 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.

Candorbulina universa Jedlitschka, CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 69, pl. 13, fig. 10, 1945.

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).

Orbulina universa d'Orbigny

PLATE 27, FIGURE 5

Orbulina universa d'Orbigny, BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 282, pl. 21, fig. 3, 1949.—BRONNIMANN, Cushman Lab. Foram. Res., vol. 2, pt. 4, p. 134, pl. 4, fig. 1, 1951.—BLOW, Micropaleontol., vol. 2, No. 1, p. 66, text-fig. 2, Nos. 8–9, 1956.

STRATIGRAPHIC RANGE (in Cipero and Lengua formations): Topmost part of the *Globigerinatella insueta* zone to the *Globorotalia menardii* zone.

Locality: Figured hypotype (USNM P5652) from the type locality of the *Globorotalia mayeri* zone, sample KR 23422 (TTOC 160021).

Orbulina bilobata (d'Orbigny)

Plate 27, Figure 6

Globigerina bilobata d'Orbigny, Foraminifères fossiles du bassin tertiaire de Vienne, p. 164, pl. 9, figs. 11–14, 1846.

Orbulina bilobata (d'Orbigny), Palmer, Mem. Soc. Cubana Hist. Nat., vol. 15, p. 286, pl. 28, fig. 3, 1941.—Bermudez, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 282, pl. 22, fig. 4, 1949.—Bronnimann, Contr. Cushman Found. Foram. Res., vol. 2, pt. 4, pp. 135, 136, text-fig. 3, figs. 1–2, 9–10, 17, 19; text-fig. 4, figs. 5–6, 17–18, 1951.

Biorbulina bilobata (d'Orbigny), Blow, Micropaleontol., vol. 2, No. 1, pp. 69–70, text-fig. 2, No. 16, 1956.

Stratigraphic range (in Cipero and Lengua formations): Topmost part of the *Globigerinatella insueta* zone to the *Globorotalia menardii* zone.

Locality: Figured hypotype (USNM P5653) from the *Globorotalia fohsi 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]

Globigerina dissimilis Cushman and Bermudez, Contr. Cushman Lab. Foram. Res., vol. 13, pt. 1, p. 25, pl. 3, figs. 4–6, 1937.—Bermudez, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 279, pl. 21, fig. 47, 1949.—Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, (1953), p. 391, pl. 25, fig. 10, 1954.

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 291A (TTOC 215656).

Catapsydrax unicavus Bolli, Loeblich, and Tappan

Catapsydrax unicavus Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 37, pl. 7, fig. 9, 1957.

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

Catapsydrax stainforthi Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 37, pl. 7, fig. 11, 1957.

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

Catapsydrax parvulus Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 36, pl. 7, fig. 10, 1957.

Stratigraphic range (in Cipero and Lengua formations): *Catapsydrax dissimilis* zone to *Globorotalia menardii* zone.

Locality: Holotype (USNM P4219) from the type locality of the *Globorotalia mayeri* zone, sample KR 23422 (TTOC 160634).

Genus Globigerinita Bronnimann, 1951

Globigerinita naparimaensis Bronnimann

Globigerinita naparimaensis Bronnimann, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3–4, p. 82, pl. 14, fig. 11, 1951.—Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 37, pl. 8, figs. 1, 2.

Stratigraphic range (in Cipero and Lengua 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 Globigerinoita Bronnimann, 1952

Globigerinoita morugaensis Bronnimann

Globigerinoita morugaensis Bronnimann, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1, p. 26, text-fig. 1, figs. a–m; text-fig. 2, figs. a–h, 1952.—Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 38, pl. 8, fig. 3.

Stratigraphic range (in Lengua formation): *Globorotalia mayeri* zone to *Globorotalia menardii* zone.

Locality: Holotype (USNM P3913) from the *Globorotalia menardii* zone, sample GF 4028 (TTOC 3514).

Genus Globigerinatella Cushman and Stainforth, 1945

Globigerinatella insueta Cushman and Stainforth

Globigerinatella insueta Cushman and Stainforth, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 69, pl. 13, figs. 7–9, 1945.—Bronnimann, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3–4, pp. 80–82, pl. 13, figs. 1–12, pl. 14, figs. 1–13, 1950.—Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 38, pl. 8, figs. 4–7.

Stratigraphic range (in Cipero formation): *Catapsydrax stainforthi* zone to *Globigerinatella insueta* zone.

Locality: Figured paratypes (Cushman Coll. 44043a, b) from the *Globigerinatella insueta* zone; figured topotype (USNM P3932b) from the *Globigerinatella insueta* zone.

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[2] Inasmuch as Cipero specimens of this and other species of *Catapsydrax*, *Globigerinita*, *Globigerinoita*, and *Globigerinatella* have been figured in the present volume (pls. 7 and 8), they are not refigured here. References to the earlier figures may be found in the synonymy.

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-extraumbilical, 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-extraumbilical 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 slightly 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 bulla-like chamber. Aperture a slit or low arch; interiomarginal, umbilical-extraumbilical in early stage, later becoming interiomarginal, umbilical, which in mature specimens becomes covered by a bulla-like chamber with usually one, rarely two or more infralaminal apertures. Coiling random or some predominance for dextral. Largest diameter of holotype 0.35 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-extraumbilical in early stage, later becoming umbilical, which in the mature stage becomes covered by a bulla-like chamber with one infralaminal aperture. Coiling random. Largest diameter of holotype 0.45 mm.

Stratigraphic range (in Cipero and Lengua formations): *Globorotalia fohsi barisanensis* zone to *Globorotalia menardii* zone. Most typical and common in the Lengua formation.

Locality: Holotype (USNM P5657) and figured paratypes (USNM P5658a–e) from the *Globorotalia menardii* zone, Lengua 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 opima* zone.

Locality: Holotype (USNM P5659) and figured paratype (USNM P5660) from the type section of the *Globorotalia opima opima* zone, Cipero type section, Trinidad, sample JS 20 (TTOC 193265).

Remarks: *Globorotalia opima opima*, 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 opima* has a very restricted range whereas *G. mayeri* can be followed through most of the Cipero formation into the lower Lengua. *G. opima opima* differs from *G. opima 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 opima* 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 opima*, 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

Globorotalia mayeri Cushman and Ellisor, Contr. Cushman Lab. Foram. Res., vol. 15, pt. 1, p. 11, pl. 2, figs. 4a–4c, 1939.—Bermudez, Cushman Lab. Foram. Res., Spec. Publ. No. 25, p. 286, pl. 22, figs. 24–26, 1949.

Globorotalia (*Turborotalia*) *mayeri* Cushman and Ellisor, Cushman and Bermudez, Contr. Cushman Lab. Foram. Res., vol. 25, pt. 1, p. 44, pl. 8, figs. 16–18, 1949.

Globorotalia cf. *mayeri* Cushman and Ellisor, Palmer, Mem. Soc. Cubana Hist. Nat., vol. 14, No. 1, p. 292, pl. 28, figs. 5a–c, 1940.

Stratigraphic range (in Cipero and Lengua formations): *Globigerina opima opima* 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

Globorotalia barisanensis LE ROY, Natuurk. Tijdschr. Nederl.-Indie, vol. 99, pt. 6, p. 265, pl. 1, figs. 8–10, 1939.

Globorotalia fohsi barisanensis Le Roy, BOLLI, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3–4, p. 88, pl. 15, figs. 6a–c, 1950.

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

Globorotalia fohsi CUSHMAN and ELLISOR, Contr. Cushman Lab. Foram. Res., vol. 15, pt. 1, p. 12, pl. 2, figs. 6a–c, 1939.—RENZ, Geol. Soc. Amer. Mem. 32, p. 137, pl. 11, figs. 2a–c, 1948.—CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, pt. 1, pp. 30–31, pl. 5, figs. 14–16, 1949.—BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 285, pl. 22, figs. 18–20, 1949.

Globorotalia cf. *fohsi* Cushman and Ellisor, PALMER, Mem. Soc. Cubana Hist. Nat., vol. 14, No. 1, p. 291, pl. 29, figs. 3a–c, 1940–41.

Globorotalia barisanensis Le Roy, CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 70, pl. 13, figs. 15a–c, 1945.

Globorotalia fohsi fohsi Cushman and Ellisor, BOLLI, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3–4, p. 88, pl. 15, figs. 4a–c, 1950.

STRATIGRAPHIC RANGE (in Cipero formation): *Globorotalia fohsi fohsi* zone to the basal part of the *Globorotalia 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

Globorotalia fohsi Cushman and Ellisor, CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 70, pl. 13, figs. 13a–c, 1945.

Globorotalia lobata BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 286, pl. 22, figs. 15–17, 1949.

Globorotalia fohsi lobata Bermudez, BOLLI, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3–4, p. 88, pl. 15, figs. 7–8c, 1950.

STRATIGRAPHIC RANGE (in Cipero formation): *Globorotalia fohsi lobata* zone to the basal part of the *Globorotalia fohsi robusta* zone.

LOCALITY: Figured hypotypes (USNM P5669a, b) from the type section of the *Globorotalia fohsi lobata* zone, sample JS 32 (TTOC 193786).

Globorotalia fohsi robusta Bolli

PLATE 28, FIGURES 16a–c

Globorotalia fohsi robusta BOLLI, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3–4, pp. 84, 89, pl. 15, figs. 3a–c, 1950.

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-extraumbilical. 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-extraumbilical. 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 rhomboid, 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 part of the *Globorotalia fohsi fohsi* zone.

Locality: Holotype (USNM P5676) from the type locality of the *Globorotalia fohsi barisanensis* 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. 14a–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 hypotype (USNM P5677) from the type locality of the *Globorotalia fohsi fohsi* zone, sample Bo 185 (TTOC 153997).

Globorotalia menardii (d'Orbigny)

Plate 29, Figures 6a–10b

Rotalia menardii d'Orbigny, Ann. Sci. Nat., vol. 7, p. 273, modèle No. 10, 1826.

Globorotalia menardii (d'Orbigny), Nuttall, Journ. Paleontol., vol. 6, pp. 29–30, pl. 4, fig. 16, 1932.—Coryell 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–c, 1948.—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 formations): *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 specimens are from the same sample.

Globorotalia scitula (Brady)

Plate 29, Figures 11a–12c

Pulvinulina scitula Brady, Proc. Roy. Soc. Edinburgh, vol. 11, p. 716, 1884 (figs. in Brady, Rep. Voy. *Challenger*, Zool., vol. 9, pl. 103, figs. 7a–c, 1884).

Globorotalia canariensis (d'Orbigny), Cushman and Stainforth, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 70, pl. 13, figs. 12a–b, 1945.—Renz, Geol. Soc. Amer., Memoir 32, p. 136, pl. 11, figs. 3a–b, 1948.

Stratigraphic range (in Cipero and Lengua formations): *Globorotalia fohsi fohsi* zone to *Globorotalia menardii* zone.

Locality: Figured hypotypes (USNM P5679, P5680), from the *Globorotalia mayeri* zone, sample GF 3695 (TTOC 3320).

Remarks: *Globorotalia scitula* was previously described from the Cipero formation (Cushman and Stainforth, 1945) as *G. canariensis* (d'Orbigny). D'Orbigny describes this form (*Rotalia canariensis*) as elongate-depressed and carinate which brings it close to the *G. menardii* (d'Orbigny) group. Compared with this group, the equatorial periphery of *G. scitula* 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 lenguaensis 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-extraumbilical. Coiling apparently random in the *Globorotalia mayeri* zone; almost exclusively sinistral in the *Globorotalia menardii* zone. Largest diameter of holotype 0.3 mm.

Stratigraphic range (in Lengua formation): *Globorotalia mayeri* zone to *Globorotalia menardii* zone.

Locality: Holotype (USNM P5681) from the type locality of the *Globorotalia menardii* zone, Trinidad, sample KR 23425 (TTOC 178890).

Remarks: *Globorotalia lenguaensis*, new species, resembles *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 fohsi barisanensis* zone to *Globorotalia fohsi fohsi* zone of the Cipero formation), whereas *Globorotalia lenguaensis* 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[1]

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=Faxöe), 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 (Požaryska, 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.

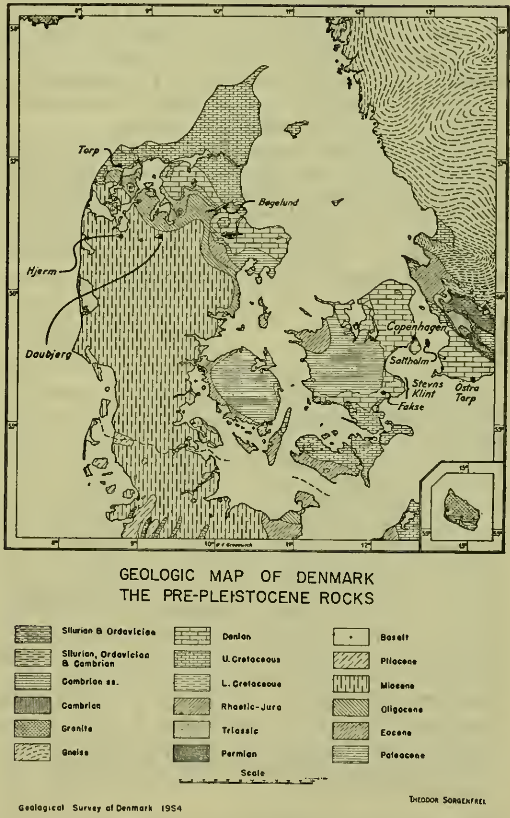

Figure 22.—Geological map of Denmark and south Sweden (by Th. Sorgenfrei), showing the location of the exposures mentioned in the text.

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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 *Globigerinae* 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).

STAGES	LITHOLOGY		LOCALITIES	TYLOCIDARIS ZONES
Selandian	glauconitic clay silt and cgl + 6 m.		Copenhagen	no Tylocidaris
	minor (?) hiatus			
Danian	Danskekalk formation	Calcarenite with chert. 30-50 m.	Copenhagen Saltholm	T. vexilifera Schlüter
		minor hiatus		
		Bryozoan reef ls. with chert; locally coral reef ls. + 66 m.	Fakse, Stevns Klint	T. brünnichi Ravn T. abildgaardi Ravn T. ödumi Brünnich Nielsen
		minor hiatus		
		Calcilutite with marl at base, c. ½ m.	Stevns Klint	no Tylocidaris
	major hiatus			
Maestrichtian	White chalk with chert. + 20 m.		Stevns Klint	T. baltica Schlüter

FIGURE 23.—Composite section through the Danian stage of east Denmark (adapted from A. Rosenkrantz, 1937, p. 201; only the more important localities are listed).

Biostratigraphy

A few remarks on the planktonics of the Danian stage of Sweden have been published by Munthe (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 *Globigerinae* which in the Tethys area commonly occurs between the *Globotruncana* assemblage of undoubted Maestrichtian age and the *Globigerina-Globorotalia* assemblage of assumed Paleocene age (see also Z. Reiss (1952, 1954, 1955), J. Schweighauser (1953, p. 28), S. E. Nakkady (1955), Bettenstaedt and Wicher (1956, pp. 501, 514–515), and others). Bronnimann (1953) lists the following *Globigerina* species which he found in a sample of Danian coccolithic limestone from Daubjerg in northwest Denmark and which also occur in the Lizard Springs formation of Trinidad, B. W. I.: *G. pseudobulloides* Plummer, *G. triloculinoides* Plummer, *G. linaperta* Finlay, *G. hornibrooki* Bronnimann, *G. stainforthi* Bronnimann, *G. daubjergensis* Bronnimann, and *G. compressa* Plummer (another sample from Hjerm contained only two poorly preserved species).

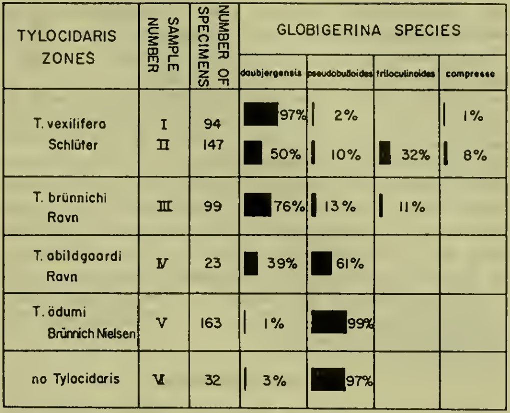
Globigerinae occur throughout the Danian stage, whereby the theory that the Danian sea was at one time transformed into a completely enclosed basin seems to have been refuted (Ravn, 1939, p. 23, and others). In the Danian of eastern Denmark, the only horizons in which *Globigerinae* are even fairly abundant are, however, the base of the zone of *Tylocidaris ödumi* 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, *Globotruncana* (s. l.), the only planktonics to occur in the type Danian are small *Guembelinae* and *Globigerinae*, 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 identifiable 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 insure 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. daubjergensis* Bronnimann, which in the type Danian is most abundant in the upper part of the stage. It occurs in the basal 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. triloculinodes* 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. triloculinoides* 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).



TYLOCIDARIS ZONES	SAMPLE NUMBER	NUMBER OF SPECIMENS	GLOBIGERINA SPECIES			
			daubjergensis	pseudobulloides	triloculinoides	compressa
T. vexilifera Schlüter	I	94	97%	2%		1%
	II	147	50%	10%	32%	8%
T. brünnichi Ravn	III	99	76%	13%	11%	
T. abildgaardi Ravn	IV	23	39%	61%		
T. ödumi Brünnich Nielsen	V	163	1%	99%		
no Tylocidaris	VI	32	3%	97%		

FIGURE 24.—Diagram illustrating the vertical distribution of *Globigerinae* within the Danian stage of east Denmark and South Sweden. *Sample numbers:* I, Östra Torp, Sweden; calcarenite, horizon with many sponges. II, Östra Torp, 2 meters below Sample I. III, Fakse; 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.)

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 group). 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 *Epistomina* (*Hoglundina*) *scalaris* Franke, *Lamarckina naheolensis* Cushman and Todd, *Ceratobulimina perplexa* (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 "*Allomorphina*" (i. e., *Quadrimorphina*) *halli* Jennings.

The question of the first appearance of *Globorotalia* (sensu lato) in relation to the Danian-Montian (or Danian-Sélandian) 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 (Sélandian) 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 (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 Danian 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

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Figured hypotypes are deposited in the U. S. National Museum collections, Washington, D. C. Additional hypotypes from all samples are in the Mineralogisk-Geologisk Museum, Copenhagen, Denmark.

Systematic Descriptions

Globigerina daubjergensis Bronnimann

Plate 30, Figures 1–2

Globigerina daubjergensis Bronnimann, Eclog. Geol. Helvetiae, vol. 45, No. 2, p. 340, fig. 1, 1953.

? *Globigerina daubjergensis* Reichel, Eclog. Geol. Helvetiae, vol. 45, No. 2, p. 344, fig. 1, h, i, j, l, 1953.

? *Globigerina triloculinoides* Plummer, Brotzen, Sveriges Geol. Undersökning, ser. C, No. 493, pp. 89–90, pl. 17, fig. 2, 1948.

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 volution, 4 subglobular chambers which increase gradually in size; the other, a low spire and 3 to 3½ 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 imperceptly 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 nevertheless refrained from referring the species to the (probably polyphyletic) genus *Globigerinoides*.

The occurence 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 *Tylocidaris brünnichi:* Fakse, 56. percent dextral (±5.7). Zone of *T. vexilifera:* 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 diameter of the test as follows: Basal Danian (Bögelund and Stevns Klint), 0.11–0.12 mm.; zone of *T. ödumi* (Stevns Klint), 0.21 mm.; zone of *T. abildgaardi* (Stevns Klint), 0.19–0.32 mm.; zone of *T. brünnichi* (Fakse), 0.19–0.27 mm.; zone of *T. vexilifera* (Torp, Östra Torp), 0.17–0.26 mm.

Globigerina pseudobulloides Plummer

Plate 30, Figures 6–8

Globigerina pseudobulloides, Plummer, Univ. Texas Bull. 2644, pp. 133–134; pl. 8, figs. 9a–c, 1926.

Remarks: The specimens from the Danskekalk formation have been compared with a large number of specimens of typical *G. pseudobulloides* (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 depressed 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 the Danian stage in Denmark and Sweden and does not occur in the underlying Maestrichtian White Chalk. In the basal part of the overlying Sélandian 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 Danian: Bögelund, 49. percent dextral (±4.9); north of Holtug quarry, Stevns Klint, 48. percent dextral (±9.). Zone of *Tylocidaris ödumi:* Höjerup, Stevns Klint, 56.9 percent dextral (±6.); Boesdal, Stevns Klint, 51. percent dextral (±3.9). Zone of *T. brünnichi:* Fakse, 76.9 percent dextral(±11.7).

Dimensions: Specimens range in greatest diameter of test as follows: Basal Danian (Bögelund), 0.16–0.29 mm.; zone of *Tylocidaris ödumi* (Stevns Klint), 0.29–0.34 mm. (gerontic specimens, 0.40 mm); ? zone of *T. ödumi* (Hjerm), 0.26–0.34 mm.; Zone of *T. abildgaardi* (Stevns Klint), 0.17–0.19 mm.; zone of *T. brünnichi* (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.

Non *Globigerina triloculinoides* Brotzen, Sveriges Geol. Undersökning, ser. C, No. 493, pp. 89–90, pl. 17, fig. 2, 1948.

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. trilocutinoides* 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. brünnichi:* 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 ödumi* (Hjerm), 0.20–0.27 mm.; zone of *T. brünnichi* (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* inasmuch as it possesses "a distinct umbilicus and umbilical apertures, covered by small lips on the base of the last chambers." This character has also 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 ödumi:* 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 ödumi* (Hjerm), 0.22–0.26 mm.; zone of *T. vexilifera* (Östra Torp), 0.16–0.30 mm.

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A Revision of the Foraminiferal Family Heterohelicidae

By Eugenia Montanaro Gallitelli[1]

Introduction

The family Heterohelicidae, as established by Cushman (1927a), is accepted at present by only a few authors (Colom, 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 Foraminifera 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 *Bolivinita* 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.

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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 hypotypes. 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 (=*Tubitextularia* Sulc), *Ventilabrella* Cushman (=*Planoglobulina* Cushman), *Bronnimannella* 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 (× 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

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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, columellar 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 *Guembelina,* 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 *Guembelina,* 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 *Pseudouvigerina* 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 *Spiroplectoides,* and the Gümbelininae, including *Gümbelina, Gümbelitria, 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 Gümbelinidae 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 Gümbelinidae, 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 Pokorný (1954) followed Glaessner's classification in general, both these authors place the family Gümbelinidae (with *Guembelina*) in the superfamily Rotaliidea, and place the family Heterohelicidae (with *Heterohelix*) in the superfamily Buliminidea. They continued to interpret *Bolivinita, Bolivinitella,* 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 *Guembelina.* Moreover, Kikoïne considered only six genera, leaving undiscussed the trio *Bolivinita, 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 "*Gümbelina,*" and "*Ventilabrella,*" and noted the biserial, rather than triserial, initial stage in *Eouvigerina.* Hofker (1951b) examined the structure of *Bolivinoides* and the "toothplate" in *Bolivinita,* discussing new morphologic elements. Stone (1946) described the inner structure of *Siphogenerinoides* in comparison with *Siphogenerina.*

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. pseudotessera* (=*G. pulchra* Brotzen). 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 *Racemiguembelina* is here demonstrated. This character is documented for each genus in the illustrations.

Loeblich (1951) demonstrated that *Eouvigerina* 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: *Bolivinella* (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 apertural 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 accelerated genus *Tubitextularia*, 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*, *Bolivinita* (the drawings by Hofker are discussed in the systematic description), and *Tappanina;* (3) a simple, open terminal aperture is present in the genera *Zeauvigerina* and *Trachelinella;* (4) a terminal aperture, reduced to an elliptical opening by internal tubercles or costae, is observed in *Bolivinitella* and *Plectofrondicularia;* and (5) a radiate cribrate aperture is observed in *Amphimorphina* and a typically cribrate aperture seems to be occasionally present in *Bolivinella*.

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 *Bolivinita* and, less carefully, in *Bolivinoides.* Stone (1946) illustrated the same character for *Siphogenerinoides*. In the present investigation an internal process is also demonstrated for *Eouvigerina* and *Pseudouvigerina*. *Bolivinoides* has no "plate" but a continuous tube arising from the first chamber. *Bolivinita* 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 misinterpreted by Stone. *Eouvigerina* 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 "guembelinoid" genus, as in *Tubitextularia* Sulc (=*Rectoguembelina* Cushman) where the first heterohelicoid stage is clearly visible. Five different morphological types are distinguishable:

- (1) triserial (subfamily Guembelitriinae)
  - (a) constantly triserial *Guembelitria*
  - (b) with proliferation *Guembelitriella*
- (2) biserial or planispiral (subfamily Heterohelicinae)
  - (a) with average proportion of thickness to breadth 1:2 *Heterohelix* *Pseudoguembelina* *Tubitextularia*
  - (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 *Gublerina* *Planoglobulina*
  - (d) planispiral and biserial, average proportion of thickness to breadth 1.5:1 to 4:1 *Pseudotextularia*

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 subcribrate.

The subfamily Plectofrondiculariinae 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 Plectofrondiculariinae as a distinct family, the Plectofrondiculariidae.

Bolivinita Cushman, *Bolivinoides* 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 Buliminidae 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 Plectofrondiculariidae 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.

Zeauvigerina Finlay, *Trachelinella* Montanaro Gallitelli, and *Bolivinitella* Marie are biserial, with apertural neck, without columellar process, and are still *incertae sedis,* perhaps near the Bolivininae, 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 seen 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.

Pseudouvigerina Cushman must be placed unquestionably in the Uvigerininae, as was done by Glaessner (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, spherical, 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 Guembelitriinae Montanaro Gallitelli, new subfamily

Test triserial; chambers globular; aperture basal, arched, simple.

Genus Guembelitria Cushman, 1933

Plate 31, Figures 1, 2

Gümbelitria Cushman, Contr. Cushman Lab. Foram. Res., vol. 9, p. 37, 1933.

Type species: *Guembelitria cretacea* Cushman, 1933, Upper Cretaceous Navarro (Maestrichtian), from pit of Seguin Brick and Tile Company, 0.8 mile south of McQueeny Station, Guadelupe 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

Guembelitriella TAPPAN, Journ. Paleontol., vol. 14, p. 115, 1940.

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 *Pseudoguembelina* Bronnimann and Brown.

Subfamily Heterohelicinae Cushman, 1927

Genus Heterohelix Ehrenberg, 1841

PLATE 31, FIGURES 5–20

Heterohelix EHRENBERG, Abhandl. Akad. Wiss. Berlin, p. 429, 1841.

Guembelina EGGER, Abhandl. Akad. Wiss. Munchen, Classe II, vol. 21, p. 31, 1889.

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 megalospheric 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 Heterohelicinae, with *Bolivinopsis* and *Nodoplanulis*—and included in the family the two subfamilies Bolivinitinae and Plectofrondiculariinae of Cushman, emended. *Guembelina* was placed in the superfamily Rotaliidea, family Guembelinidae, 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:

Name	*Specimens*	*Number coiled*	*Percent coiled*
G. globulosa	447	113	25. 3
G. globocarinata	1, 067	175	16.
G. carinata	4	2	50.
G. planata	5	4	80.
G. striata	130	5	3. 8
G. glabrans	6	2	30.
G. reussi	2, 000	12	0. 5
G. pseudotessera (=G. pulchra)	127	5	3. 9
G. cubensis	45		
G. ultimatumida	15		
G. venezuelana	42		
G. trinitatensis	1		
G. wilcoxensis	2		

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 *Tubitextularia*, *Pseudoguembelina*, *Gublerina* and *Racemiguembelina*. 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 superfamily, 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

Pseudotextularia RZEHAK, Verh. Naturf. Ver. Brünn, vol. 24, p. 8, 1886 (nomen nudum); (part), Ann. Naturhist. Hofmus., Wien., vol. 6, No. 1, p. 2, 1891.

Bronnibrownia MONTANARO GALLITELLI, Mem. Accad. Sci. Lett. Arti Modena, ser. 5, vol. 13, pp. 215, 220, 222 (nomen nudum), 1955.

Bronnimannella MONTANARO GALLITELLI, Contr. Cushman Found. Foram. Res., vol. 7, p. 35, 1956. Type species: *Guembelina plummerae* Loetterle, 1937; fixed by original designation.

TYPE SPECIES: *Cuneolina elegans* Rzehak, 1891. Fixed by subsequent monotypy, Rzehak, 1891. From the Upper Cretaceous (Alttertiär, Paläogen), glaukonitischer Tegelsand, from Bruderndorf, Niederösterreich, 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 appressed 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; Pokorný, 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. *acervulinoides* (Egger). Glaessner included within *Pseudotextularia* Rzehak, 1891, both the forms with and without proliferation, included therein by Rzehak, and also the genera *Planoglobulina* Cushman, 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 refigured.

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.

Kikoïne (1948, pl. 1, figs. 5 and 8) figured specimens of this genus from the Upper Cretaceous of Hendaye and Gan (Southern Pyrenees). He interprets the specimen of his figure 8 as a new variety of *Guembelina striata* (Ehrenberg), *G. striata* var. *deformis* Kikoïne, 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 Kikoïne 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

Pseudoguembelina BRONNIMANN and BROWN, Contr. Cushman Found. Foram. Res., vol. 4, pt. 4, p. 150, 1953.

TYPE SPECIES: *Guembelina excolata* 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 the accessory apertures are not the rule. Rare accessory apertures were also observed by Tappan in *Guembelitriella* Tappan, are not rare in *Ventilabrella*, and can also be observed in *Pseudotextularia elegans* (Rzehak). Consequently, as this character is not constant, with related pecularities 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* (*Guembelina*) *globulosa* and *H. planata*, and *H. pseudotessera* (=*H. pulchra* (Brotzen), 1936; see Montanaro Gallitelli, 1955b, p. 188). Consequently, the genus *Pseudoguembelina* 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 *Pseudoguembelina*, but are here considered to belong to *Heterohelix*.

Bronnimann and Brown (1953, p. 153) stated that "*Textularia striata* Ehrenberg is the only species of *Pseudogeumbelina* 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

Gublerina Kikoïne, Soc. Géol. France, Bull., ser. 5, vol. 18, fasc. 1–3, p. 26, 1948.

Type species: *Gublerina cuvillieri* Kikoïne, 1948 (= *Ventilabrella ornatissima* 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 pparatyes available.

Discussion: Comparison of the holotype and paratypes of *Ventilabrella ornatissima* Cushman and Church with the topotypes of *Gublerina cuvillieri*, in the National Museum collections, showed that the specific name *cuvillieri* is also invalid as it is a synonym of *Gublerina ornatissima* (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. ornatissima*).

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 ornatissima* 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. ornatissima* 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 Klasz, and *Gublerina* aff. *G. cuvillieri* Kikoine described by de Klasz (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 nonseptate 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 Klasz) examined for this study shows that following an early coiled stage there are eight chambers with a typical guembelinoid development (chambers inflated and sutures deep and narrow). The four mature chambers which follow become reniform 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 bicamerate end stage, not multicamerate 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 genetical position between *Heterohelix* and *Planoglobulina*.

Genus Planoglobulina Cushman, 1927

PLATE 32, FIGURES 10–13

Planoglobulina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, p. 77, 1927.

Ventilabrella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, p. 2, 1928.

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 Klasz is a typical *Gublerina*. The figure given by de Klasz (1953) seems to represent a real *Ventilabrella* (=*Planoglobulina*). However, examination of a paratype in the de Klasz 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 planispiral 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

Pseudotextularia RZEHAK (part), Ann. Naturhist. Hofmus. Wien, vol. 6, No. 1, p. 2, 1891.

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* Rzehak by various authors. As the emendation of the genus *Pseudotextularia*, earlier in the present paper, on the basis of its type species, *P. elegans* (Rzehak), 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 Rzehak's description (1891, p. 2) of *Cuneolina elegans*, and later both forms were figured by Rzehak (1895) as *Pseudotextularia varians*.

Because Rzehak (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 Rzehak. The biserial specimen of Rzehak (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 *fruticosa*) to be identical with *Pseudotextularia varians*. Thus the first valid name available for the proliferated form of Rzehak (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

Tubitextularia SULC, Vestník Stát. Geol. Českosl. Rep., vol. 5' p. 148, 1929.
Rectogümbelina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 8, p. 6, 1932.

TYPE SPECIES: *Pseudotextularia bohemica* 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 Glaessner (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 an aberrant 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

Bolivinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, p. 79, 1927.

TYPE SPECIES: *Textularia agglutinans* d'Orbigny var. *folium* Parker and Jones, 1865, from Recent shore sand, near Melbourne, 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 *Bolivinitella*, in the Bolivinitinae. Sigal maintains its placement in the Heterohelicidae (super family Buliminidea). Pokorný 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 *Bolivinita* and *Bolivinitella*, as all the three genera "sautent 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 × 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 *Bolivinita* and *Bolivinitella*.

Genus Plectofrondicularia Liebus, 1903

PLATE 33, FIGURES 10,11

Plectofrondicularia LIEBUS, Jahrb. Geol. Reichs., vol. 52, p. 76, 1903.

TYPE SPECIES: *Plectofrondicularia concava* Liebus, 1903, Tertiary (upper glass sand) Promberger Schichten?, from Probe 69, southeast of Heimberg bei Meisbach, 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 *Pletofrondicularia* 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.

Glaessner (1945) placed *Plectofrondicularia* in his superfamily Buliminidea, family Buliminidae, subfamily Plectofrondiculariinae, and in this was followed by Pokorný (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

Amphimorphina NEUGEBOREN, Verh. Mitth. Siebenbürgischer Ver. Naturw., vol. 1, p. 125, 1850.

Nodomorphina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, p. 80, 1927.

TYPE SPECIES: *Amphimorphina hauerina* Neugeboren, 1850, 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 cribrate 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 *Amphimorphina* 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 *Nodomorphina* 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 *Amphimorphina* 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 *Amphimorphina* also). But most specimens of *Amphimorphina* 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, Figures 14–16

Bolivinoides Cushman, Contr. Cushman Lab. Foram. Res., vol. 2, p. 89, 1927.

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 Hiltermann and 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. Hofker (1952) noted the existence of a "toothplate" and attempted a reconstruction of the internal structure of the test.

The present work partially confirms Hofker's results, and gives some new structural information. The biseriality of the early stage is confirmed. Hiltermann and Koch (1950, p. 598) suppose that "der scheinbar planispirale Aufbau der Embryonal-kammern findet sich nach unseren 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 Hofker. In the specimens observed, the aperture is proportionally narrower and more reduced than was figured by Hiltermann and 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 columella, 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).

Hiltermann and Koch (1950, p. 597) described the internal structure as follows: "jede Kammer überdeckt die darunter liegende mit ihrer aussen etwas herabgezogenen Kammerbasis; die Einzelkammern besitzen eine Anzahl zu ihrer Basis rechtwinklig angeordnete Kammervertsätze, 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 Rippenskulptur sogar unsichtbar. . . . Kammerraum langlich halbmondformig; Anfangsteil verjüngt, manchmal etwas verdreht."

Hofker (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 ("Überlappungen"), 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 watersi* Cushman as an extreme form of *Bolivinoides.* However, *B. watersi,* 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

Bolivinita CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, p. 90, 1927.

TYPE SPECIES: *Textilaria 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 megalospheric 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 sutural 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, Eouvigerina 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

Tappanina MONTANARO GALLITELLI, Mem. Accad. Sci. Lett. Arti Modena, ser. 5, vol. 13, p. 18, 1955.

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. Sutures 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 (1946, 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 *Eouvigerina 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. costerifera* (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. crawfordenis* 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 excavata* 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

Eouvigerina Cushman, Contr. Cushman Lab. Foram. Res., vol. 2, p. 4, 1926.

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, subtriangular 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 columellar 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 excavata* 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 subtriangular 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, subrectangular 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 columellar proccess.

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

Siphogenerinoides Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, p. 63, 1927.

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 megalospheric 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 diametrally 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 megalospheric forms. No specimen showed a triserial beginning. The biserial stage is very short in the megalospheric 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

Zeauvigerina Finlay, Trans. Proc. Roy. Soc. New Zealand, vol. 68, p. 541, 1939.

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 *Eouvigerina* Cushman on the complete biseriality of the new genus, compared to the "coiled" first stage and the "triserial" arrangement of the mature stage in *Eouvigerina*. The critical review made by Loeblich (1951) recognized that neither coiled early stage nor triseriality are present in *Eouvigerina*. Consequently, Loeblich considered *Zeauvigerina* a synonym.

The present investigation revealed the presence of a toothplate in *Eouvigerina*. 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 *Eouvigerina*, 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

Trachelinella Montanaro Gallitelli, Contr. Cushman Found. Foram. Res., vol. 7, p. 38, pl. 7, figs. 8–10, 1956.

Trakelina Montanaro Gallitelli, Mem. Accad. Sci. Lett. Arti Modena, ser. 5, vol. 13, p. 5 (nomen nudum), 1955.

Type species: *Bolivina watersi* 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. Sutures 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*" *watersi* 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 biserial 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 refigured.

Genus Bolivinitella Marie, 1941

Plate 34, Figures 14–17

Bolivinitella Marie, 1941, Mem. Mus. Hist. Nat., new ser., vol. 12, p. 189.

Type species: *Bolivinita eleyi* Cushman, 1927, Upper Cretaceous Brownstown marl, 8.1 miles west of Arkadelphia, 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 cribrate.

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

Tosaia TAKAYANAGI, Inst. Geol. Paleontol. Sendai, Short Paper No. 5, p. 30, 1953.

TYPE SPECIES: *Tosaia hanzawai* 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

Pseudouvigerina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, p. 81, 1927.

TYPE SPECIES: *Uvigerina cristata* Marsson, 1878, Cretaceous of Rügen Island (Pomerania). Figured hypotype from the Upper Cretaceous, Gerhardtsreuter Schichten (Maestrichtian), 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 *Angulogerina* with *Pseudouvigerina* is at present only suspected. Sigal (1952, p. 219) follows Galloway in stating that *Angulogerina* 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*, *Angulogerina* would become a junior synonym of *Pseudouvigerina*.

Class Crustacea

Order Isopoda ?

Genus Nodoplanulis Hussey, 1943

PLATE 34, FIGURE 23

Nodoplanulis HUSSEY, Journ. Paleontol., vol. 17, p. 166, 1943.

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. Chace, 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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Planktonic Foraminifera from the Eocene Navet and San Fernando Formations of Trinidad, B. W. I.

By Hans M. Bolli[1]

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 *Hantkenina*, *Cribrohantkenina*, *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 Hantkeninae and Cribrohantkeninae 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.

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Mr. R. A. Pallant, senior draftsman of The Trindad 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.

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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 Foraminifera, 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 *Hantkenina* 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 *Globigerapsis 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 *Globigerapsis 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:

Globigerapsis semiinvoluta zone	Hospital Hill formation
Truncorotaloides rohri zone	
Porticulasphaera mexicana zone	Penitence Hill marl
Globorotalia lehneri zone	Fitt Trace marl–Navet River marl
Globigerapsis kugleri zone	Dunmore Hill marl–Nariva River marl
Hantkenina aragonensis zone	Friendship Quarry marl
Globorotalia palmerae zone	

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 12¾ 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 12¾, 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).

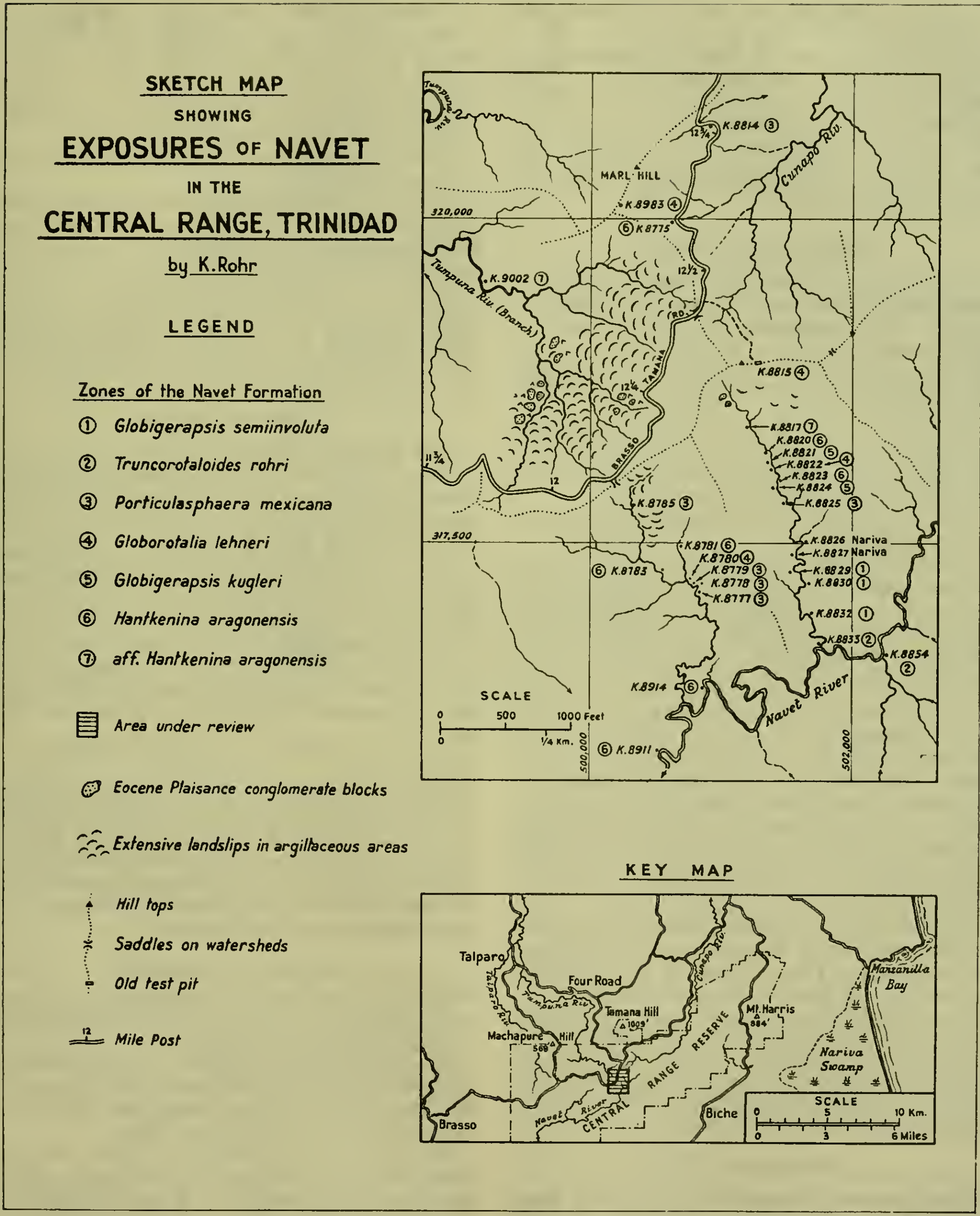

FIGURE 25.—Exposures of the Navet formation in the Central Range, Trinidad, B.W.I.

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*" *higginsi* 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 teak plantation, about 100 yards north of the road, south Trinidad (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 bullbrooki* 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 akersi* 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:486945 links), samples Gunther 7865, 7200–7204 (Shell Trinidad) (Nariva River marl of Cushman and Renz, 1948); in small ravine between mileposts 12¼ 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 index* (Finlay), *Globigerapsis kugleri* Bolli, Loeblich, and Tappan, *Globorotalia lehneri* Cushman and Jarvis, and *Globorotalia centralis* Cushman and Bermudez make their first appearance in the *Globigerapsis kugleri* zone, while several species, e. g., *Globorotalia aragonensis* Nuttall, *Globorotalia broedermanni* Cushman and Bermudez, *Globigerina boweri* Bolli, new species, and "*Globigerinoides*" *higginsi* 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 17¼, eastern Trinidad (coordinates N:311300 links; E:528110 links), type sample KS 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 1285). (Navet River marl of Cushman and Renz, 1948). In small ravines 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 12¾ (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 broedermanni* Cushman and Bermudez do not extend into this zone.

Porticulasphaera mexicana Zone

Type locality: Outcrop in road cut near milepost 12¾ 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

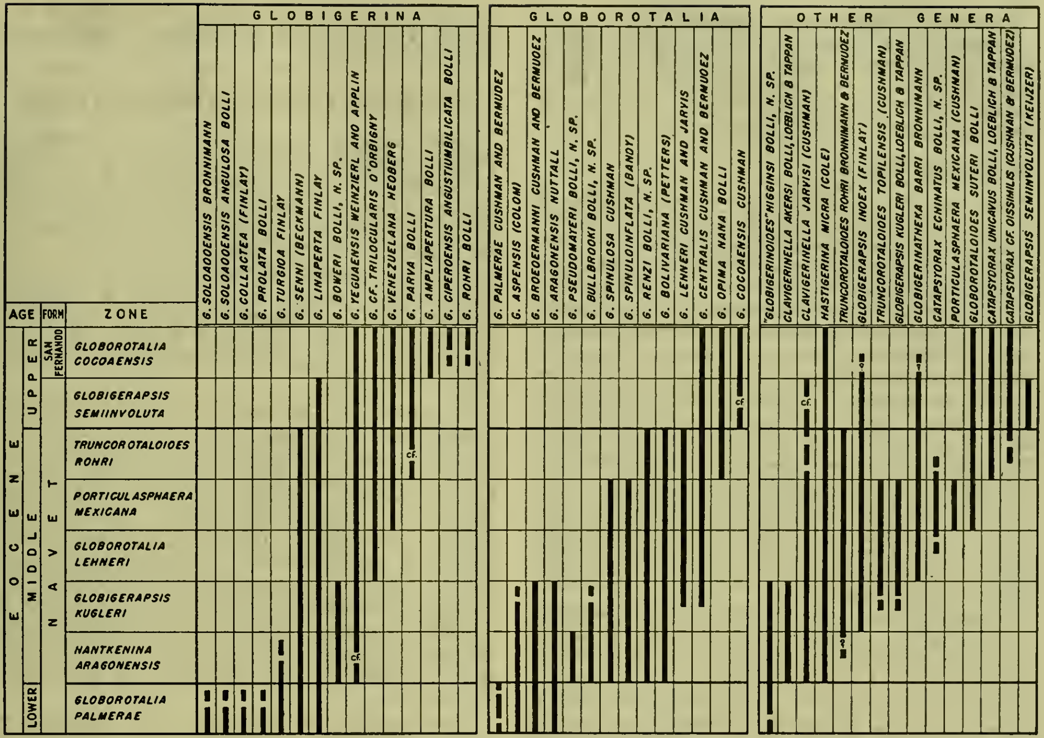

FIGURE 26.—Distribution of planktonic Foraminifera in the Eocene Navet and San Fernando formations of Trinidad, B.W.I.

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 8581, 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 kugleri* 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:502260 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 index* (Finlay) and *Globigerinatheka 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 northeast from small bridge, 0.2 miles south of Kings Wharf (coordinates N:234850 links; E:355650 links), type sample Rz 75 (TTOC 23130) (Hospital Hill formation of Cushman and Renz).

COTYPE LOCALITIES: In small ravine between mileposts 12¼ and 12½ of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25), samples K 8829, 8830, 8832 (TTOC 177769, 177770, 177771).

Lithology: Yellowish-grey, nodular marl.

Remarks: The *Globigerapsis semiinvoluta* zone is characterized by the zonal marker, and by the absence of the middle Eocene spinose *Truncorotaloides rohri* 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 benthonic marker Foraminifera such as *Hantkenina*, *Globorotalia cocoaensis* Cushman, *Globorotalia centralis* Cushman and Bermudez, *Bulimina jacksonensis* Cushman etc. 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 cocoaensis 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 238769).

Lithology: Dark grey-brown calcareous silt.

Remarks: The zone is characterized by the presence of *Globorotalia cocoaensis* 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*, *Globigerinatheka*, and *Porticulasphaera* obviously represent a related group. Transitional specimens indicate that *Globigerapsis kugleri* Bolli, Loeblich, and Tappan branched off from the long-ranging *Globigerapsis index* (Finlay) and later developed into *Porticulasphaera mexicana* (Cushman). *Globigerinatheka 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*, *Globigerinatheka*, and *Porticulasphaera* 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. rohri* Bronnimann and Bermudez and *T. topilensis* (Cushman) in the *Globigerapsis kugleri* to *Truncorotaloides rohri* zones is over 90 percent.

The strong preference for sinistral coiling (over 90 percent) shown by *Globorotalia aragonensis* Nuttall and *Globorotalia broedermanni* 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.

Globorotalia lehneri Cushman and Jarvis, together with *Globorotalia spinulosa* Cushman and *Globorotalia spinuloinflata* (Bandy), belongs to a group of *Globorotalia* species that does not develop a distinct preference for one coiling direction. This is rather exceptional, because it is known that most *Globorotalia* species from the upper Paleocene to the Recent, especially the more highly developed angular and keeled forms, do develop a distinct preference for either sinistral or dextral coiling (Bolli, 1950, 1957a).

A number of specimens of *Globorotalia centralis* Cushman and Bermudez, from the *Globigerapsis kugleri* zone to the *Globorotalia cocoaensis* zone, were checked for the direction of coiling. During the early stage of evolution in the *Globigerapsis kugleri* and *Globorotalia lehneri* zones specimens coiled at random, but a 60–80 percent preference for sinistral coiling was found in the *Porticulasphaera mexicana*, *Globigerapsis semiinvoluta* and *Globorotalia cocoaensis* zones. The preference for sinistral coiling in *Globorotalia cocoaensis* Cushman, a species thought to have developed from *Globorotalia centralis*, is probably over 80 percent.

Forty-four planktonic Foraminifera species and subspecies belonging to eleven genera are recorded though full descriptions are given only for the six new species. Synonymy lists are restricted to the original description and to literature concerning the Caribbean, the Gulf Coast region, Central America and northern South America. The species of the genera *Hantkenina*, *Cribrohantkenina*, and *Chiloguembelina* have previously been described in detail and are left out of this paper.

The range of many of the species is not restricted to the Navet and San Fernando formations. Several originate in the Paleocene-lower Eocene Lizard Springs formation while some continue into the Oligocene-Miocene Cipero formation. However, the complete range as observed in Trinidad is given in the notes on each species.

For the description and stratigraphic distribution of the Chiloguembelinae and related genera in the Navet and San Fernando formations reference is made to Beckmann (1957).

Bronnimann (1950a,b) described the species of the genera *Hantkenina* and *Cribrohantkenina* fully but discussed their stratigraphic distribution only in a generalized way. Within the new zonation the range of some of the better known species was found to be as follows:

Hantkenina aragonensis Nuttall, a species closely related to *H. mexicana* Cushman and *H. lehneri* Cushman and Jarvis, is restricted to the zone of the same name. A probable descendant of *Hantkenina aragonensis* is *H. dumblei* Weinzierl and Applin which succeeds it in the *Globigerapsis kugleri* zone. *Hantkeninae* of the *longispina-alabamensis* type follow *H. dumblei* in the higher zones of the Navet formation. In the San Fernando formation the *Hantkeninae* have a tendency to become smaller. This could either be an indication of a gerontic stage or be due to less favorable ecologic conditions. *Hantkenina primitiva* Cushman and Jarvis, originating in the uppermost Navet, is the most abundant *Hantkenina* species in the San Fernando formation where it occurs with *Cribrohantkenina bermudezi* (Thalmann).

Systematic Descriptions

Family Hantkeninidae Cushman, 1927

Subfamily Hastigerininae Bolli, Loeblich, and Tappan, 1957

Genus Hastigerina Thomson

Hastigerina micra (Cole)

PLATE 35, FIGURES 1a–2b

Nonion micrus COLE, Bull. Amer. Paleontol., vol. 14, No. 51, p. 22, pl. 5, fig. 12, 1927.

Globigerinella micra (Cole), GLAESSNER, Publ. Lab. Paleontol. Moscow Univ., vol. 1, fasc. 1, p. 30, pl. 1, figs. 4a–b, 1937.

STRATIGRAPHIC RANGE: *Hantkenina aragonensis* zone, Navet formation to *Globorotalia cocoaensis* zone, San Fernando formation.

LOCALITY: Figured hypotypes (USNM P5698a,b) 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 (TTOC 215782). The block is no longer existant.

REMARKS: With the exception of the *Globorotalia palmerae* zone, *Hastigerina micra* (Cole) occurs throughout the Navet and San Fernando formations but does not continue into the Oligocene-Miocene Cipero formation. Glaessner (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

Clavigerinella akersi BOLLI, LOEBLICH, and TAPPAN, U. S. Nat. Mus. Bull. 215, p. 30, pl. 3, figs. 5a-b, 1957.

Hastigerinella eocanica Nuttall, CUSHMAN AND RENZ, Cushman Lab. Foram. Res., Spec. Publ. 24, p. 38, pl. 7, fig. 17, 1948.—WEISS, Micropaleontology, vol. 1, No. 4, p. 309, pl. 2, figs. 11, 13, 1955.

STRATIGRAPHIC RANGE: *Hantkenina aragonensis* zone to *Globigerapsis kugleri* zone, Navet formation.

LOCALITY: Figured topotype (USNM P5699) from the *Hantkenina aragonensis* zone, Navet formation; in small ravine between mileposts 12¼ and 12½ of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25). Sample HGK 8820 (TTOC 177760).

Remarks: *Clavigerinella 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.

Petters (1954, p. 40) described *Hastigerinella columbiana* 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 *Clavigerinella 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 *Clavigerinella 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 eocanica* Nuttall belongs to *Clavigerinella*, although the aperture is not preserved on the types figured by Nuttall.

Clavigerinella jarvisi (Cushman)

Plate 35, Figures 5–6

Hastigerinella jarvisi Cushman, Cushman Lab. Foram. Res., vol. 6, p. 18, pl. 3, figs. 8–11, 1930.

Hastigerinella eocanica var. *aragonensis* Nuttall, Journ. Paleontol., vol. 4, No. 3, p. 290, pl. 24, figs. 16, 17, 1930.

Stratigraphic range: *Hantkenina aragonensis* zone to *Globigerapsis semiinvoluta* zone, Navet formation.

Locality: Figured hypotypes (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 4347, KS 233 (TTOC 1285, 18360).

Family Orbulinidae Schultze, 1854

Subfamily Globigerininae Carpenter, 1862

Genus Globigerina d'Orbigny, 1826

Globigerina soldadoensis Bronnimann

Plate 35, Figures 9a–c

Globigerina soldadoensis Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 9–11, pl. 1, figs. 1–9, 1952.—Bolli, U. S. Nat. Mus. Bull. 215, p. 71, pl. 16, figs. 7–12, 1957.

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, Malgretout Estate, west of Princes Town, south Trinidad (coordinates N:235390 links; E:398620 links); sample KTO 145 (TTOC 143701).

Globigerina soldadoensis angulosa Bolli

Plate 35, Figures 8a–c

Globigerina soldadoensis angulosa Bolli, U. S. Nat. Mus. Bull. 215, p. 71, pl. 16, figs. 4–6, 1957.

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

Locality: Figured hypotype (USNM P5703) from the *Globorotalia palmerae* zone, Navet formation; same locality as given for *Globigerina soldadoensis* Bronnimann; sample KTO 145 (TTOC 143701).

Remarks: Transitional forms indicate that *Globigerina soldadoensis angulosa* is likely to be the ancestor of *Globorotalia aspensis* (Colom).

Globigerina collactea (Finlay)

Plate 35, Figures 18a–b

Globorotalia collactea Finlay, Trans. Proc., Roy. Soc. New Zealand, vol. 69, p. 37, pl. 29, figs. 164–165, 1939.

Globigerina collactea (Finlay), Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 13–14, pl. 1, figs. 13–15, 1952.—Bolli, U. S. Nat. Mus. Bull. 215, p. 72, pl. 15, figs. 21–23, 1957.

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

Locality: Figured hypotype (USNM P5710) from the *Globorotalia palmerae* zone, Navet formation; same locality as given for *Globigerina soldadoensis* Bronnimann; sample KTO 145 (TTOC 143701).

Globigerina prolata Bolli

Plate 35, Figures 7a–b

Globigerina prolata Bolli, U. S. Nat. Mus. Bull. 215, p. 72, pl. 15, figs. 24–26, 1957.

Globigerina pseudobulloides Plummer, Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 21–23, pl. 3, figs. 7–9, 1952.

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

Locality: Figured hypotype (USNM P5702) from the *Globorotalia palmerae* zone, Navet formation; same locality as given for *Globigerina soldadoensis* Bronnimann; sample KTO 145 (TTOC 143701).

Globigerina turgida Finlay

Plate 35, Figures 13a–c

Globigerina turgida Finlay, Trans. Proc., Roy. Soc. New Zealand, vol. 69, p. 125, 1939.—Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 19–21, pl. 3, figs. 1–3, 1952.—Bolli, U. S. Nat. Mus. Bull. 215, p. 73, pl. 15, figs. 3–5, 1957.

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

Locality: Figured hypotype (USNM P5706) from the *Globorotalia palmerae* zone, Navet formation; same locality as given for *Globigerina soldadoensis* Bronnimann; 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

Globigerina linaperta FINLAY, Trans. Proc. Roy. Soc. New Zealand, vol. 69, p. 125, pl. 13, figs. 54–57, 1939.—BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 16–17, pl. 2, figs. 7–9, 1952.—BOLLI, U. S. Nat. Mus. Bull. 215, p. 70, pl. 15, figs. 15–17, 1957.

STRATIGRAPHIC RANGE: *Globorotalia pseudomenardii* zone, Lizard Springs formation to *Globigerapsis semiinvoluta* zone, San Fernando formation.

LOCALITY: Figured hypotype (USNM P5715) from the *Porticulasphaera mexicana* zone, Navet formation; Brasso-Tamana Road, near milepost 12¾, Central Range (see text-fig. 25); sample K 8814 (TTOC 177755).

Globigerina boweri Bolli, 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 *Globigerapsis kugleri* zone, Navet formation. Largest diameter of holotype 0.4 mm.

STRATIGRAPHIC RANGE: *Hantkenina aragonensis* zone to *Globigerapsis 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 12¼ and 12½ 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 cocoaensis* zone, San Fernando formation.

LOCALITY: Figured hypotype (USNM P5708) from the type locality of *Globigerapsis 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 3–3½ 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. triloculariis 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 cocoaensis* zone, San Fernando formation; Soldado Rock Island (see Kugler, 1938); sample K3741 (TTOC 190838).

Globigerina venezuelana Hedberg

Plate 35, Figures 16a–17

Globigerina venezuelana Hedberg, Journ. Paleontol., vol. 11, No. 8, p. 681, pl. 92, figs. 7a–b, 1937.—Cushman and Stainforth, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 67, pl. 12, figs. 13a–b, 1945.—Bermudez, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 280, pl. 21, figs. 39–40, 1949.—Bolli, U. S. Nat. Mus. Bull. 215, p. 110, pl. 23, figs. 6a–8b, 1957.

Globigerina conglomerata Schwager, Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 391, pl. 25, figs. 6–9, 1953.

Stratigraphic range: *Porticulasphaera mexicana* zone, Navet formation to *Globorotalia menardii* zone, Lengua formation, probably continuing into younger beds.

Locality: Figured hypotypes (USNM P5709a–b) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina micra* (Cole) (p. 161); sample Hg 8581 (TTOC 215782).

Globigerina parva Bolli

Plate 36, Figures 7 a–c

Globigerina parva Bolli, U. S. Nat. Mus. Bull. 215, p. 108, pl. 22, figs. 14 a–c, 1957.

?*Globigerina ouachitaensis* Howe and Wallace, Geol. Surv. Bull. Louisiana Dep. Conserv., No. 2, p. 74, pl. 10, figs. 10 a–b, 1932.

Stratigraphic range: *Truncorotaloides 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 ouachitaensis* Howe and Wallace, described from the upper Eocene is probably very close to this species.

Globigerina ampliapertura Bolli

Plate 36, Figures 8 a–c

Globigerina ampliapertura Bolli, U. S. Nat. Mus. Bull. 215, p. 108, pl. 22, figs. 4a–7b, 1957.

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 gerontic stage of the *G. centralis-G. cocoaensis* strain, reverting before its extinction to a globigerinid form and also to random coiling.

Globigerina ciperoensis angustiumbilicata Bolli

Plate 36, Figures 6a–b

Globigerina ciperoensis angustiumbilicata Bolli, U. S. Nat. Mus. Bull. 215, p. 109, pl. 22, figs. 12a–13c, 1957.

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

Globigerina rohri Bolli, U. S. Nat. Mus. Bull. 215, p. 109, pl. 23, figs. 1a–4b, 1957.

Globigerina venezuelana Hedberg, Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 392, pl. 10, figs. 12–13, 1953.

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" higginsi 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 sutural 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 Nariva 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*" *higginsi*, 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*" *higginsi* from *Globigerinoides*. It has been thought that "*Globigerinoides*" *higginsi* 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

Globigerinoides index Finlay, Trans. Proc., Roy. Soc. New Zealand, vol. 69, pt. 1, p. 125, pl. 14, figs. 85–88, 1939.

Stratigraphic range: *Globigerapsis kugleri* zone to *Globigerapsis 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 12¼ and 12½ of the Brasso–Tamana Road and the Navet River, Central Range (see text-fig. 25); sample HGK 8824 (TTOC 177764). Figured hypotypes (figs. 16–18; USNM P5723–5725) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina micra* (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 umbilicus and in higher arched sutural supplementary apertures.

Globigerapsis kugleri Bolli, Loeblich, and Tappan

Plate 36, Figures 21a–b

Globigerapsis kugleri Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 34, pl. 6, figs. 6a–b, 1957.

Globigerinoides mexicana (Cushman), Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 393, pl. 25, figs. 15, 17, 1953.

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

Globigerinoides semiinvolutus Keijzer, Univ. Utrecht Geogr. Geol. Med., Phys.-Geol. Reeks, ser. 2, No. 6, p. 206, pl. 4, figs. 58a–e, 1945.

Globigerinoides index Finlay, Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 392, pl. 25, fig. 14, 1953.

Globigerapsis semiinvoluta (Keijzer), Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 34, pl. 6, figs. 7a–c, 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.

Globigerina mexicana Cushman, Contr. Cushman Lab. Foram. Res., vol. 1, No. 3, p. 6, pl. 1, figs. 8a–b, 1925.—Weiss, Micropaleontology, vol. 1, No. 4, p. 309, pl. 2, fig. 15, 1955.

Globigerinoides mexicana (Cushman), Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, pp. 393–394, pl. 25, fig. 19, 1953.

Porticulasphaera mexicana Bolli, Loeblich, and Tappan, U. S. Nat. Mus. Bull. 215, p. 35, pl. 6, figs. 8, 9a–b, 1957.

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 micra* (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. unicavus* 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 bulla, 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 unicavus Bolli, Loeblich, and Tappan

PLATE 37, FIGURES 7a–b

Catapsydrax unicavus BOLLI, LOEBLICH, and TAPPAN. U. S. Nat. Mus. Bull. 215, p. 37, pl. 7, figs. 9a–c, 1957.

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 *Globigerapsis 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 bullae have commonly only two and more rarely only one infralaminal accessory aperture, whereas the bullae of Oligocene-lower Miocene specimens often display three or four accessory apertures. *C. unicavus* Bolli, Loeblich, and Tappan, whose bulla 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

Globigerinatheka barri BRONNIMANN, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1, pp. 27–28, text figure 3a, 1952.—BOLLI, LOEBLICH, and TAPPAN, U. S. Nat. Mus. Bull. 215, p. 38, pl. 7, figs. 12a–c, 1957.

Globigerinoides mexicana (Cushman), BECKMANN, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 393, pl. 25, fig. 16, 1953.

STRATIGRAPHIC RANGE: *Globorotalia lehneri* zone to *Globigerapsis 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

Globorotaloides suteri BOLLI, U. S. Nat. Mus. Bull. 215, p. 117, pl. 27, figs. 9a–13c, 1957.

STRATIGRAPHIC RANGE: *Porticulasphaera mexicana* zone, Navet formation to *Globigerinatella insueta* zone, Cipero formation.

LOCALITY: Figured hypotypes (USNM P5734a-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

Globorotalia palmerae CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 13, p. 26, pl. 2, figs. 51–53, 1937.—BERMUDEZ, Mem. Soc. Cubana Hist. Nat., vol. 11, p. 167, 1937; vol. 12, p. 11, 1938.—CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, pt. 2, pp. 31–32, pl. 6, figs. 4–6, 1949.

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 aspensis (Colom)

PLATE 37, FIGURES 18a–c

Globigerina aspensis COLOM, Bol. Inst. Geol. y Min. España, vol. 66, pp. 151–54, pl. 3, figs. 1–5, pl. 4, figs. 1–3, 1954.

STRATIGRAPHIC RANGE: *Globorotalia palmerae* zone to *Globigerapsis kugleri* zone, Navet formation.

LOCALITY: Figured hypotype (USNM P5738) from the *Globorotalia palmerae* zone, Navet formation; same locality as given for *Globigerina soldadoensis* Bronnimann (p. 162); sample KTO 145 (TTOC 143701).

REMARKS: The position of the apertures in the type specimens of *Globigerina aspensis* 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

Globorotalia (Truncorotalia) brödermanni CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, pt. 2, p. 40, pl. 7, figs. 22–24, 1949.

Globorotalia broedermanni CUSHMAN and BERMUDEZ. Bolli, U. S. Nat. Mus. Bull. 215, p. 80, pl. 19, figs. 13–15, 1957.

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* Bronnimann (p. 162); sample KTO 145 (TTOC 143701).

Globorotalia aragonensis Nuttall

PLATE 38, FIGURES 1a–c

Globorotalia aragonensis NUTTALL, Journ. Paleontol. vol. 4, No. 3, p. 288, pl. 24, figs. 6–8, 10–11, 1930.—CUSHMAN and RENZ, Cushman Lab. Foram. Res., Spec. Publ. 24, p. 40, pl. 8, figs. 1–2, 1948.—BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 284, pl. 22, figs. 33–35, 1949.—BOLLI, U. S. Nat. Mus. Bull. 215, p. 75, pl. 18, figs. 7–9, 1957.

Globorotalia (Truncorotalia) aragonensis Nuttall. CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, pt. 2, pp. 38–39, pl. 7, figs. 13–15, 1949.

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 trochospiral; 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 12¼ 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 bullbrooki Bolli, new species

PLATE 38, FIGURES 4a–5c

Shape of test on spiral side almost flat or low trochospiral, 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 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 bullbrooki*, 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 (coordinates N:314350 links; E:487360 links); paratype from upper part of small ravine between mileposts 12¼ and 12½ of the Brasso-Tamana Road and Navet River (see text-fig. 25); samples K 9077, 8817 (TTOC 178166, 177758).

Remarks: *Globorotalia bullbrooki*, new species, is distinguished from *G. aspensis* (Colom) by its more subangular test and by the presence of 4 chambers in the last whorl instead of the 5–7 of that species.

Globorotalia crassata (Cushman), often referred to in publications, may be close to the new species. The single spiral view of the holotype given by Cushman (1925) is not sufficient for an accurate determination and comparison. *G. crassata* as figured by Cushman and Bermudez (1949) shows 5½ chambers in the last whorl as against the 4 commonly found in *G. bullbrooki*. *G. crassata* var. *densa* (Cushman) is described as differing from *G. crassata* in its more rounded compact form, rounded periphery, and in having only 4 chambers in the last formed coil instead of 5 or 6 as in the typical form. No figure was given by Cushman for this variety. On the basis of the scanty description alone it is not possible to compare it with *Globorotalia bullbrooki* or any other possibly synonymous Navet species.

Specimens found among the middle Eocene foraminiferal fauna of a Mid-Pacific core (see p. 169), are indistinguishable from *Globorotalia bullbrooki*, with the exception that they possess small sutural supplementary apertures on the spiral side, which are typical of the genus *Truncorotaloides*. It is likely that *G. bullbrooki* also possesses such accessory apertures which, however, cannot be seen due to the poor preservation, and should therefore be placed in the genus *Truncorotaloides*.

The species is named for Mr. J. A. Bullbrook, geologist and archeologist, Trinidad.

Globorotalia spinulosa Cushman

Plate 38, Figures 6a–7c

Globorotalia spinulosa Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, p. 114, pl. 23, figs. 4a–c, 1927.—Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 397, pl. 26, fig. 13, 1953.

Globorotalia (*Truncorotalia*) *spinulosa* Cushman, Cushman and Bermudez, Cushman Lab. Foram. Res., vol. 25, pt. 2, pp. 40–41, pl. 8, figs. 1–3, 1949.

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 ravine between mileposts 12¼ and 12½ of the Brasso-Tamana Road and the Navet River, Central Range (see text-fig. 25); sample K8820 (TTOC 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

Globigerina spinuloinflata Bandy, Bull. Amer. Paleontol., vol. 32, No. 131, p. 122, pl. 23, figs. 1a–c, 1949.

Globorotalia crassula Cushman and Stewart, Beckmann, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 397, pl. 26, fig. 12, 1953.

?*Globorotalia crassata* var. *densa* (Cushman), Cushman and Renz, Cushman Lab. Foram. Res., Spec. Publ. 24, p. 40, pl. 8, figs. 7, 8, 1948.

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 (TTOC 215782).

Remarks: The figure of the holotype of *Globigerina spinuloinflata* Bandy shows a subangular test with an interiomarginal, umbilical-extraumbilical 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 3a–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-extraumbilical. 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 (TTOC 215782). The block is no longer existant.

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 (Petters)

PLATE 37, FIGURES 14a–16

Globigerina wilsoni Cole subsp. *bolivariana* PETTERS, Contr. Cushman Found. Foram. Res., vol. 5, pt. 1, p. 39, pl. 8, figs. 9a–c, 1954.—WEISS, Micropaleontology, vol. 1, No. 4, p. 309, pl. 2, figs. 6–8, 1955.

Globigerina wilsoni Cole, WEISS, Micropaleontology, vol. 1, No. 4, p. 309, pl. 2, figs. 22–23, 1955.

STRATIGRAPHIC RANGE: *Hantkenina aragonensis* zone to *Truncorotaloides rohri* zone, Navet formation.

LOCALITY: Figured hypotypes (USNM P5736a–c) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina micra* (Cole) (p. 161); sample Hg 8581 (TTOC 215782).

REMARKS: *Globorotalia bolivariana* (Petters), originally described as subspecies of *Globigerina wilsoni* Cole, displays a distinctly interiomarginal, umbilical-extraumbilical aperture; the very narrow slit often extends towards the spiral side. The species differs from the *Globorotalia opima* Bolli in being more involute (chambers of the earlier whorls are almost invisible) and in being almost planispiral. *G. bolivariana* is restricted to the middle Eocene while *G. opima* ranges from the uppermost middle Eocene to the Oligocene.

Globorotalia lehneri Cushman and Jarvis

PLATE 38, FIGURES 9a–13

Globorotalia lehneri CUSHMAN and JARVIS, Contr. Cushman Lab. Foram. Res., vol. 5, p. 17, pl. 3, figs. 16a–c, 1929.—CUSHMAN and RENZ, Cushman Lab. Foram. Res., Spec. Publ. 24, p. 40, pl. 8, figs. 3–4, 1948.—CUSHMAN and BERMUDEZ, Cushman Lab. Foram. Res., vol. 25, pt. 2, p. 32, pl. 6, figs. 7–9, 1949.

STRATIGRAPHIC RANGE: *Globigerapsis kugleri* zone (probably upper part only) to *Truncorotaloides rohri* zone, Navet formation.

LOCALITY: Figured hypotypes from the *Porticulasphaera mexicana* zone, Navet formation: (figs. 9, 10, 12, 13; USNM P5746a–d): same locality as given for *Hastigerina micra* (Cole) (p. 161); sample Hg 8581 (TTOC 215782); (figs. 11a–b; USNM P5747), block in Moruga River, south Trinidad; sample BB 124 (TTOC 2548).

Globorotalia centralis Cushman and Bermudez

PLATE 39, FIGURES 1a–4

Globorotalia centralis CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 13, p. 26, pl. 2, figs. 62–65, 1937.—BECKMANN, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 396, pl. 26, figs. 8, 9, 1953.—BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 284, pl. 22, figs. 30–32, 1949.

Globorotalia (*Turborotalia*) *centralis* Cushman and Bermudez, CUSHMAN and BERMUDEZ, Cushman Lab. Foram. Res., vol. 25, pt. 2, pp. 44–45, pl. 8, figs. 19–21, 1949.

STRATIGRAPHIC RANGE: *Globigerapsis kugleri* zone (probably upper part), Navet formation to *Globorotalia cocoaensis* zone, San Fernando formation.

LOCALITY: Figured hypotypes (figs. 1a–3c; USNM P5748a–c) from the *Porticulasphaera mexicana* zone, Navet formation; same locality as given for *Hastigerina 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 20521a (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 opima nana Bolli

Globorotalia opima nana BOLLI, U. S. Nat. Mus. Bull. 215, p. 118, pl. 28, figs. 3a–c, 1957.

STRATIGRAPHIC RANGE: *Truncorotaloides rohri* zone, Navet formation to *Globigerina ciperoensis ciperoensis* zone, Cipero formation.

Globorotalia cocoaensis Cushman

PLATE 39, FIGURES 5a–7b

Globorotalia cocoaensis CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, pt. 3, p. 75, pl. 10, figs. 3a–c, 1928.—BANDY, Bull. Amer. Paleontol., vol. 32, No. 131, p. 79, pl. 12, figs. 1a–c, 1949.

Globigerina cerro-azulensis COLE, Bull. Amer. Paleontol., vol. 14, No. 53, p. 217, pl. 32, figs. 11–13, 1928.

Globorotalia (*Turborotalia*) *cerro-azulensis* (Cole), CUSHMAN and BERMUDEZ, Cushman Lab. Foram. Res., vol. 25, pt. 2, pp. 42–43, pl. 8, figs. 10–12, 1949.

STRATIGRAPHIC RANGE: *Globigerapsis semiinvoluta* 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 25684 (TTOC 238769).

Genus Truncorotaloides Bronnimann and Bermudez, 1953

After completion of the present study on the planktonic 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 *Globoratalia 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 wilcoxensis* 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 became extinct at the end of the middle Eocene.

Truncorotaloides rohri Bronnimann and Bermudez

PLATE 39, FIGURES 8–12c

Truncorotaloides rohri BRONNIMANN and BERMUDEZ, Journ. Paleontol., vol. 27, No. 6, pp. 818–819, pl. 87, figs. 7–9, 1953.—BECKMANN, Eclog. Geol. Helvetiae, vol. 46, No. 2, p. 396, pl. 26, figs. 10, 11, 1953.—BOLLI, LOEBLICH, and TAPPAN, U. S. Nat. Mus. Bull. 215, p. 42, pl. 10, figs. 5a–c, 1957.

STRATIGRAPHIC RANGE: ?*Hantkenina aragonensis* zone; *Globigerapsis kugleri* zone to *Truncorotaloides rohri* zone, Navet formation.

LOCALITY: Figured hypotypes (USNM P5751a–e) from the *Porticulasphaera mexicana* zone, Navet formation: same locality as given for *Hastigerina micra* (Cole) (p. 161); sample Hg 8581 (TTOC 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. *guaracaraensis* are included specimens with spherical chambers. *T. rohri* var. *piparoensis* is an intermediate form between *T. rohri* var. *guaracaraensis* and *T. rohri*. The chambers of *T. rohri* var. *mayoensis* are angular conical, the test umbilicoconvex. This variety may be regarded as related to *T. topilensis* (Cushman).

Truncorotaloides topilensis (Cushman)

PLATE 39, FIGURES 13–16b

Globigerina topilensis CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 1, No. 3, p. 7, pl. 1, figs. 9a–c, 1925.

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 micra* (Cole), (p. 161); sample Hg 8581 (TTOC 215782).

REMARKS: The Trinidad specimens of *Truncorotaloides topilensis* (Cushman) compare closely with the holotype of *Globigerina topilensis* Cushman, except that many specimens possess sutural, supplementary apertures on the spiral side, such as characterize the genus *Truncorotaloides*.

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Planktonic Foraminifera of Paleocene and Early Eocene Age from the Gulf and Atlantic Coastal Plains

By Alfred R. Loeblich, Jr., and Helen Tappan[1]

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 Maestrichtian 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 interregional 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 Tamesí 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 ulrichi* 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 existance 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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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 Tuscahoma 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 (Bashi) 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. Shifflet (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.

Brightseat 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. Brotzen (1948, p. 32) correlated the Vincentown with the Thanetian, Landenian (Paleocene) and the Ypresian (lower Eocene). McLean (1953, p. 1) identified Paleocene benthonic 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 (*Globotruncana*, *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

(1957), the Paleocene has the most restricted generic assemblage of coiled planktonic Foraminifera found since the mid-Cretaceous, containing only species of *Globigerina, Globigerinoides* and *Globorotalia.*

Reiss (1955) described a planktonic faunal sequence in Israel, with only *Globigerina* (and *Globorotalia* with rounded periphery) in the oldest strata (Reiss believed this stage represented Danian, but belonged in the Tertiary), followed by a *Globigerina*-keeled *Globorotalia* assemblage in the Paleocene. This same sequence can be recognized throughout much of the world. In Sweden, Denmark, Russia, the near East, Egypt, the American Gulf and Atlantic coasts, and Trinidad, no angular or keeled *Globorotalia* are found in the lower Paleocene. They do occur in middle and upper Paleocene strata in these and other areas, so that correlations within the Paleocene may even be made on a generic or subgeneric level in the planktonic Foraminifera, and much more refined correlations may be based on the species.

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 triloculinoides* 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 Tamesí) formation of Mexico. All these formations are therefore regarded here as lower Paleocene. Species most typical of this

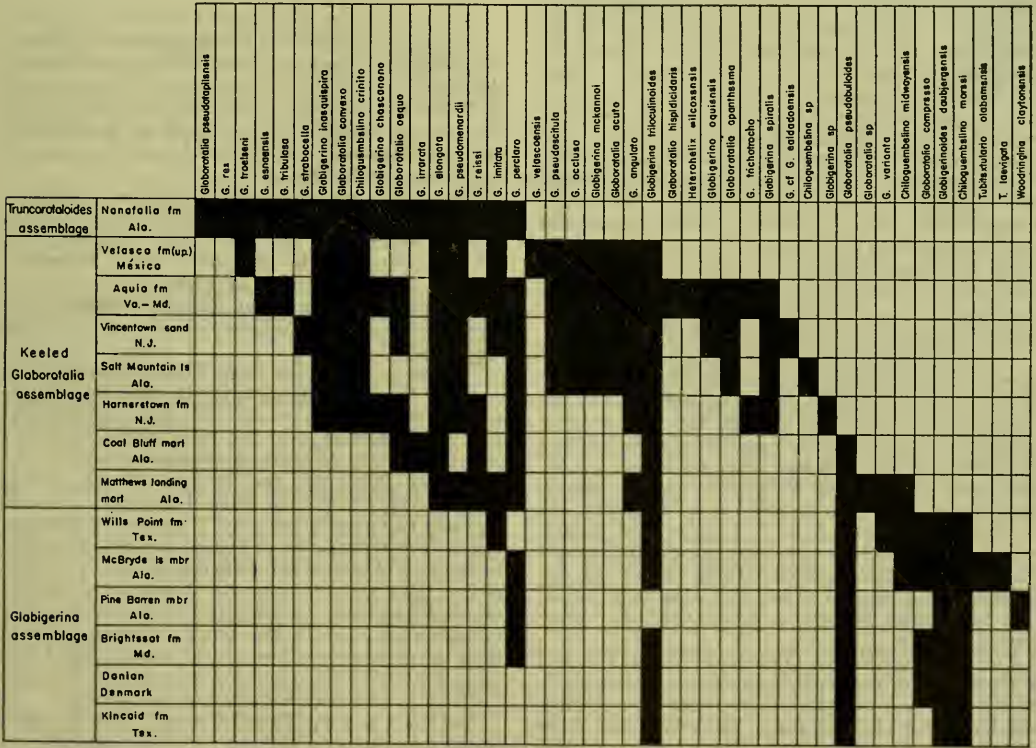


FIGURE 27.—Range chart of planktonic Foraminifera in the Paleocene and lower Eocene of the Gulf and Atlantic coastal regions. Location of formations in the chart, within each assemblage, does not necessarily imply their relative stratigraphic position, which is given in fig. 28. Ranges of species in 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*. *C. 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. acuta*. 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. acuta*, 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 *varianta* have disappeared, as have *Chiloguembelina morsei*, and *midwayensis*. The species *Chiloguembelina crinita, Globigerina spiralis*, and *Globorotalia angulata, aequa,* and *convexa* have taken their place. However, the *G. acuta-velascoensis* group, *G. pseudoscitula, occlusa,* 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 *Globigerina triloculinoides* (it is replaced in many regions by the similar *G. linaperta*, which is possibly a derivative), *mckannai*, and *spiralis*, and *Globorotalia velascoensis, acuta, angulata, occlusa,* and *pseudoscitula*. The lower Eocene is characterized by the appearance of *Globorotalia rex* (elsewhere also considered a zone fossil for the Ypresian) and *G. pseudotopilensis*. 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 pseudotopilensis* Subbotina, is similar to those which elsewhere did develop the supplementary apertures.

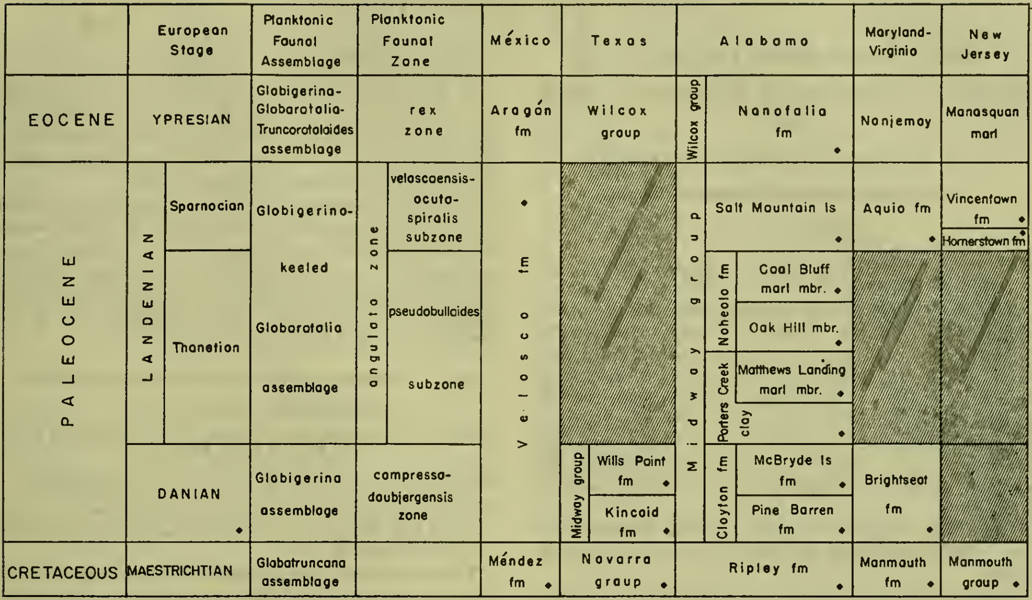
Summary

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 in 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 *rex* faunal zone of the *Truncorotaloides* assemblage.



	European Stage		Planktonic Faunal Assemblage	Planktonic Faunal Zone		México	Texas	Alabama			Maryland-Virginia	New Jersey
EOCENE	YPRESIAN		Globigerina-Globorotalia-Truncorotaloides assemblage	rex zone		Aragón fm	Wilcox group	Wilcox group	Nanafalia fm ◆		Nanjemoy	Manasquan marl
PALEOCENE	LANDENIAN	Sparnacian	Globigerina-keeled Globorotalia assemblage	angulata zone	velascoensis-acuta-spiralis subzone	Velasco fm ◆	▨	Midway group	Salt Mountain ls ◆		Aquia fm ◆	Vincentown fm ◆ Hornerstown fm ◆
		Thanetian			pseudobulloides subzone				Naheola fm	Coal Bluff marl mbr. ◆	▨	▨
										Oak Hill mbr. ◆		
									Porters Creek clay	Matthews Landing marl mbr. ◆		
										◆		
	DANIAN ◆		Globigerina assemblage	compressa-daubjergensis zone			Midway group Wills Point fm ◆		Clayton fm	McBryde ls fm ◆	Brightseat fm ◆	▨
							Kincaid fm ◆			Pine Barren fm ◆		
CRETACEOUS	MAESTRICHTIAN		Globotruncana assemblage			Méndez fm ◆	Navarro group ◆	Ripley fm ◆			Monmouth fm ◆	Monmouth group ◆

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 Hornerstown 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 Orbulinidae. The family Globorotaliidae is represented by 26 species of *Globorotalia*, and the family Heterohelicidae by 1 *Heterohelix*, 4 *Chiloguembelina*, 2 *Tubitextularia*, 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 Guembelitriinae Montanaro Gallitelli, 1957

Genus Woodringina Loeblich and Tappan, 1957

Woodringina claytonensis Loeblich and Tappan

Plate 40, Figure 6

Woodringina claytonensis Loeblich and Tappan, Journ. Wash. Acad. Sci. vol. 47, p. 39, figs. 1a–d, 1957.

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 biseriality 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 P5685) from the Pine 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 Albama state highway 28, Wilcox County, Alabama. Collected by Alfred R. Loeblich, Jr., July 1956.

Subfamily Heterohelicinae Cushman, 1927

Genus Heterohelix Ehrenberg, 1841

Heterobelix wilcoxensis (Cushman and Ponton)

Plate 56, Figures 2a, b

Gümbelina wilcoxensis Cushman and Ponton, Contr. Cushman Lab. Foram. Res., vol. 8, pt. 3, p. 66, pl. 8, figs. 16, 17, 1932.

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.

Types and occurrence: Figured hypotype (USNM P5834) from the Aquia formation, 10 to 13 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. Geological Survey Nanjemoy Md.-Va. Quadrangle, 1:62,500, 1913, reprinted 1945. Collected by A. R. Loeblich, Jr., and Richard A. Page.

Genus Chiloguembelina Loeblich and Tappan, 1956

Chiloguembelina crinita (Glaessner)

Plates 49, Figure 1; 51, Figures 1a–3; 56, Figures 1a, b; 60, Figure 6; 62, Figure 1

Gümbelina crinita Glaessner, Probl. Paleontol., Moscow Univ. Lab. Paleontol., vol. 2–3, p. 383, pl. 4, figs. 34a, b, 1937.

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 pair 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 globose 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 thirsae* 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 P5852) 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. Geological Survey Nanjemoy Md.-Va. Quadrangle, 1:62,500, 1913, reprinted 1945. Collected by A. R. Loeblich, Jr., and Richard A. Page.

Figured hypotype (USNM P5853) 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.

Figured hypotype (USNM P5890) 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.

This species also occurs in the Salt Mountain limestone of Alabama, and has been recorded from the Aquia 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

Gümbelina midwayensis Cushman, Contr. Cushman Lab. Foram. Res., vol. 16, pt. 3, p. 65, pl. 11, fig. 15, 1940.

Chiloguembelina midwayensis (Cushman) Loeblich and Tappan (part; not *Gümbelina morsei* Kline, 1943), Journ. Washington Acad. Sci., vol. 46, No. 11, p. 340, 1956.

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: This species was originally described from the Midway group of Alabama and appears to be restricted to the lower and middle Paleocene. It is here recorded from the McBryde limestone member of the Clayton formation, the Wills Point formation and the Matthews Landing marl member of the Porters Creek clay.

Types and occurrence: Figured hypotype (USNM P5829) 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 P5830) 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 Jachin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5831) 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.

Chiloguembelina morsei (Kline)

Plates 40, Figures 2a, b; 41, Figure 4; 42, Figures 1a, b; 43, Figures 2, 6a, b

Gümbelina morsei Kline, Mississippi Geol. Surv. Bull. 53, p. 44, pl 7, fig. 12, 1943.

Chiloguembelina midwayensis (Cushman) Loeblich and Tappan (part), Journ. Washington Acad. Sci., vol. 46, No. 11, p. 340, 1956.

Test free, small, relatively narrow and elongate; 5 to 7 pair of biserially arranged subglobular, inflated chambers, of nearly equal breadth and height; sutures distinct, depressed, nearly horizontal; wall calcareous, finely perforate, terminal part finely hispid; aperture a relatively high arch with a narrow, everted lip at one side expanding into a relatively wide apertural flange at the opposite side, and thus directing the aperture somewhat to one of the flat sides of the test.

Hypotypes range from 0.23 to 0.30 mm. in length.

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, Mors, north of the village, west of Töving 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 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 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, Prince Georges County, Maryland. Collected by A. R. Loeblich, Jr. and Richard A. Page.

This species occurs also in the Pine Barren member of the 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 wilcoxensis* (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, ½ 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

Rectogümbelina alabamensis CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 16, pt. 3, p. 65, pl. 11, fig. 16, 1940.

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 P5686) 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'Orbigny, 1826

Globigerina aquiensis 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. aquiensis*, 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.

TYPES AND OCCURRENCE: Holotype (USNM P5839) from the Aquia formation, 10 to 13 feet above base of the exposure, 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 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 8a–c

Test free, trochospiral, subglobular to high spired, periphery rounded, peripheral outline lobulate, all chambers of the 2½ 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. aquiensis*, 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, *chaskanon*.

TYPES AND OCCURRENCE: Holotype (USNM P5842) and figured paratype (USNM P5843) 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.

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

Globigerina inaequispira SUBBOTINA, Trudy Vses. Neft. Nauchno-Issledov. Geol.-Razved. Inst., new ser., vol. 76, p. 69, pl. 6, figs. 1–4, 1953.

Globigerina triloculinoides Plummer, SHIFFLETT, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 71, pl. 4, figs. 16, 17, 1948.

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 pseudoscitula*, 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 (Landenian) age, not in the underlying lower Paleocene (Danian) strata.

TYPES AND OCCURRENCE: Hypotype (USNM P5729) from the Salt Mountain limestone in a limestone sink, ½ mile north of Salt Mountain in the NW¼NW¼, 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 P5731) from the Aquia formation, 15 to 17 feet above base, 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 hypotype (USNM P5732) 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.

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.

Globorotalia mckannai (White), BOLLI, U. S. Nat. Mus. Bull. 215, p.79, pl. 19, figs. 16–18, 1957.

Globigerina cretacea var. *esnehensis* NAKKADY, Journ. Paleontol., vol. 24, p. 689, pl. 90, figs. 14–16, 1950.

Globigerina gravelli BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, p. 160, pl. 11, figs. 16–18, 1952.—BOLLI, U. S. Nat. Mus. Bull. 215, p. 72, pl. 16, figs. 1–3, 1957.

Globigerina sp., HOFKER, Rep. McLean Foram. Lab., No. 2, p. 15, pl. 5, 1955.

Test free, subglobular to slightly compressed, spiral side convex, in a low trochospiral coil of 2½ 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 backwards 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 extraumbilical 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 extraumbilical 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 mckannai shows a tendency to develop the somewhat truncate chamber form typical of *Globoquadrina*, 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. Nakkady 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 P5120) from the Aquia formation, 14 to 16 feet above base of exposure, 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 hypotype (USNM P5833) from the Salt Mountain limestone, in a limestone sink, ½ 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.

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 Rusias 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 extraumbilical-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 3 a–c; 49, Figures 3 a–c; 51, Figures 6 a–9 c; 53, Figures 3 a–c

Globigerina spiralis Bolli, U. S. Nat. Mus. Bull. 215, p. 70, pl. 16, figs. 16–18, 1957.

Globigerina cf. *ouachitaensis* Howe and Wallace, Shifflet, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 71, pl. 4, figs. 11–13, 1948.

Test free, the high trochospiral coiling resulting in a nearly globular test; chambers globular, increasing rapidly in size, those of the 2 to 3 whorls 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 Sohl.

Figured hypotype (USNM P5122) from the Salt Mountain limestone, in a limestone sink, ½ 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 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 Sohl.

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; 8a–9c; 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 triloculinoides PLUMMER, Univ. Texas Bull. 2644, p. 134, pl. 8, figs. 10a–c, 1926.—JENNINGS, Bull. Amer. Paleontol., vol. 23, No. 78, p. 193, pl. 31, fig. 7, 1936.—HOFKER, Rep. McLean Foram. Lab., No. 2, p. 15, pl. 2, 1955.—SHIFFLET, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 71, pl. 4, figs. 16, 17, 1948.

Globigerina pseudotriloba WHITE, Journ. Paleontol., vol. 2, No. 3, p. 194, pl. 27, fig. 17, 1928.

Globigerina triangularis WHITE, Journ. Paleontol., vol. 2, No. 3, p. 195, pl. 28, fig. 1, 1928.

Globigerina velascoensis var. *compressa* WHITE (not *Globigerina compressa* Plummer, 1926), Journ. Paleontol., vol. 2, No. 3, p. 196, pl. 28, fig. 3, 1928.

Globigerina bulloides d'Orbigny, JENNINGS, Bull. Amer. Paleontol., vol. 23, No. 78, p. 193, pl. 31, fig. 7, 1936.

Globigerina linaperta Finlay, BRONNIMANN, Bull. Amer. Paleontol., vol. 34, p. 164, pl. 2, figs. 7–9, 1952.—BOLLI, U. S. Nat. Mus. Bull. 215, p. 70, pl. 15, figs. 15–17, 1957.

Globigerina stainforthi BRONNIMANN, Bull. Amer. Paleontol., vol. 34, p. 171, pl. 3, figs. 10–12, 1952.

Globigerina finlayi BRONNIMANN, Bull. Amer. Paleontol., vol. 34, p. 166, pl. 2, figs. 10–12, 1952.

Globigerina hornibrooki BRONNIMANN, Bull. Amer. Paleontol., vol. 34, p. 163, pl. 12, figs. 4–6, 1952.

Globorotalia tortiva BOLLI (new name for *Globigerina velascoensis* var. *compressa* White, 1928; not *Globigerina compressa* Plummer, 1926), U. S. Nat. Mus. Bull. 215, p. 78 (not pl. 19, figs. 19–21), 1957.

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 ⅓ to ½ 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* Bronnimann a synonym of *G. linaperta* Finlay and *G. hornibrooki* Bronnimann a synonym of *G. triangularis* White. He considered *G. stainforthi* transitional between *G. triloculinoides* Plummer and *G. pseudobulloides* Plummer. *Globigerina stainforthi*, *G. hornibrooki*, *G. finlayi*, *G. triangularis*, and *G. pseudotriloba* 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 punctuate surface, and the tendency of some specimens of *G. triloculinoides* to develop an extra-umbilical aperture, strongly suggest that *G. linaperta* is a descendant of the earlier *G. triloculinoides*. The specimens referred to *G. linaperta* by Bronnimann (1952) from the lower Lizard Springs are typical *G. triloculinoides*, not *linaperta*, and are of Paleocene age.

Globigerina pseudobulloides Plummer does not have a coarsely reticulate surface, has more chambers per whorl, a more gradual rate of increase in chamber size and a more definitely extraumbilical aperture.

Globigerina hornibrooki Bronnimann 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. triloculinoides*. A large suite of topotypes of *G. triloculinoides* contains specimens with all of these variations and many others. *Globigerina hornibrooki* 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 triloculinoides* Plummer with somewhat flattened final chamber. This varietal name is a homonym of *G. compressa* Plummer, 1926. Bolli (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 *Tylocidaris ödumi* Brünnich Nielsen, Hjerm (western quarry), northwestern Denmark. Collected by J. C. Troelsen.

Figured hypotype (USNM P5815) 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 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, SE¼, 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, ½ mile north of Salt Mountain, in the NW¼NW¼, 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 hypotype (USNM P5700) from the Aquia formation, 15 to 17 feet above base, 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 hypotypes (USNM P5123a–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.

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 Rusias 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 occurence: 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 (Bronnimann)

Plates 40, Figures 1a–c, 8a–c; 41, Figures 9a–c; 42, Figures 6a–7c; 43, Figures 1a–c; 44, Figures 7–8c

Globigerina daubjergensis Bronnimann, Eclog. Geol. Helvetiae, vol. 45 (1952), No. 2, p. 340, text-fig. 1, 1953

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 position, 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 supplementary apertures of the spiral side were not observed. 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 Bronnimann (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 Alabama, and in the Brightseat formation of Maryland.

TYPES AND OCCURRENCE: The holotype was described from the Danian at Daubjerg, quarry southwest 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 *Tylocidaris vexilifera* Schlüter, from calcarinite 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 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 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 wilcoxensis Cushman and Ponton var. *acuta* TOULMIN, Journ. Paleontol., vol. 15, p. 608, pl. 82, figs. 6–8, 1948.—SHIFFLET, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 73, pl. 4, figs. 23a–c, 1948.

Globorotalia (*Truncorotalia*) *lacerti* Cushman and Renz, HOFKER, Rep. McLean Foram. Lab., No. 2, p. 14, pl. 1, 1955.

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 surface, oblique and directed sharply backwards on the spiral side, radial and depressed on the umbilical side; wall calcareous, distinctly and coarsely perforate, surface 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, extraumbilical-umbilical, with a distinctly triangular toothlike lip, earlier apertures remaining 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 wilcoxensis* (by Toulmin, 1941, p. 608) or as a variety of *G. velascoensis* (by Grimsdale, 1951, p. 471). Bolli (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 represented, 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 ¼ to

⅙ of the umbilical side, and the final chamber of *G. velascoensis* comprises ⅙ to ¼ 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 surface.

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 ½ 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.

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.

Figured hypotype (USNM P5865) 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.

Globorotalia aequa Cushman and Renz

Plates 46, Figures 7a–8c; 50, Figures 6a–c; 55, Figures 8a–c(?); 59, Figures 6a–c; 60, Figures 3a–c; 64, Figures 4a–c

Globorotalia crassata (Cushman) var. *aequa* Cushman and Renz, Contr. Cushman Lab. Foram. Res., vol. 18, pt. 1, p. 12, pl. 3, figs. 3a–c, 1942.

Test free, trochospiral, spiral side flat or slightly convex, umbilical side strongly convex, peripery 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 constricted 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 constricted 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, extraumbilical-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 aequa* 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. aequa* 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 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.

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 Aquia formation, 15 to 17 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.

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 Naheola formation, in creek bottom, just west of store at Caledonia, about ¼ 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

Globigerina angulata WHITE, Journn. Paleontol., vol. 2, p. 191, pl. 27, figs. 13a–c, 1928.

Globorotalia wilcoxensis Cushman and Ponton, SHIFFLETT, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 73, pl. 4, figs. 20–22, 1948.

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 NW¼NW¼, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5859) from the Aquia formation, 15 to 17 feet above the base of the exposure, 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 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, SE¼, 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 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.

Globorotalia apanthesma Loeblich and Tappan, new species

PLATES 48, FIGURES 1a–c; 55, FIGURES 1a–c; 58, FIGURES 4a–c; 59, FIGURES 1a–c

Globorotalia cf. *angulata* (White) SHIFFLETT, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 72, pl. 4, figs. 18a–c,1948.

Test free, trochospiral, planoconvex, 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 apanthesma*, 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 *apanthisma*, 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 NW¼NW¼, 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.
Globorotalia ehrenbergi Bolli, U. S. Nat. Mus. Bull. 215, p. 77, pl. 20, figs. 18–20, 1957.

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, extraumbilical-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* Bolli 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 a 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 calcarenite 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

Globorotalia convexa Subbotina, Trudy Vses. Neft. Nauchno-Issledov. Geol.-Razved. Inst., new ser., vol. 76, p. 209, pl. 17, figs. 2a–3c, 1953.

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, extraumbilical-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 0.23 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 Bermudez 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 broedermanni* Cushman and Bermudez from the lower Eocene Capdevila formation of Cuba, but differs in being only about ⅔ 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 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.

Figured hypotypes (USNM P5846a, b) from the Aquia formation, 14–16 feet above base of exposure, 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 hypotype (USNM P5847) from the Salt

Mountain limestone, in a limestone sink, ½ 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 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 hypotype (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 Glaessner

Plates 45, Figures 5a–c; 46, Figures 5a–c; 48, Figures 5a–c; 49, Figures 7a–c; 54, Figures 1a–5c; 59, Figures 4a–c; 60, Figures 9a–c; 63, Figures 2a–c.

Globorotalia pseudoscitula Glaessner var. *elongata* Glaessner, Studies in Micropaleontol., Univ. Moscow Lab. Paleontol., vol. 1, fasc. 1, p. 33, text-figs. 3d–f, 1937.

Globorotalia elongata Glaessner, 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, trochospirally 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. *pseudomenardii* Bolli in lacking the peripheral keel and thickened sutures and in having a more incised spiral suture.

Types and occurrence: Figured hypotype (USNM P5813) 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.

Figured hypotype (USNM P5692) 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 P5693) from the Salt Mountain limestone, in a limestone sink, ½ mile north of Salt Mountain, in the NW¼NW¼, Sec. 34, T. 6 N., R. 2 E., Clarke County, Alabama. Collected by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5694) from the *Ostrea thirsae* 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 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 hypotype (USNM P5697) 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.

Figured hypotypes (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 hypotype (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 esnaensis (Le Roy)

Plates 57, Figures 7a–c(?); 61, Figures 1a–2c, 9a–c

Globigerina esnaensis 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 extraumbilical position.

Hypotypes range in diameter from 0.25 to 0.38 mm.

Remarks: The specimens here figured are similar to the holotype of *Globorotalia esnaensis* (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. wilcoxensis* Cushman and Ponton, but the latter is almost truncate and the sutures are curved and oblique on the spiral side.

Because of the extraumbilical position of the aperture, the species is here regarded as a *Globorotalia*.

The specimen here figured from the Aquia 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 Aquia 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 Kimbrough 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.

Figured hypotype (USNM P5878) from the Aquia formation, 15 to 17 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.

Globorotalia bispidicidaris 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, extraumbilical-umbilical arch extending to the periphery.

Holotype 0.35 mm. in diameter.

Remarks: This species resembles *Globorotalia conicotruncata* 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 apanthesma, 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.

Types and occurrence: Holotype (USNM P5875) from the Aquia formation, 15 to 17 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. Geological Survey Nanjemoy Md.-Va. Quadrangle, 1:62,500, 1913, reprinted 1945, Collected by A. R. Loeblich, Jr., and Richard A. Page.

Globorotalia imitata Subbotina

Plates 44, Figures 3a–c; 45, Figures 6a–c; 54, Figures 8a–9c; 59, Figures 5a–c; 63, Figures 3a–c

Globorotalia imitata Subbotina, Trudy Vses. Neft. Naukno-Issledov. Geol.-Razved. Inst., new ser., vol. 76, p. 206, pl. 16, figs. 14–16, 1953.

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, extraumbilical-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 Aquia 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, SE¼, 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 P5691) from the Aquia formation, 15 to 17 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. Geological Survey Nanjemoy, Md.-Va. Quadrangle, 1:62,500, 1913, reprinted 1945. Collected by A. R. Loeblich, Jr., and Richard A. Page.

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 *Ostrae thirsae* 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 irrorata 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 irrorata*, 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, *irroratus*, bedewed, 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-Fatama road, Wilcox County, Alabama. Collected by A. R. Loeblich, Jr.

Figured paratype (USNM P5873) from the Coal Bluff marl member of the Naheola formation, in creek bottom just west of store at Caledonia, about ¼ mile south of the center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stearns MacNeil.

Globorotalia occlusa Loeblich and Tappan, new species

Plates 55, Figures 3a–c; 64, Figures 3a–c

Test free, of medium size, trochospiral, spiral 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 occlusa*, 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 *occlusus*, 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 11a–c; 46, Figures 3a–c; 47, Figures 6a–c; 50, Figures 1a–c; 54, Figures 6a–7c; 57, Figures 3a–4c; 60, Figures 5a–c

Globigerina cf. *pseudo-bulloides* Plummer, Shifflet, Maryland Dep. Geol., Mines and Water Resources Bull. 3, p. 71, pl. 4, figs. 14, 15, 1948.

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. *pseudobulloides* Plummer, belong to the present species. It differs from *G. pseudobulloides* (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 Jachin, 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 ¼ 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 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.

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 Aquia formation, 6 to 9 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 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, ½ mile north of Salt Mountain, in the NW¼NW¼, 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 trochospiral, 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 extraumbilical-umbilical, interiomarginal, 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. varianta* (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. varianta.*

TYPES AND OCCURRENCE: Figured hypotype (USNM P5720) from the lower Danian, zone of *Tylocidaris ödumi*, bryozoan limestone, filling cavities in underlying calcilutite (*Cerithium* limestone with *Cerithium baltica*) Höjerup, 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 Jachin, Choctaw County, Alabama. Collected by A. R. Loeblich, Jr.

Figured hypotype (USNM P5727) 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 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 1a–c

Globorotalia pseudomenardii Bolli, U. S. Nat. Mus. Bull. 215, p. 77, pl. 20, figs. 14–17, 1957.

Globorotalia membranacea (Ehrenberg) Toulmin, Journ. Paleontol., vol. 15, No. 6, p. 608, pl. 82, figs. 4, 5, 1941.

Globorotalia cf. *membranacea* (Ehrenberg) Hofker, Rep. McLean Foram. Lab., No. 2, p. 14, pl. 4, 1955.

Test free, biconvex but compressed, trochospirally coiled, periphery with a narrow but distinct keel; all chambers of the 2½ whorls 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 whorls 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, extraumbilical-umbilical with a narrow lip, and in specimens with nearly closed umbilicus the aperture tends to become completely extraumbilical 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 whorls, whereas in *G. elongata* the more incised radial and spiral sutures give a depressed appearance to the early whorls.

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, 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.

Figured hypotype (USNM P5702) from the Salt Mountain limestone, in a limestone sink, ½ 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 P5703) from the Aquia formation, 15 to 17 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. Geological Survey Nanjemoy, Md.-Va. Quadrangle, 1:62,500, 1913, reprinted 1945. Collected by A. R. Loeblich, Jr., and Richard A. Page.

Figured hypotype (USNM P5704) 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.

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 pseudoscitula Glaessner

Plates 46, Figures 4a–c; 48, Figures 3a–c; 53, Figures 5a–c; 59, Figures 2a–c; 63, Figures 6a–c

Globorotalia pseudoscitula Glaessner, Studies in Micropaleontol., Univ. Moscow Lab. Paleontol., vol. 1, No. 1, pp. 32, 49, text figs. 3a–c, 1937.

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 flattened 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 Nanjemoy Md.-Va. Quadrangle, 1:63,500, 1913, reprinted 1945.

Figured hypotype (USNM P5140) from the Salt Mountain limestone, in a limestone sink ½ mile north of Salt Mountain. in the NW¼NW¼, 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 Rusias 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 ¼ mile south of center of Sec. 29, T. 11 N., R. 10 E., Wilcox County, Alabama. Collected by F. Stearns MacNeil.

Globorotalia pseudotopilensis (Subbotina)

Plate 60, Figures 2a–c

Acarinina pseudotopilensis Subbotina, Trudy Vses. Neft. Naukno-Issledov. Geol.-Razved. Inst., new ser. vol. 76, p. 227, pl. 21, figs. 8, 9; pl. 22, figs. 1–3, 1953.

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 thirsae* 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 P5869) 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. perclara*, 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.

Types and occurrence: Holotype (USNM P5835) from the Aquia formation, 0 to 3 feet above base of the exposure, 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 P5836) 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.

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

Globorotalia rex MARTIN, Stanford Univ. Publ., Univ. Ser., Geol. Sci., vol. 3, No. 3, p. 117, pl. 8, fig. 2, 1943.

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 ⅓ to ⅖ 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 thirsae* 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 whorls 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 *strabus*, 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 hispid; 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 pseudobulloides* (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.

Paratype (USNM P5851) from the Aquia formation, 14 to 16 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. Geological Survey Nanjemoy Md.-Va. Quadrangle, 1:62,500, 1913, reprinted, 1945. Collected by A. R. Loeblich, Jr., and Richard A. Page.

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 trichotrocha*, 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. conicotruncata* Subbotina in its smaller size, fewer chambers per whorl and narrower umbilicus. *Globorotalia perclara*, 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 *thrix*, *trichos*, hair, and *trochus*, wheel.

Types and occurrence: Holotype (USNM P5355) and figured paratype (USNM P5705) from the Aquia formation, 3 to 6 feet above base of section exposed, 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 P5690) 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.

Globorotalia troelseni 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 whorls 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 whorls 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 thirsae* 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 Rusias and Soto la Marina, Tamaulipas, Mexico. Collected by R. Wright Barker.

Globorotalia varianta (Subbotina)

Plates 44, Figures 1a–2b; 45, Figures 4a–c

Globigerina varianta Subbotina, Trudy Vses. Neft. Naukno-Issledov. Geol.-Razved. Inst., new ser., vol. 76, p. 63, pl. 3, figs. 5–12; pl. 4, figs. 1–3; pl. 15, figs. 1–3.

Test free, medium sized, low trochospiral coil of approximately 2½ whorls, 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, SE¼, 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

Pulvinulina velascoensis Cushman, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, p. 19, pl. 3, figs. 5a–c, 1925.

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, extraumbilical-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 occlusa*, 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, extraumbilical-umbilical, bordered above by a narrow lip.

Greatest diameter of figured specimen 0.20 mm.

Remarks: This species somewhat resembles *Globorotalia pseudoscitula* Glaessner, 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 [1]

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 occuring 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.

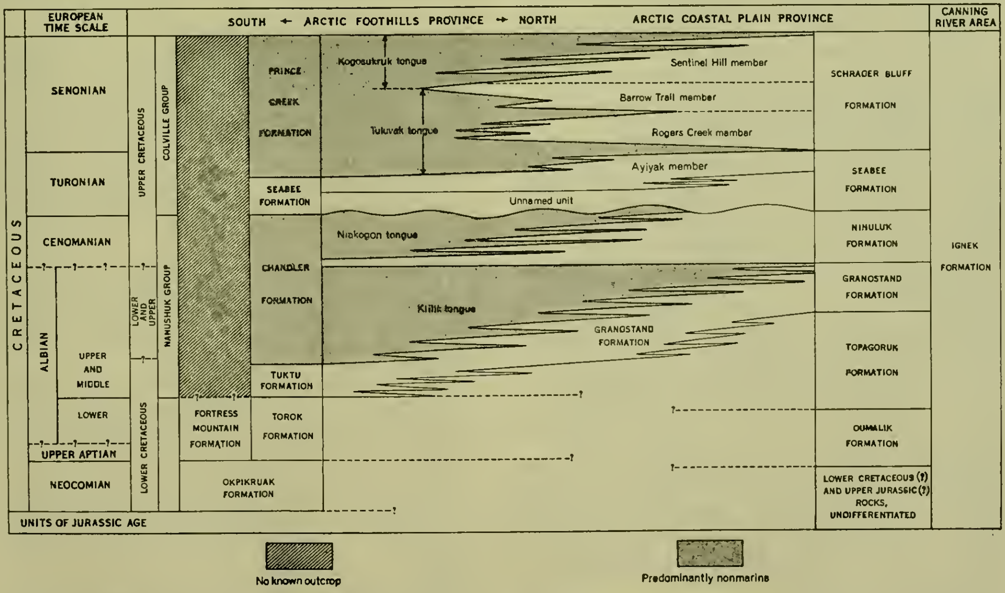

FIGURE 29.—Cretaceous strata of Northern Alaska and correlation with European time scale (modified after Gryc and others, 1956, and Imlay and Reeside, 1954).

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[1] U. S. Geological Survey and Research Associate, Smithsonian Institution. Publication authorized by the Director, U. S. Geological Survey.

Assistance is also acknowledged from George Gryc, from Harlan Bergquist, who has discussed with the writer many features of the micropaleontology and stratigraphic zonation, and from Florence Robinson 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.

Systematic Descriptions

Family Rhizamminidae 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 1.66 mm. in length and from 0.10 to 0.32 mm. in breadth.

Remarks: *Bathysiphon brosgei* Tappan, new species, differs from the associated *B. vitta* 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. alexanderi* 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. Brosgé, 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 3,930–3,940 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), on a small north-flowing tributary to Fortress Creek, which flows into the Ayiyak River, northeast of Fortress Mountain, lat. 68°30′ N., long. 153°05′30″ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

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 constrictions 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., south-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. Detterman, 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, 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 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 proloculus 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 Arcon 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 characters. 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 collyra* Nauss in having more numerous chambers in the final whorl and a less lobulate periphery. It is distinguished from *H. eggeri* 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 565–578 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, 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 2,365–2,370 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 Dt 223), 5 miles airline 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 Dt 227), about ¼ mile farther upstream; unfigured paratypes (USNM P4282) from the Grandstand formation, 2,000 feet below the top (field sample 47A Dt 236), about ¼ mile farther upstream; and unfigured paratypes (USNM P4283) from the Grandstand formation, 1,450 feet below the top (field sample 47A Dt 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 Dt 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 Ninuluk formation (field sample 48A Dt 268), Chandler River, Niakogon syncline to Big Bend anticline, lat. 69°04′ N., long. 151°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* Lalicker 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′ N., long. 156°40′ 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 155) both samples from an outcrop on the Nanushuk River, south-southeast of Umiat, at approximately lat. 69°03′ N., long. 150°56′ 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′ N., long. 151°48′ 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′ 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′ N., long. 154°20′ W., in the northern foothills of the Brooks Range, northern Alaska.

Genus Textularia Defrance, 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 Alsaka.

Unfigured paratypes (USNM P4298) from a core at 2,235–2,245 feet, unfigured paratypes (USNM P4299) from a core at 2,939–2,949 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. washitensis* 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.

The specific name is in honor of R. G. Ray, geologist, U. S. Geological Survey.

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 Verneuilinidae Cushman, 1911

Genus Verneuilinoides Loeblich and Tappan, 1949

Verneuilinoides 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 *Verneuilinoides perplexa* var. *gleddiei* Stelck 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°07′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 Oumalik 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 P4334) from 180–230 feet above the base of the Grandstand formation, on the north flank of the Awuna anticline (field sample 47A Tr 289), lat. 69°09′30″ N., long. 155°59′ 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 P4336) from field sample 48A Dt 187, in marine zone of the Chandler formation, lat. 68°45′30″ N., long. 152°15′ W., northern Alaska. Collected by R. L. Detterman, 1948.

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.

Verneuilinoides 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, triserially 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.

Verneuilinoides fischeri, new species, differs from *Verneuilina 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 *Verneuilina*. *V. bearpawensis* (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. Lathram, 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′40″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.

Verneuilinoides tailleuri Tappan, new species

Plate 66, Figures 19–22

Test free, relatively narrow, elongate, sides nearly parallel; chambers numerous, low, triserially 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: *Verneuilinoides tailleuri*, new species, differs from *V. borealis*, 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 *Tritaxia spiritensis prolongata* Stelck 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, south-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 P 4370) 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 Kiruktagiak 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 2¾ 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 Kiruktagiak 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 2,980–2,990 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 Ayiyak 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′24″ N., long. 147°33′35″ W., at the eastern end of the northern foothills of the Brooks Range, northern Alaska.

Unfigured 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. Lathram, 1946.

Unfigured paratypes (USNM P4398) from the Ayiyak 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 Ayiyak 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 Dorothia Plummer, 1931

Dorothia 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: *Dorothia 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 Oumalik 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 section 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 Oumalik 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 P4405) from field sample 49A Tr 685, in the Torok formation, on the south limb of the Ayiyak anticlinorium on the Kiruktagiak River, north of Castle Mountain, at lat. 68°39′15″ N., long. 152°43′ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by I. L. Tailleur, 1949.

Unfigured paratype (USNM P4406) from field sample 49A Tr 756, in the Torok formation, on Okok Creek, tributary to the Okpikruak 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 unrecognizable as based on its type species, *Involutina polymorpha* Terquem, 1863. Of the three type 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 unrecognizable 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 unrecognizable; *Involutina* Terquem, 1862, was shown (Loeblich and Tappan, 1954, p. 308) to be an agglutinated form (including species previously referred to *Ammodiscus*); and *Problematina* 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 Tolypamminidae (see Loeblich and Tappan, 1954, p. 308).

Sigal (1952, p. 159) restricted the Involutinidae to include only *Silicina*, *Problematina*, and *Involutina*, and placed the family under the suborder Biloculinidea. 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 Pluriloculinidea, superfamily Miliolidea. 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 unrecognizable, 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, *Spiroiocammina* Earland, 1934, *Bramletteia* Israelsky, 1951, *Trilocularena* Loeblich and Tappan, 1955, and the new genus *Psamminopelta*, here described.

The Rzehakinidae 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, quinqueloculine 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. manitobensis* 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 Gransdtand 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 Tr 293, from a marine zone 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 M. L. Troyer, 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°15′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 awunensis*, 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. 152°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, 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: *psamminos*, Gr., of sand + *pelte*, 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 *Rzehakina* 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 end 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: *Psamminopelta bowsheri*, new species, differs from *Massilina texasensis* 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°55′ 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 Kukpowruk 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, 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 4¾ 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 608), 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. Zumberge, 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 manitobensis* 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, thickened, 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, Kukpowruk 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 Kiruktagiak 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 5,500 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. Tailleur, 1949.

Unfigured paratypes (USNM P4482) from the Torok formation (field sample 49A Tr 695), on the south limb of the Ayiyak anticlinorium, on the Kiruktagiak River, due north of Castle Mountain, at lat. 68°38′40″ N., long. 152°44′ W., in the southern foothills of the Brooks Range, northern Alaska. Collected by I. L. Tailleur, 1949.

Trochammina stefanssoni Tappan, new species

PLATE 67, FIGURES 30–33

Test free, trochoid, low spired, periphery rounded; all chambers of the approximately two whorls 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 Stefansson, 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 Kigalik 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. Whitington, 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 Ninuluk 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.

151°25′ W., along the Chandler River, near the Schrader anticline, southeast of Umiat, in the northern foothills of the Brooks Range, northern Alaska. Collected by R. L. Detterman, 1948.

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′52″ 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

PLATE 68, FIGURES 7, 8

Test free, robust, early portion with a curved axis, but not a distinct coil, later uncoiled 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 uncoiled 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 4¾ 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 uniserially 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 hauteriviana* 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, Topagoruk, and Fortress Mountain formations. The specific name is in honor of R. L. Detterman, 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 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.

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, 1855) 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, Topagoruk, 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 Topagoruk 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. 152°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 Topagoruk 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 Topagoruk formation; unfigured paratypes (USNM P4534) from a core at 438–443 feet, unfigured paratype (USNM P4535) from a core at 493–503 feet, unfigured paratypes (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 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.

Figured paratype (USNM P4540) from well cuttings at 1,392–1,397 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.

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. obesa* 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 Skull 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* (Nauss) 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. 152°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 543–545 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 2,024–2,026 feet, and figured paratypes (USNM P4611a,b) from well cuttings at 2,390–2,395 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 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 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.

Unfigured paratypes (USNM P4617) from 2,390 feet below the top of the Grandstand formation (field sample 47A Dt 227), about 4¾ 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 R. L. Detterman, 1947.

Unfigured paratypes (USNM P4618) from the lower part of a 50-foot section of the Topagoruk formation (field sample 47A Tr 167) on the west fork of Birthday Creek, at approximately lat. 69°12′30″ N., long. 156°47′ W., which flows south into the Awuna River, north-central 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 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 diamter.

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* Loeblich 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 Utukok 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 *Conorbina* 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 umiatensis 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 *Conorbina 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. 152°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 Kiruktagiak 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 Brotzen, 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. multisepta* (Brotzen) 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. 154°43′52″ W., near Cape Simpson, northern Alaska.

Family Chilostomellidae Brady, 1881

Genus Pallaimorphina Tappan, new genus

Type species: *Pallaimorphina ruckerae* Tappan, new species. (Derivation: *pallai*, Gr., plural of *palla*, f., ball + *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 *Allomorphina* 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, trochoid coiling, and apertural flap 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 sutural 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 *Quadrimorphina 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 *Quadrimorphina*.

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 P4665) from a core at 533–543 feet, figured paratypes (USNM P4666a,b) and unfigured paratypes (USNM P4667) from a core at 206–211 feet, unfigured paratypes (USNM P4668) from a core at 238–256 feet, figured paratype (USNM P4669) and unfigured paratypes (USNM P4670) from a core at 256–266 feet, figured paratypes (USNM P4671a,b) from a core at 273–283 feet, unfigured paratypes (USNM P4672) from a core at 338–348 feet, figured paratype (USNM P4673) from a core at 358–368 feet, unfigured paratypes (USNM P4674) from a core at 438–443 feet, unfigured paratypes (USNM P4675) from a core at 503–513 feet, unfigured paratypes (USNM P4676) from a core at 533–543 feet, unfigured paratypes (USNM P4677) from a core at 565–578 feet, unfigured paratypes (USNM P4678) from a core at 663–673 feet, all in the Grandstand formation; and unfigured paratypes (USNM P4679) 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 P4680) 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 P4681) from a core at 256–264 feet and unfigured paratypes (USNM P4682) from a core at 461–466 feet all in the Grandstand formation, in Skull Cliff core test 1, lat. 70°55′ N., long. 157°38′ W., between Point Barrow and Point Franklin, northern Alaska.

Unfigured paratypes (USNM P4683) 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 P4684) from well cuttings at 2,545–2,550 feet in the Grandstand formation and unfigured paratype (USNM P4685) 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 P4686) 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. 159°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 P4687) 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 P4688) 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 P4689) 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 P4690) 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, southwest of Fortress Mountain in the southern foothills of the Brooks Range, northern Alaska. Collected by W. W. Patton, Jr., 1949.

Unfigured paratypes (USNM P4691) from the Fortress Mountain formation (field sample 49A Pa 561), on Castle Creek, about 2¾ 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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Eleven New Genera of Foraminifera

By Alfred R. Loeblich, Jr., and Helen Tappan [1]

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 *Favocassidulina 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-

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[1] Helen Tappan Loeblich, U. S. Geological Survey and Research Associate, Smithsonian Institution.

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 oustanding 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 Blancaforte, 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), Rep. Voy. *Challenger*, Zoology, vol. 9, p. 350, pl. 41, fig. 11, 1884.

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 polymorphinid 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 suface 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 *Tawitawia* 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 *Poritextularia* 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. 4a,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 Bocuno 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

Berthelinella 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 pair 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: *Berthelinella*, new genus, differs from *Frondicularia* Defrance in having a reduced biserial early stage of one or two pair of chambers preceding the uniserial development, and a slitlike rather than radiate aperture. *Palmula* Lea and *Neoflabellina* Bartenstein differ in having a distinctly coiled early portion, *Citharinella* 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 *Palmula 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 *P. 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 *Palmula* by Loeblich and Tappan and to *Citharinella* by ten Dam. Specimens of the common pseudobiserial form and the rare *Citharinella* form of *C. tarrantensis* (Loeblich and Tappan) are here figured (pl. 72, figs. 14–16) for comparison with *Berthelinella*, new genus. These Cretaceous species also differ from *Berthelinella* in having a typical radiate aperture, as in *Citharinella*.

Types and occurrence: Topotypes (USNM P4473a–e) of *Berthelinella 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 *Citharinella 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 Nodosariidae 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 Nodosariidae and Polymorphinidae.

Tentifrons barnardi Loeblich and Tappan, new species

Plate 72, Figures 17, 18

Flabellina cf. *angulosa* d'Orbigny Barnard, 1949 (not *Frondicularia angulosa* d'Orbigny, 1840), Proc. Geol. Assoc., vol. 60, pt. 4, p. 285, pl. 12, figs. 1–6.

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, the early stage of the present species compares favorably with that of *Cristellaria gaudryana* 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 Nodosariidae, 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 gaudryana* d'Orbigny in size and shape of the early test, but *C. gaudryana* lacks any tendency to develop the fistulose growth in the later stage, and does not show the pustulose 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 *Belemnitella 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 *Belemnitella mucronata* zone of the Upper Chalk (BMNH P40272 and P40273).

Family Polymorphinidae d'Orbigny, 1846

Genus Webbinella Rhumbler, 1904, emended

Webbinella Rhumbler, Archiv. Protistent., Band 3, Teil 1, p. 228, 1904.

Plate 72, Figure 19

Type species: *Webbina 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: *aiolos*, Gr., changeable + *streptos*, Gr., twisted; gender feminine.)

Test free, elongate, base bluntly rounded, the early portion in a low discorbine 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 *Lacosteina* 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 spire instead of an abrupt change in the plane of coiling from the early coil to the later spire.

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 referrable to *Praebulimina* Hofker, since typical *Buliminella* apparently is not found below the Eocene. *Aeolostreptis*, new genus, differs from *Praebulimina* in having the early many-chambered coil forming a bluntly rounded base, instead of being triserial throughout and increasing gradually in diameter.

It resembles *Virgulina* in having a granular wall, unlike the radial-walled Buliminidae, 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, Dermopolis 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

Sigmavirgulina 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 sigmoiline 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: *Sigmavirgulina*, new genus, differs from *Bolivina* d'Orbigny in having a granular instead of a radial wall structure, in the early sigmoiline 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.

Sigmavirgulina 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.

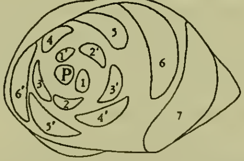

Figure 30.—Outline camera lucida drawing of basal view of *Sigmavirgulina tortuosa* (Brady) to show spiral biserial chamber arrangement and sigmoid curve of plane of biseriality. *P*, proloculus, 1–7, and 1'–6' showing the two spiralling series of chambers. × 125.

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 *Sigmavirgulina*. 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 Loeblich and Tappan, new genus

Type species: *Sejunctella earlandi* Loeblich 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 lateseptata Terquem, 1875, from the Recent beach at Dunkerque, Dept. du Nord, France, and *S. vivipara* 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 Loeblich and Tappan, new species

Plate 73, Figure 6

Spirillina lateseptata 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 planoconcave, 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 lateseptata* Terquem, but differs in being about one-half to one-third as large, and in the presence of a peripheral fimbriate keel, as *S. lateseptata* has a smoothly rounded periphery and only the intercalated plate between whorls. *S. vivipara* 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 16, 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 Loeblich and Tappan, new genus

Type species: *Eurycheilostoma altispira*, new species. (Derivation: *eurys*, 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 subglobular 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* Brotzen in being higher spired, with less inflated chambers and in 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.

Sestronophora Loeblich and Tappan, new genus

Type species: *Sestronophora 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: *Sestronophora*, 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 *Poroeponides* Cushman in having a few rounded openings on the umbilical side of the final chamber, but differs in possessing the complex perforated umbilical plates.

Sestronophora 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 ½ 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: *favo* from *favus*, L., m., honeycomb+*cassid* from *cassida*, L., helmet (*cassidula*), f., diminutive+*ina*, L., diminutive; gender feminine.)

Test free, lenticular, robust, periphery acute; chambers biserially arranged and spiralling, as in *Cassidulina*, each chamber extending to the umbilicus on one side with only a small triangular portion extending over onto the opposite side; sutures not visible from the surface, obscured by the coarse surface ornamentation; wall calcareous, finely perforate, granular in structure, ornamented by a honeycomblike secondary growth, with relatively wide hexagonal open areas separated by narrow but much elevated "partitions"; aperture elongate, a slightly curved slit bordered by a very narrow lip, and extending upward from the base of the final chamber, near to and paralleling the anterior margin of the chamber, and opening toward the side opposite that on which the final chamber lies, each successive aperture appearing on alternate sides of the test, the region immediately surrounding the aperture relatively smooth.

Remarks: *Favocassidulina*, new genus, differs from *Cassidulina* d'Orbigny in having the honeycomblike secondary growth of the wall completely covering the surface except for the area immediately surrounding the aperture, and obscuring all traces of sutures.

Wood (1949, p. 250) recorded *Cassidulina favus* as radial in structure. We have rechecked the wall structure of four different specimens, from *Challenger* localities, and all have been granular in wall structure, as are all true *Cassidulina*. Apparently, some mistake must have been made in the original diagnosis or in the listing of this species as radial.

Types and occurrence: Figured topotypes of *Favocassidulina favus* (Brady) (USNM P3376a–d) and unfigured topotypes (USNM P3102) from *Challenger* station 300, at lat. 33°42′ S., long. 78°18′ W., at a depth of 1375 fathoms, off the coast of Chile, southern Pacific Ocean.

Figured sectioned hypotype (USNM P4469) and unfigured hypotypes (USNM P3210) of *Favocassidulina favus* (Brady) from *Challenger* station 224, at lat. 7°45′ N., long. 144°20′ E., at a depth of 1,850 fathoms, Caroline Islands, Pacific Ocean.

Family Anomalinidae Cushman, 1927

Paromalina Loeblich and Tappan, new genus

Type species: *Paromalina bilateralis*, new species. (Derivation: *parōmalos*, Gr., nearly even or equal+*ina*, diminutive suffix; 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 *Discanomalina*, 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, biumbilicate, 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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The Foraminiferal Genus Cruciloculina d'Orbigny, 1839

By Alfred R. Loeblich, Jr., and Helen Tappan [1]

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, refigured, and described. An additional topotype specimen of *C. triangularis* has also been illustrated.

A topotype 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.

The ontogenetic apertural development of all species is similar to that described by Asano for *C. japonica.*

The genus is thus fairly widespread in the Recent seas, and in the future will probably be found more widespread in fossil faunas as well.

The writers are grateful to the Smithsonian Institution for making possible the visit of Alfred R. Loeblich, Jr., to the Museum National d'Histoire Naturelle in Paris, and to the John Simon Guggenheim Memorial Foundation for a fellowship grant to Helen Tappan Loeblich, which thus made possible the restudy of the d'Orbigny types.

Grateful acknowledgment is given of the cooperation of M. Jean Roger, Museum National d'Histoire Naturelle, Paris, France, in permitting the restudy and reillustration of the d'Orbigny type specimens.

We are indebted to Dr. K. Asano, Institute of Geology and Paleontology, Tohoku University, Sendai, Japan, and to Mr. T. Uchio, Institute of Petroleum Engineering, Tokyo University, Tokyo, Japan, for furnishing us an excellent series of the species *Cruciloculina japonica* Asano from Japan.

Systematic Descriptions

Family Miliolidae d'Orbigny, 1839

Genus Cruciloculina d'Orbigny, 1839

Cruciloculina D'Orbigny, Foraminifères *in* de la Sagra, Hist. Phys., Polit. et Nat. de l'île de Cuba, p. 182, 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 dendritic 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 triradial aperture in the young to a cruciform or dendritic 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 dendritic in appearance.

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[1] Helen Tappan Loeblich, U. S. Geological Survey and Research Associate, Smithsonian Institution.

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

Plate 74, Figures 3–7

Test free, ovate in section, nearly circular in side view, chambers triloculine 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, triloculine in chamber development, subtriangular 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'Amerique Mérid., Foraminifères, p. 72, 1839.

Test free, triloculine 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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PLATES

Plate 1. HANTKENINIDAE: PLANOMALININAE

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Figures 1a, b. *Globigerinelloides algeriana* Cushman and ten Dam 21

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 23

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 P5394) 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 24

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) 24

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.

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Figures 7a–10b. *Hastigerinoides alexanderi* (Cushman) 24

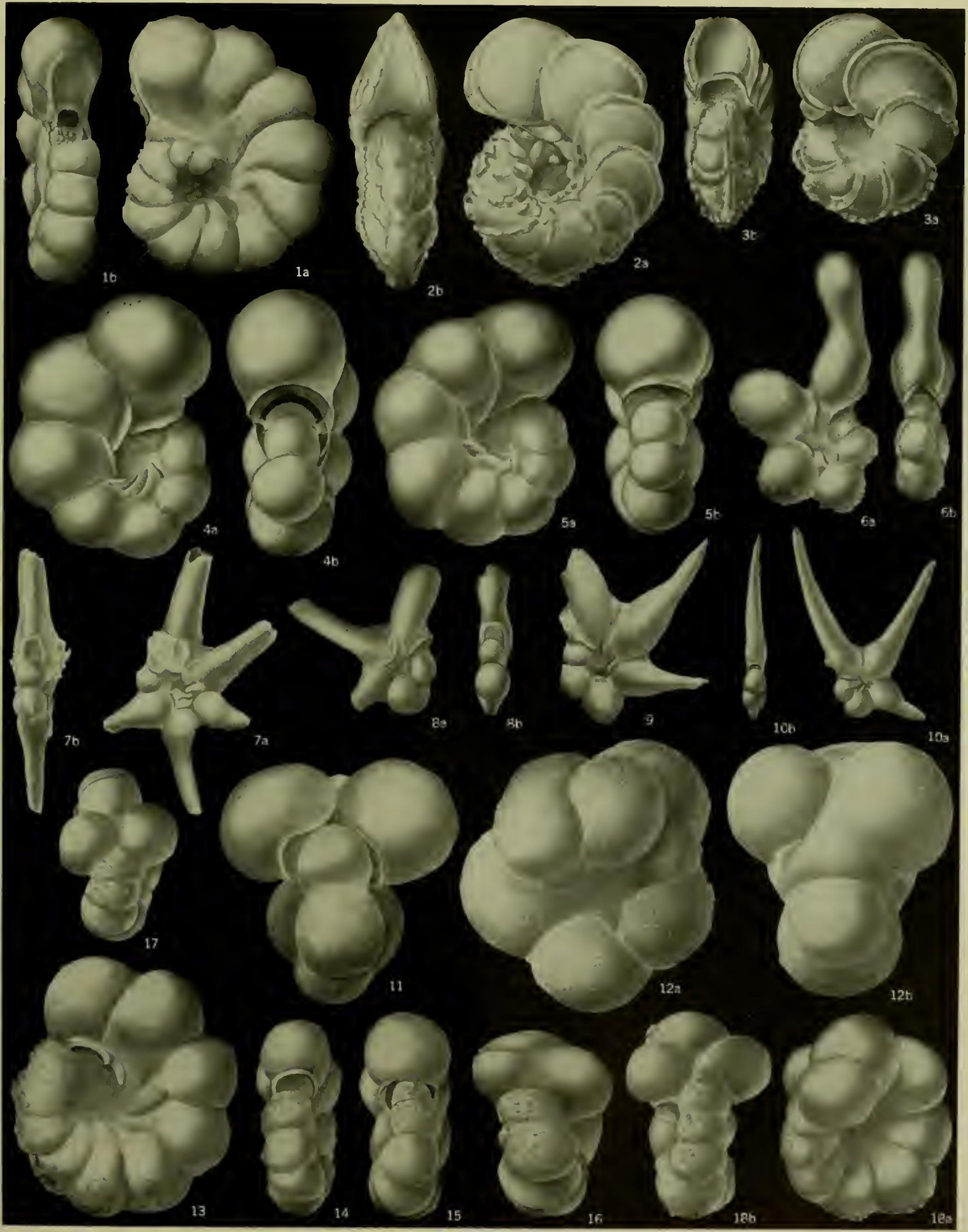
7a, Side view of holotype (Cushman Coll. 15750), showing radial elongate chambers. **7b,** Edge view. **8a, 10a,** Side views of topotypes (USNM P3920a, b), showing relict apertures around umbilical region, and variation in the shape of the radial elongate chambers. **8b, 10b,** Edge views, showing low arched equatorial aperture. **9,** Paratype (Cushman Coll. 15754). All from the Austin chalk (Upper Cretaceous) of Texas. × 95.

Figures 11–12b. *Biglobigerinella multispina* Lalicker 25

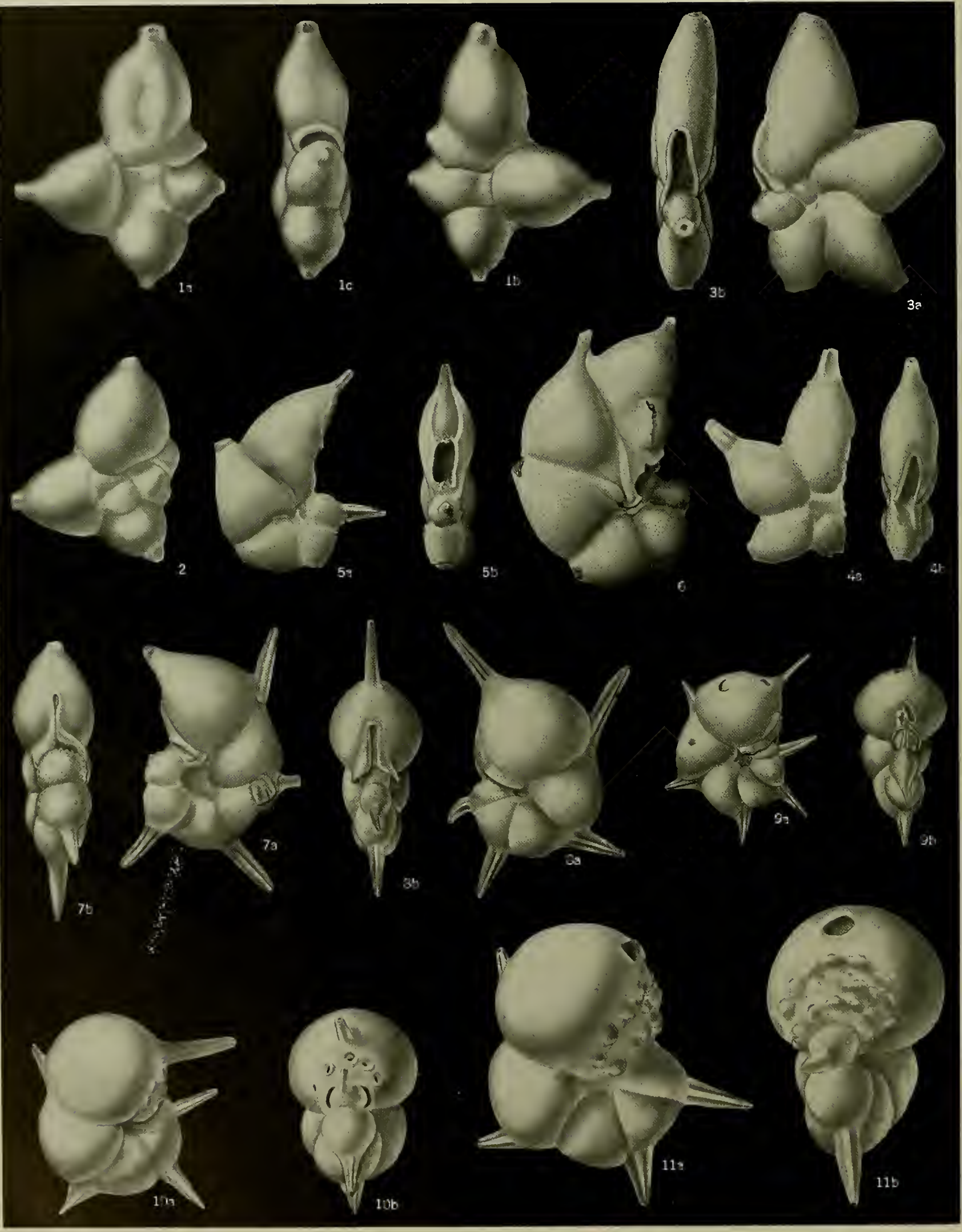
11, Edge view of hypotype (USNM P3214a), showing lateral paired apertures. From the Upper Cretaceous Taylor marl (Campanian) of Texas. **12a,** Side view of holotype (Cushman Coll. 51898), showing spherical chambers and deeply umbilicate test. **12b,** Edge view, showing final paired chambers. From the Upper Cretaceous Marlbrook marl (Campanian) of Arkansas. × 160.

Figures 13–18b. *Biglobigerinella barri* Bolli, Loeblich, and Tappan, new species 25

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

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Figures 1a–2. *Schackoina cenomana* (Schacko) 26

1a, b, Opposite sides of hypotype (USNM P4644a), 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 P4644b). 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 var. *primitiva* Cushman and Jarvis 26

Designated as type species for the subgenus *Hantkeninella* Bronnimann. **7a,** Side view of holotype (Cushman Coll. 10067), showing the absence of spine on earlier chamber, which was the basis for the subgenus *Hantkeninella*, 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.

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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 triradial aperture and lateral apertural flanges. From the Pachuta formation, Jackson Eocene of Alabama. × 35.

Figures 9a–11b. *Cribrohantkenina bermudezi* Thalmann 28

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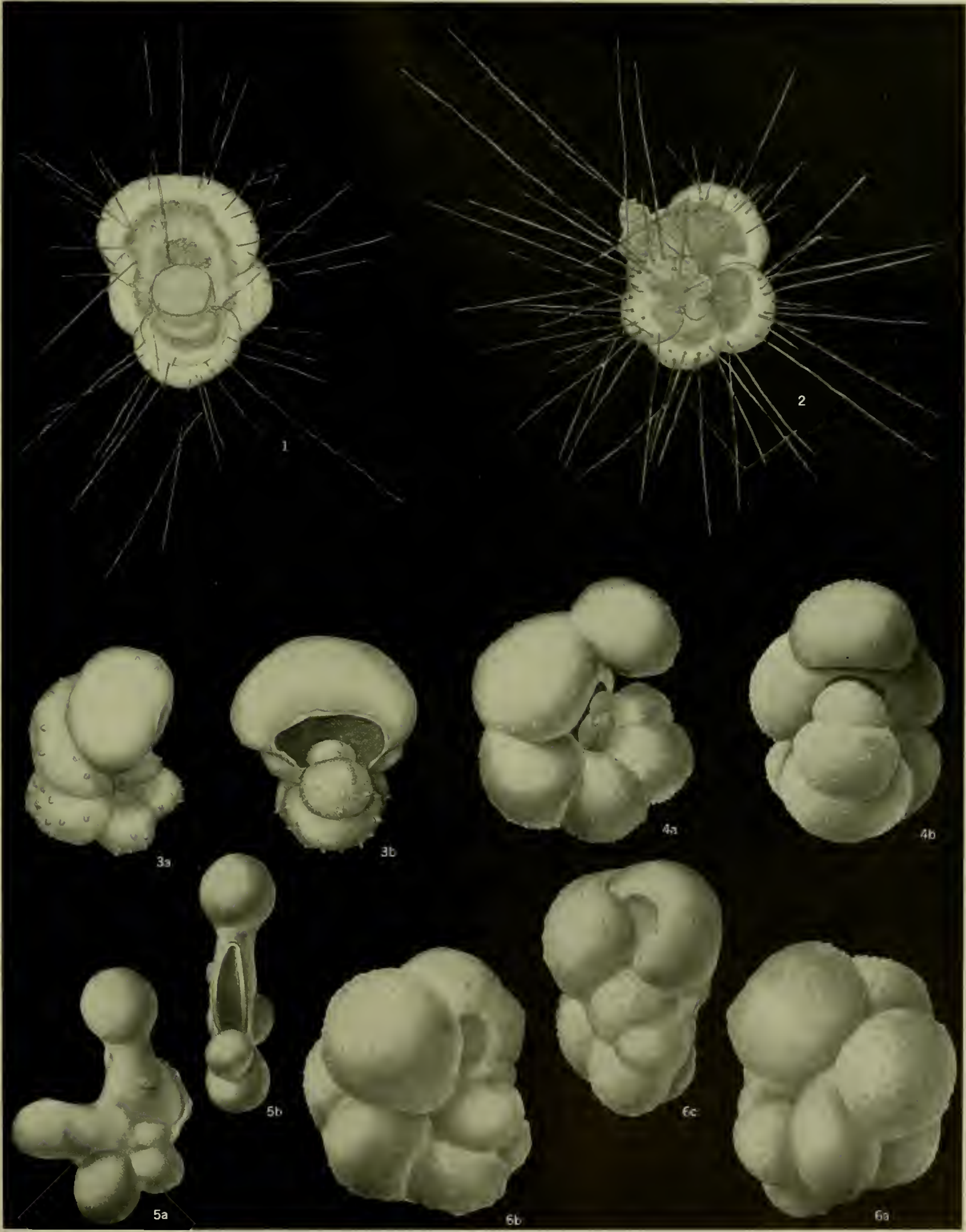
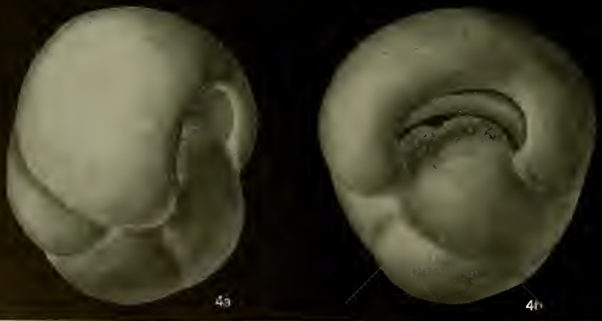


HANTKENINIDAE : HASTIGERININAE, CASSIGERINELLINAE



ORBULINIDAE : GLOBIGERININAE

PLATE 4. ORBULINIDAE : GLOBIGERININAE

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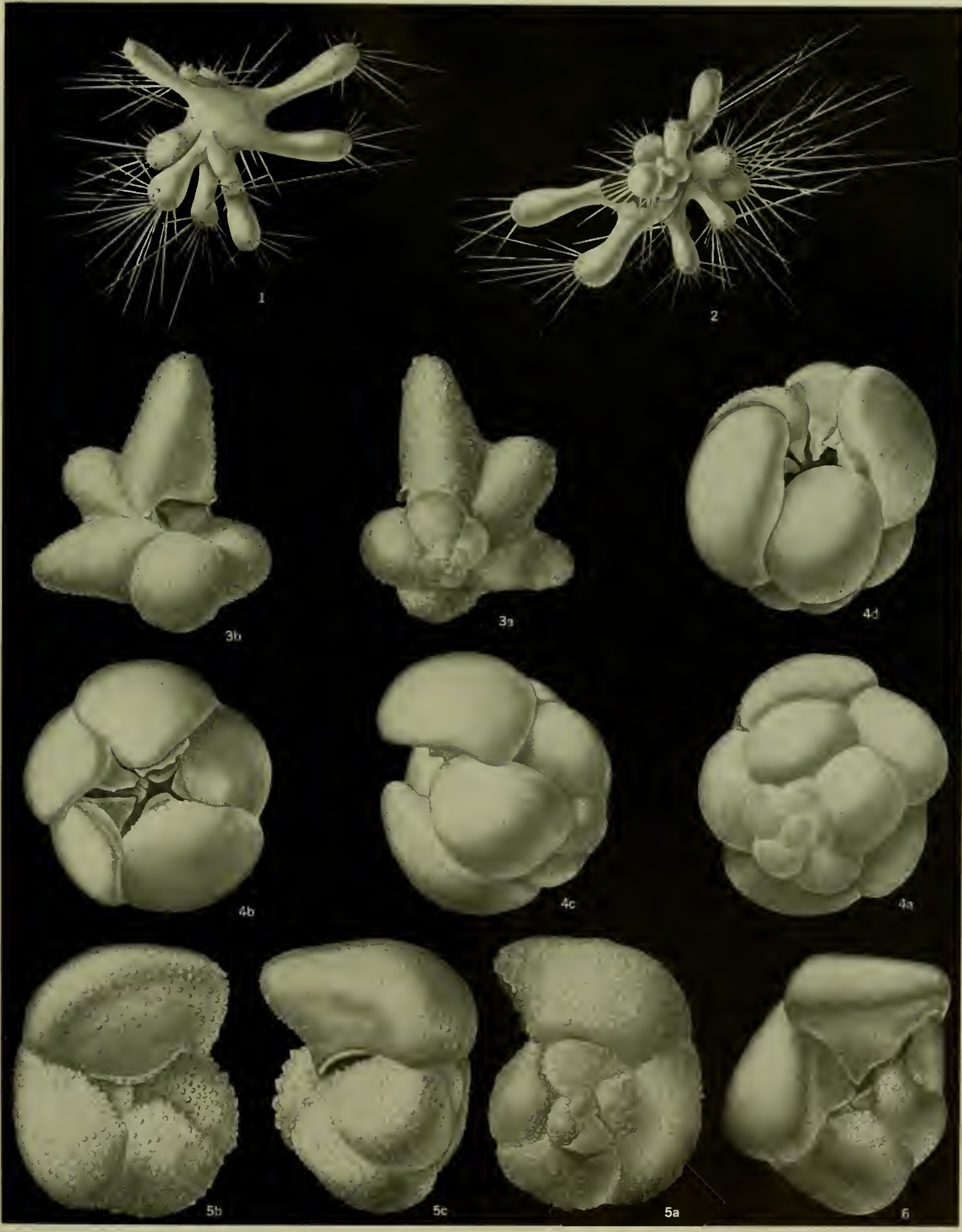
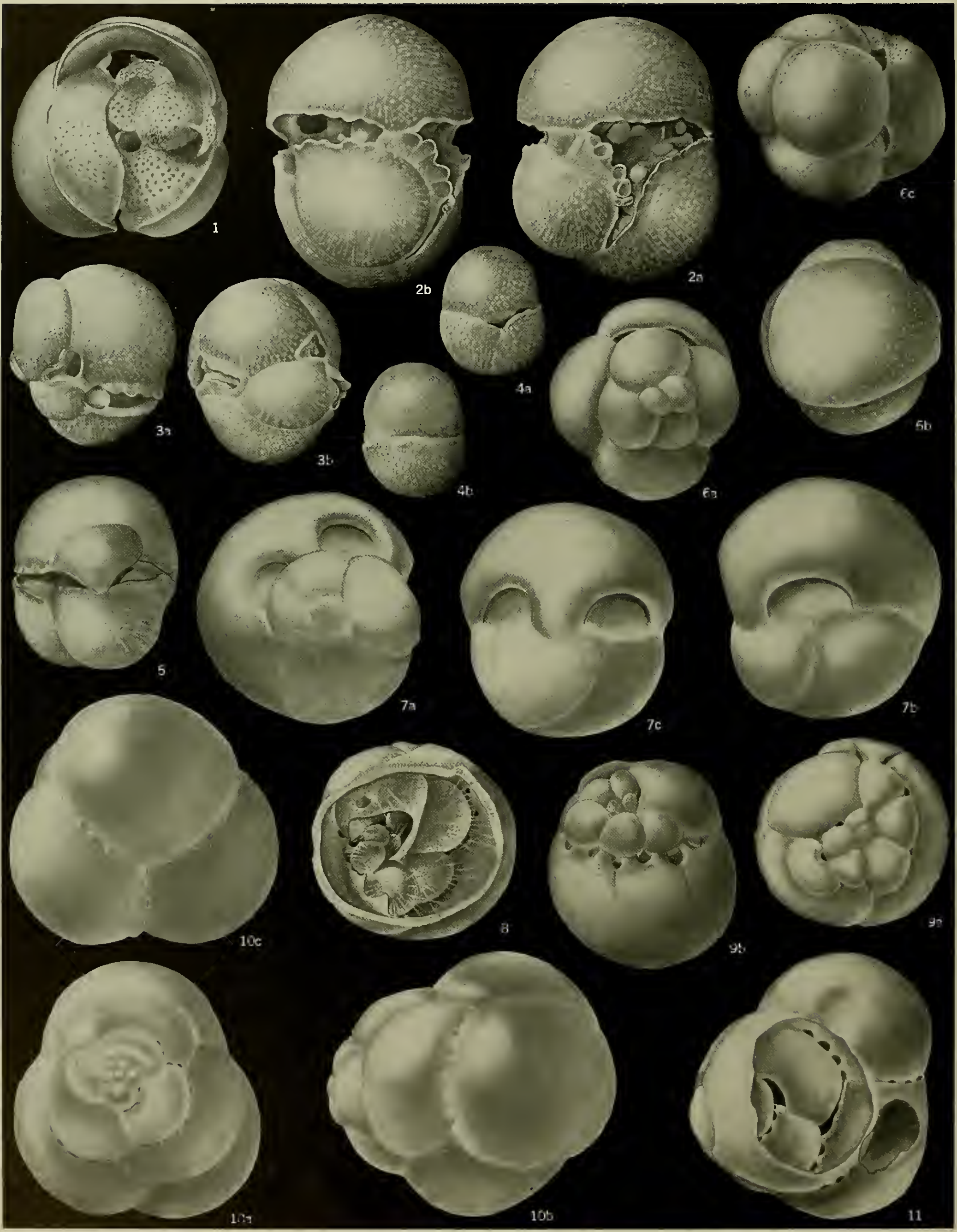


ORBULINIDAE : GLOBIGERININAE



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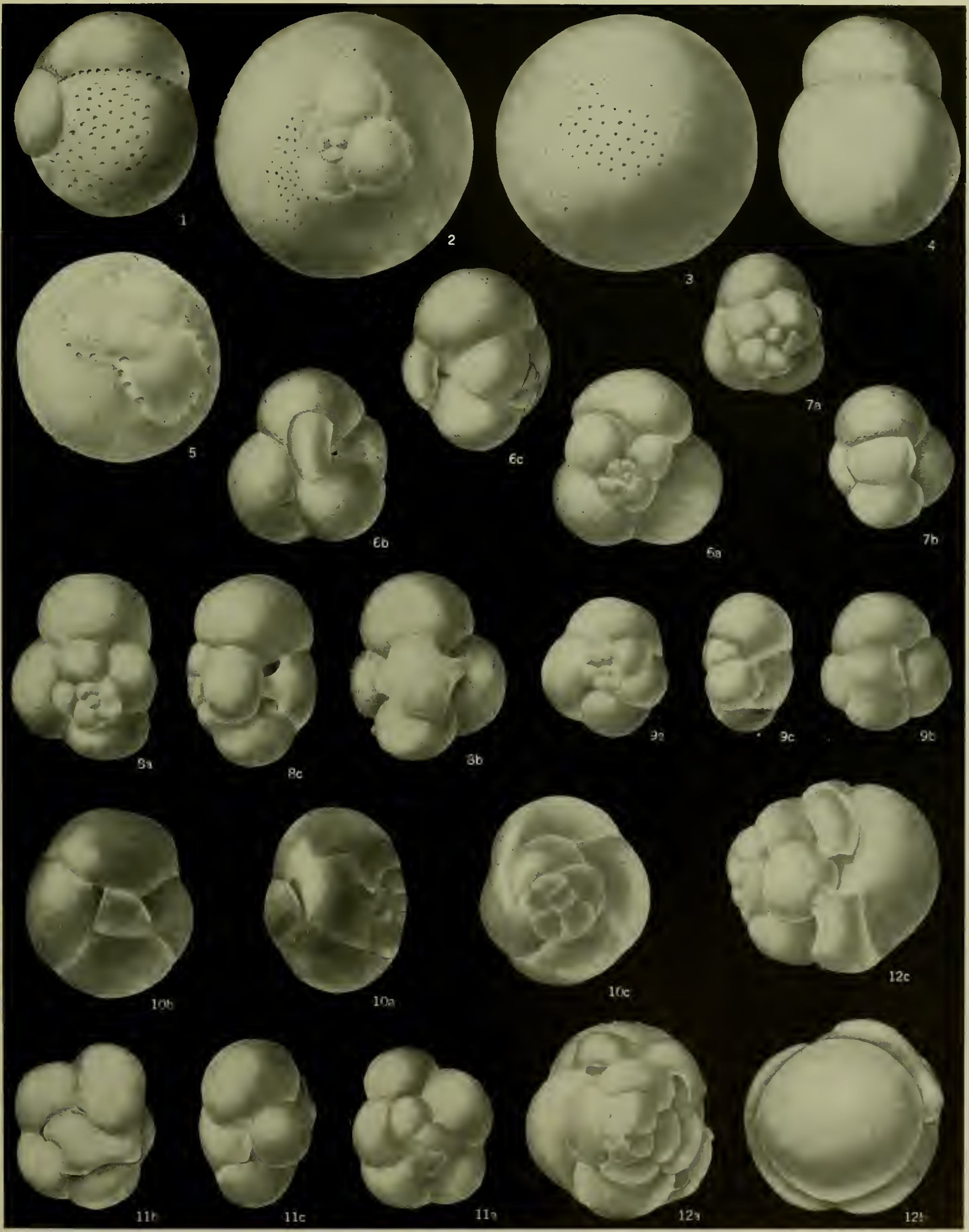

ORBULINIDAE: ORBULININAE, CATAPSYDRACINAE

ORBULINIDAE: CATAPSYDRACINAE

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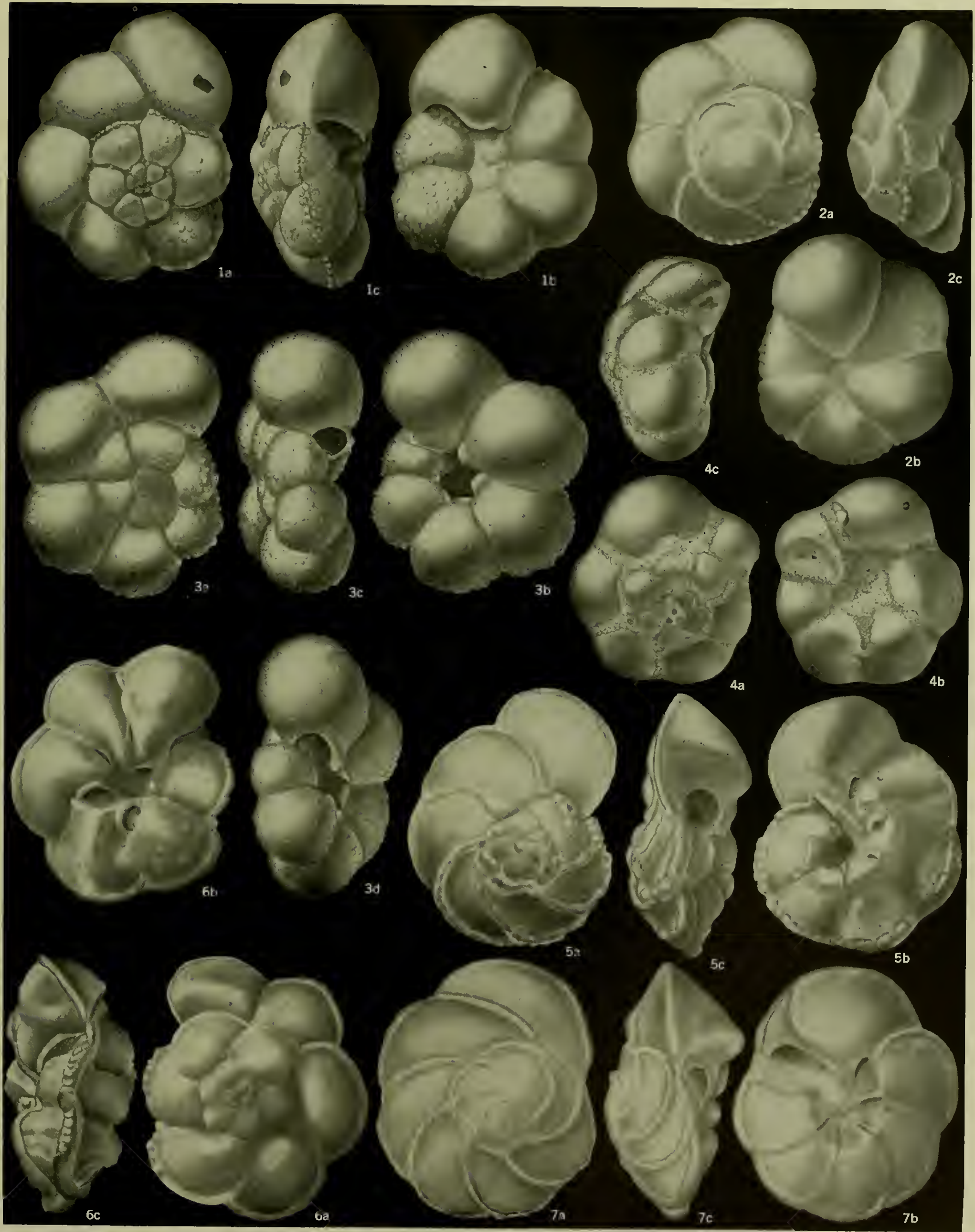

GLOBOROTALIIDAE

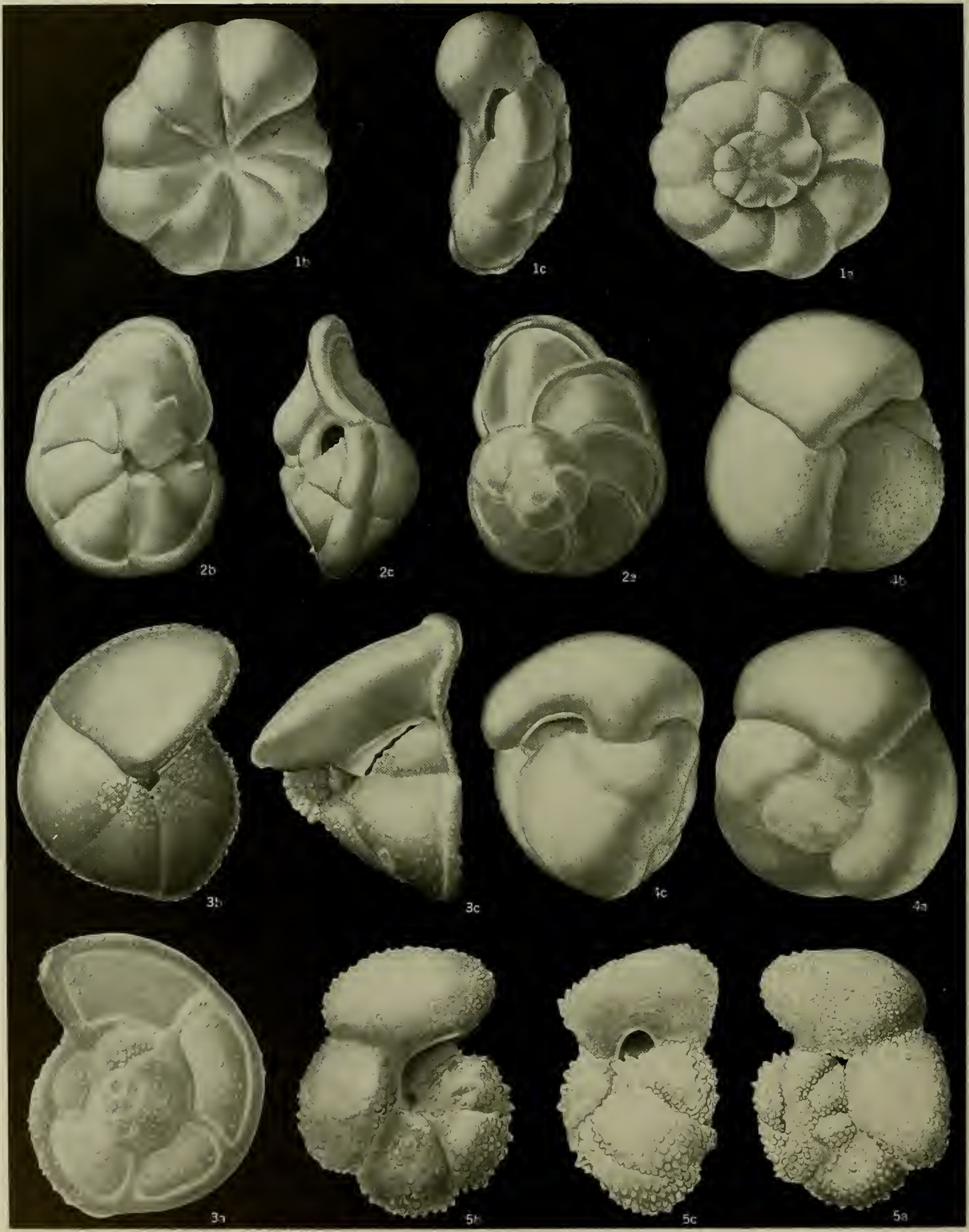

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PLATE 10. GLOBOROTALIIDAE

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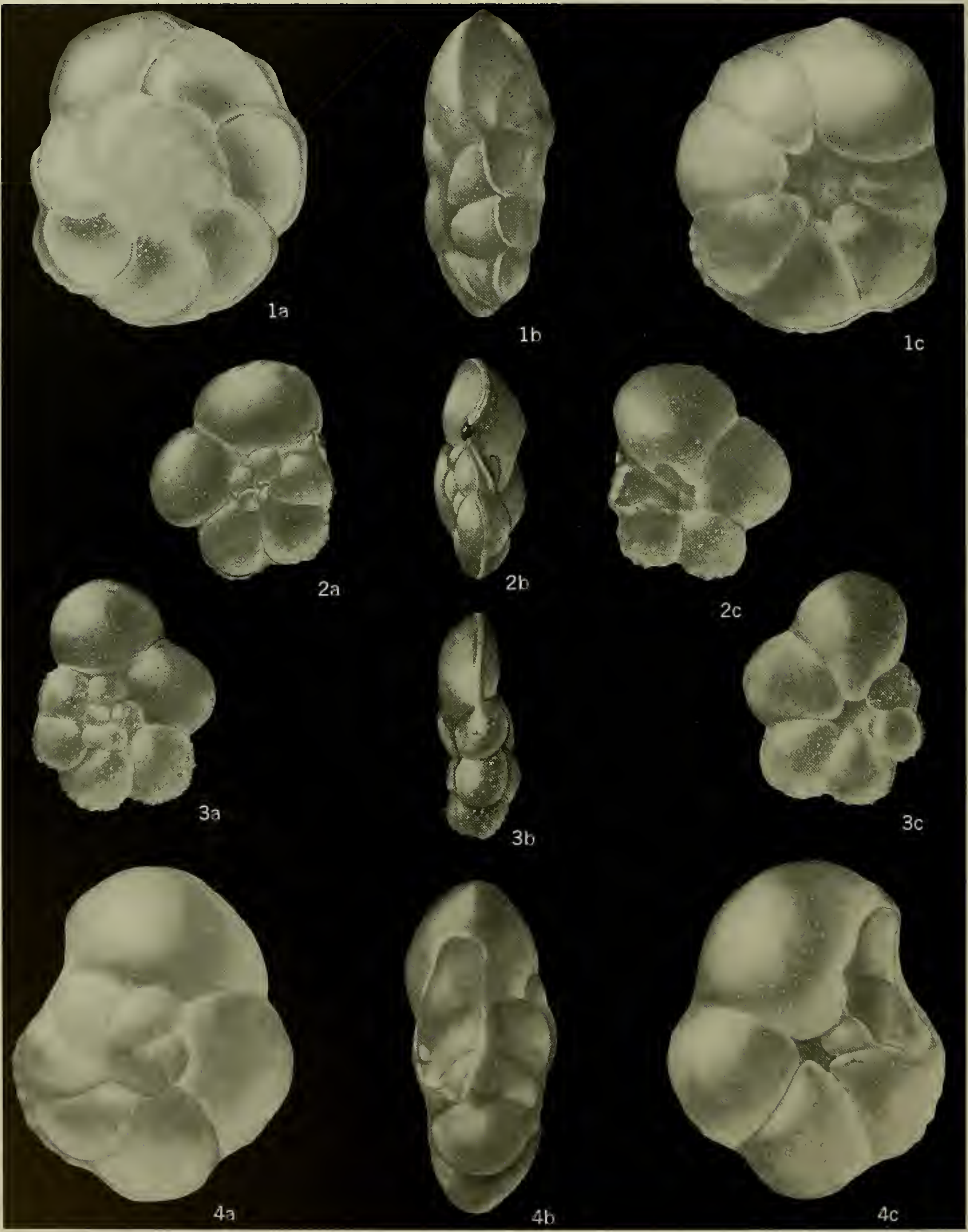

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PLATE 12. ROTALIPORA, PRAEGLOBOTRUNCANA

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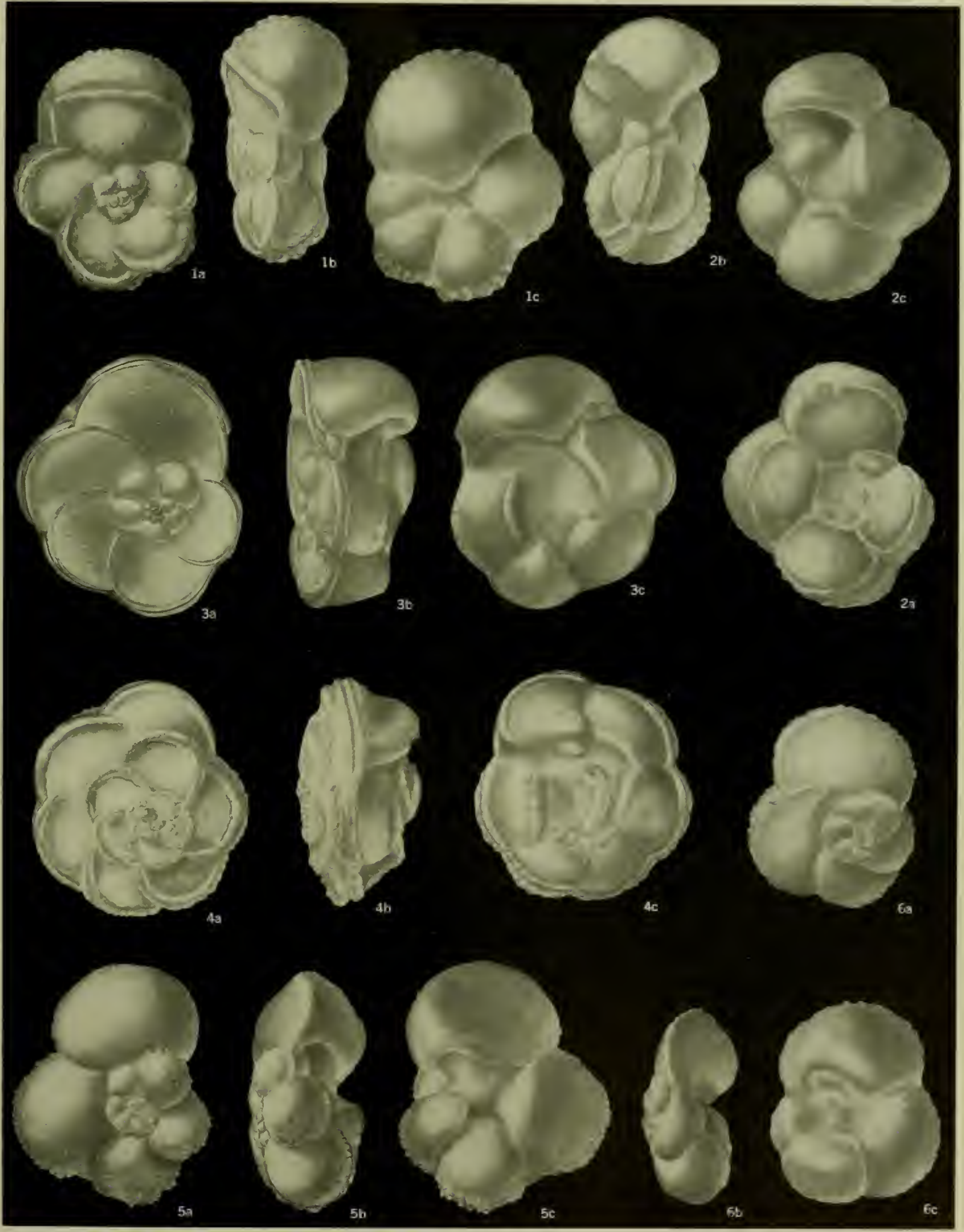

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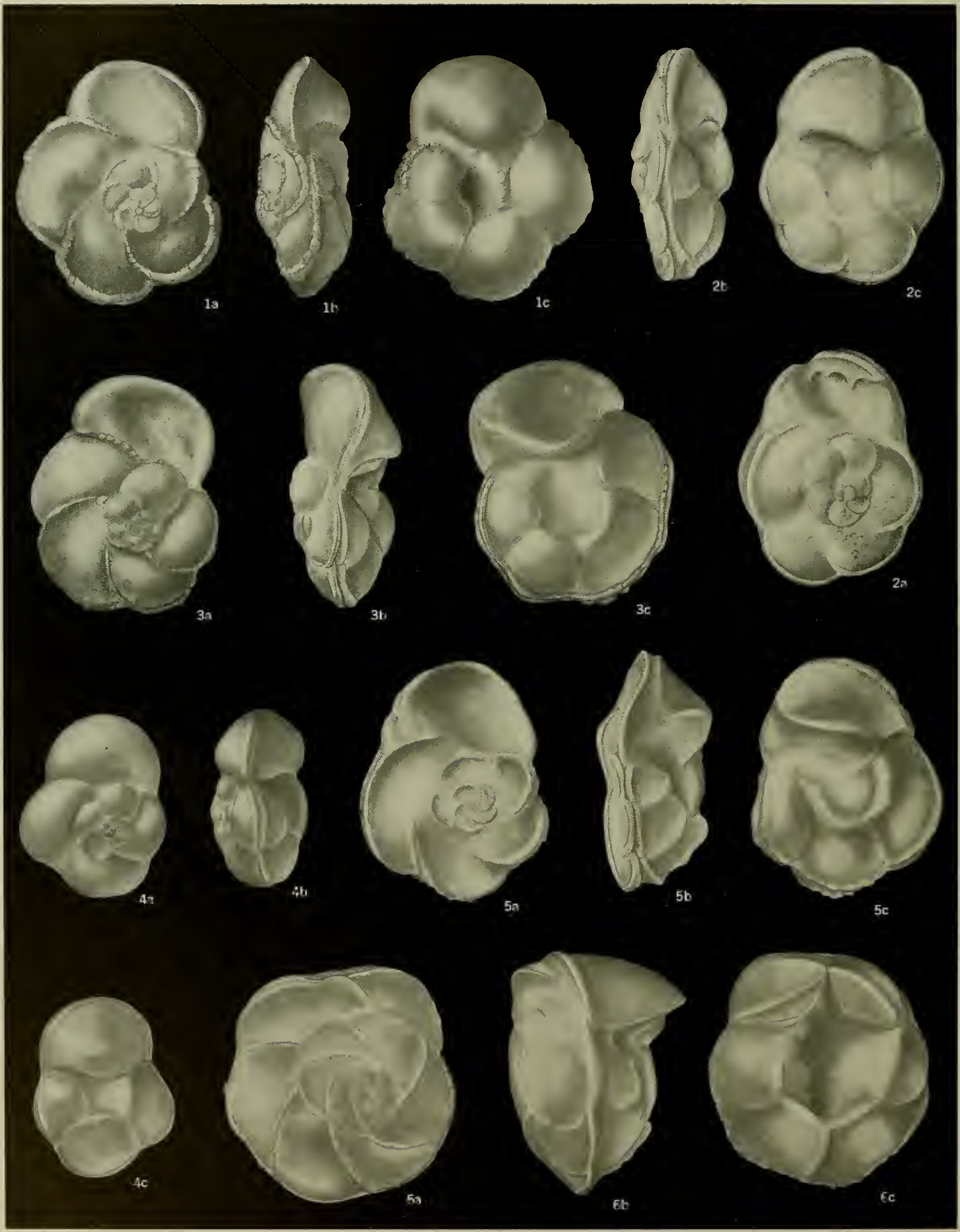

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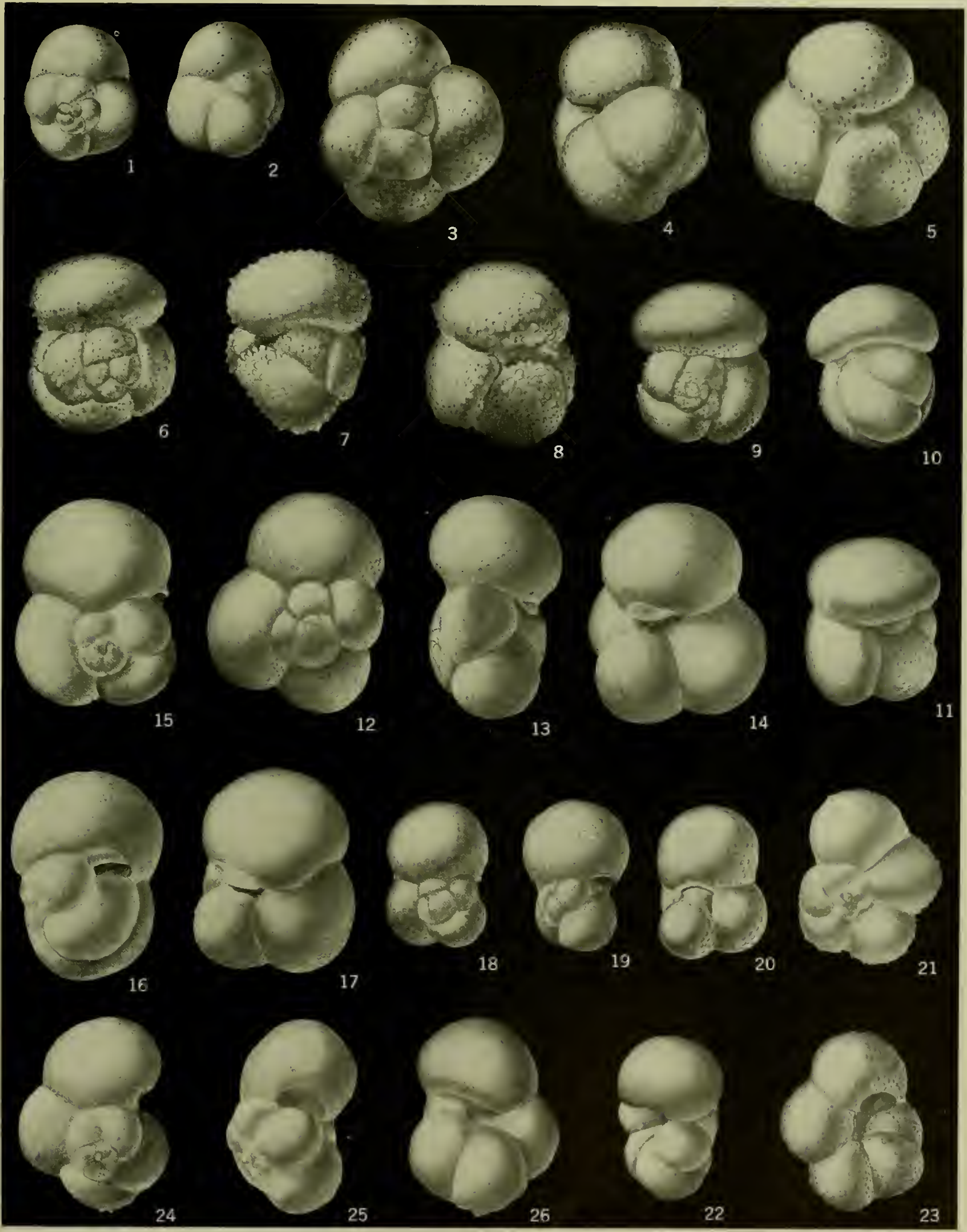

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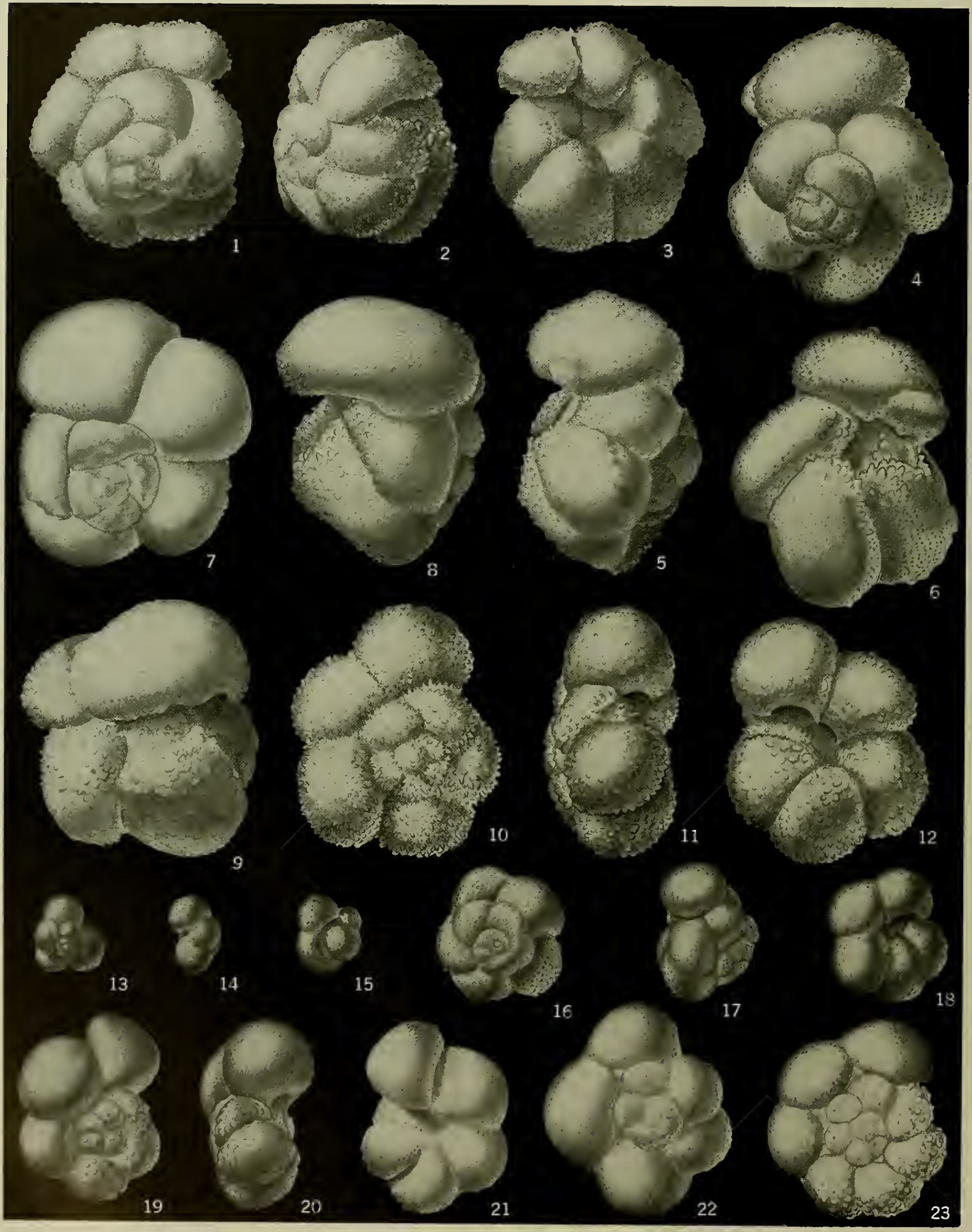

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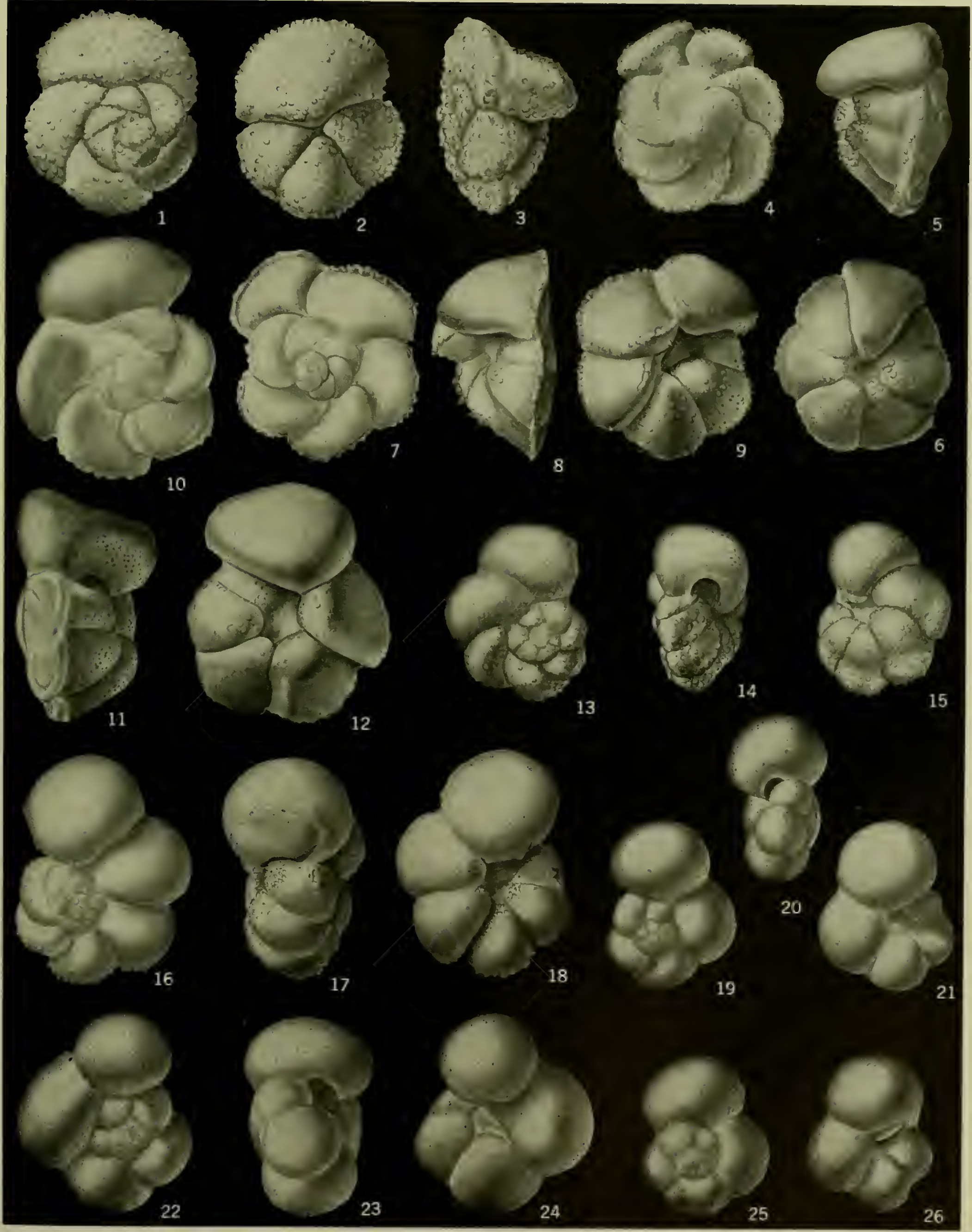

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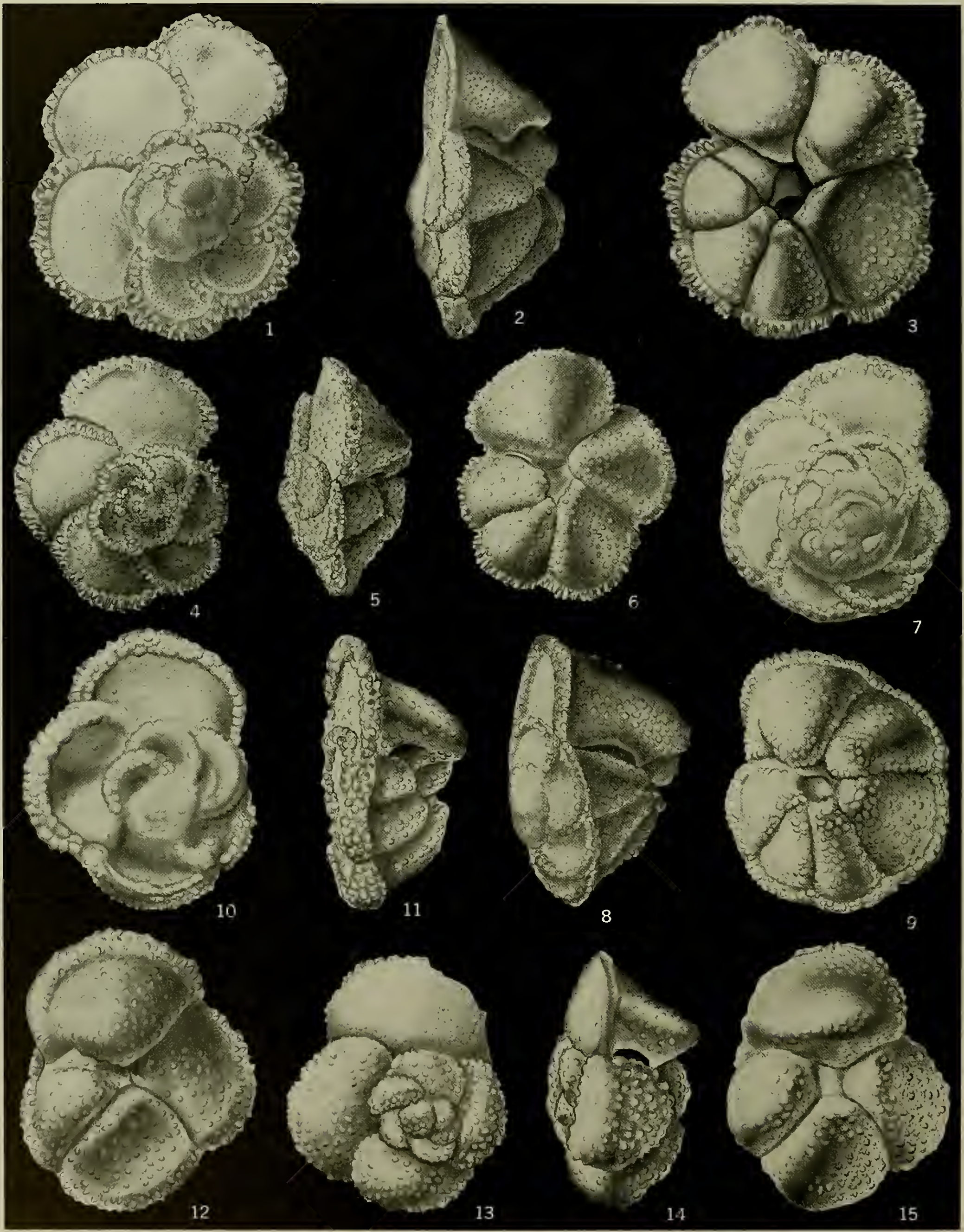

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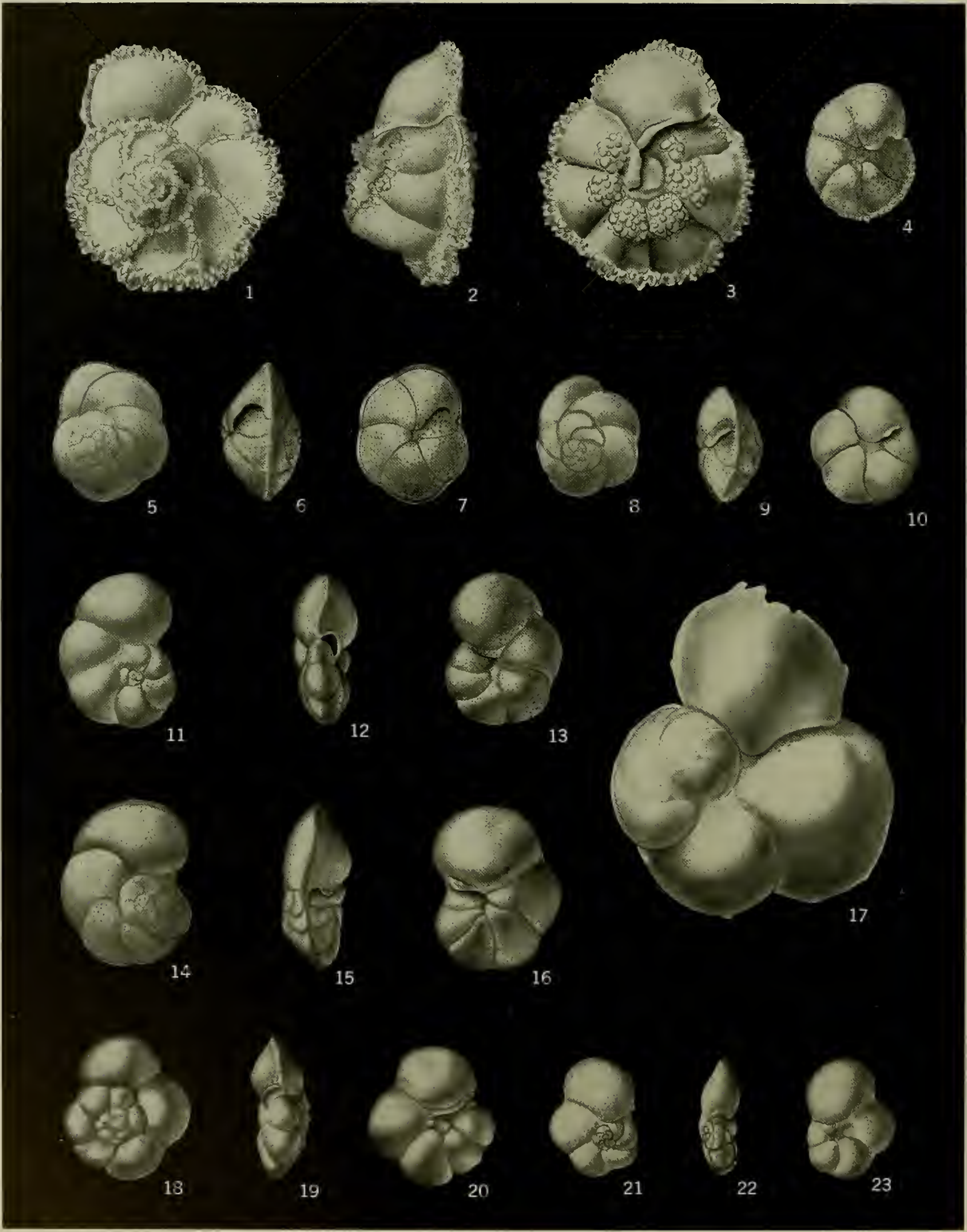

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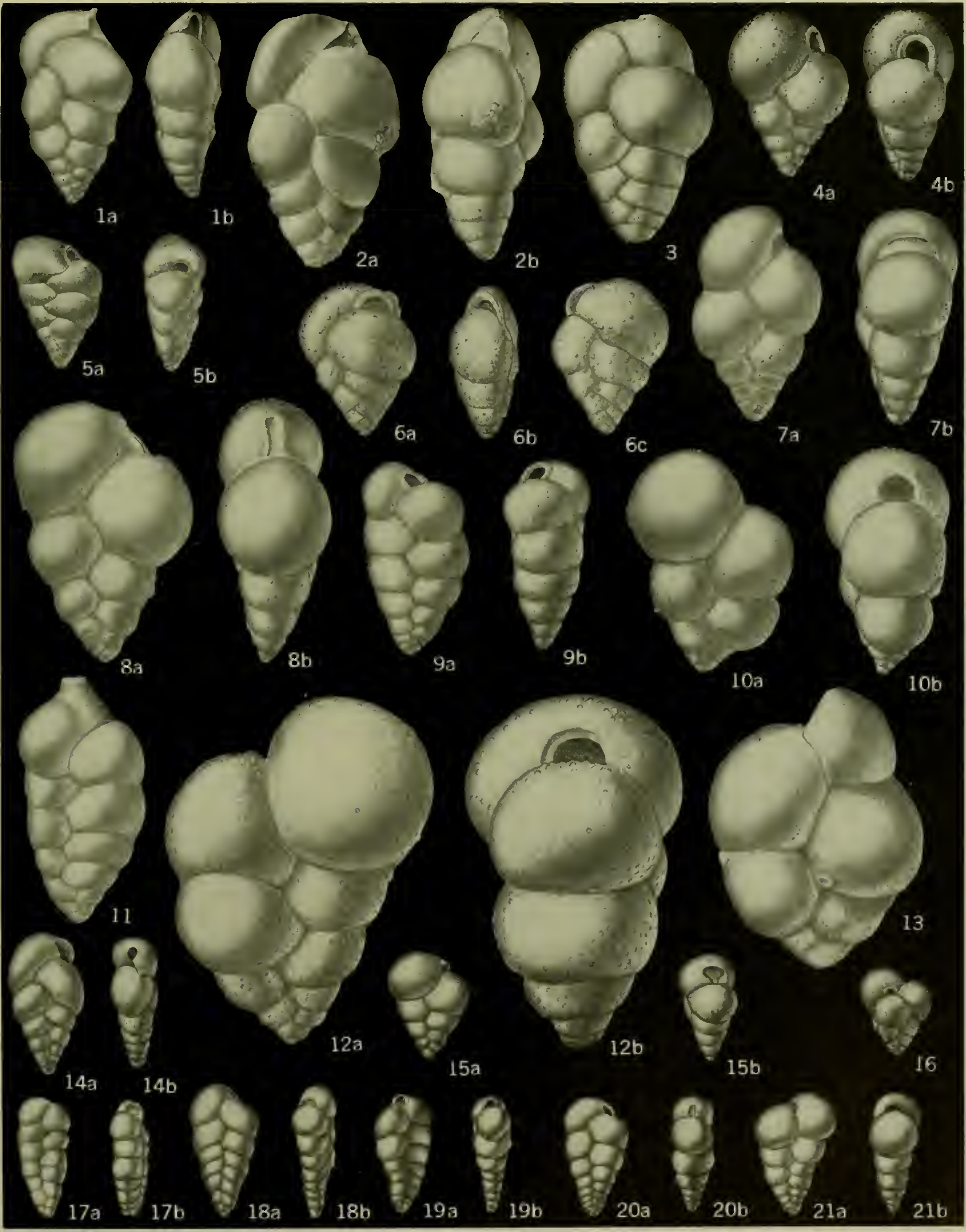

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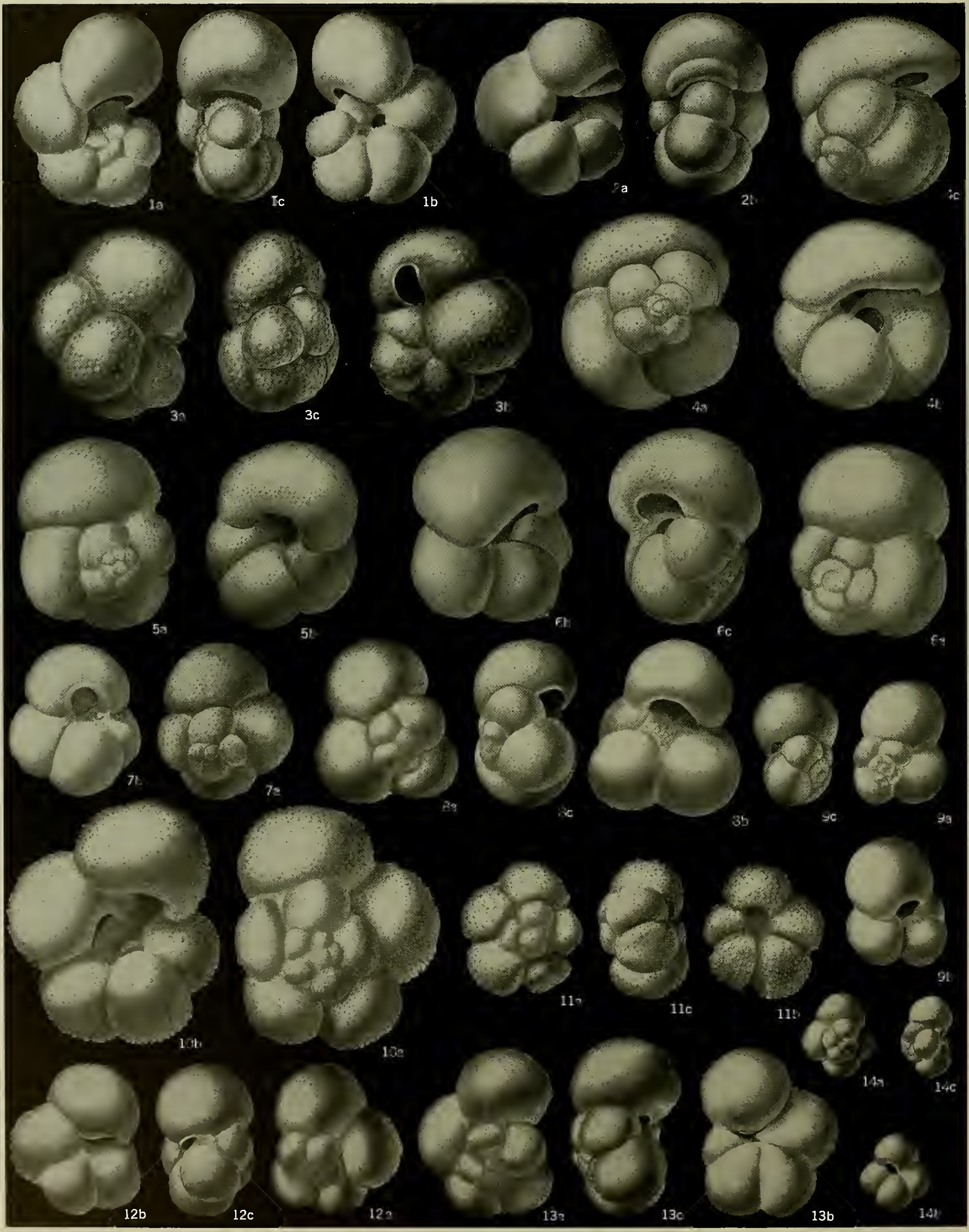

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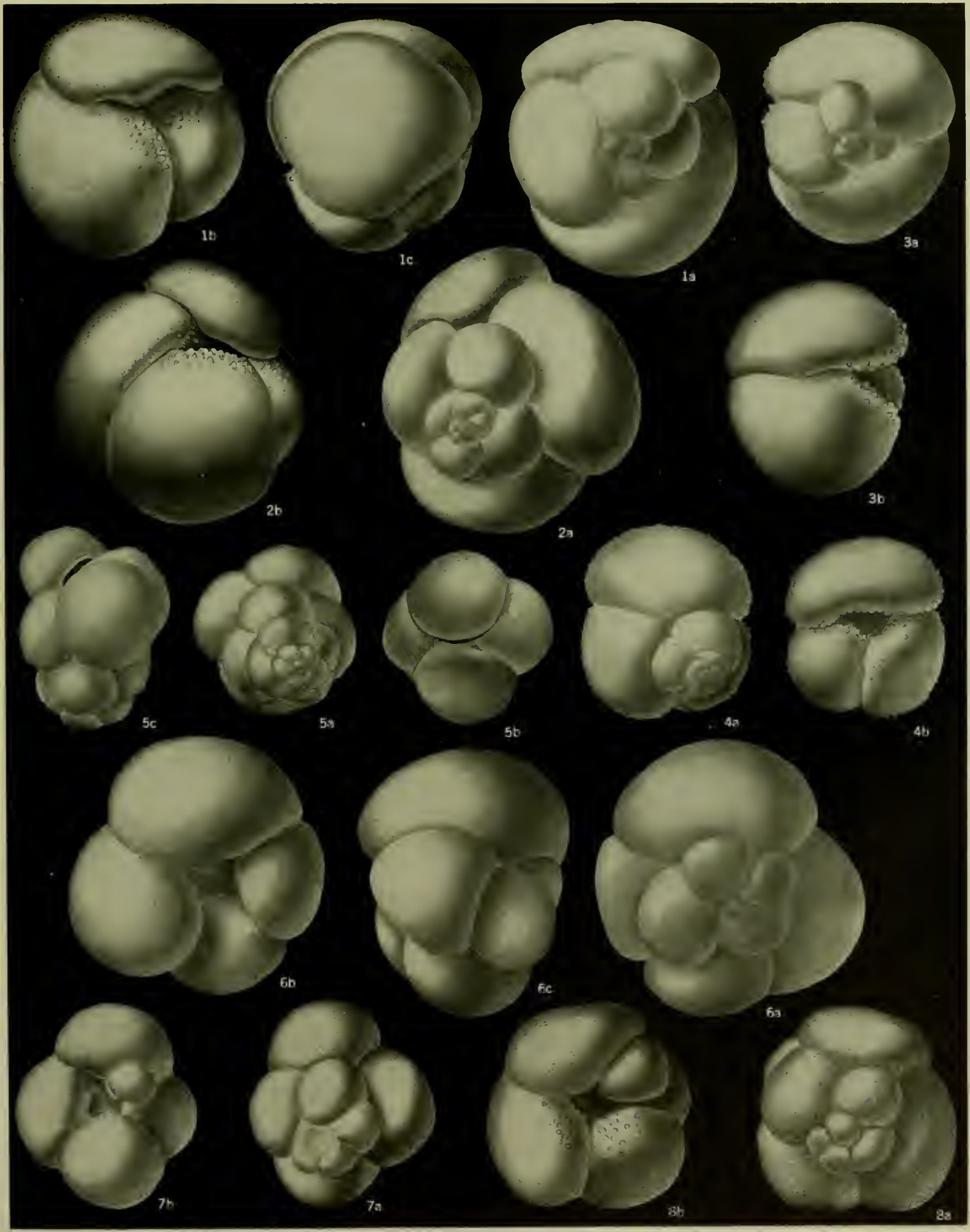
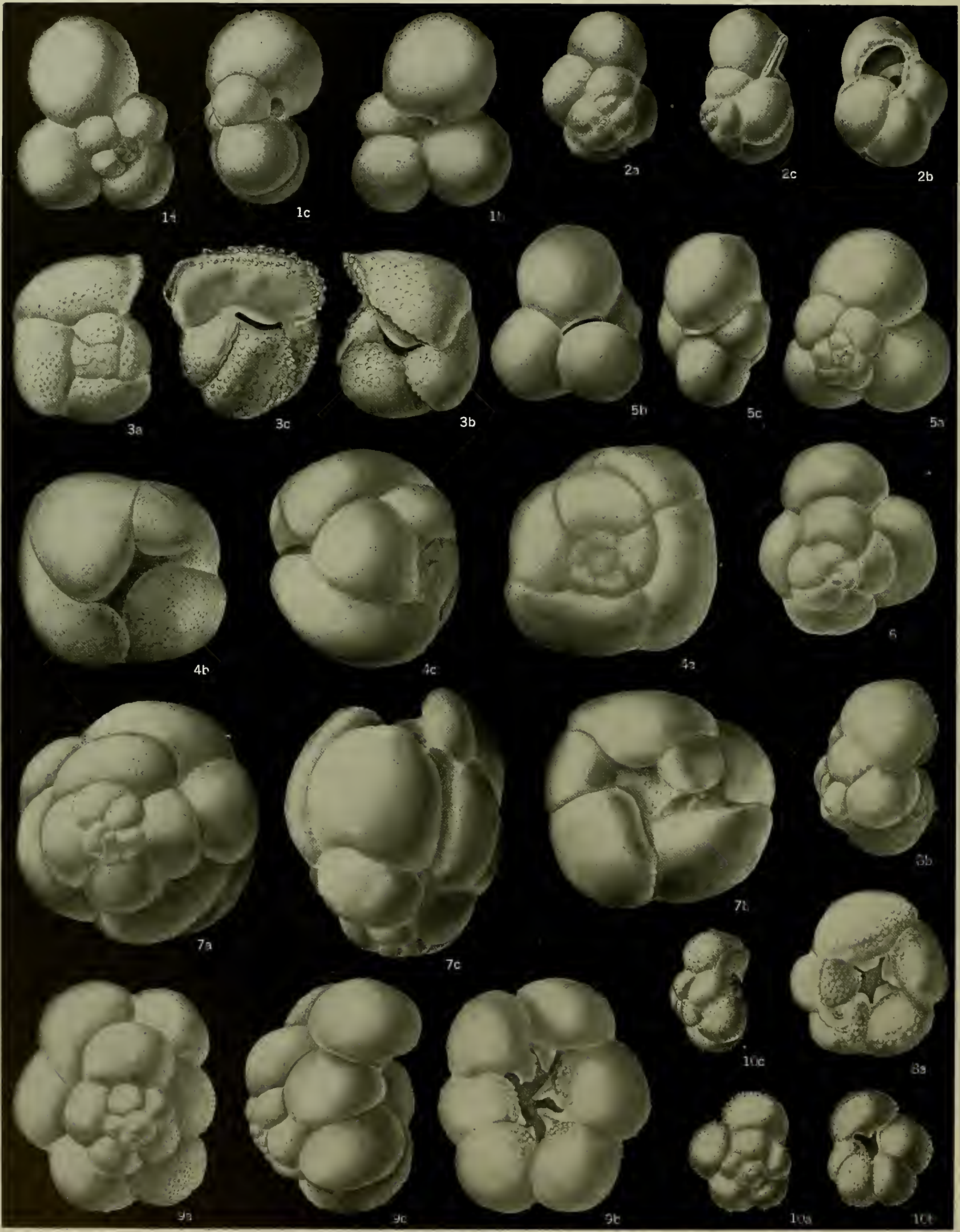


GLOBIGERINA



GLOBIGERINA, GLOBOQUADRINA

Plate 24. GLOBIGERINA, GLOBOQUADRINA

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1a, Spiral view of holotype (USNM P5620). **1b,** Umbilical view. **1c,** Side view. From the *Globorotalia fohsi robusta* zone, Cipero formation, Trinidad, × 68.

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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.

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PLATE 25. HASTIGERINELLA, GLOBIGERINOIDES

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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) 112

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FIGURES 3a–4c. *Globigerinoides triloba immatura* Le Roy 113

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.

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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.

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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.

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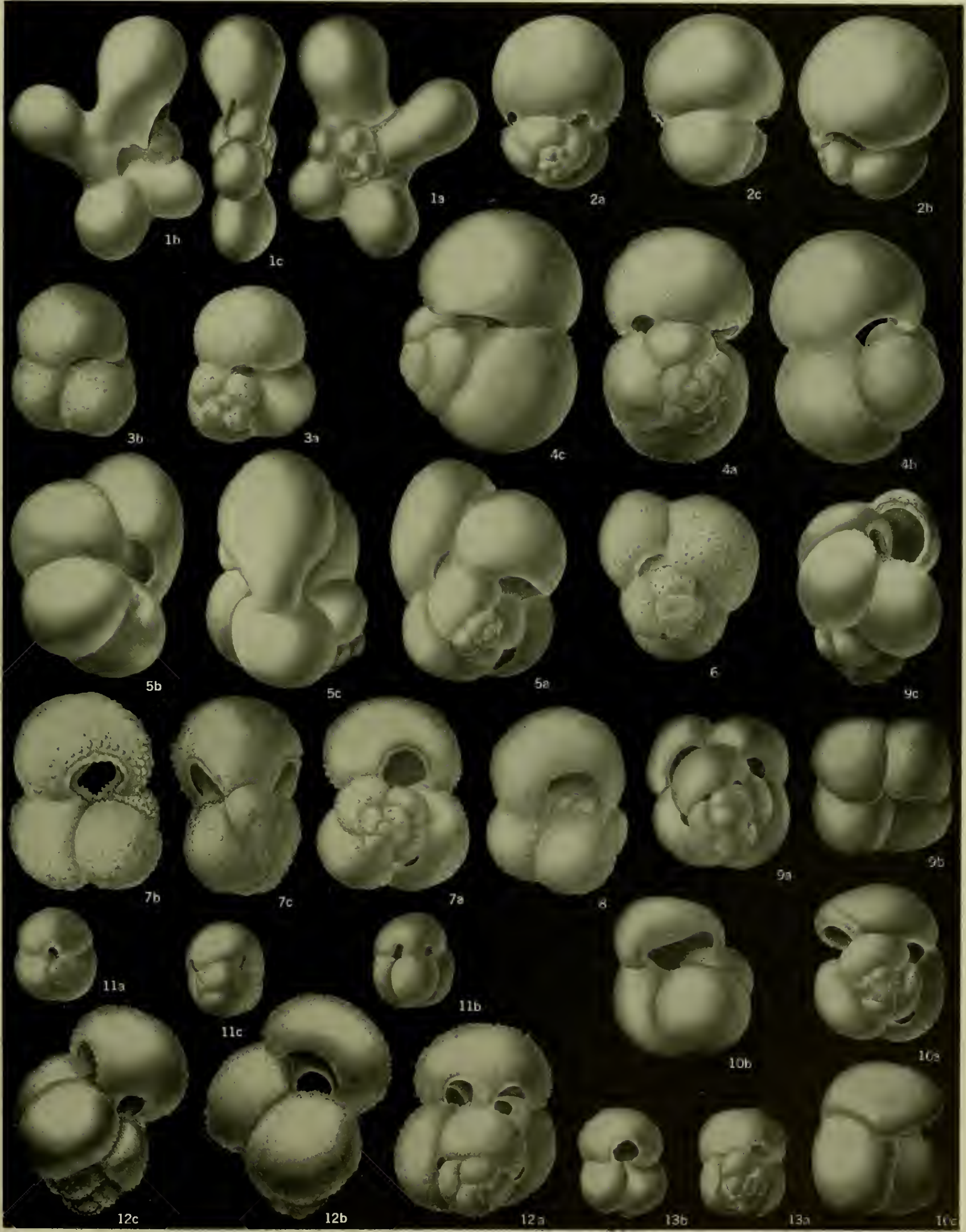
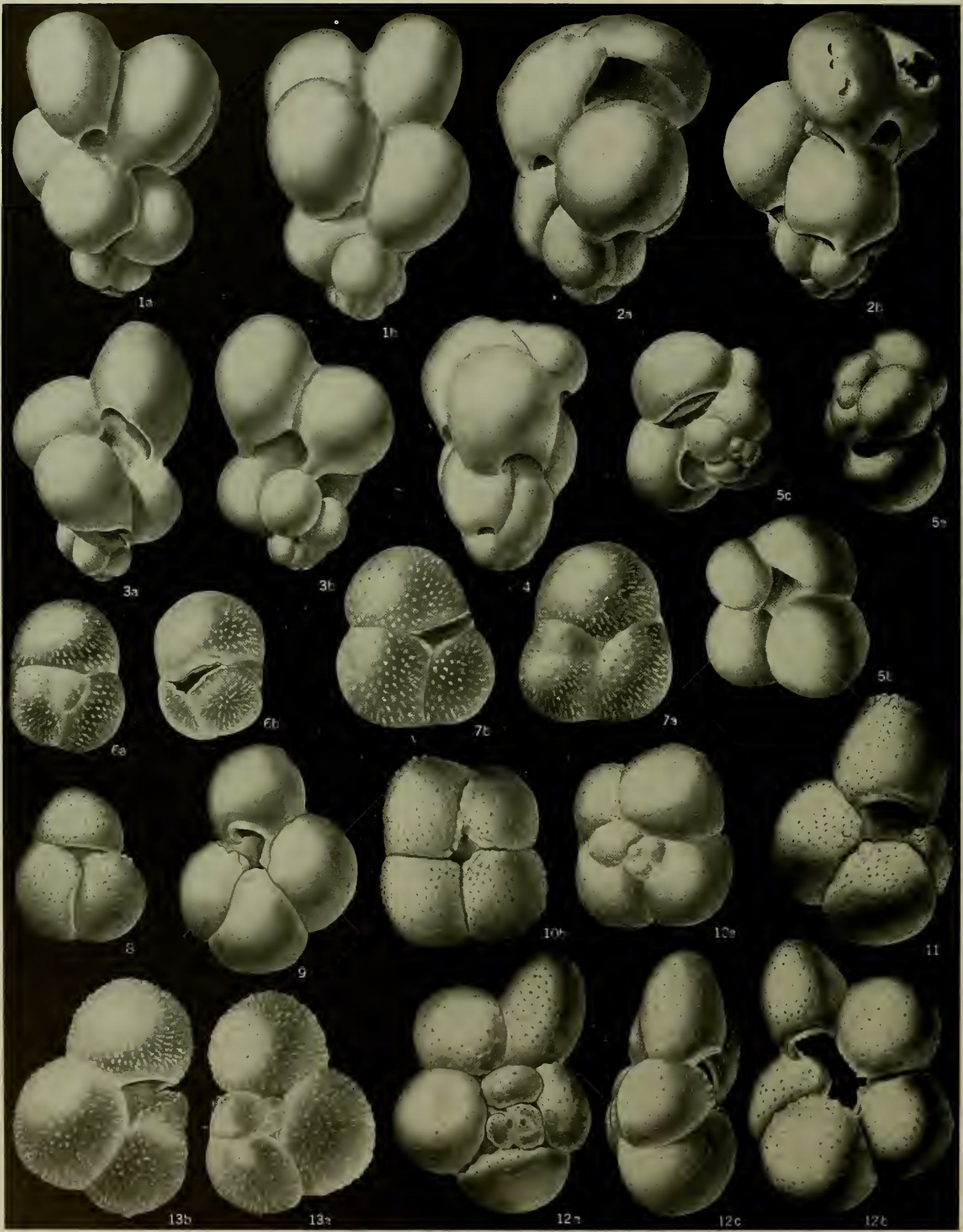
FIGURES 12a–13b. *Globigerinoides rubra* (d'Orbigny) 113

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.



HASTIGERINELLA, GLOBIGERINOIDES



GLOBIGERINOIDES, SPHAEROIDINELLA

PLATE 26. GLOBIGERINOIDES, SPHAEROIDINELLA

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PLATE 27. GLOBIGERINOIDES, PORTICULASPHAERA, ORBULINA, GLOBOROTALOIDES

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FIGURES 1a, b. *Globigerinoides bispherica* 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* (Blow) 115

2, Hypotype (USNM P5649). From the *Globigerinatella insueta* zone, Cipero formation, Trinidad.

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FIGURE 6. *Orbulina bilobata* (d'Orbigny) 116

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FIGURE 7. *Porticulasphaera glomerosa curva* (Blow) 115

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FIGURE 8. *Porticulasphaera glomerosa glomerosa* (Blow) 115

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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.

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14a, Spiral view (USNM P5656). **14b,** Umbilical view. **14c,** Side view. From the *Globigerina ampliapertura* zone, Cipero formation, Trinidad.

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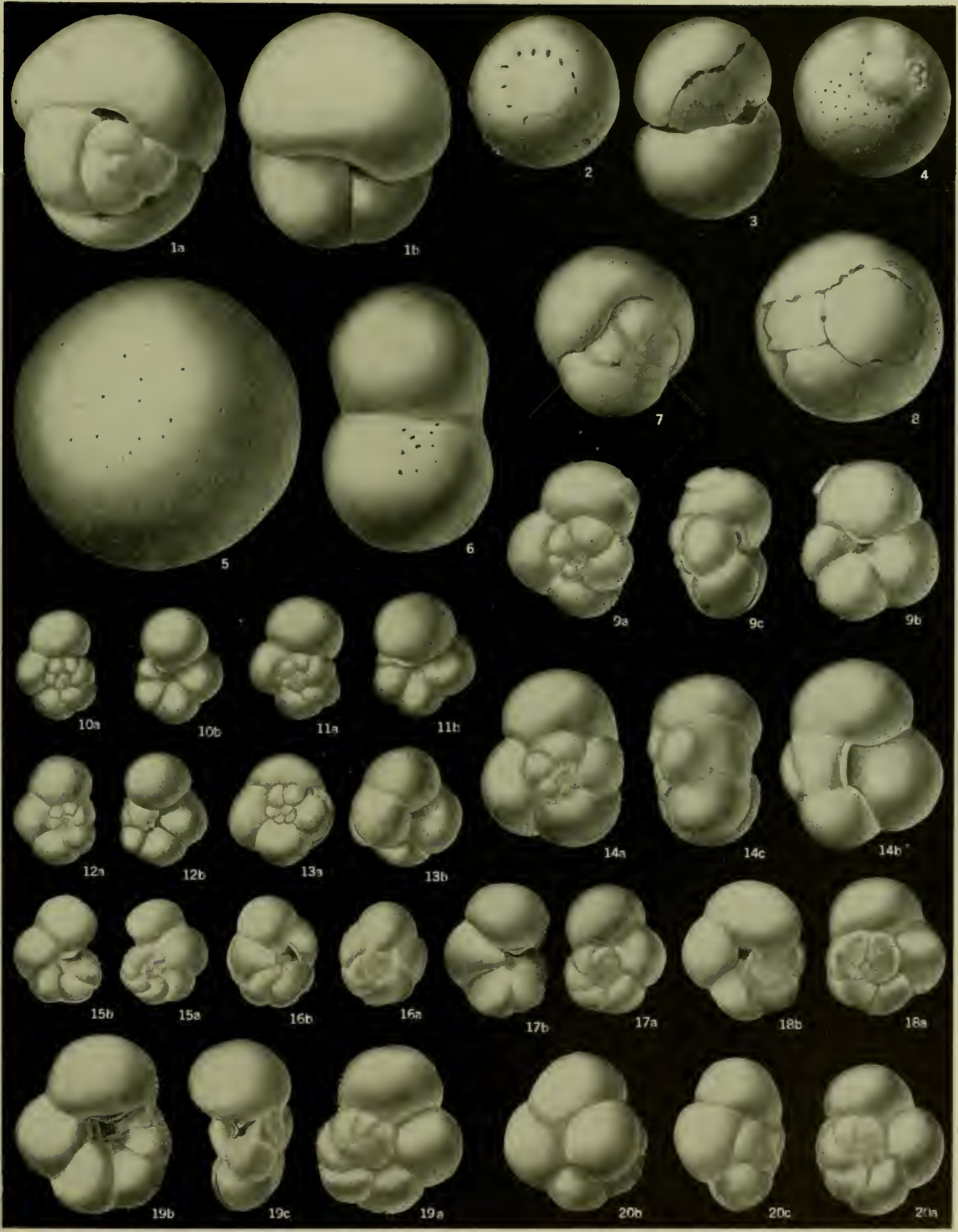
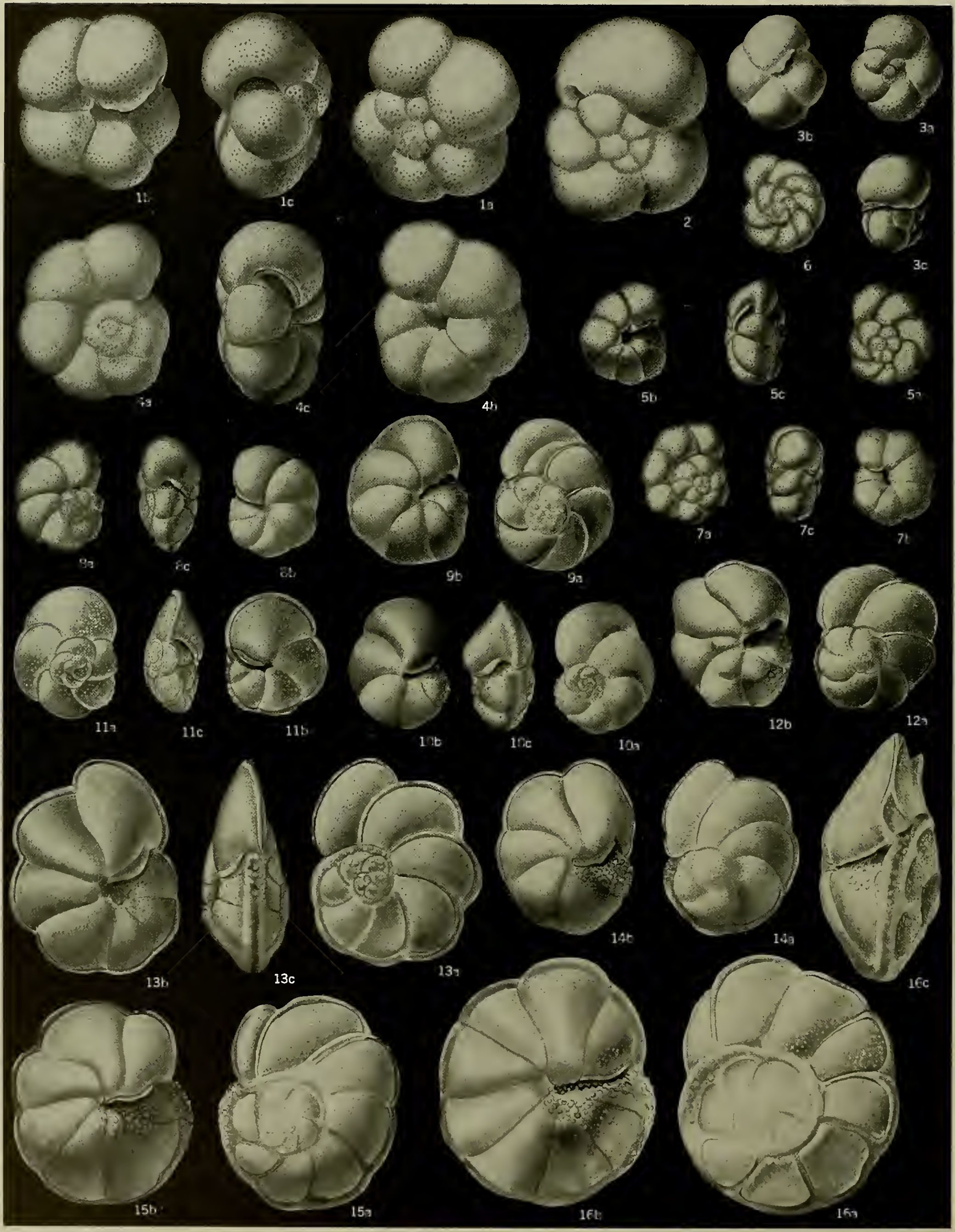


GLOBIGERINOIDES, PORTICULASPHAERA, ORBULINA, GLOBOROTALOIDES



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Figures 1a–2. *Globorotalia opima opima* Bolli, new species, new subspecies. 117

1a, Spiral view of holotype (USNM P5659). **1b,** Umbilical view. **1c,** Side 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. 118

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 118

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 118

5a, Spiral view of holotype (USNM P5663). **5b,** Umbilical view. **5c,** Side view. **6,** Spiral view of paratype (USNM P5664). Both from the *Globorotalia kugleri* zone, Cipero formation, Trinidad.

Figures 7a–c. *Globorotalia* cf. *kugleri* Bolli 118

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 119

8a, Spiral view of hypotype (USNM P5666). **8b,** Umbilical view. **8c,** Side view. From the *Globorotalia fohsi barisanensis* zone, Cipero formation, Trinidad.

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Figures 9a–10c. *Globorotalia fohsi fohsi* Cushman and Ellisor 119

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 119

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 119

12a, Spiral view (USNM P5670). **12b,** Umbilical view. From the *Globorotalia fohsi fohsi* zone, Cipero formation, Trinidad.

Figures 13a–14b. *Globorotalia fohsi lobata* Bermudez 119

13a, Spiral view of hypotype (USNM P5669a). **13b,** Umbilical view. **13c,** Side view. **14a,** Spiral view of hypotype (USNM P5669b). **14b,** Umbilical view. Both from the *Globorotalia fohsi lobata* zone, Cipero formation, Trinidad.

Figures 15a–b. Transitional specimen of *Globorotalia fohsi lobata* Bermudez to *Globorotalia fohsi robusta* Bolli 119

15a, Spiral view (USNM P5672). **15b,** Umbilical view. From the *Globorotalia fohsi robusta* zone, Cipero formation, Trinidad.

Figures 16a–c. *Globorotalia fohsi robusta* Bolli 119

16a, Spiral view of paratype (USNM P5671). **16b,** Umbilical view. **16c,** Side view. From the *Globorotalia fohsi robusta* zone, Cipero formation, Trinidad.

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FIGURES 1a–c. *Globorotalia minutissima* Bolli, new species 119

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 119

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 120

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 120

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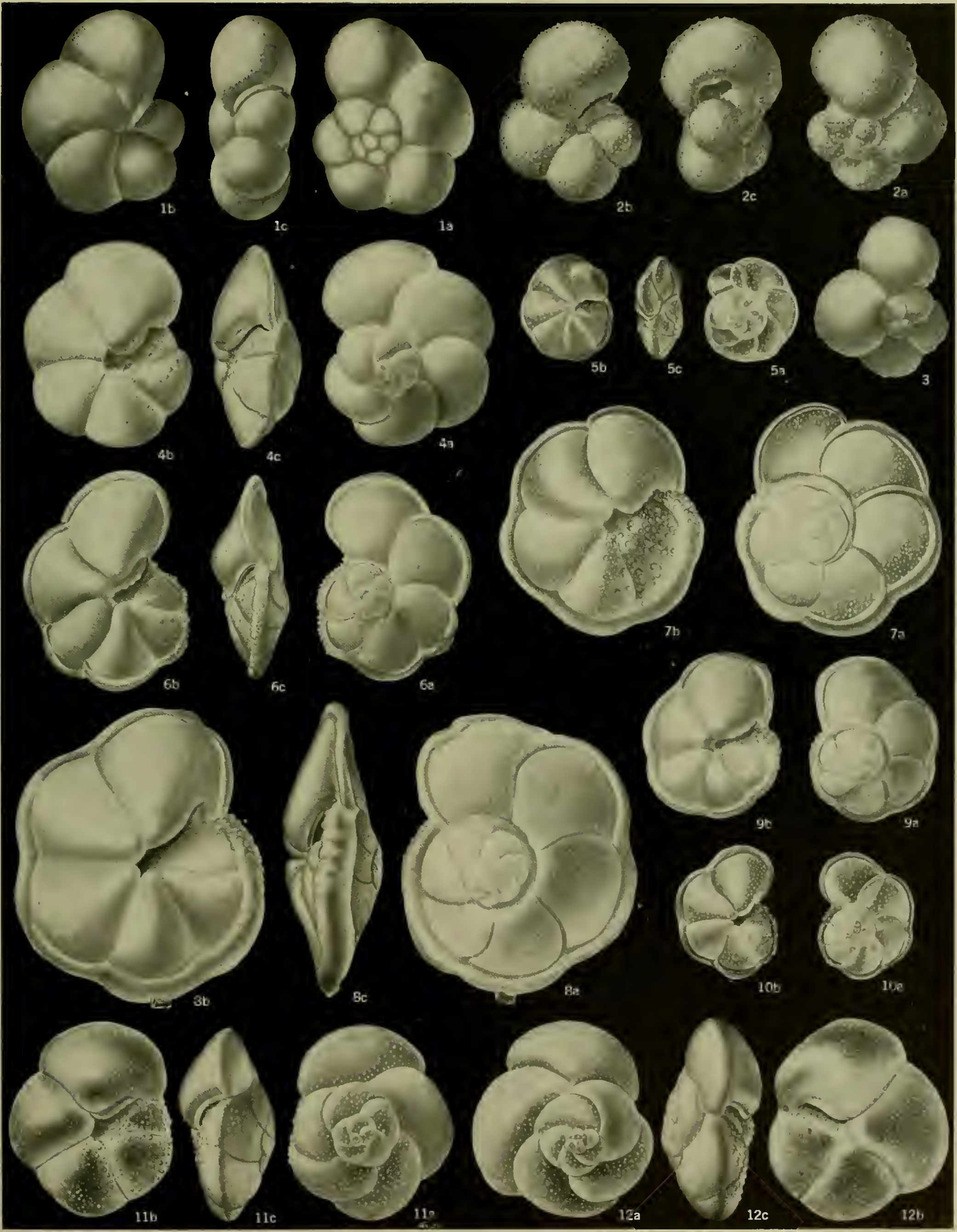
5a, Spiral view of holotype (USNM P5681). **5b,** Umbilical view. **5c,** Side view. From the Lengua formation, Trinidad, × 68.

FIGURES 6a–10b. *Globorotalia menardii* (d'Orbigny) 120

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) 120

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.



GLOBOROTALIA

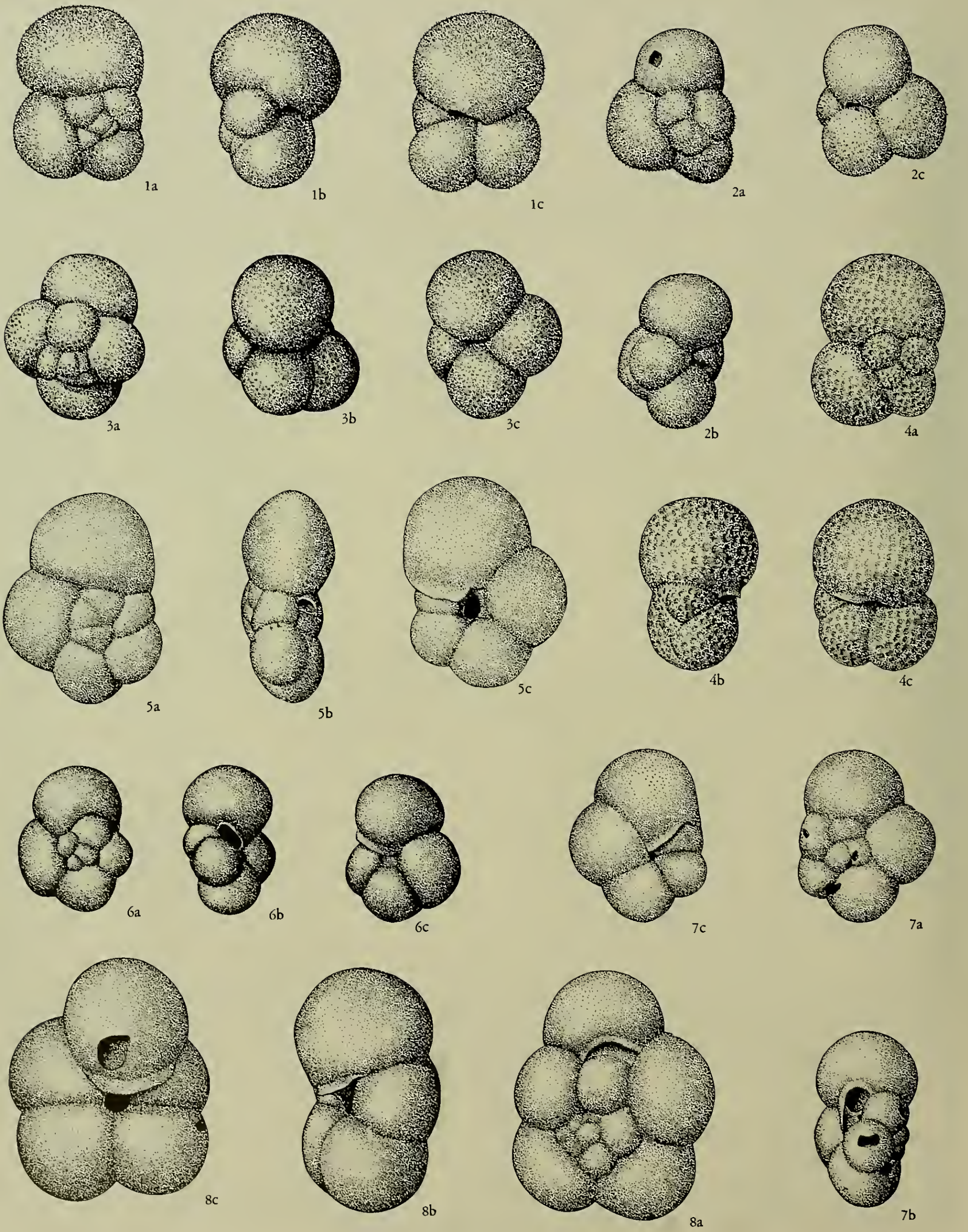


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PLATE 30. GLOBIGERINA

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FIGURES 1a–2c. *Globigerina daubjergensis* Bronnimann 128

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 129

3a, Spiral view of hypotype (USNM P5575) from sample 3 (see text-fig. 24), *Tylocidaris brünnichi* 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 129

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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 128

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.

PLATE 31. HETEROHELICIDAE: GUEMBELITRIINAE, HETEROHELICINAE

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FIGURES 1a,b. *Guembelitria cretacea* Cushman 136

1a, Side view of holotype (Cushman Coll. 19022) from the Navarro formation, Upper Cretaceous, Guadelupe County, Texas. **1b,** Top view. × 310.

FIGURE 2. "*Guembelitria*" *vivans* Cushman 136

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 137

3, Paratype (Cushman Coll. 44713), 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, 3½ miles northeast of Roanoke, Denton County, Texas. Coll. by A. R. Loeblich, Jr., and Helen Tappan Loeblich. × 175.

FIGURES 5a–11. *Heterohelix navarroensis* Loeblich 137

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., McQueeny, Guadelupe County, Texas. Coll. by A. R. Loeblich, Jr.

FIGURES 12–15. *Heterohelix globulosa* (Ehrenberg) 137

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., McQueeny, Guadelupe 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) 137

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) 137

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 reussi* (Cushman) 137

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) 137

19, Hypotype (Cushman Coll. 31513) from the Upper Cretaceous, Hopflinger Mühle, Upper Bavaria, showing small early coil, and somewhat elongated chambers. × 125.

FIGURE 20. *Heterohelix pulchra* (Brotzen) 137

20, Hypotype (Cushman Coll. 24417) of *Guembelina pseudotessera* Cushman (=*H. 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.

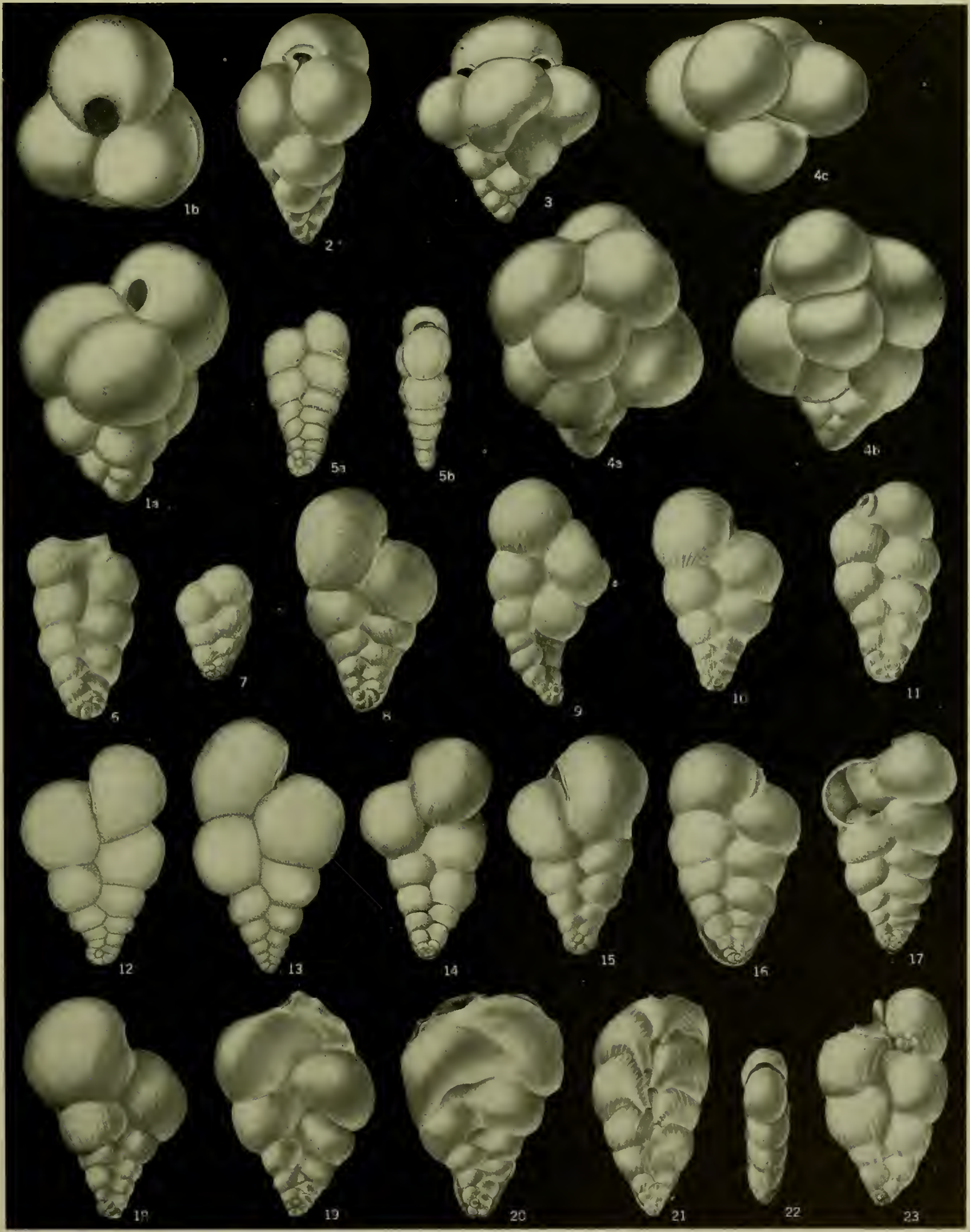
FIGURES 21, 22. *Pseudoguembelina costulata* (Cushman) 139

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.

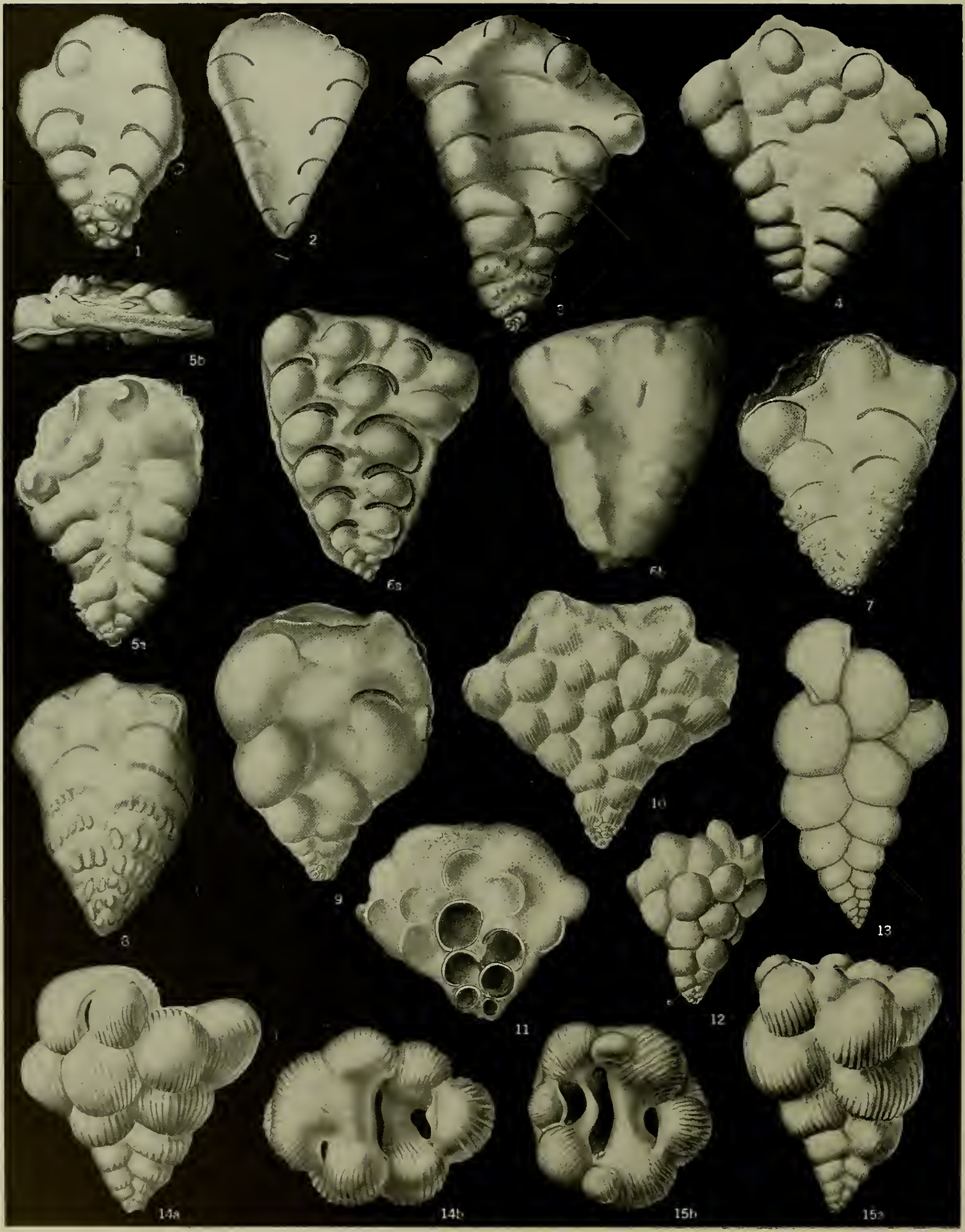
FIGURE 23. *Pseudoguembelina excolata* (Cushman) 139

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

PLATE 32. HETEROHELICIDAE: HETEROHELICINAE

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FIGURES 1–6b. *Gublerina ornatissima* (Cushman and Church) 140

1, Topotype (USNM P5446) of *Gublerina cuvillieri* Kikoïne (=*G. ornatissima*) the type species of *Gublerina*, from the Upper Cretaceous, Maestrichtian, between Gan and Rebenacq, 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-camerate central area; **3,** specimen showing ornamented basal portion, diverging chambers, and surface horizontal grooves suggesting septa across the central non-camerate 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. **5a,** Side view of hypotype (USNM P5448) of *G. cuvillieri*, from south of Gan, Dept. Basses Pyrenees, France. Coll. by I. de Klasz. **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 glaessneri* Bronnimann and Brown 140

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) 140

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.

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FIGURE 9. *Gublerina acuta robusta* de Klasz 140

9, Paratype (USNM P5441) of *Gublerina hedbergi* 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) 141

10, Large specimen, paratype of *Ventilabrella eggeri* var. *glabrata* Cushman (Cushman Coll. 24408), from the Upper Cretaceous, Taylor marl, 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 carseyae* (Plummer) 141

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, Guadelupe County, Texas. Coll. by A. R Loeblich, Jr. × 105.

FIGURES 14a–15b. *Racemiguembelina fructicosa* (Egger) 142

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

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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* (Rzehak) 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 quadrate outline, with gradual change 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 megalospheric form; **8b,** top view, showing aperture. **9,** Side view of microspheric form, showing biserial early stage. All × 75.

FIGURE 10. *Plectofrondicularia floridana* 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 and Siegfus 144

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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.

BULIMINIDAE

FIGURES 14–16c. *Bolivinoides draco* (Marsson) 145

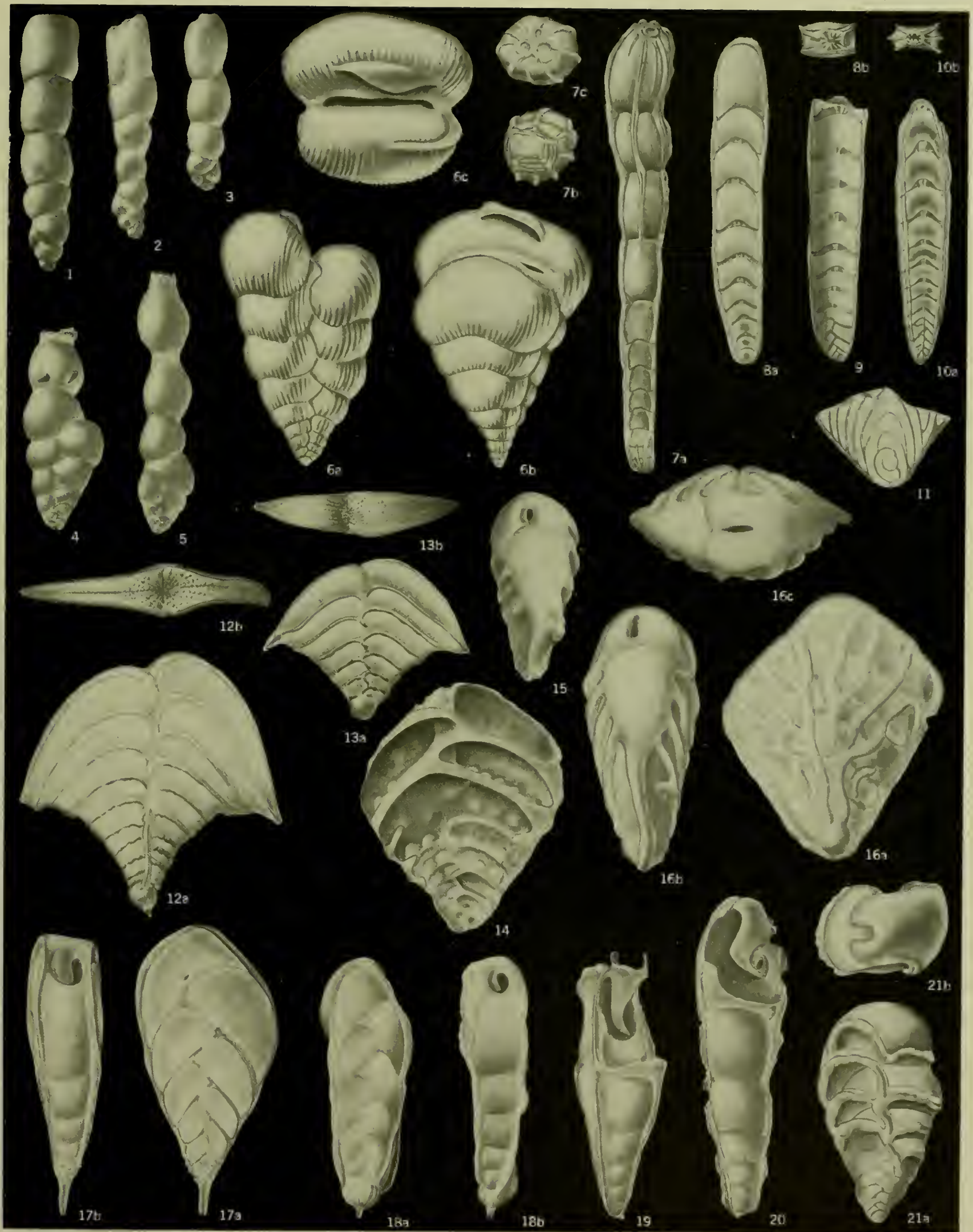
14, 16, Topotypes (Cushman Coll. 12108; USNM P5435), from Upper Cretaceous, Campanian, at Sassnitz, Island of Rugen, Germany. Coll. by R. S. Bassler. **14,** Showing interior of acid-treated specimen, with smooth, gently curved septa and internally tuberculate wall; **16a,** side view, showing surface ornamentation; **16b,** edge view; **16c,** apertural view. **15,** Oblique edge view of hypotype (Cushman Coll. 9383), from Upper Cretaceous, Pattenauer Stöllen, Germany, with specimen tilted to show apertural opening. All × 100.

FIGURES 17a–20. *Bolivinita quadrilatera* (Schwager) 146

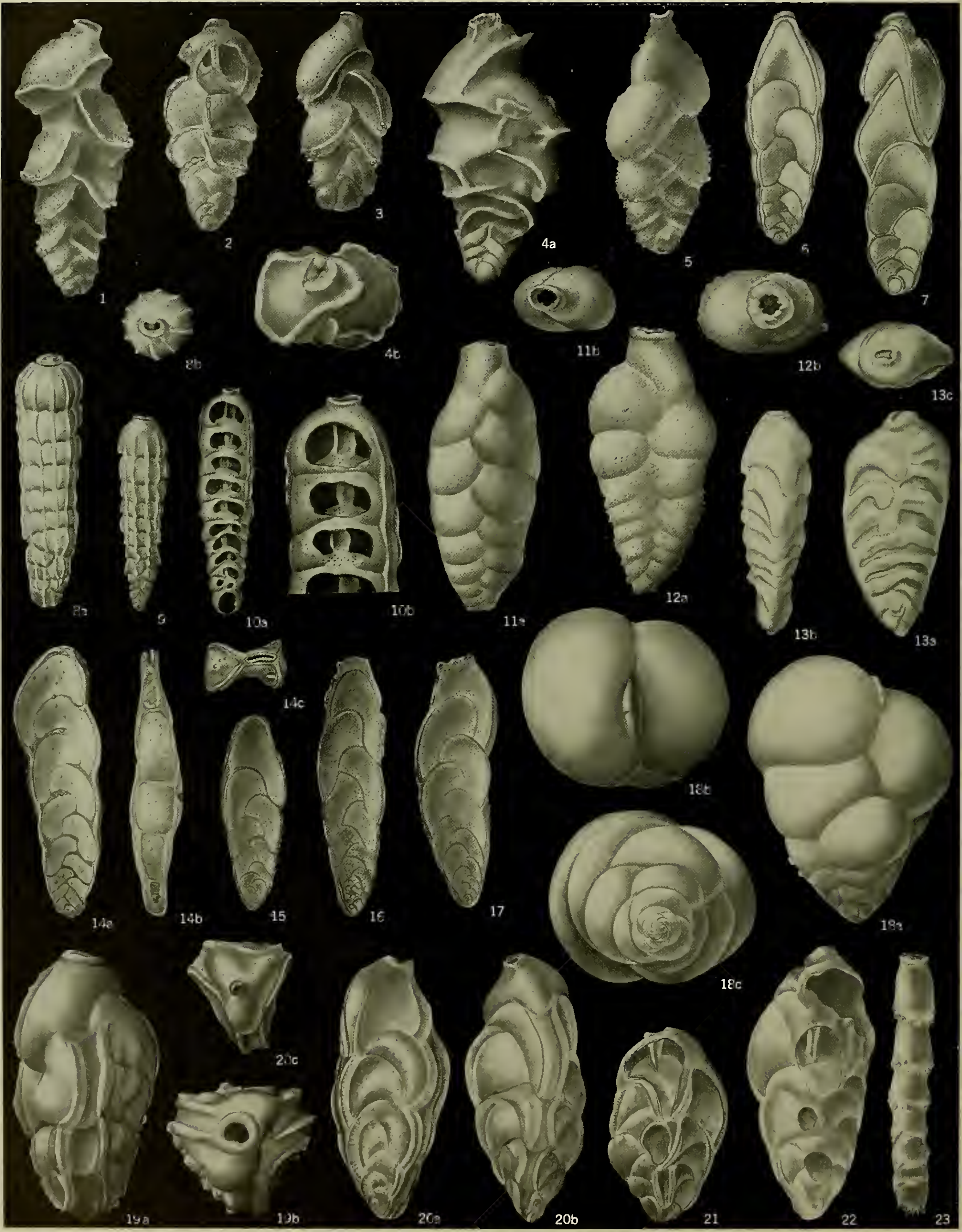
17a, 18a, Side views of hypotypes (USNM P5439a–d) from the Recent at 383 fathoms, *Albatross* Station D5445, Atalaya Point, Batag Island, Philippines, S. 56° E., 5.3 mi. at lat. 12°44′42″ N., long. 124°59′50″ E. **17b, 18b,** Edge views to show variation in shape in microspheric and megalospheric generations. **19, 20,** Edge views of acid-dissected specimens to show internal tooth. All × 65.

FIGURES 21a, b. *Tappanina selmensis* (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



BULIMINIDAE, UVIGERINIDAE

Plate 34. BULIMINIDAE, UVIGERINIDAE

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Eouvigerininae

Figures 1–5. *Eouvigerina 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, Collins 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. *Eouvigerina 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. *Zeauvigerina zelandica* Finlay 149

11a, Side view of paratype (Cushman Coll. 26775) from the type Wanstead (upper middle Eocene), Danneverke 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 watersi* (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 McQueeny, Guadelupe County, Texas. Coll. by A. R. Loeblich, Jr. **13b,** Edge view. **13c,** Top view, showing terminal aperture. × 190.

Figures 14–17. *Bolivinitella eleyi* (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.

?Buliminidae

Figures 18a-c. *Tosaia hanzawai* 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. *Pseudouvigerina cristata* (Marsson) 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, Gerhardtsreuter 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)

?ISOPODA

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FIGURE 23. *Nodoplanulis elongata* Hussey 151

23, 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, SW¼, Sec. 24, T. 10 N., R. 2 E., La Salle Parish, Louisiana. × 100. Figured to show characters of this probable arthropod appendage.

PLATE 35. HASTIGERINA, CLAVIGERINELLA, GLOBIGERINA

(Figures 1–2 × 144, all others × 73)

FIGURES 1a–2b. *Hastigerina micra* (Cole) 161

1a, Equatorial view of small hypotype (USNM P5698a). **1b,** Side view. **2a,** Equatorial view of hypotype (USNM P5698b). **2b,** Side view. Both from the *Porticulasphaera mexicana* zone, Navet formation, Trinidad.

FIGURES 3a, b. *Clavigerinella* aff. *akersi* Bolli, Loeblich, and Tappan 162

3a, Equatorial view of specimen (USNM P5700). **3b,** Side view. From the *Hantkenina aragonensis* zone, Navet formation, Trinidad.

FIGURE 4. *Clavigerinella akersi* Bolli, Loeblich, and Tappan 161

4, Equatorial view of topotype (USNM P5699) from the *Hantkenina aragonensis* zone, Navet formation, Trinidad

FIGURES 5, 6. *Clavigerinella jarvisi* (Cushman) 162

5, Equatorial view of large hypotype (USNM P5701a). **6,** Equatorial view of hypotype (USNM P5701b). Both from the *Globorotalia lehneri* zone, Navet formation, Trinidad.

FIGURES 7a, b. *Globigerina prolata* Bolli 162

7a, Spiral view of hypotype (USNM P5702). **7b,** Umbilical view. From the *Globorotalia palmerae* zone, Navet formation, Trinidad.

FIGURES 8a–c. *Globigerina soldadoensis angulosa* Bolli 162

8a, Spiral view of hypotype (USNM P5703). **8b,** Umbilical view. **8c,** Side view. From the *Globorotalia palmerae* zone, Navet formation, Trinidad.

FIGURES 9a–c. *Globigerina soldadoensis* Bronnimann 162

9a, Spiral view of hypotype (USNM P5704). **9b,** Umbilical view. **9c,** Side view. From the *Globorotalia palmerae* zone, Navet formation, Trinidad.

FIGURES 10a–12. *Globigerina senni* (Beckmann) 163

10a, Side view of hypotype (USNM P5705a). **10b,** Umbilical view. **11,** Umbilical view of hypotype (USNM P5705b). **12,** Side view of hypotype (USNM P5705c). All from the *Porticulasphaera mexicana* zone, Navet formation, Trinidad.

FIGURES 13a–c. *Globigerina turgida* Finlay 163

13a, Spiral view of hypotype (USNM P5706). **13b,** Umbilical view. **13c,** Side view. From the *Globorotalia palmerae* zone, Navet formation, Trinidad.

FIGURES 14a–15c. *Globigerina yeguaensis* Weinzierl and Applin 163

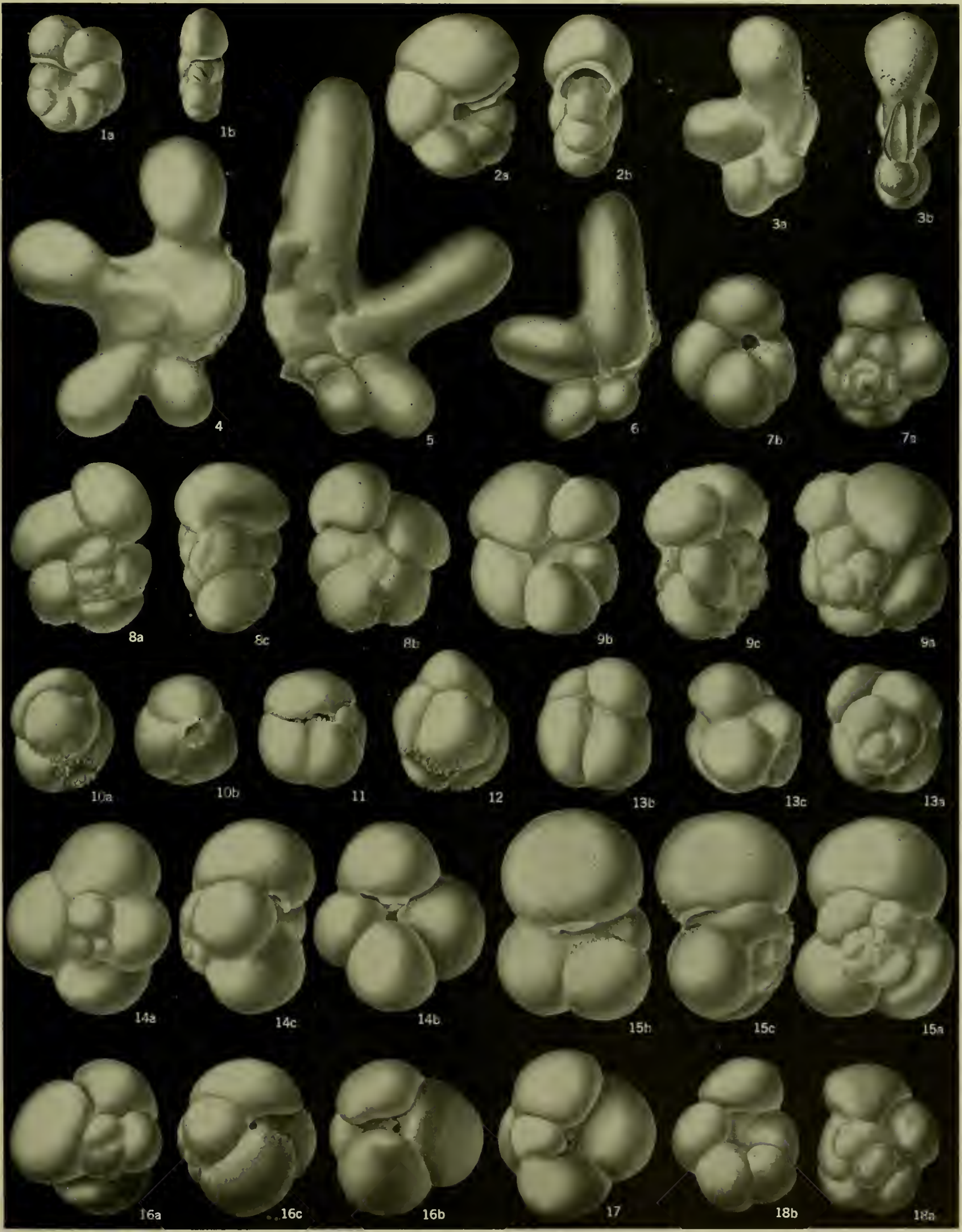
14a, Spiral view of hypotype (USNM P5707). **14b,** Umbilical view. **14c,** Side view. From the *Porticulasphaera mexicana* zone, Navet formation, Trinidad. **15a,** Spiral view of hypotype (USNM P5708). **15b,** Umbilical view. **15c,** Side view. From the *Globigerapsis semiinvoluta* zone, Navet formation, Trinidad.

FIGURES 16a–17. *Globigerina venezuelana* Hedberg 164

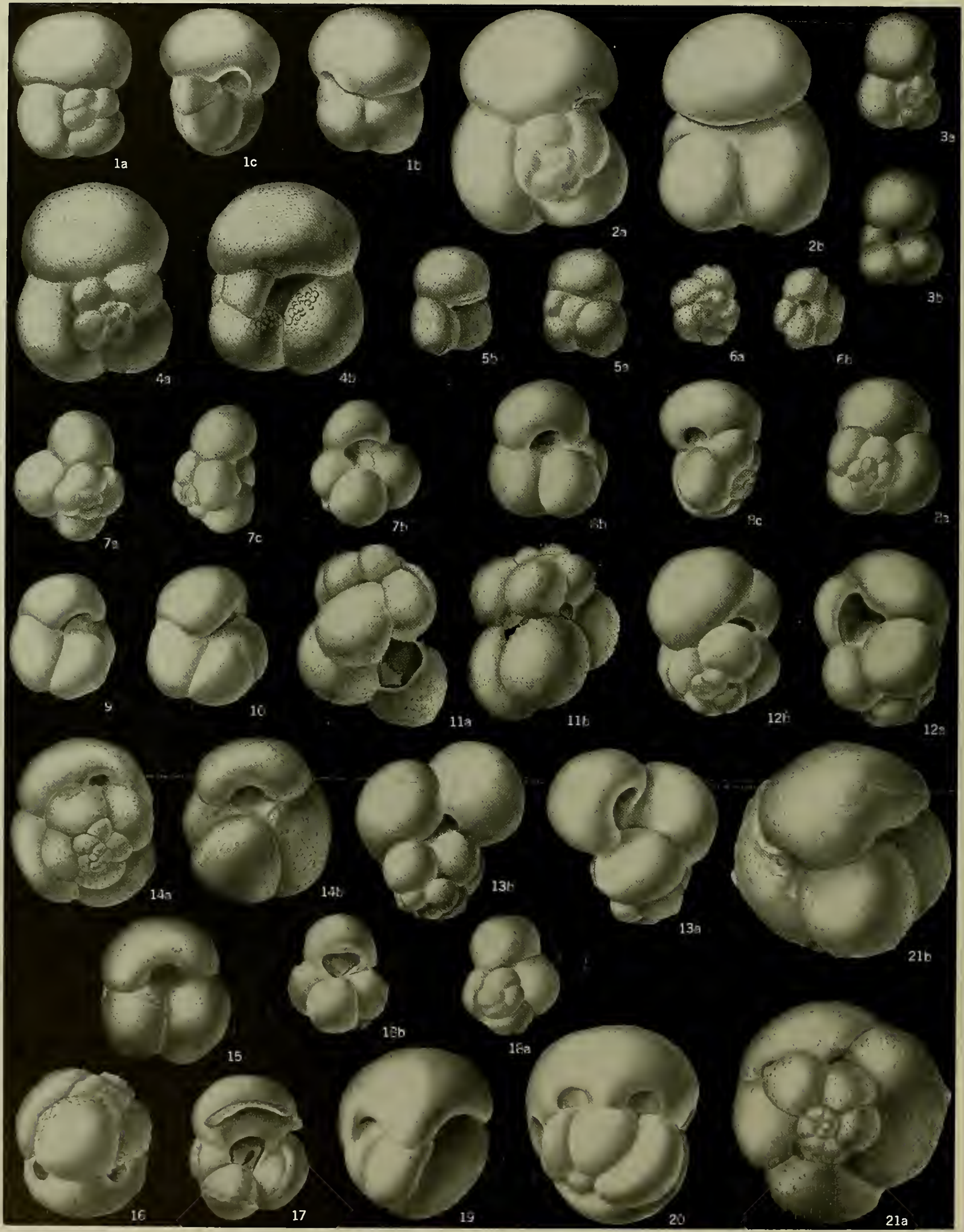
16a, Spiral view of hypotype (USNM P5709a). **16b,** Umbilical view. **16c,** Side view. **17,** Umbilical view of hypotype with rudimentary final chamber (USNM P5709b). Both from the *Porticulasphaera mexicana* zone, Navet formation, Trinidad.

FIGURES 18a, b. *Globigerina collactea* (Finlay) 162

18a, Spiral view of hypotype (USNM P5710). **18b,** Umbilical view. From the *Globorotalia palmerae* zone, Navet formation, Trinidad.



HASTIGERINA, CLAVIGERINELLA, GLOBIGERINA



GLOBIGERINA, "GLOBIGERINOIDES," GLOBIGERAPSIS

PLATE 36. GLOBIGERINA, "GLOBIGERINOIDES", GLOBIGERAPSIS

(All figures × 73)

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FIGURES 1a–2b. *Globigerina bowreri* Bolli, new species 163

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 cocoaensis* 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 cocoaensis* 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 ciperoensis angustiumbilicata* Bolli 164

6a, Spiral view of hypotype (USNM P5716). **6b,** Umbilical view. From the *Globorotalia cocoaensis* zone, San Fernando formation, Trinidad.

FIGURES 7a–c. *Globigerina parva* 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 cocoaensis* zone, San Fernando formation, Trinidad.

FIGURES 9, 10. Specimens transitional between *Globorotalia centralis* Cushman and Bermudez and *Globigerina ampliapertura* Bolli 164

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9, Umbilical view of figured specimen (USNM P5719a). **10,** Umbilical view of figured specimen (USNM P5719b). Both from the *Globorotalia cocoaensis* zone, San Fernando formation, Trinidad.

FIGURES 11a–13b. "*Globigerinoides*" *higginsi* Bolli, new species 164

11a, Umbilical view of holotype (USNM P5720). **11b,** Side view. From the lower-middle Eocene, core in Atlantic Ocean, at lat. 30°43′ N., long. 62°28′ W. **12a,** Umbilical view of paratype (USNM P5721a). **12b,** Side view. **13a,** Umbilical view of paratype (USNM P5721b). **13b,** Side view. Both from the *Hantkenina aragonensis* zone, Navet formation, Trinidad.

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)

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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 species 165

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) 166

6a, Spiral view (USNM P5731); **6b,** Umbilical view. From the *Globigerapsis semiinvoluta* zone, Navet formation, Trinidad.

FIGURES 7a, b. *Catapsydrax unicavus* Bolli, Loeblich, and Tappan 166

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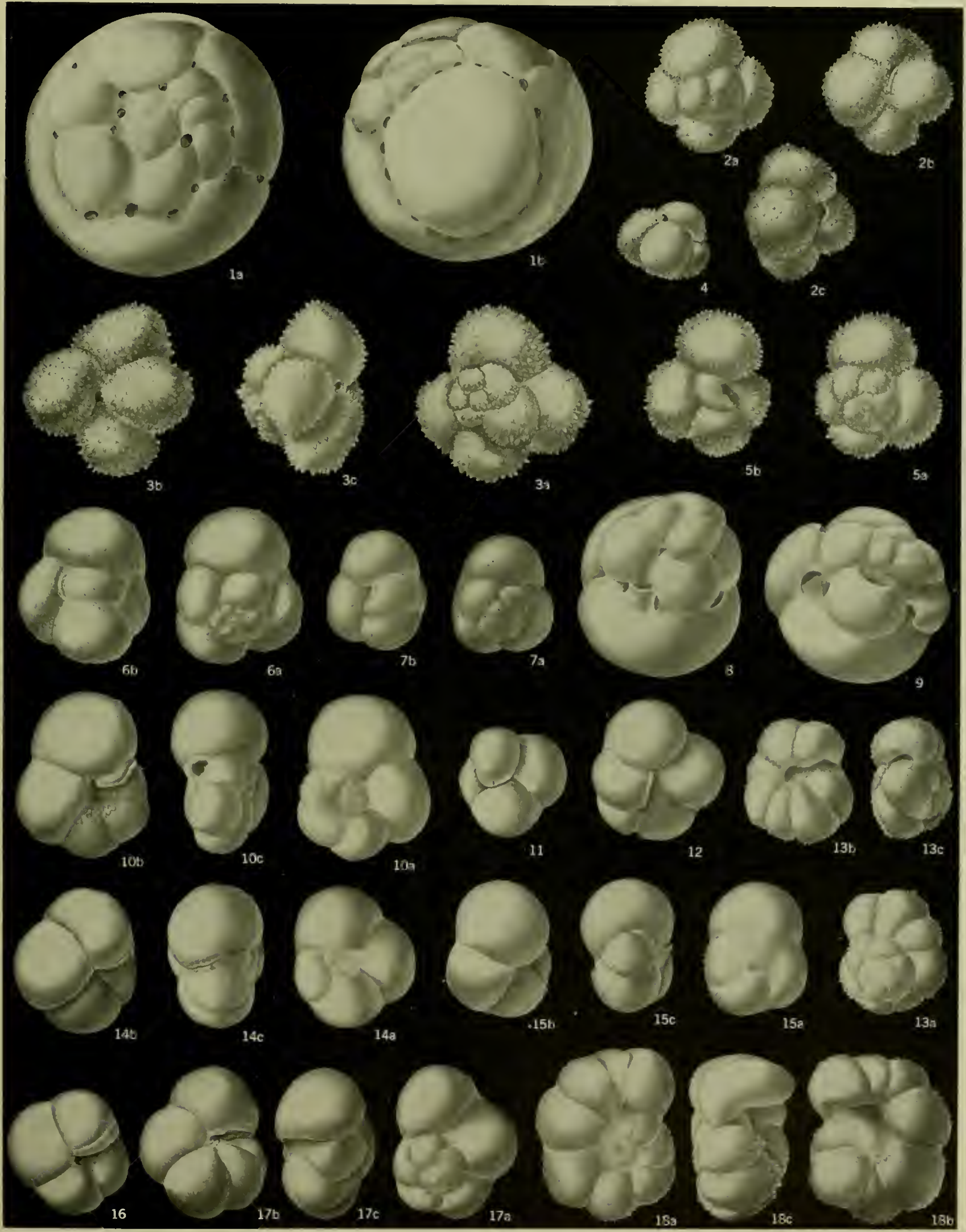
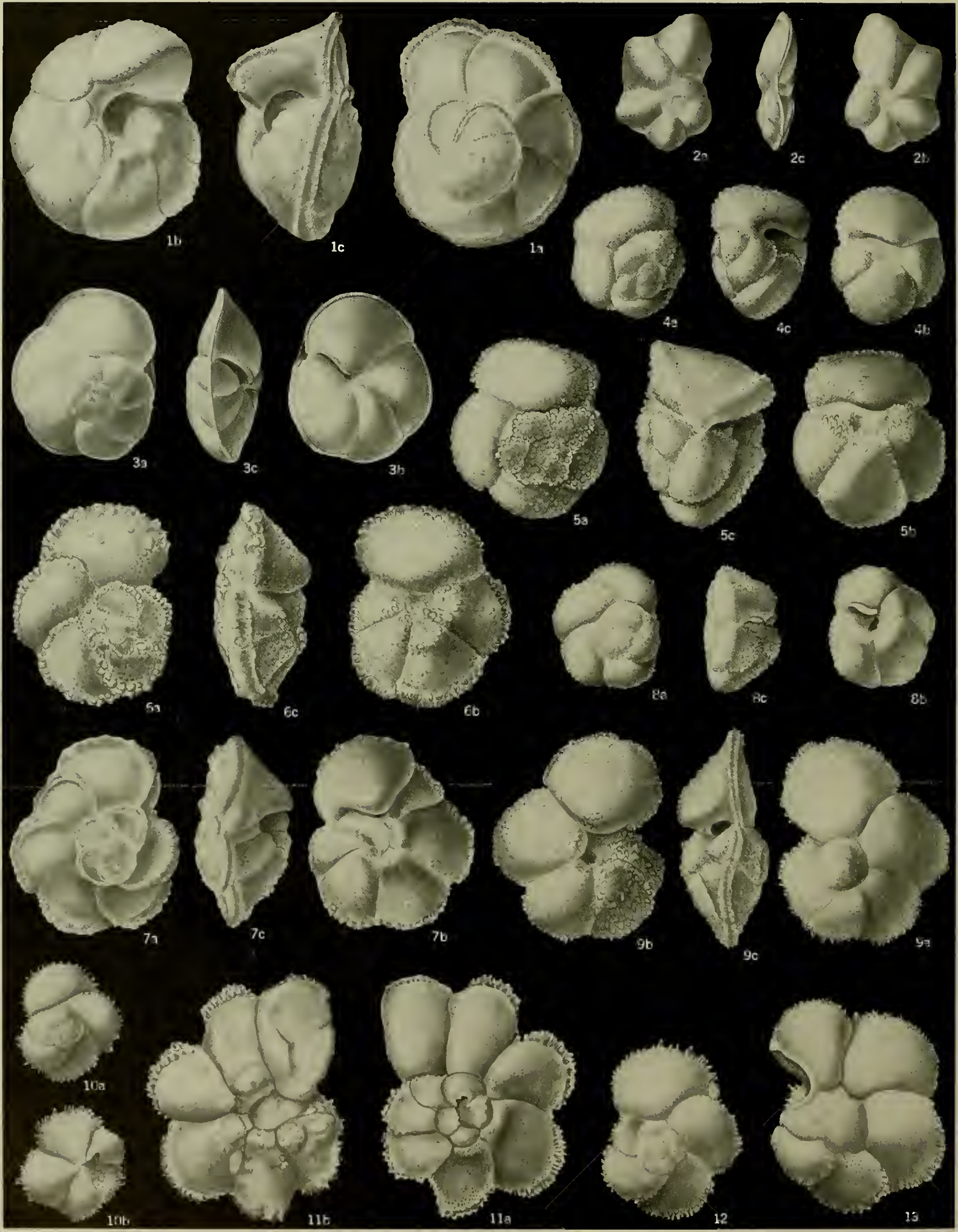


PORTICULASPHAERA, CATAPSYDRAX, GLOBIGERINATHEKA, GLOBOROTALOIDES, GLOBOROTALIA



GLOBOROTALIA

PLATE 38. GLOBOROTALIA

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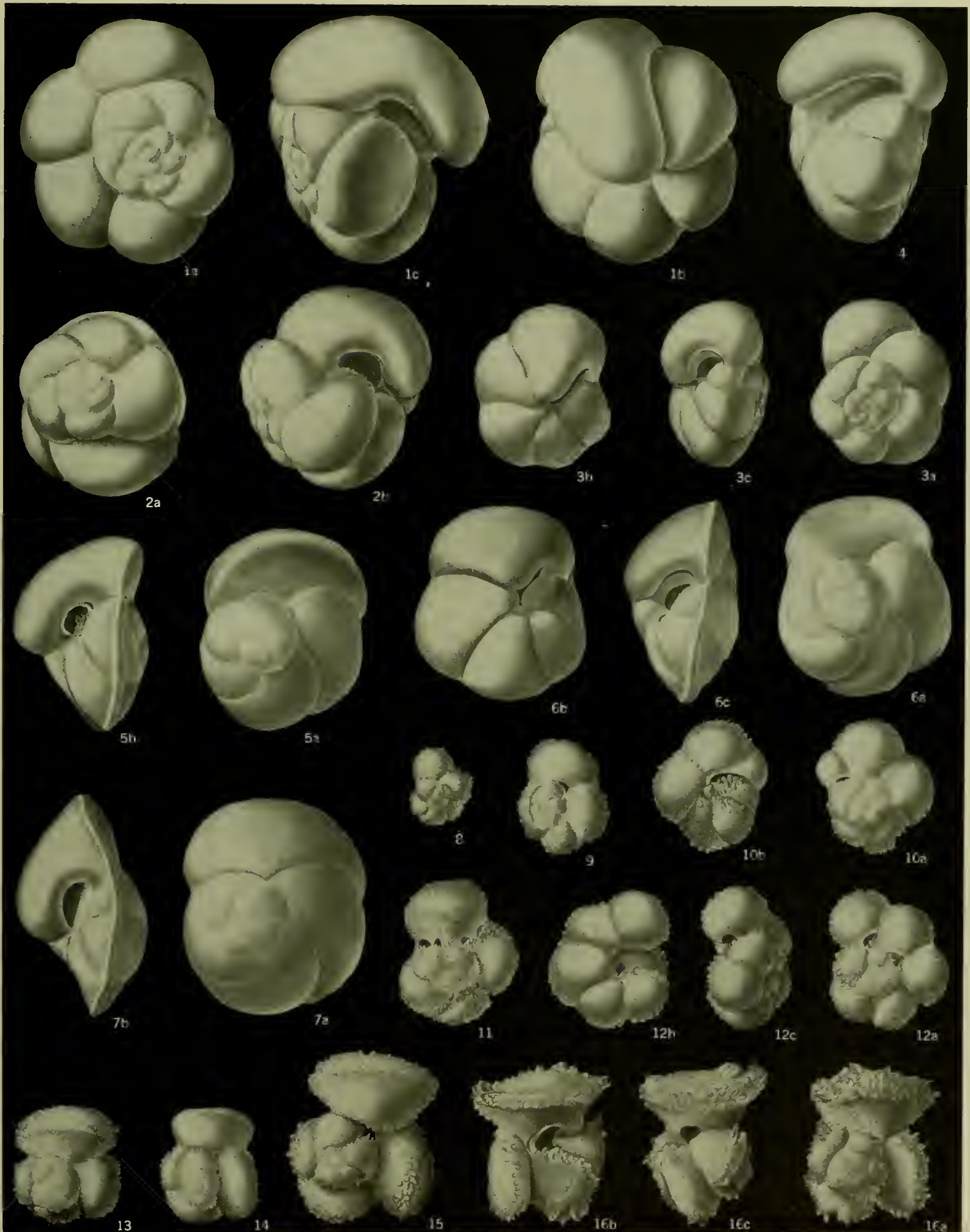
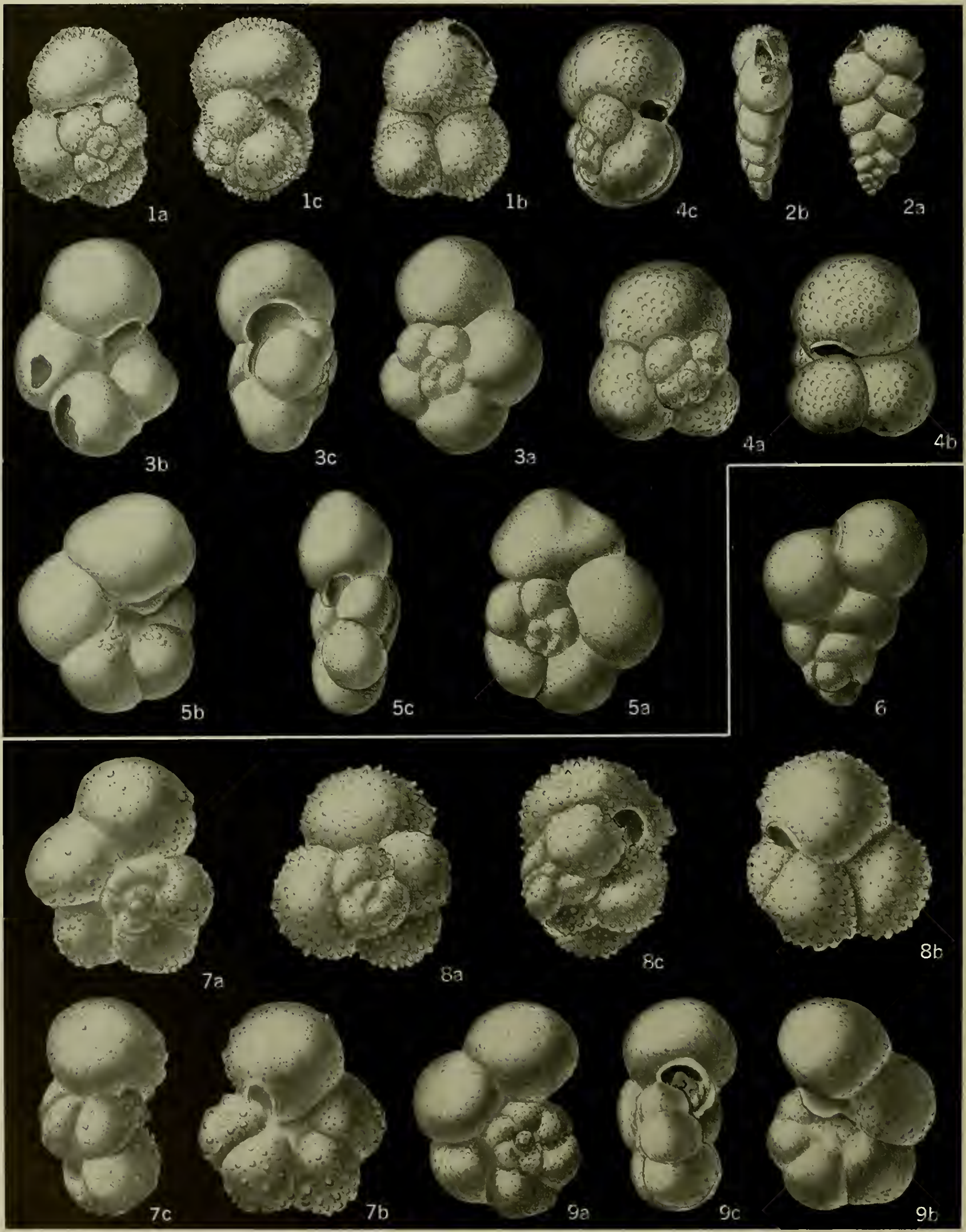


GLOBOROTALIA, TRUNCOROTALOIDES



DANIAN AND PINE BARREN PLANKTONIC SPECIES

PLATE 40. DANIAN AND PINE BARREN PLANKTONIC SPECIES

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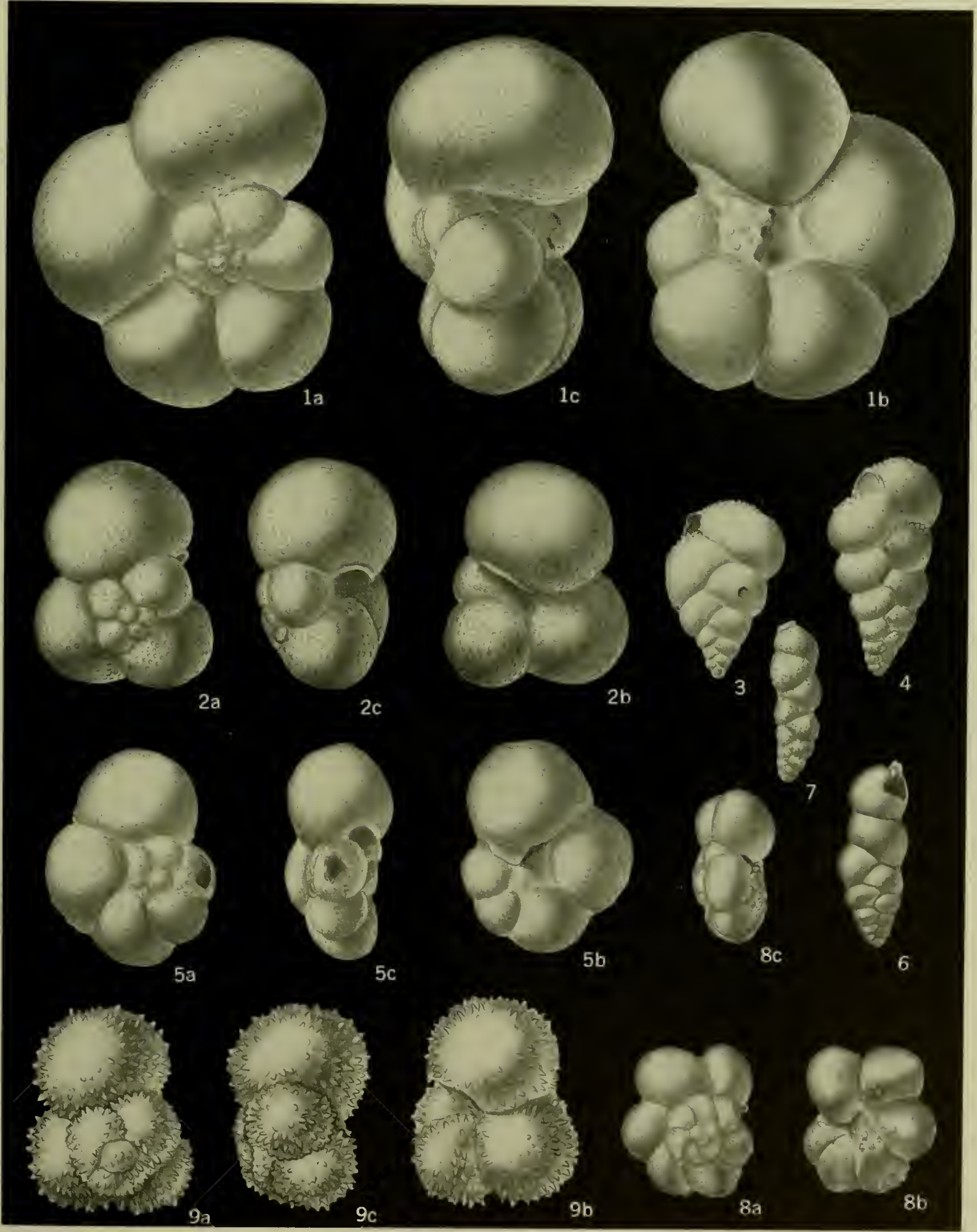
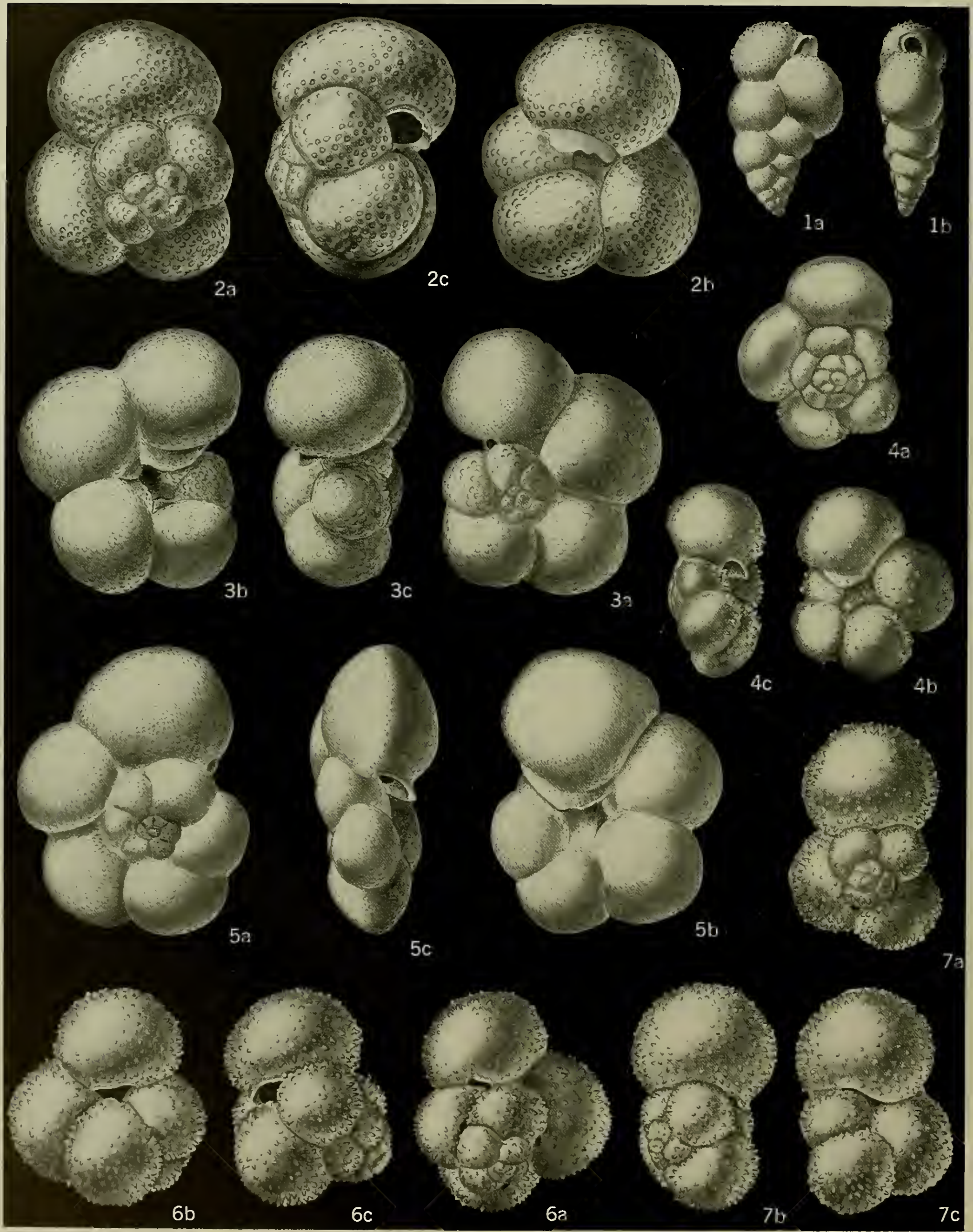


McBRYDE PLANKTONIC SPECIES



BRIGHTSEAT PLANKTONIC SPECIES

Plate 42. BRIGHTSEAT PLANKTONIC SPECIES

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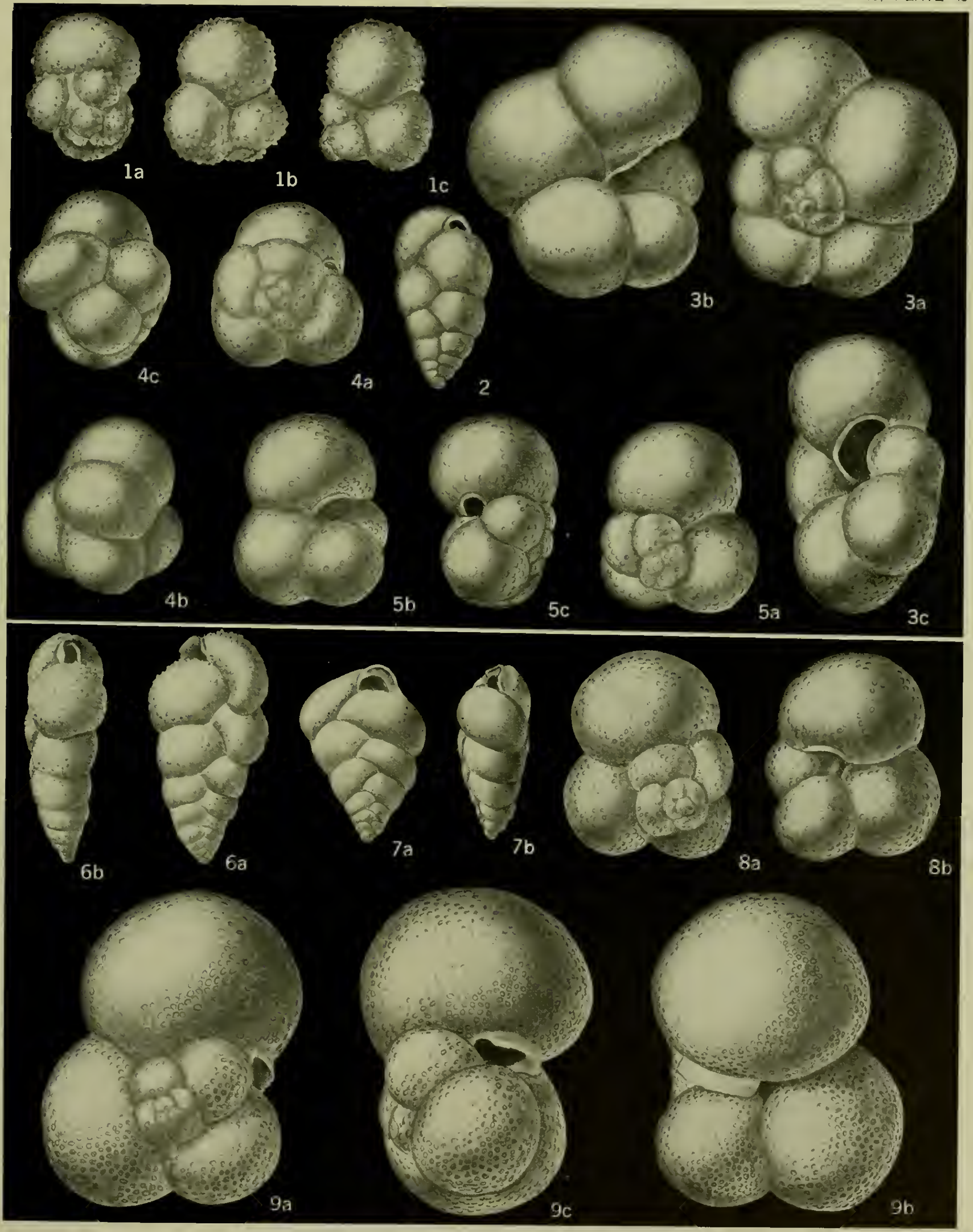
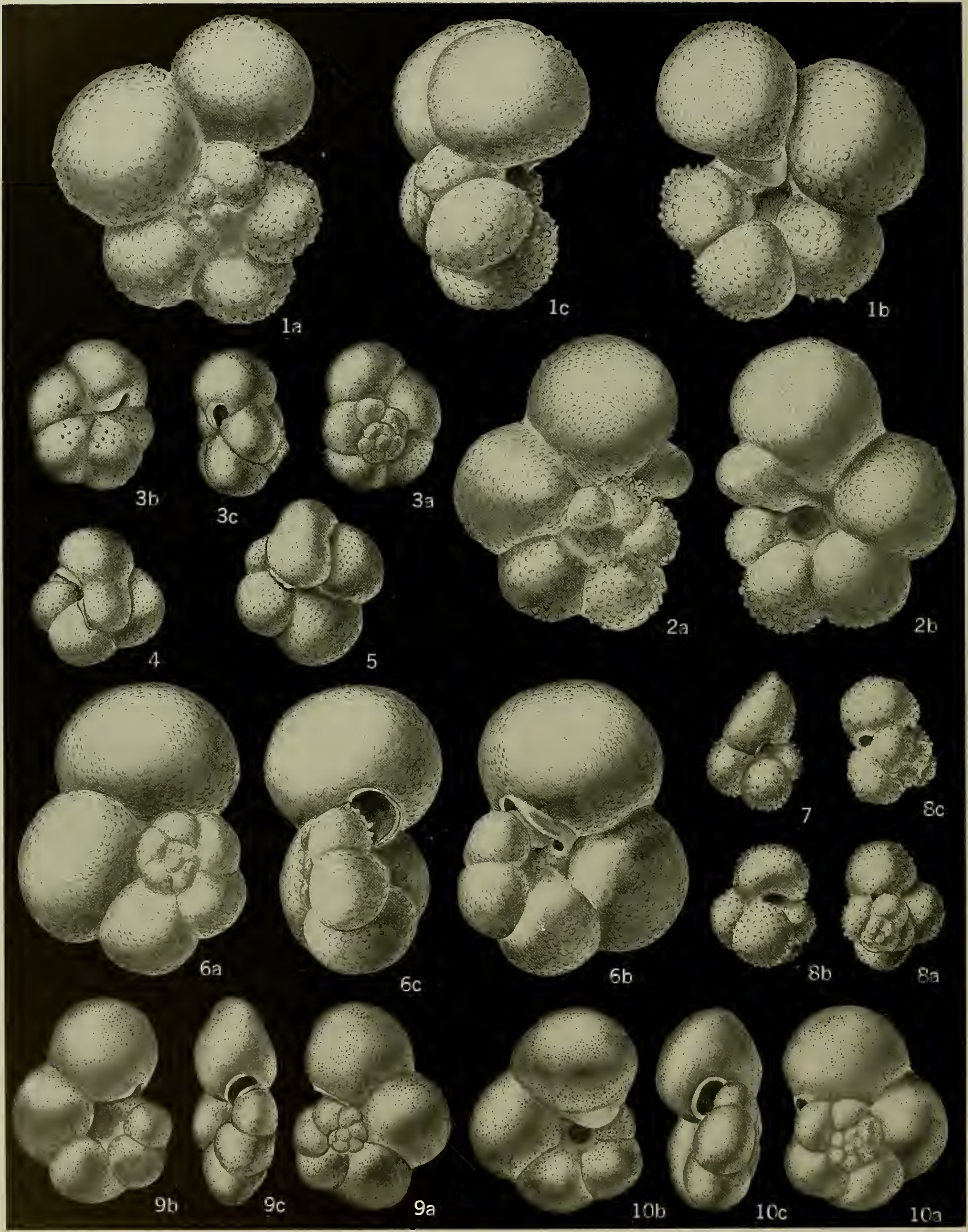


KINCAID AND WILLS POINT PLANKTONIC SPECIES



WILLS POINT GLOBOROTALIA AND GLOBIGERINOIDES

PLATE 44. WILLS POINT GLOBOROTALIA AND GLOBIGERINOIDES

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PLATE 45. MATTHEWS LANDING GLOBIGERINA, GLOBOROTALIA, AND CHILOGUEMBELINA

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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) 179

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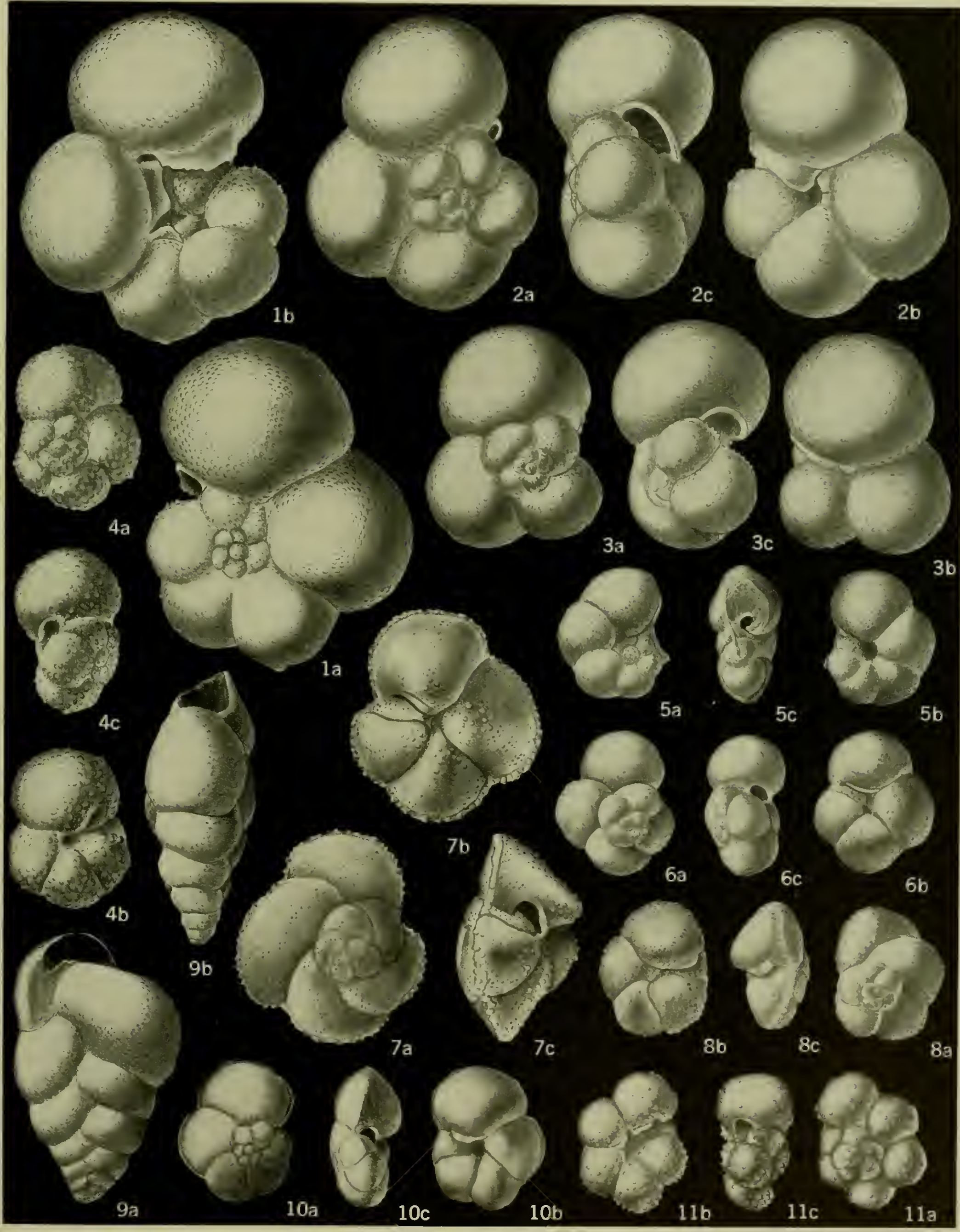
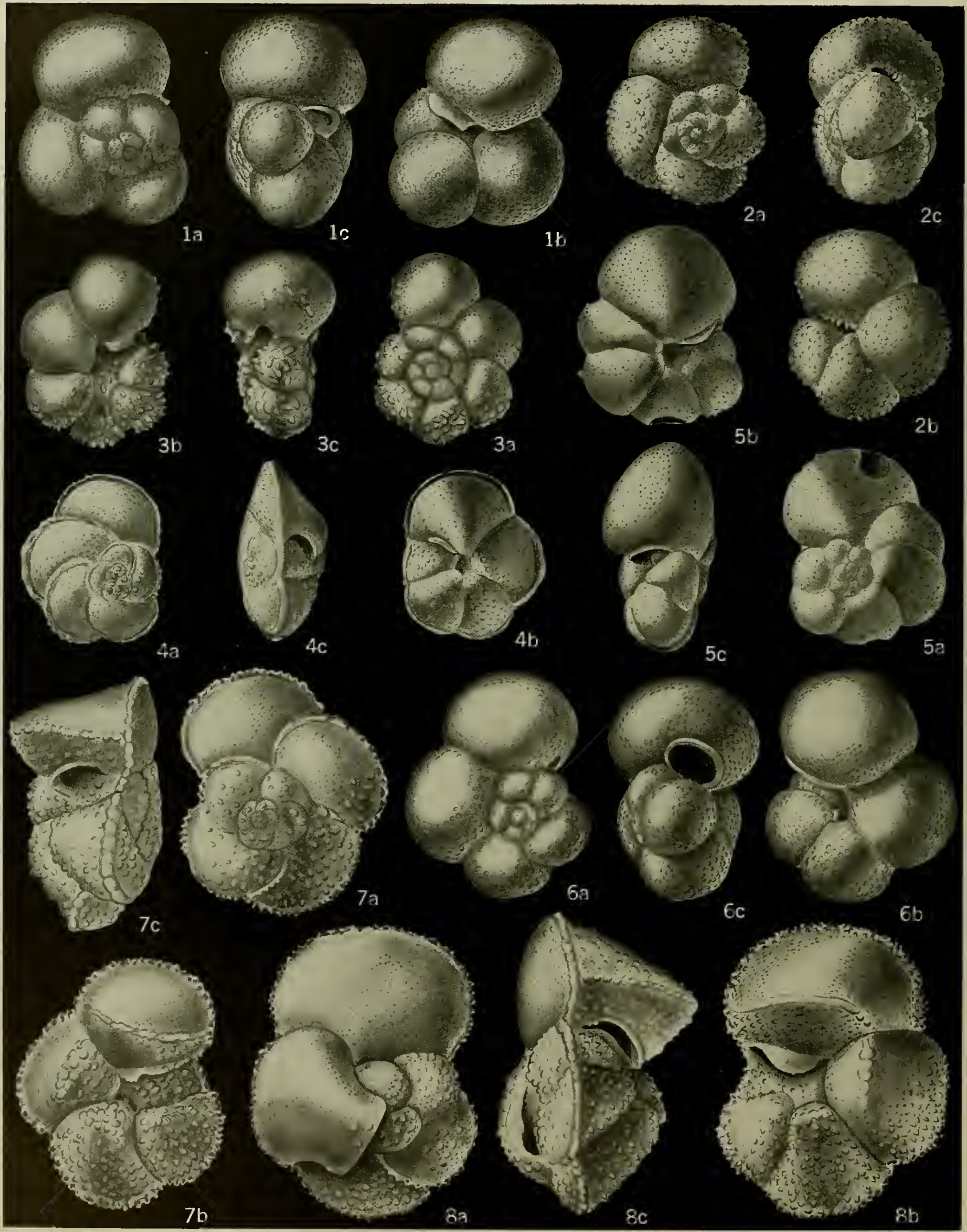


MATTHEWS LANDING GLOBIGERINA, GLOBOROTALIA, AND CHILOGUEMBELINA



COAL BLUFF GLOBIGERINA AND GLOBOROTALIA

PLATE 46. COAL BLUFF GLOBIGERINA AND GLOBOROTALIA

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FIGURES 1a–c. *Globigerina triloculinoides* Plummer 183

1a, Spiral view of hypotype (USNM P5697). **1b,** Umbilical view, with prominent apertural lip. **1c,** Edge view.

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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

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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.

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PLATE 47. SALT MOUNTAIN CHILOGUEMBELINA, GLOBIGERINA, AND GLOBOROTALIA

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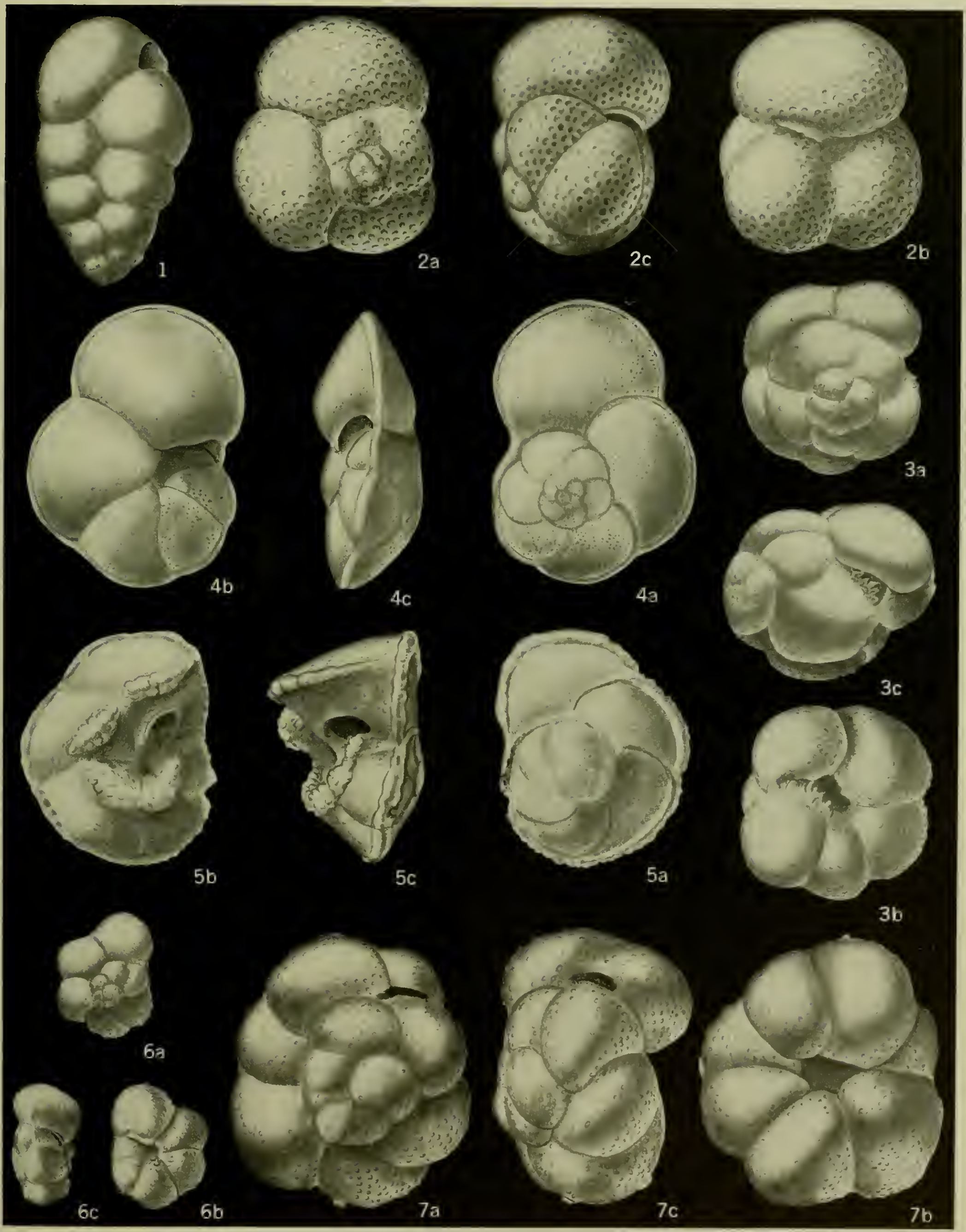
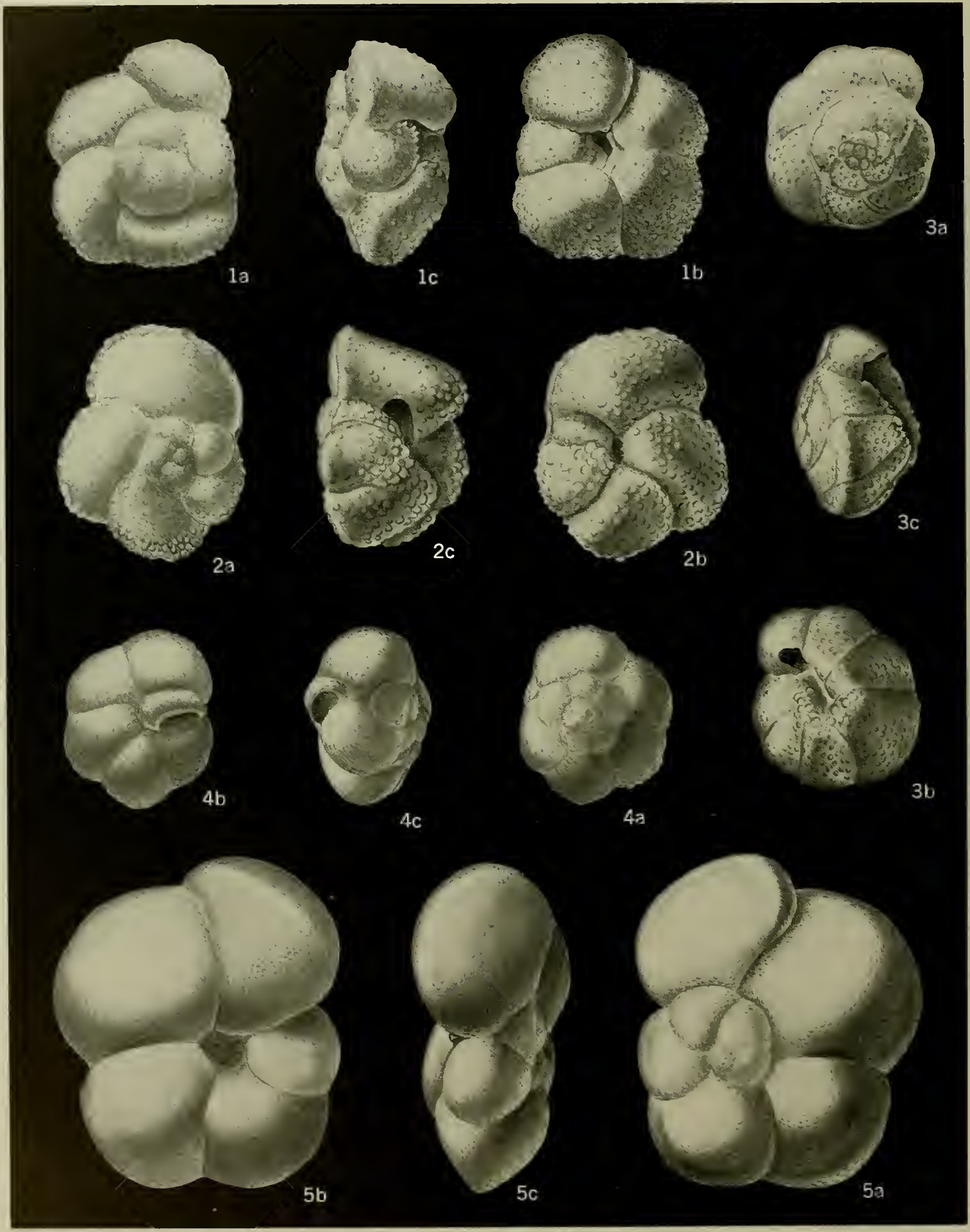


SALT MOUNTAIN CHILOGUEMBELINA, GLOBIGERINA, AND GLOBOROTALIA



SALT MOUNTAIN GLOBOROTALIA

PLATE 48. SALT MOUNTAIN GLOBOROTALIA

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FIGURES 3a–c. *Globorotalia pseudoscitula* Glaessner 193

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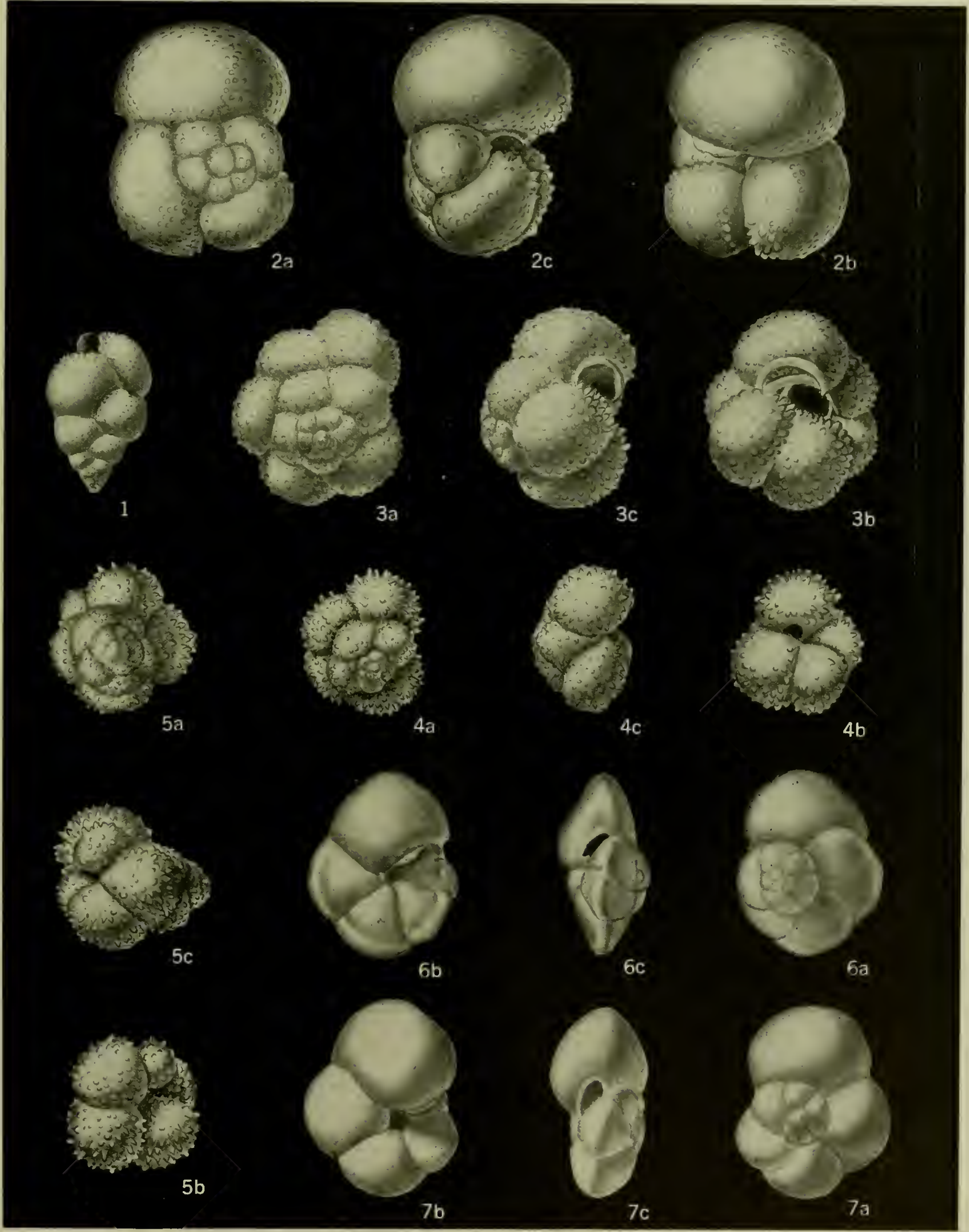
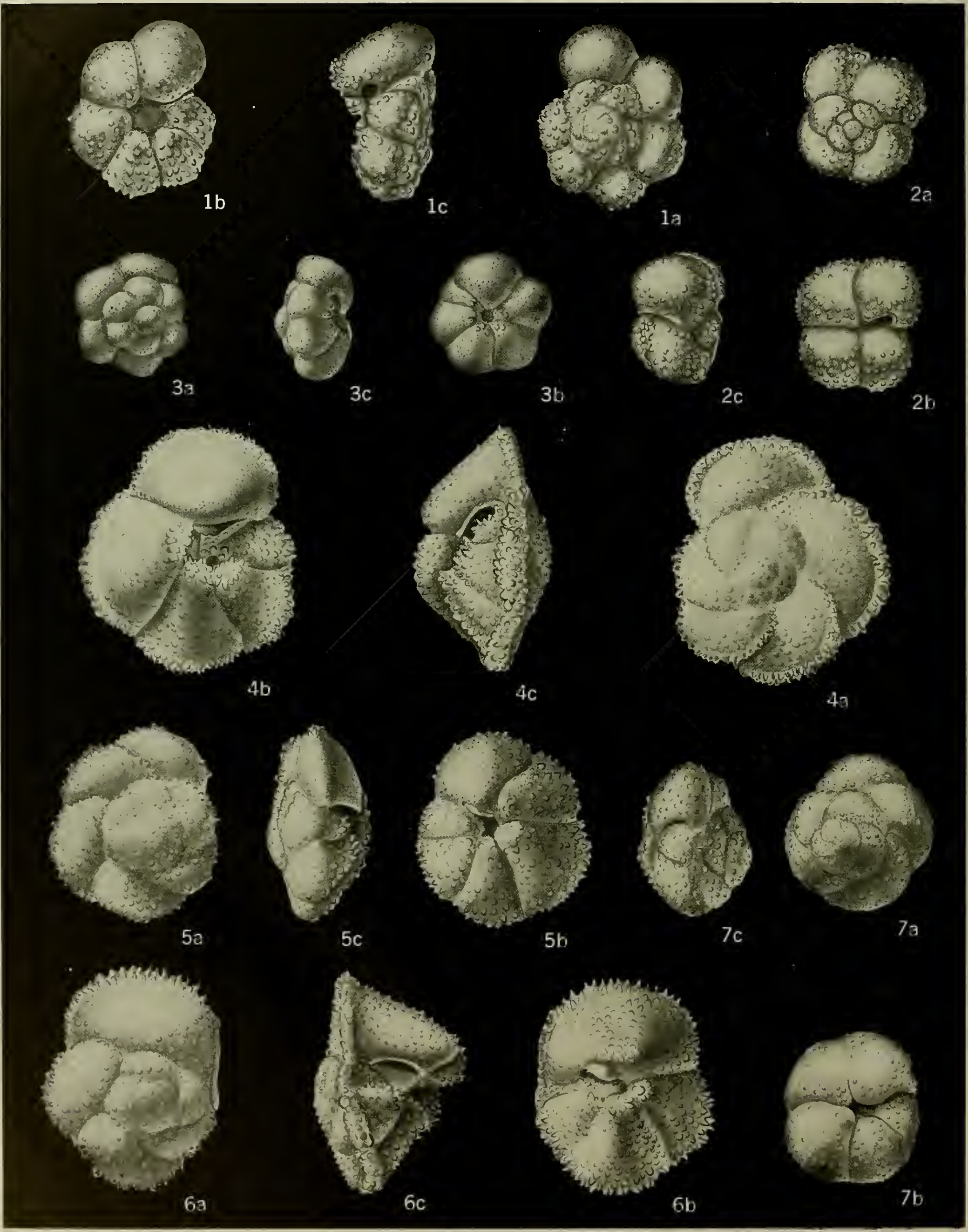


HORNERSTOWN CHILOGUEMBELINA, GLOBIGERINA, AND GLOBOROTALIA



HORNERSTOWN GLOBIGERINA AND GLOBOROTALIA

Plate 50. HORNERSTOWN GLOBIGERINA AND GLOBOROTALIA

(All figures: **a,** spiral view; **b,** umbilical view; **c,** edge view; all × 145)

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Figure 1. *Globorotalia perclara* Loeblich and Tappan, new species 191

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 184

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 194

Paratype (USNM P5836) showing small size, rounded chambers, rounded periphery and smooth wall.

Figure 4. *Globorotalia angulata* (White) 187

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.

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Figure 5. *Globorotalia trichotrocha* Loeblich and Tappan, new species 195

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 186

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Figure 7. *Globorotalia convexa* Subbotina 188

Hypotype (USNM P5845), showing subglobose 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

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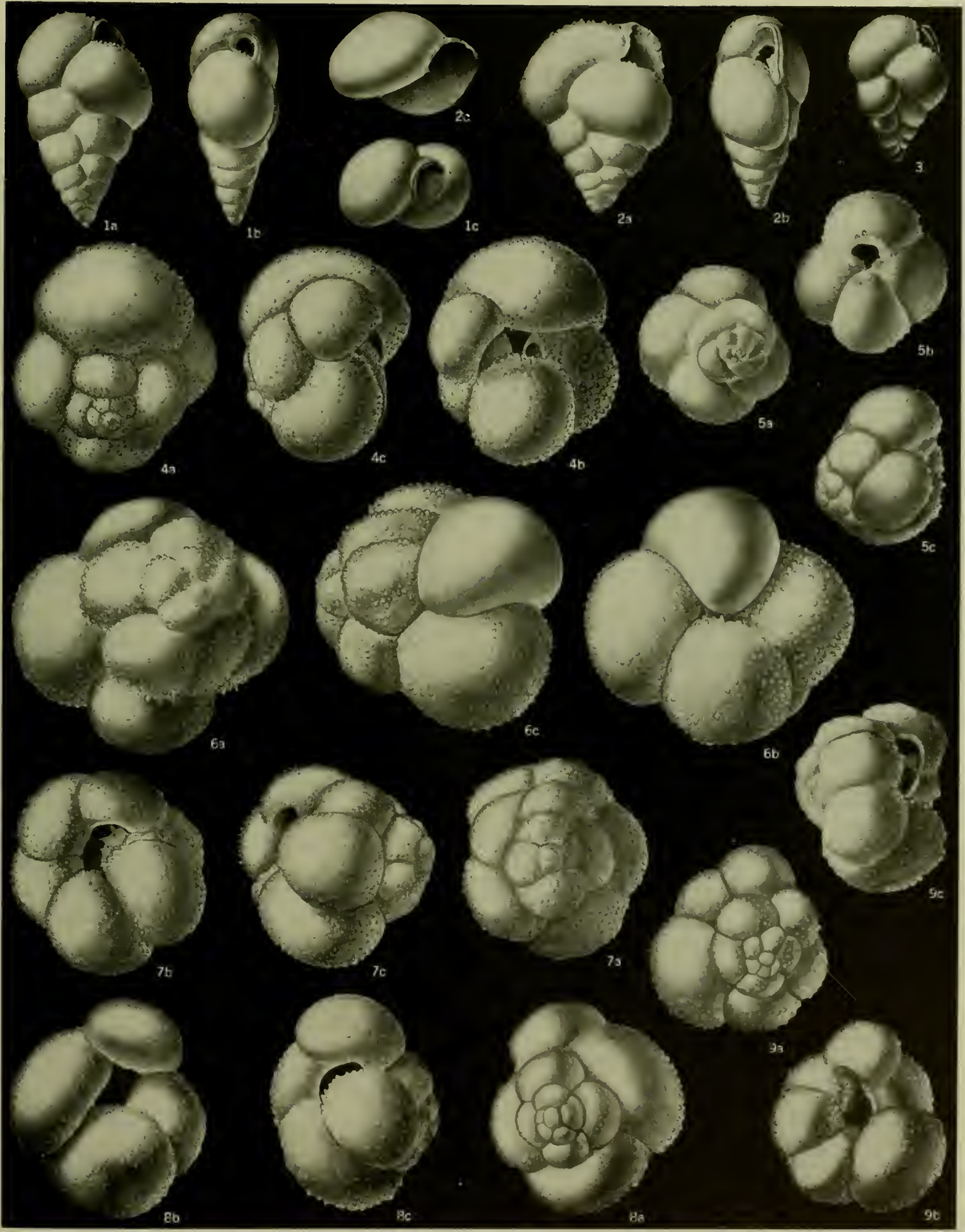
1a, 2a, 3, Side views of hypotypes (USNM P5115a–c), showing slightly twisted biserial test. **1b, 2b,** Edge views, with slightly asymmetrical aperture bordered by an apertural flange, instead of the symmetrical and open arched aperture typical of true *Heterohelix*. **1c, 2c,** Top views, showing how the bordering flange directs the apertural opening toward the side rather than the edge of the test.

Figures 4a–5c. *Globigerina aquiensis* Loeblich and Tappan, new species 180

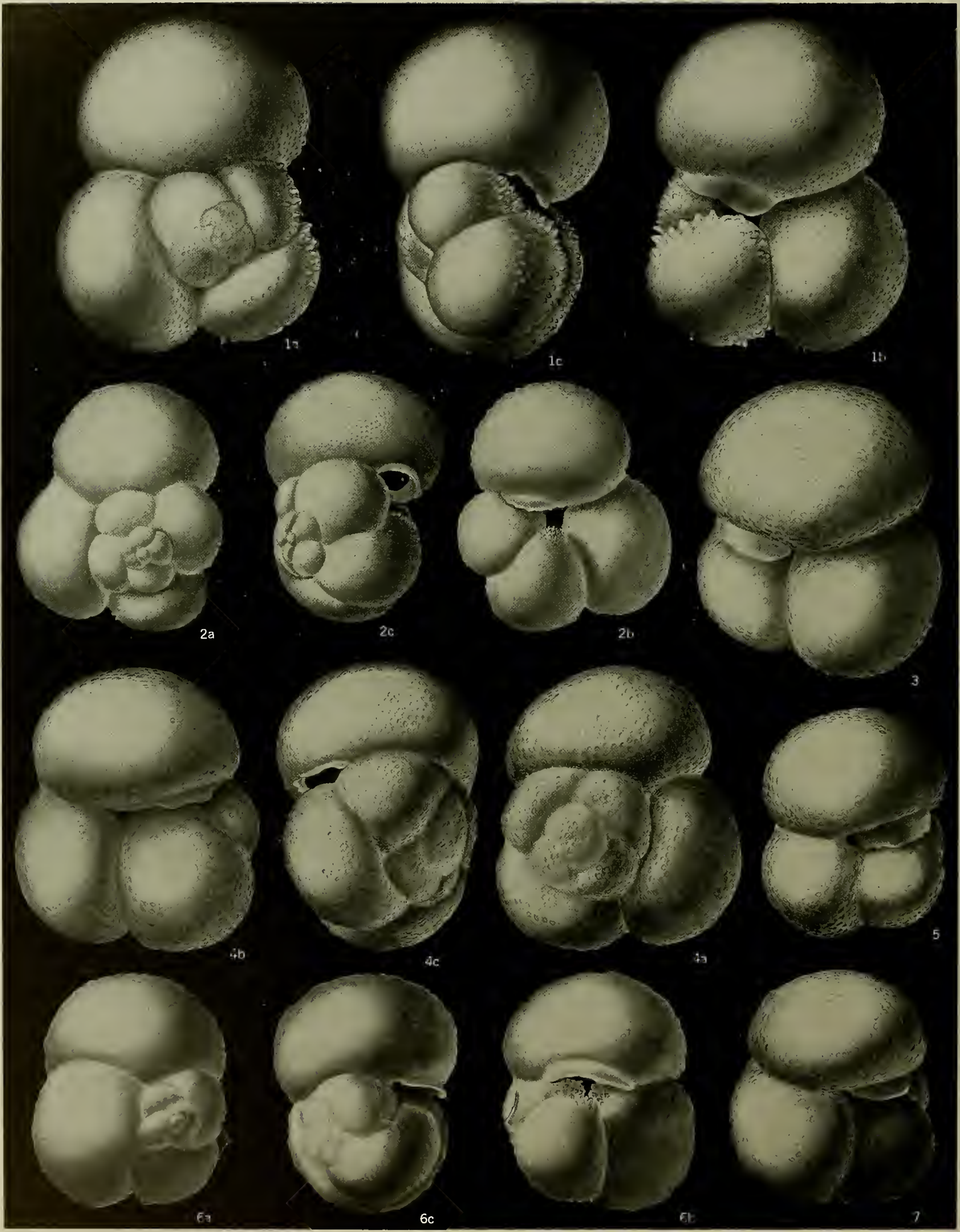
4a, 5a, Spiral views of paratypes (USNM P5841a, b), showing few chambers rapidly increasing in size. **4b, 5b,** Umbilical views, showing small umbilical aperture. **4c, 5c,** Edge views, showing inflated tests, and variation in height of spire.

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 CHILOGUEMBELINA AND GLOBIGERINA



VINCENTOWN GLOBIGERINA

PLATE 52. VINCENTOWN GLOBIGERINA

(All figures × 145)

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PLATE 53. VINCENTOWN GLOBIGERINA AND GLOBOROTALIA

(All figures: **a**, spiral view; **b**, umbilical view, **c**, edge view; all × 110)

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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, expecially in the umbilical region. **2,** Small hypotype with tendency to develop an extraumbilical aperture.	181
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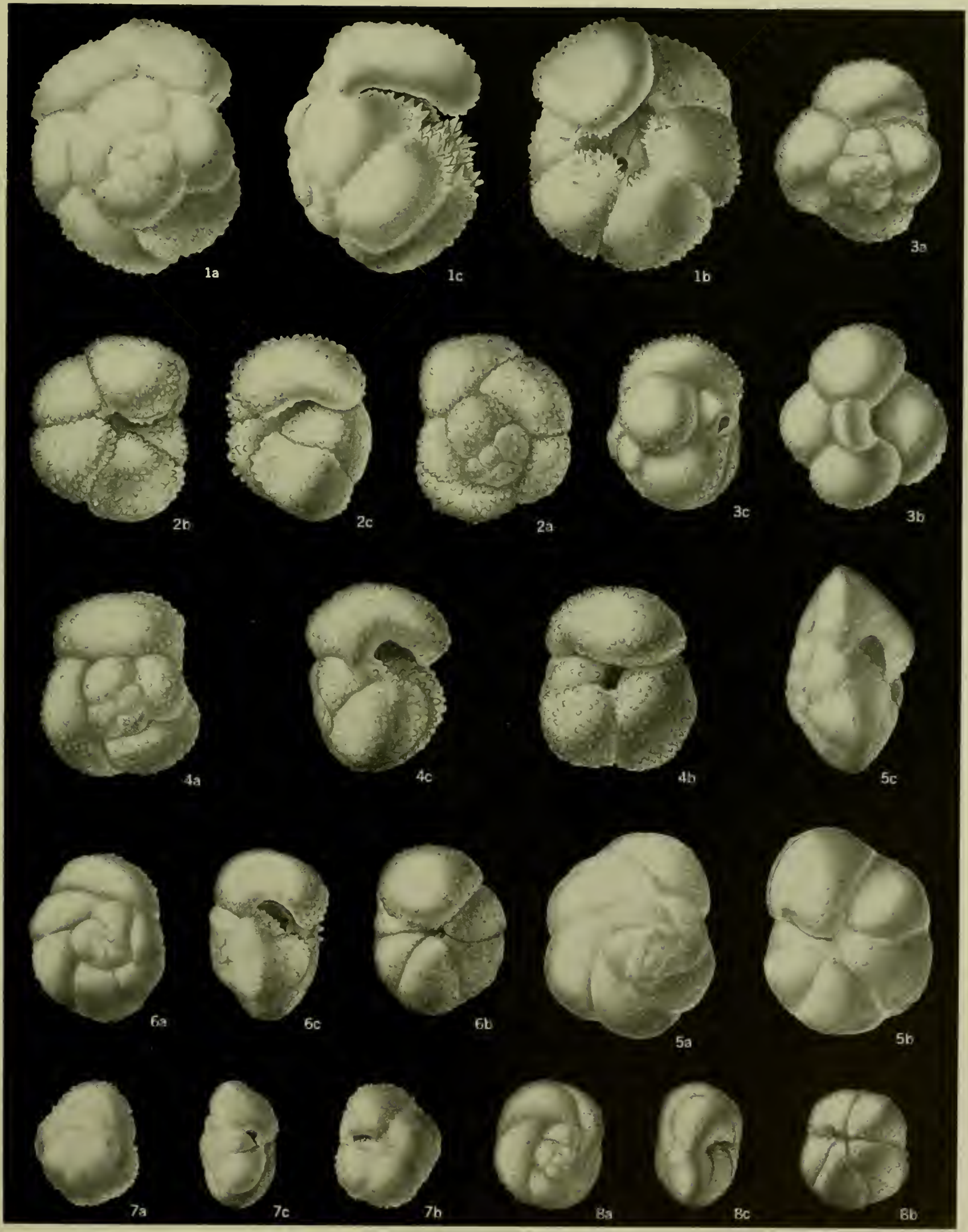
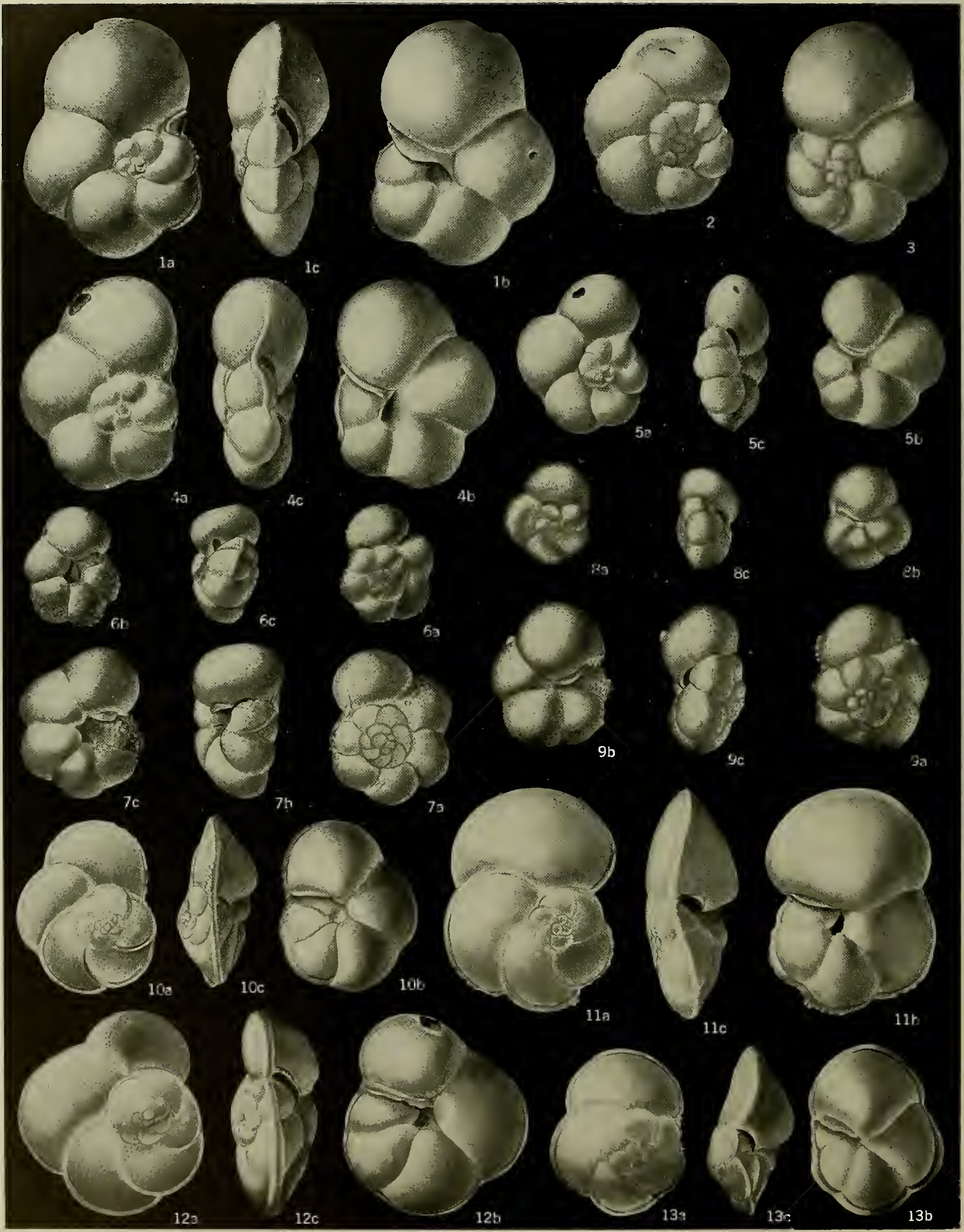


VINCENTOWN GLOBIGERINA AND GLOBOROTALIA



VINCENTOWN GLOBOROTALIA

Plate 54. VINCENTOWN GLOBOROTALIA

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Figures 1a–5c. *Globorotalia elongata* Glaessner 189

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 191

Paratypes (USNM P5135a, b), showing small size, low spire, gradually enlarging rounded chambers, open umbilicus, spinose umbilical side and extraumbilical-umbilical aperture. **a,** Spiral side; **b,** umbilical side; **c,** edge.

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Figures 8a–9c. *Globorotalia imitata* Subbotina 190

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 193

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 × 110)

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FIGURE 1. *Globorotalia apanthesma* Loeblich and Tappan, new species 187

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 191

Paratype (USNM P5866), showing flat spiral side, low convexity of umbilical side, few chambers and small umbilicus.

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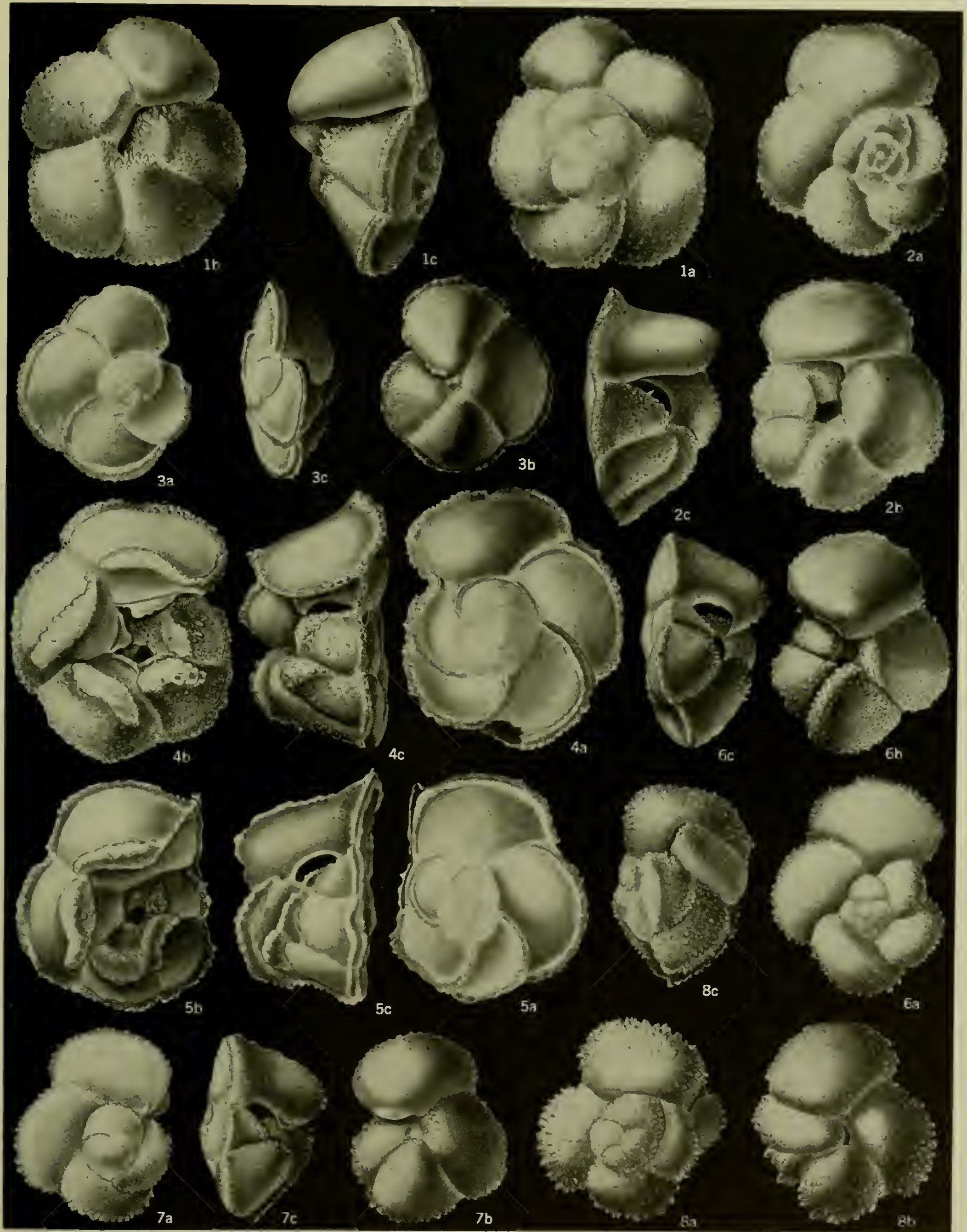
FIGURES 4, 5. *Globorotalia acuta* Toulmin 185

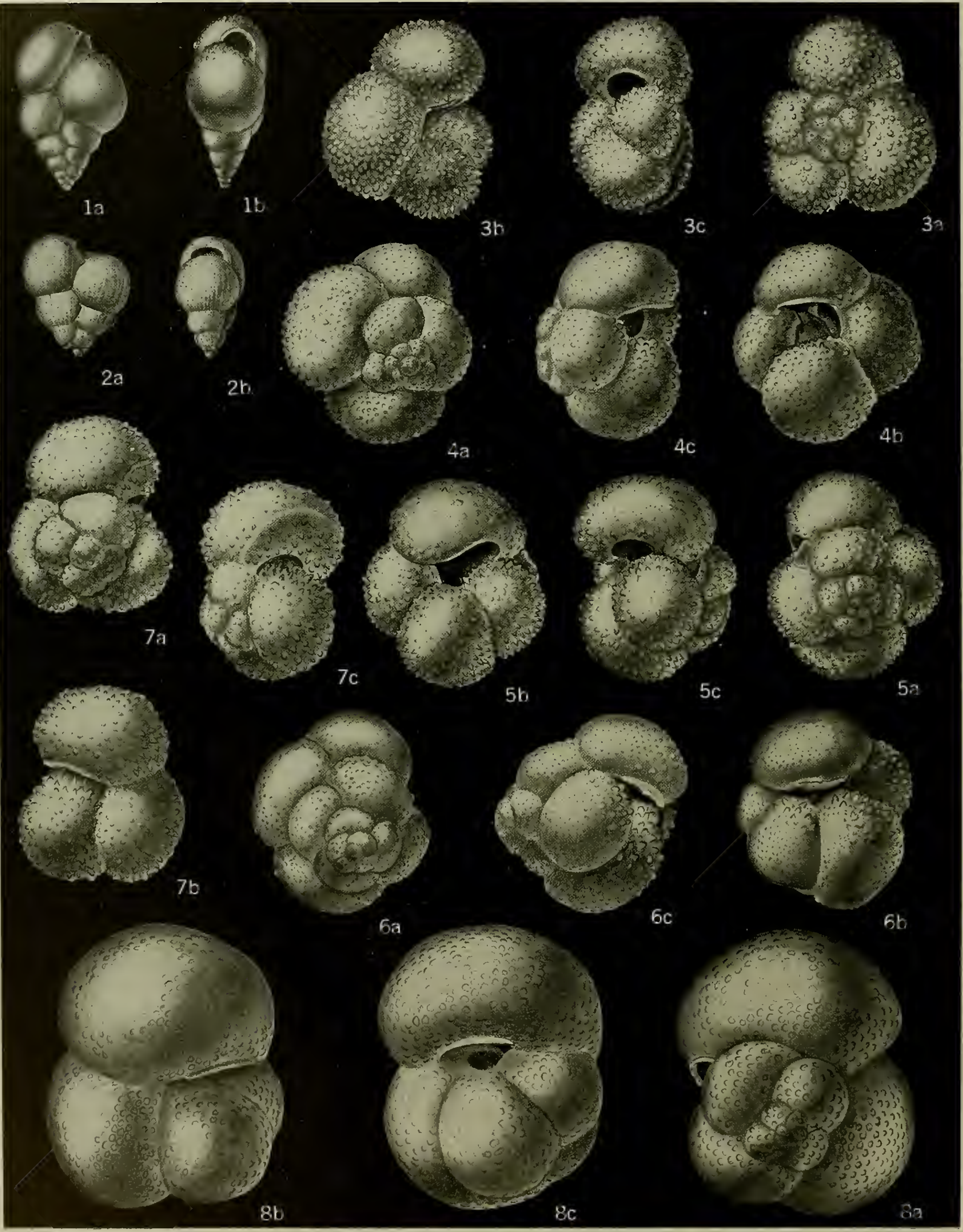
Hypotypes (USNM P5141a, b), showing flat spiral side, with crescentic appearing chambers, strongly inflated umbilical side, with limbate and rugose umbilical shoulder, broad and open umbilicus, and broad, low aperture with nearly triangular apertural flaps. Chambers are strongly angular truncate in edge view, and the limbate umbilical shoulder gives the appearance of a doubly keeled test.

FIGURE 8. *Globorotalia aequa* (?) 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

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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) 178

2a, Hypotype (USNM P5834) showing striate surface, and globular chambers. **2b,** Edge view, showing low, symmetrical arched aperture.

FIGURES 3a, c. *Globorotalia tribulosa* Loeblich and Tappan, new species 195

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.

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FIGURES 4a–6c. *Globigerina aquiensis* Loeblich and Tappan, new species 180

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.

PLATE 57. AQUIA GLOBIGERINA AND GLOBOROTALIA

(All figures: **a**, spiral view; **b**, umbilical view; **c**, edge view; all × 145)

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FIGURES 1, 2. *Globorotalia trichotrocha* Loeblich and Tappan, new species 195

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 191

Paratypes (USNM P5826a, b), showing robust test, with chambers flattened on the spiral side, but elevated near the periphery.

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FIGURES 5, 6. *Globorotalia convexa* Subbotina 188

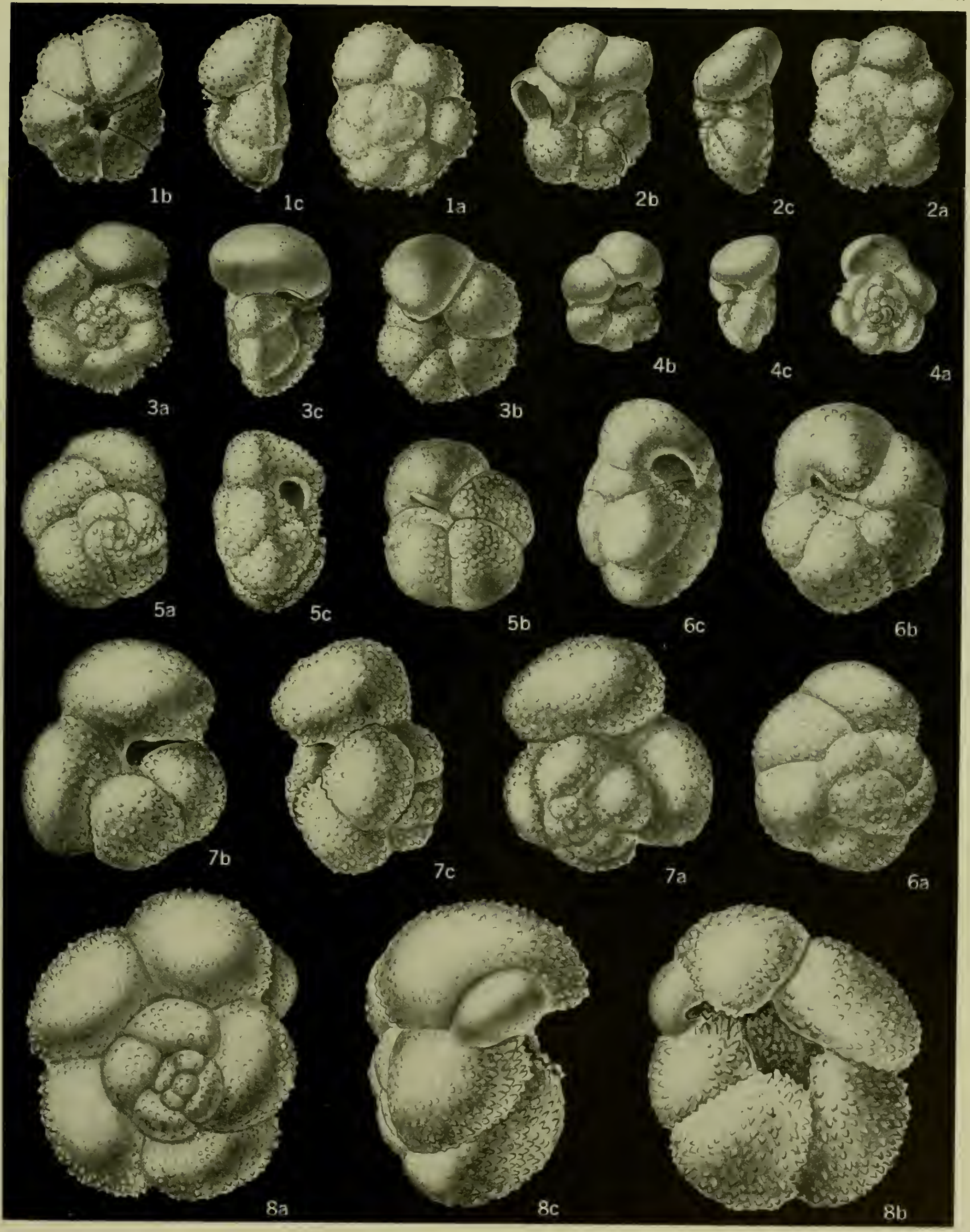
Hypotypes (USNM P5846a, b), showing gently rounded spiral side and inflated umbilical side, curved sutures, spinose surface, and low aperture with narrow bordering lip.

FIGURE 7. *Globorotalia esnaensis* (?) (Le Roy) 189

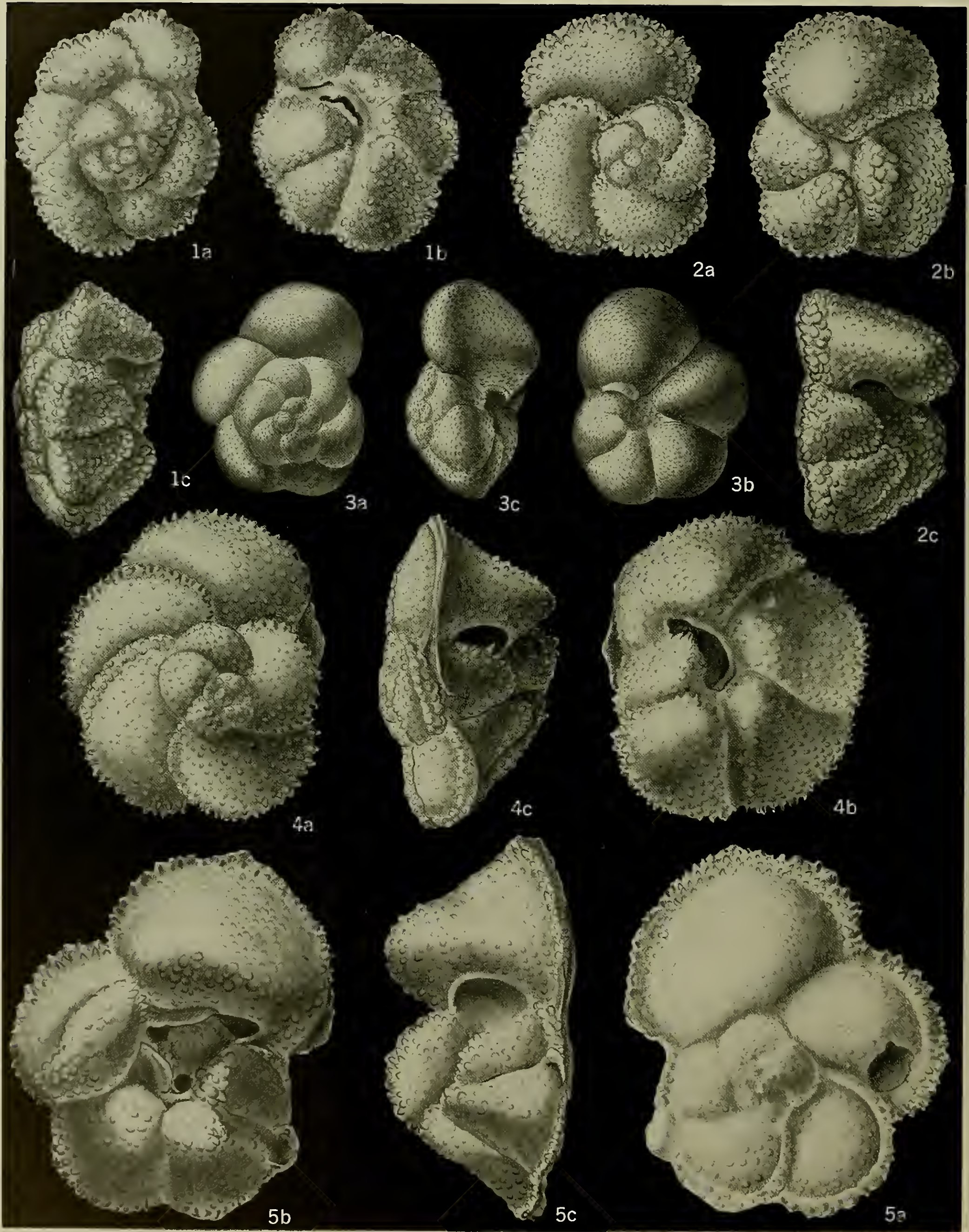
Hypotype (USNM P5878), which is relatively high spired for this species, but otherwise similar.

FIGURE 8. *Globigerina mckannai* White 181

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 GLOBIGERINA AND GLOBOROTALIA



AQUIA GLOBOROTALIA

PLATE 58. AQUIA GLOBOROTALIA

(All figures: **a**, spiral view; **b**, umbilical view; **c**, edge view; figure 3 × 280; all others × 145)

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FIGURE 2. *Globorotalia angulata* (White) Hypotype (USNM P5859), showing angular truncate chambers, few per whorl, large final chamber, flat spiral side, and angular umbilical shoulder.	187
FIGURE 3. *Globorotalia reissi* Loeblich and Tappan, new species Holotype (USNM P5835), showing small size, rounded chambers in spiral view, rounded umbilical shoulder, and subacute periphery.	194
FIGURE 4. *Globorotalia apanthesma* 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.	187
FIGURE 5. *Globorotalia acuta* Toulmin 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.	185

Plate 59. AQUIA GLOBOROTALIA

(All figures: **a,** spiral view; **b,** umbilical view; **c,** edge view; all × 145)

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Figure 1. *Globorotalia apanthesma* Loeblich and Tappan, new species 187

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 193

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. 193

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.

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Figure 4. *Globorotalia elongata* Glaessner 189

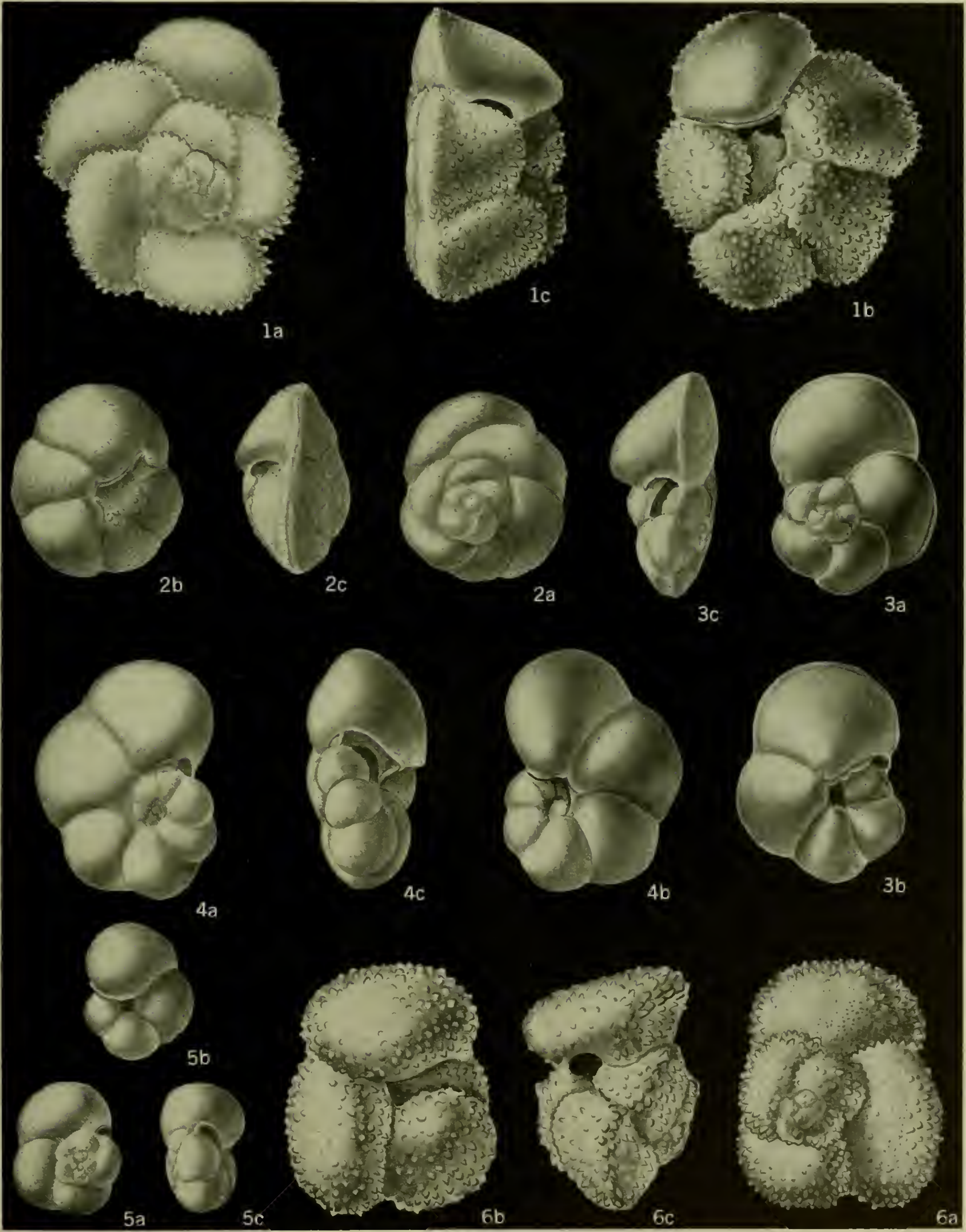
Hypotype (USNM P5695), showing rounded chambers, gradually increasing in size, with gently curved and depressed sutures on both sides.

Figure 5. *Globorotalia imitata* Subbotina 190

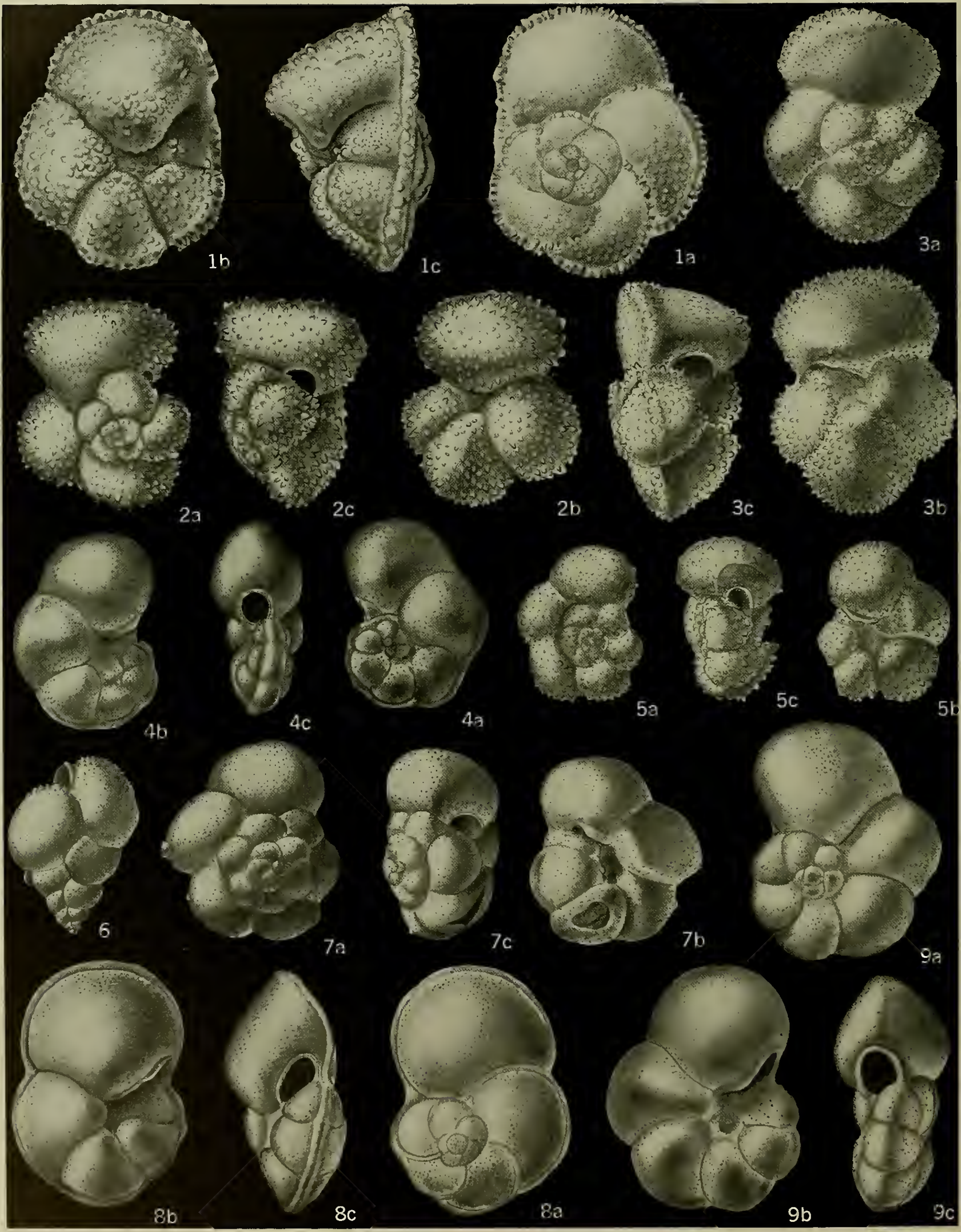
Hypotype (USNM P5691), showing small size, robust test, broadly rounded periphery, small umbilicus, and few chambers per whorl.

Figure 6. *Globorotalia aequa* Cushman and Renz 186

Hypotype (USNM P5125), showing angular truncate chambers, few per whorl, flattened spiral side, and elevated umbilical side with subacute umbilical shoulder.



AQUIA GLOBOROTALIA



NANAFALIA CHILOGUEMBELINA AND GLOBOROTALIA

PLATE 60. NANAFALIA CHILOGUEMBELINA AND GLOBOROTALIA

(All figures: **a,** spiral view; **b,** umbilical view; **c,** edge view; all ×145)

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FIGURE 1. *Globorotalia rex* Martin 195

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) 194

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 186

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, new species 196

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, new species 191

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Paratype (USNM P5827), showing small size, globular chambers, depressed spire and spinose surface.

FIGURE 6. *Chiloguembelina crinita* (Glaessner) 178

Side view of hypotype (USNM P5116), showing flared test, asymmetrical aperture and spinose upper surface.

FIGURE 7. *Globorotalia reissi* Loeblich and Tappan, new species 194

Paratype (USNM P5837), showing smooth surface, numerous chambers and somewhat elevated spire.

FIGURE 8. *Globorotalia pseudomenardii* Bolli 193

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 189

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)

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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, new species 191

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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

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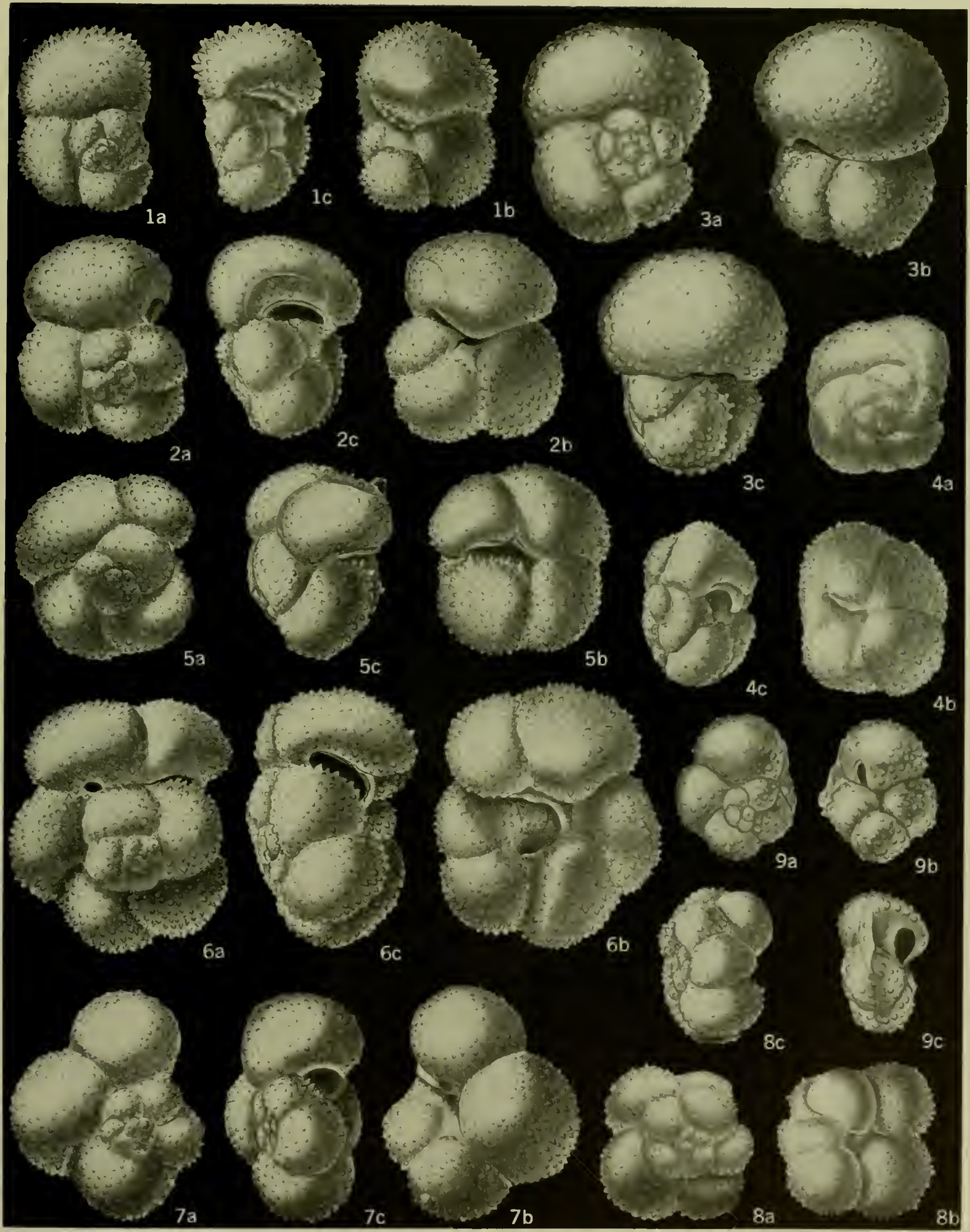
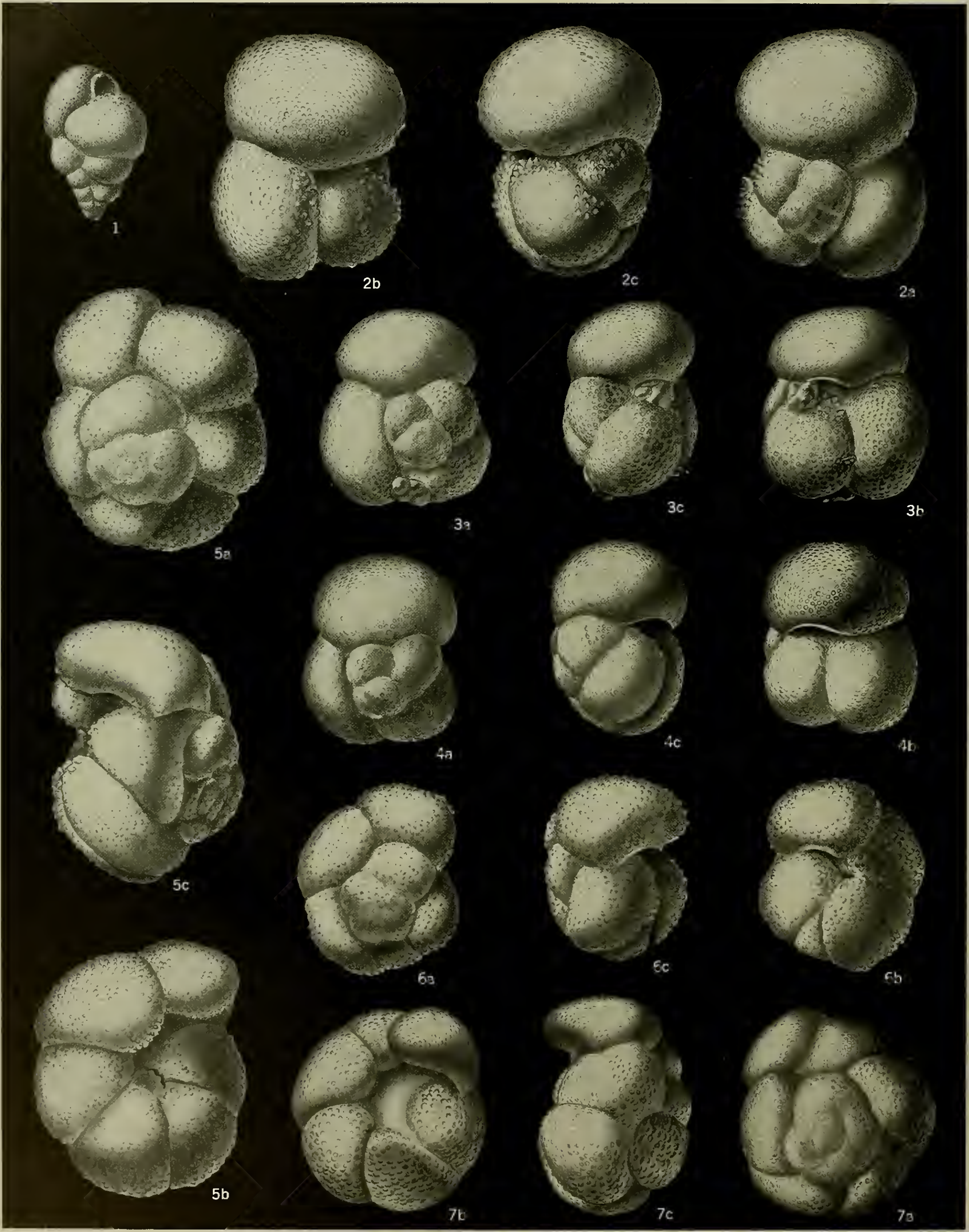
Figure 8. *Globorotalia chascanona* Loeblich and Tappan, new species 180

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)

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PLATE 63. VELASCO GLOBOROTALIA

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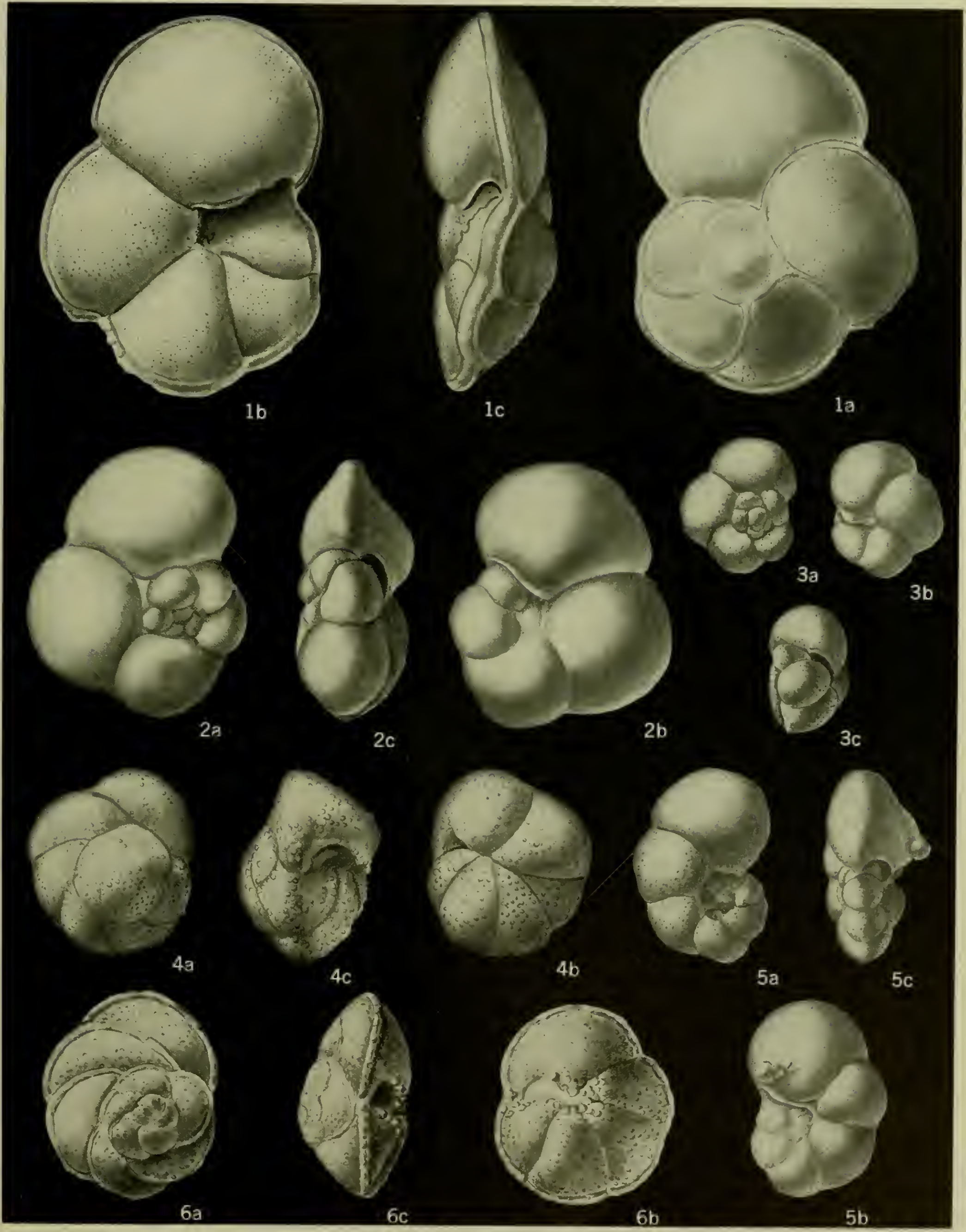
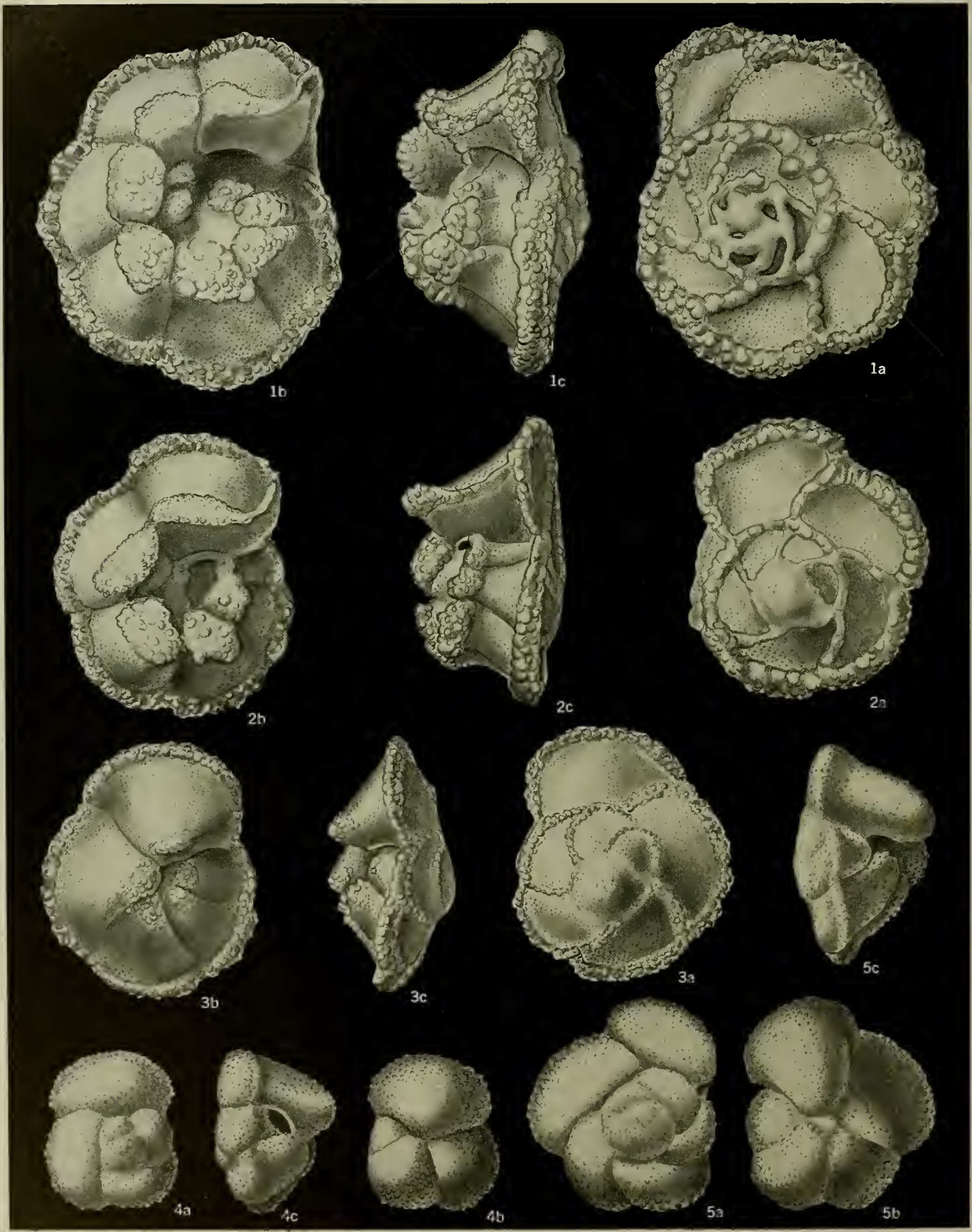


VELASCO GLOBOROTALIA



VELASCO GLOBOROTALIA

Plate 64. VELASCO GLOBOROTALIA

(All figures: **a**, spiral side; **b**, umbilical side; **c**, edge; all × 110)

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PLATE 65. BATHYSIPHON, HYPERAMMINOIDES, INVOLUTINA, HAPLOPHRAGMOIDES

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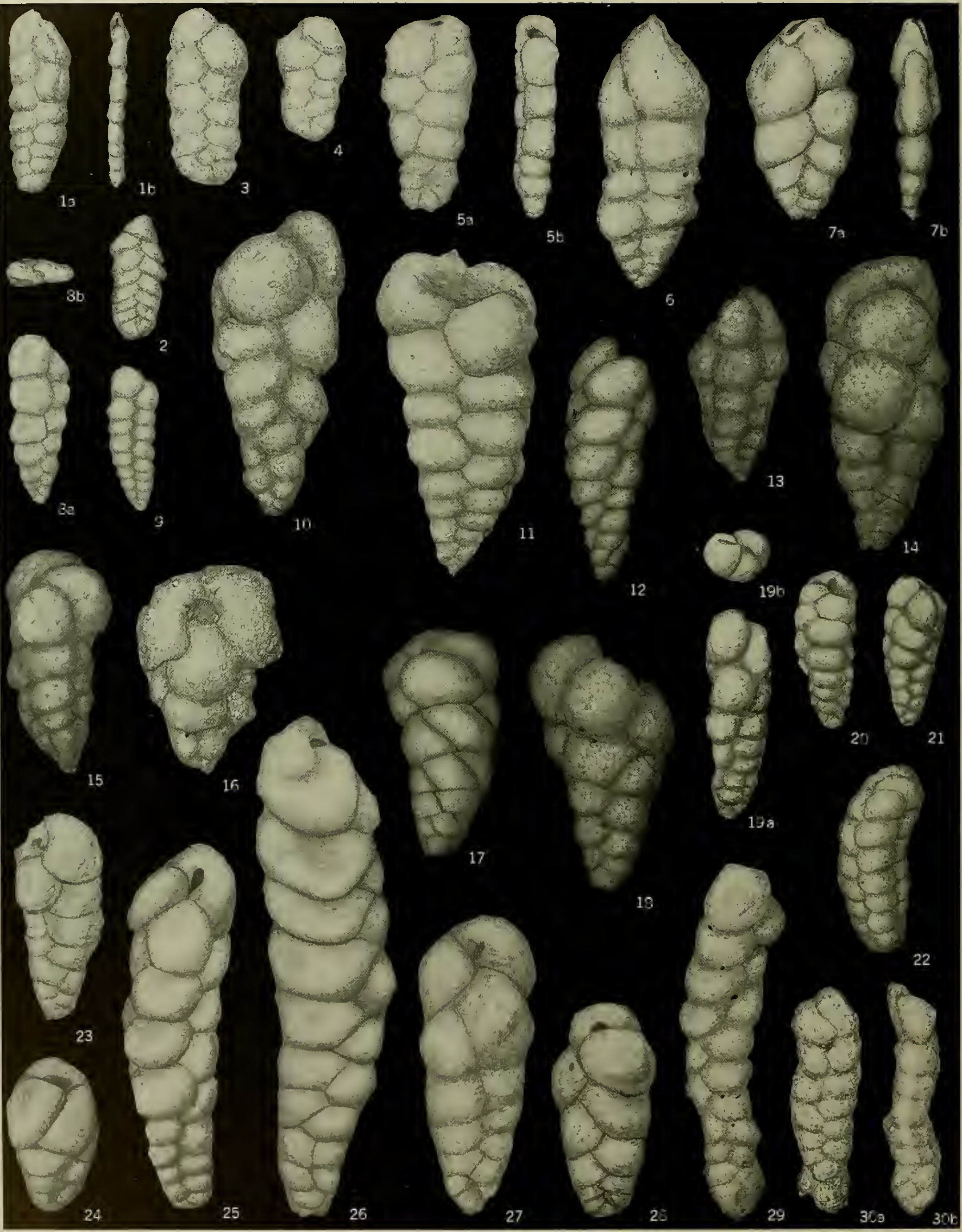
All figures are camera lucida drawings by Helen Tappan Loeblich.

BATHYSIPHON, HYPERAMMINOIDES, INVOLUTINA, HAPLOPHRAGMOIDES



SPIROPLECTAMMINA, SIPHOTEXTULARIA, TEXTULARIA, VERNEUILINOIDES, DOROTHIA

PLATE 66. SPIROPLECTAMMINA, SIPHOTEXTULARIA, TEXTULARIA, VERNEUILINOIDES, DOROTHIA

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All figures are camera lucida drawings by Helen Tappan Loeblich.

Plate 67. ARENOBULIMINA, PSAMMINOPELTA, MILIAMMINA, TROCHAMMINA

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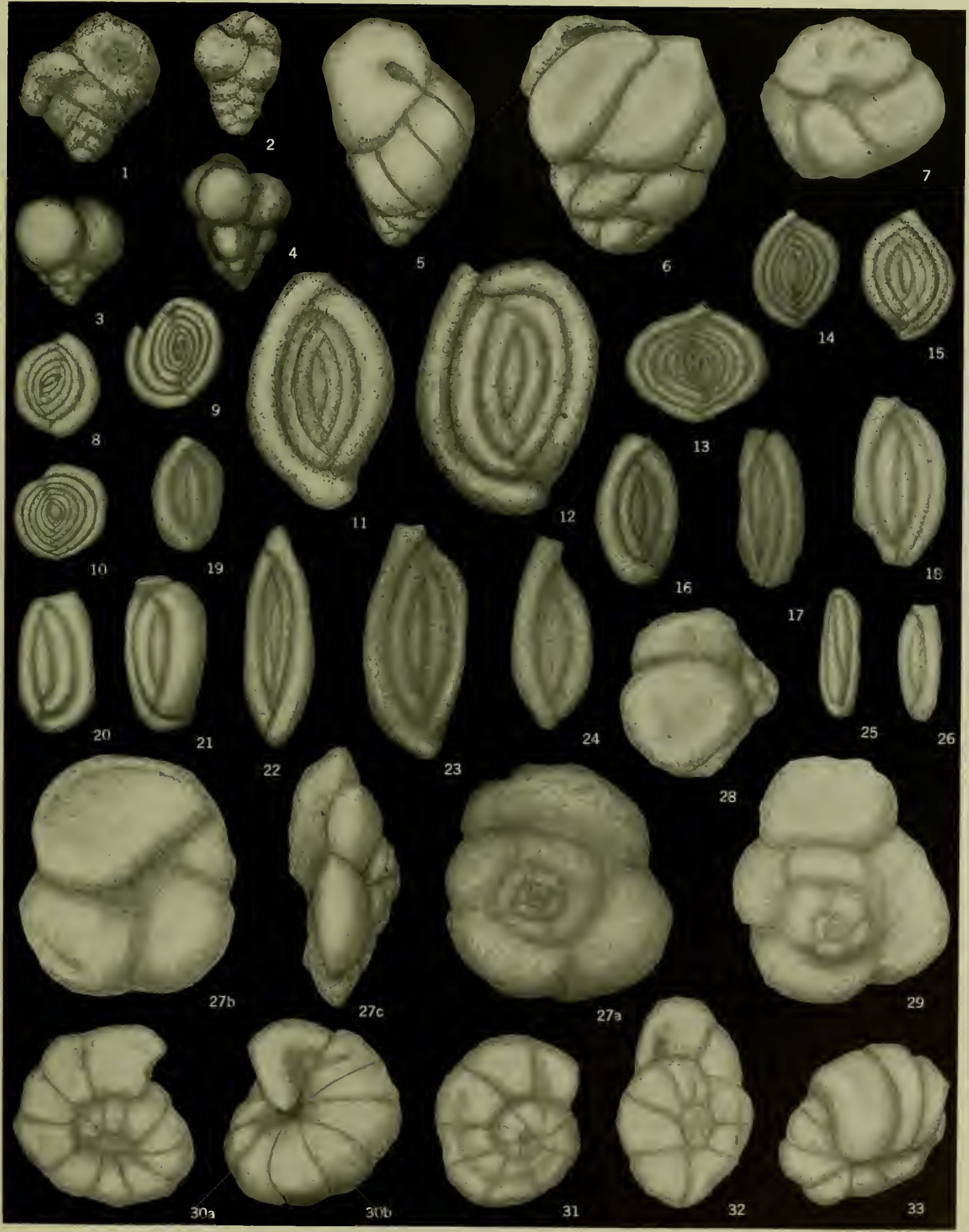
Figures 27a–29. *Trochammina umiatensis* Tappan, new species 214

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 214

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.



ARENOBULIMINA, PSAMMINOPELTA, MILIAMMINA, TROCHAMMINA

TROCHAMMINA, MARGINULINA, DENTALINA, PYRULINOIDES, SARACENARIA, RECTOGLANDULINA, EURYCHEILOSTOMA

Plate 68. TROCHAMMINA, MARGINULINA, DENTALINA, PYRULINOIDES, SARACENARIA, RECTOGLANDULINA, EURYCHEILOSTOMA

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Figures 1a–2. *Trochammina eilete* Tappan, new species 213

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 species 214

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 species 215

7, Holotype (USNM P4522). **8,** Paratype (USNM P4527). Both from the Grandstand formation, × 71.

Figures 9–12. *Dentalina? dettermani* Tappan, new species 215

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.

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Figure 13. *Pyrulinoides thurrelli* Tappan, new species 217

13, Holotype (USNM P4553) from the Grandstand formation. × 71.

Figures 14–16. *Saracenaria dutroi* Tappan, new species 216

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 216

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 217

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

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FIGURES 1–10. *Nanushukella umiatensis* Tappan, new genus, new species 219

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.

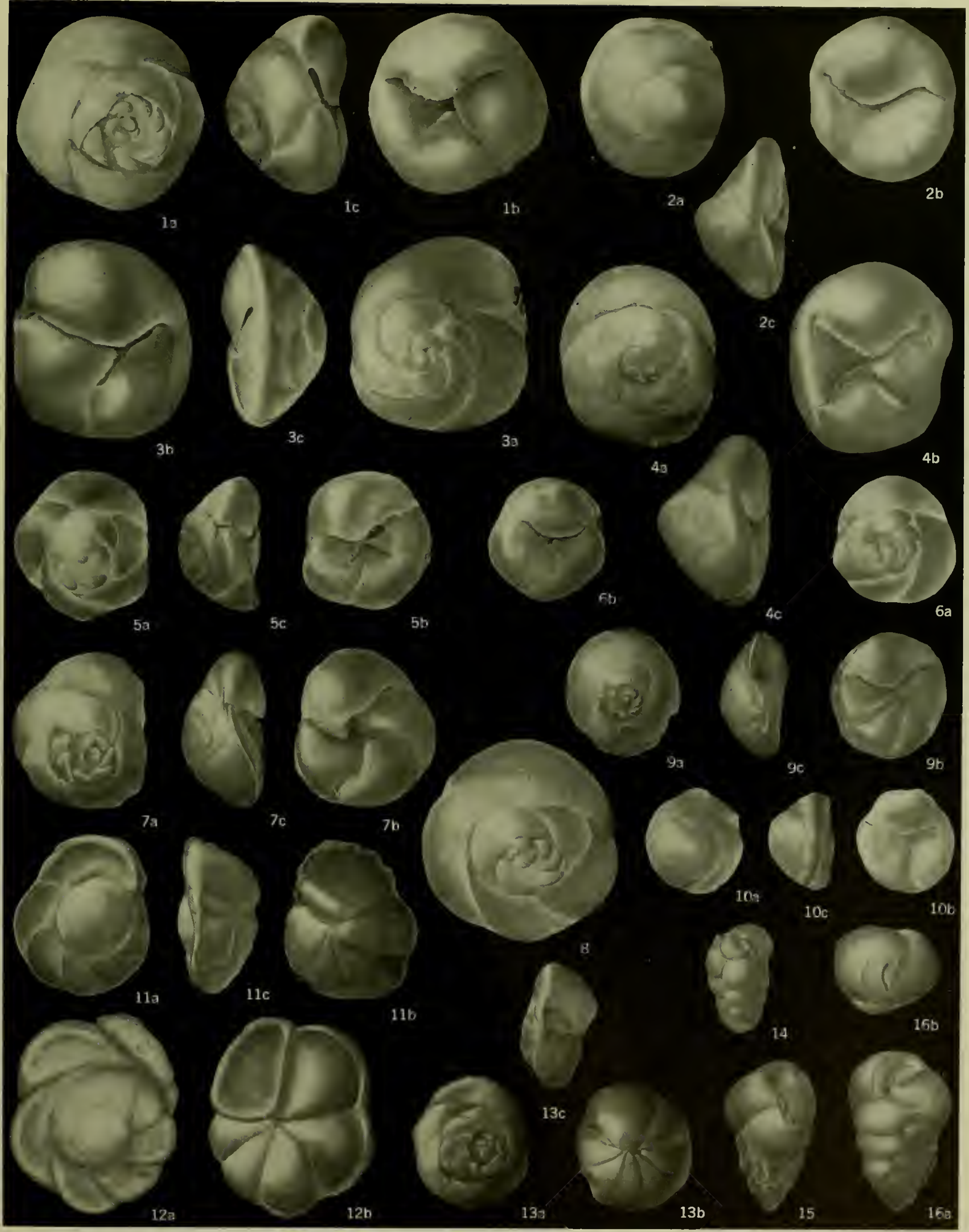
FIGURES 11a–13b. *Globorotalites alaskensis* Tappan, new species 220

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.

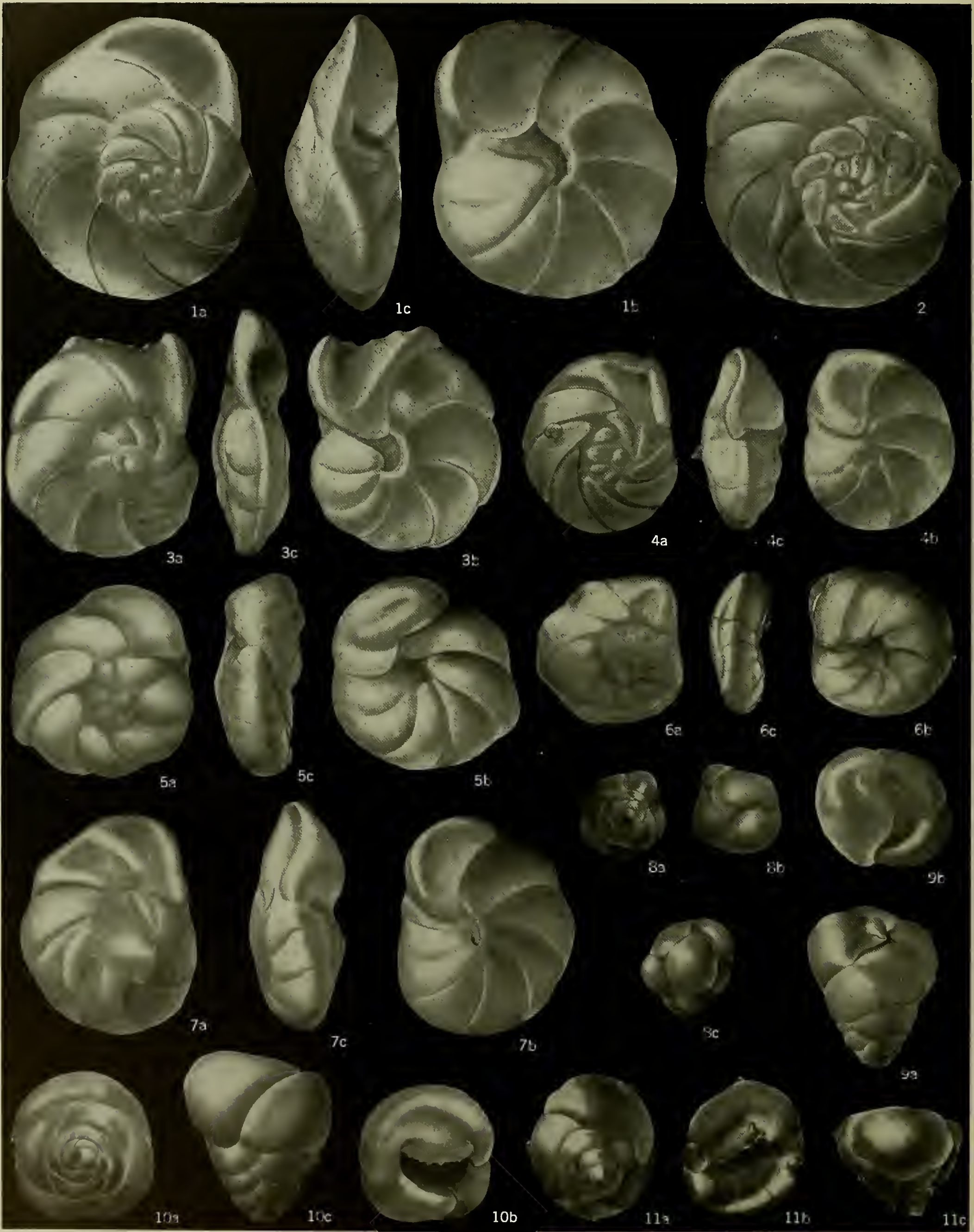
FIGURES 14–16b. *Praebulimina seabeensis* Tappan, new species 217

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.



NANUSHUKELLA, GLOBOROTALITES, PRAEBULIMINA



EPONIDES, EURYCHEILOSTOMA

PLATE 70. EPONIDES, EURYCHEILOSTOMA

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FIGURES 1a–7c. *Eponides morani* Tappan, new species 219

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 218

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.

PLATE 71. PALLAIMORPHINA

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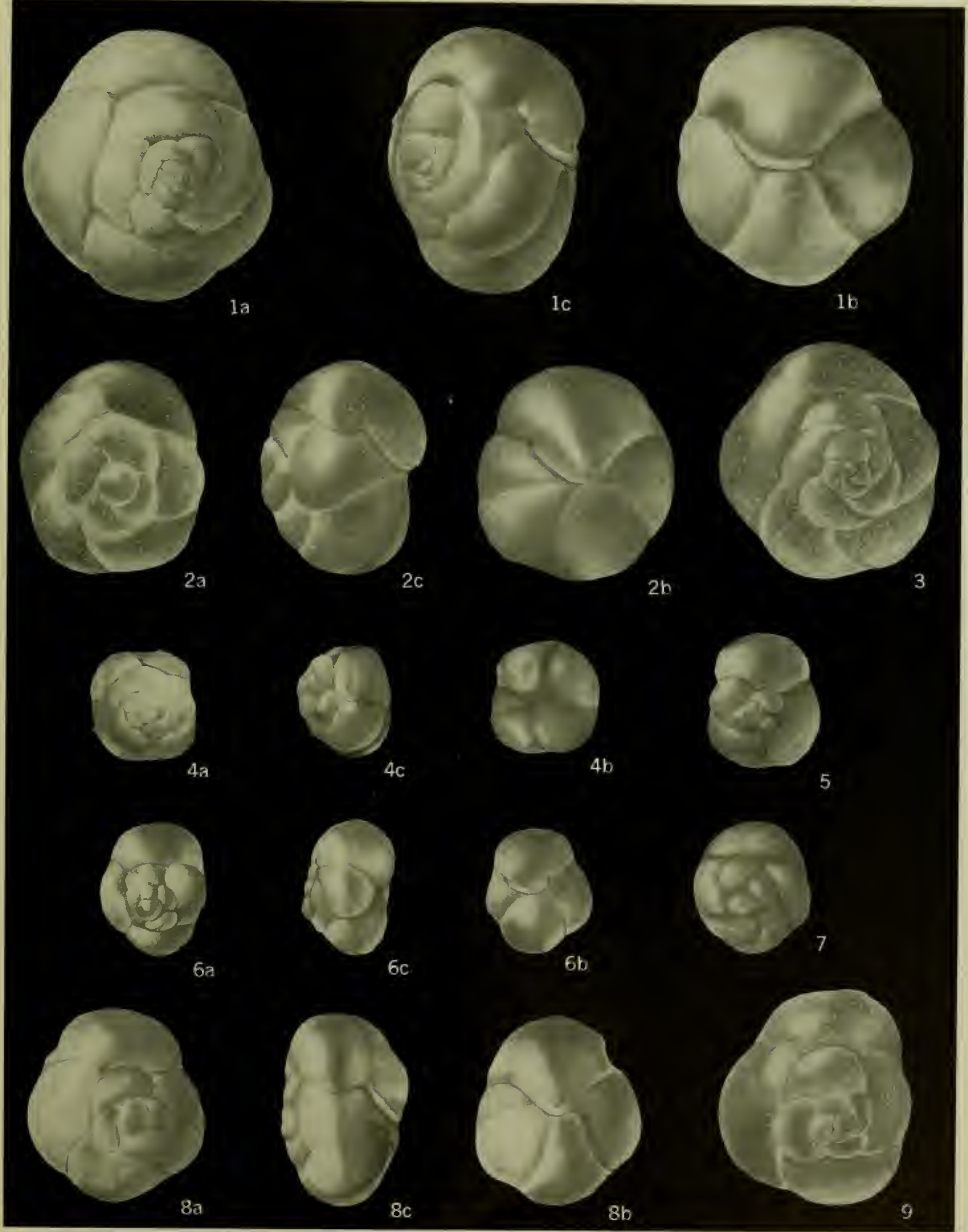
FIGURES 1a–9c. *Pallaimorphina ruckerae* Tappan, new species 221

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** 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.



PALLAIMORPHINA

HEMISPHAERAMMINA, ZOTHECULIFIDA, BERTHELINELLA, CITHARINELLA, TENTIFRONS, WEBBINELLA, AEOLOSTREPTIS

PLATE 72. HEMISPHAERAMMINA, ZOTHECULIFIDA, BERTHELINELLA, CITHARINELLA, TENTIFRONS, WEBBINELLA, AEOLOSTREPTIS

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FIGURE 1. *Hemisphaerammina depressa* (Heron-Allen and Earland) 224

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 224

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 224

3, Holotype (USNM P3095) from the Santonian of Spain, showing ovate, coarsely agglutinated test. × 10.

FIGURES 4–8. *Zotheculifida lirata* (Cushman and Jarvis) 224

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 and Tappan) 225

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 *Citharina*-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 226

17, Paratype (BMNH P40274), showing typical early 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, and Brady) 226

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) 227

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.

PLATE 73. SIGMAVIRGULINA, EURYCHEILOSTOMA, SESTRONOPHORA, SEJUNCTELLA, FAVOCASSIDULINA, PAROMALINA

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FIGURES 1a–2. *Sigmavirgulina tortuosa* (Brady) 227

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 229

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 229

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.

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FIGURE 6. *Sejunctella earlandi* Loeblich and Tappan, new genus, new species 228

6, Side view of holotype (USNM P3294), showing fimbriate 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

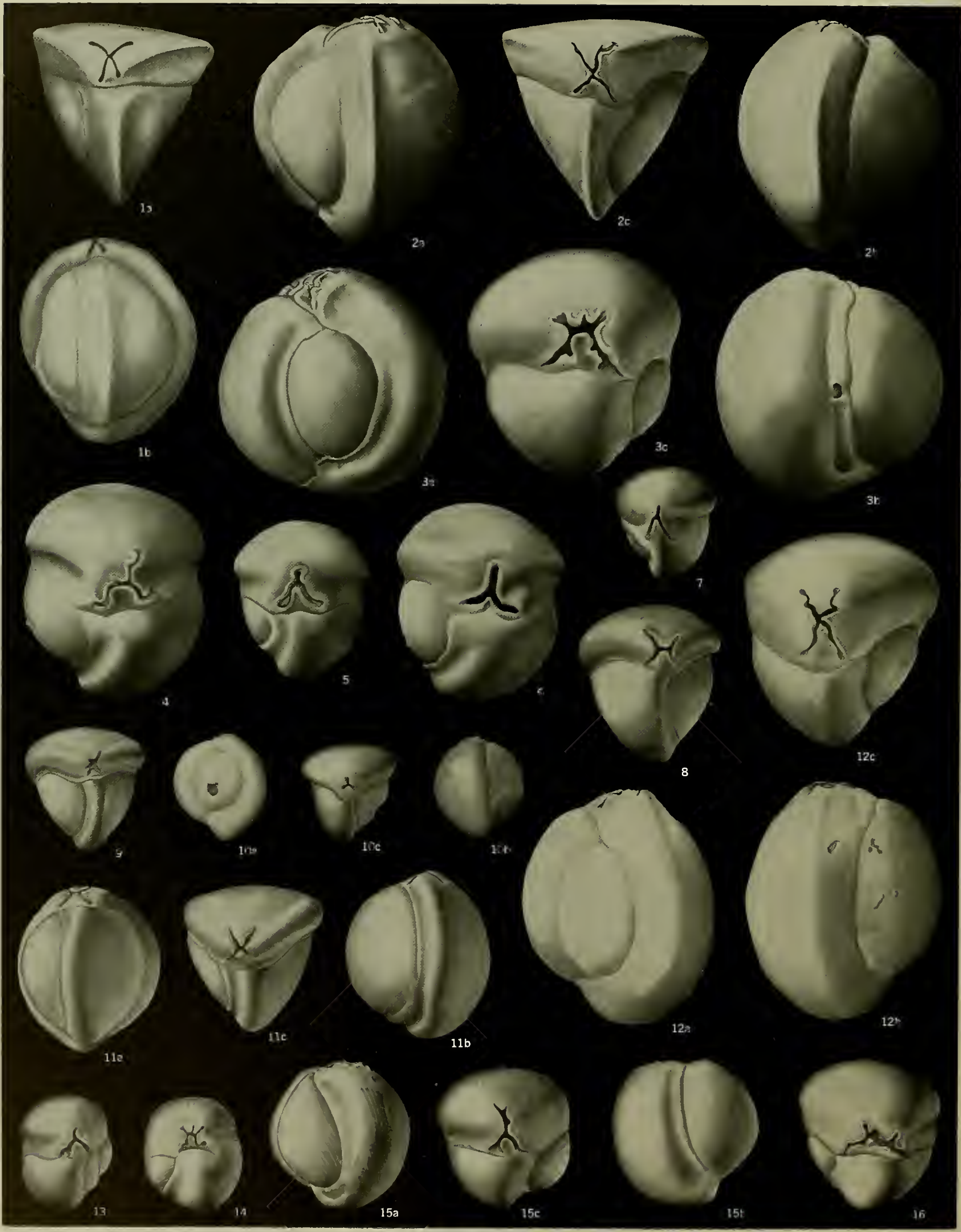
7, 10, 11, Edge views of topotypes (USNM P3376a–c), showing honeycomblike surface, and the smooth area surrounding the elongate, slitlike aperture. **8,** Sectioned hypotype (USNM P4469), showing the alternating chambers typical of the Cassidulinidae, beneath the secondary covering of the wall. **9a,** 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 231

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.

SIGMAVIRGULINA, EURYCHEILOSTOMA, SESTRONOPHORA, SEJUNCTELLA, FAVOCASSIDULINA, PAROMALINA



CRUCILOCULINA

PLATE 74. CRUCILOCULINA

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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 ericsoni* Loeblich and Tappan, new species 234

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 233

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 234

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.

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