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CUSHMAN FOUNDATION
FOR
FORAMINIFERAL RESEARCH

VOLUME XVIII, Part 4
October, 1967

9 subject cards

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1967

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FOR FORAMINIFERAL RESEARCH
VOLUME XVIII, PART 4, OCTOBER 1967

336. WALL STRUCTURE AND CEMENTATION IN *HAPLOPHRAGMOIDES CANARIENSIS*

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ABSTRACT

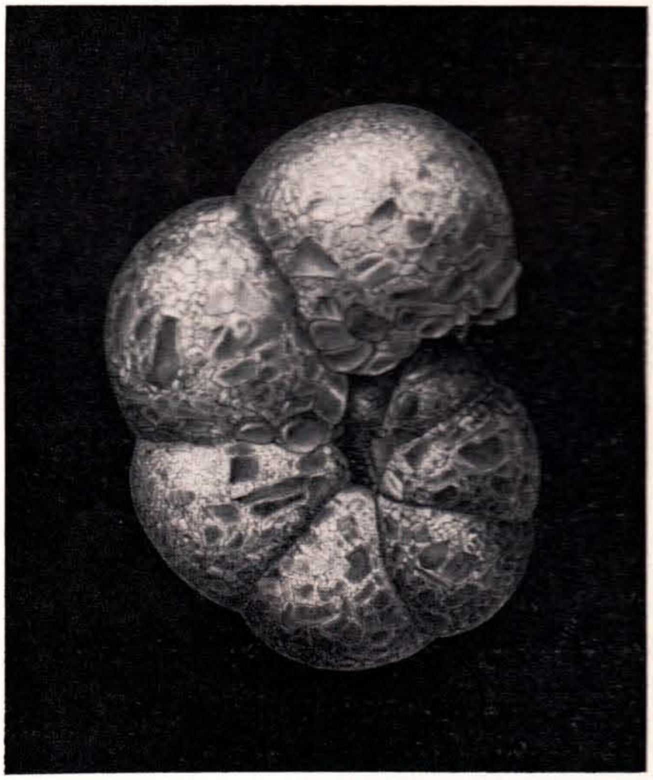
The test wall of **Haplophragmoides canariensis** is selectively constructed of smoothly finished, tightly packed quartz with subordinate feldspars in a calcium carbonate-free organic cement which can vary in its sodium hypochlorite solubility and which contains important amounts of ferric iron in individuals which are colored reddish-brown or white or both. The animal is probably not involved in a metabolic secretion of iron oxides in the usual sense. A model for test formation is offered to explain the observed data.

INTRODUCTION

Because of the difficulties inherent in studying their tests, the arenaceous Foraminifera have been largely ignored in comparison to their calcareous counterparts. In recent years only the work of Hedley on the arenaceous wall is notable from the point of view of wall structure and biochemistry. In the present study the species *Haplophragmoides canariensis* was chosen because it is common, it is the type species of the genus, and it is an important representative of the family Lituolidae. The species therefore is an ideal member of the arenaceous Foraminifera for the purpose of examining the microstructure of the arenaceous test, the nature of the cementing material, and the relationship of the mineral grains to the cementing material. The methods here used are X-ray diffraction, electron microscopy and chemical staining techniques. Representative specimens from widely scattered geographical localities were selected from the collections at the U. S. National Museum.

RESULTS

Text fig. 1 is a drawing of a representative individual of *H. canariensis*. The test is planispiral, partially involute, with simple chambers and a single wall. The arenaceous wall is smoothly finished, the mineral grains varying in size from coarse ($>20\mu$) to fine ($<1\mu$), set in a cement which is subordinate. The true amount of cement is recognized only after very careful observation at high magnification ($\sim 100\times$). Cursory observation at low magnification gives the false impression that the very fine-grained areas are true cement. All specimens of *H. canariensis* examined derive their overall color from the cement. In the average individual the reddish-brown color is clearly restricted to the cement and decreases in intensity towards the later formed chambers. The last formed chamber is often completely white, which Cushman (1950) and others observed was a common characteristic of many arenaceous Foraminifera. Other individuals are completely white in color.



TEXT FIGURE 1

Drawing of a mature individual of *Haplophragmoides canariensis* from Port William, Falkland Islands. ($\times$ 75).

It is well known that in the reddish-brown portions of the test of this and other arenaceous species cement is mineralized with an inorganic ferruginous deposit. X-ray diffraction patterns of both the reddish-brown and completely white tests show that the only crystalline components present in all of the specimens analyzed are quartz and feldspar. The feldspar is identified from the Debye-Scherrer X-ray data as an intermediate plagioclase (oligoclase-andesine?) which is quantitatively subordinate to the quartz. There is no iron or calcium carbonate either as cementing material or as arenaceous components. The ferruginous material occurring in the cement is present as an extremely fine-grained, X-ray amorphous constituent. That the ferric iron is present in the reddish-brown tests as a very fine, amorphous oxide is supported by the fact that it is chelated and removed by disodium EDTA (pH 4.6) after a 24-hour treatment. The 24-hour chelation of the iron from *H. canariensis* is rapid when compared with other iron oxides. Such rapid chelation was achieved experimentally only with very fine colloidal hydrated iron oxides and then only if the material was well dispersed. Hedley (1963) was able to sequester the iron in other ferruginous Foraminifera after five to seven days in EDTA at pH 8. Such extended treatment of *H. canariensis* at pH 11 failed to remove all of the iron; further proof that it is not a carbonate. Concomitant with the loss of iron, and as reported by Hedley (1963), the test loses strength and becomes soft and flexible.

In the electron microscope, replicas of the surface of *H. canariensis* show that the wall is constructed (Plate 12) of grains of quartz and feldspar with a degree of perfection of fit that rivals that of the stone mason's work. Almost all of the available space has been filled with grains of the appropriate size and shape and little cement is present. The majority of the arenaceous components are oriented so that a flat surface is exposed. Jagged or rough edges, except those due to minor cleavage or fracture, are rarely seen on the surface. The result is the smoothly finished test characteristic of this species.

An important feature of the wall construction is the absence of such accessory minerals as zircon, ilmenite, rutile and the like, the presence of which would show clearly on the replicas because of their insolubility in the reagents used. Also noticeably absent are micaceous minerals and detrital grains of biogenic origin. Diatom frustules, sponge spicules, coccoliths or broken shell fragments, when rarely seen, are secondary post-mortem attachments to the surface rather than an integral part of the test construction. *H. canariensis* is thus selective in its choice of arenaceous materials.

In the electron microscope the extremely fine-grained, amorphous aspect of the iron oxide-organic cement is apparent (Plate 13). The iron oxides appear as small, globular particles that are generally restricted to the interstitial areas. These particles average less than a thousand Ångstrom units (0.1μ) in size, well within the colloidal range.

The organic portion of the cement appears to exist in several different states, as indicated by the quasi-histochemical treatment of the tests with a 5% solution of sodium hypochlorite (Clorox). Some individuals, usually completely white in color, are readily and completely solubilized, leaving behind the individual grains of quartz and feldspar. Others, usually red in color, are highly resistant to even extended treatment, and a third group behaves in an intermediate fashion. The results are included in Table 1. It is not unreasonable to conclude from this that the organic cement can undergo a biochemical change during ontogeny that normally results in the final, stable acid mucopolysaccharides of the mature individuals described by Hedley (1963).

Hedley (1963) further reported that the color of the test was not a reliable indicator of its iron content, as in the twelve species he studied both pure white and reddish-brown forms contained similar amounts of iron. This feature of the arenaceous wall was confirmed in *H. canariensis* by means of the acidified potassium ferrocyanide staining test on specimens from various localities (table 1). All specimens reacted positively for ferric iron, although the intensity of blue coloration was variable.

A buffered 0.25% orthophenanthroline test for ferrous iron was performed on selected specimens; the results were negative or extremely weak at best.

In addition to the fact that all specimens, regardless of color, contain some iron, it can be further concluded that most, if not all, of the iron is in the ferric state.

TABLE 1
Chemical reactions of *Haplophragmoides canariensis* from various localities

Specimen Locality	Test Color	Clorox Reaction	Potassium Ferrocyanide Reaction
Cape Hatteras, N.C. (Albatross, D2003)	Light Brown	Negative	Blue
Port Stanley, Falkland Islands	White	Positive	Very Light Blue
Clavering Island, Greenland	Red-Brown	Negative	Blue
Port William, Falkland Islands	Red-Brown	Negative	Blue
Gulf of Mexico	White	Positive	Blue
Mangrove Swamp, Trinidad, B.W.I.	Red-Brown	Positive & Negative	Blue
Shannon Island, N.E. Greenland	Red-Brown	Positive & Negative	Blue, Light-Blue

Control studies on various colloidal hydrated iron oxides, including goethite and hematite, indicate that with varying lengths of time all give a positive Prussian blue reaction for ferric iron. In fact it was observed, as might be expected, that the finer the particle size and the poorer the crystallinity, the more rapid the formation of Prussian blue. Hedley (1960, 1963) inferred that a positive reaction to the ferrocyanide test indicates that the iron is organically bound to the cement. However, inorganically bound biologic iron will also react positively, as is shown by the fact that ferritin and hemosiderin granules react to the stain (Shoden and Richter, 1960).

Extrapolating these data to the iron in *H. canariensis*, as well as to other ferruginous arenaceous Foraminifera, the rate of formation of Prussian blue is consistent with the particle size indicated by the electron microscope and inferred from the rate of iron chelation.

DISCUSSION

Summarizing the data, it can be stated that the test wall of *Haplophragmoides canariensis* is smoothly finished and tightly constructed of selectively chosen, mineralogically distinctive grains in a subordinate calcium-free organic cement which can vary in its sodium hypochlorite solubility and contains important quantities of ferric iron in forms colored reddish-brown or white or both.

These observations, combined with those of Hedley (1960, 1963), permit a discussion of the source of the iron—whether or not it is metabolically secreted by the organism—and an hypothesis of arenaceous test formation.

Ferric iron occurring combined as inorganic oxides and hydroxides produces a strong absorption in the visible region that is the result of a photochemical oxidation-reduction process (Fyfe, 1964). Even when present in low concentrations and as very fine colloids (~20Å), the ferric oxyhydroxides interact with visible light to produce the common red to yellow colorations. It is reasonable to conclude in the case of the white, or white portions of, arenaceous Foraminifera under consideration that if the iron (1) is present in sufficient quantity to produce an intense Prussian blue reaction, (2) is not present as ferrous iron and (3) is otherwise colorless, then it cannot be present as an inorganic ferric oxide or hydroxide. This, then, rules out the possibility that the source of ferric iron is the direct adsorption of colloidal particulates to the shell from sea water. Since all other common *ferric* compounds are also colored and/or water soluble the only alternative is that the iron in the white shells is, at least initially, organically bound. Iron-protein complexes containing heme-iron, whose presence in the *wall* is unlikely, are also colored and should be eliminated from consideration on similar grounds. The remaining alternative is the presence of ferric iron as a colorless complex with amino acids, peptides or in some other metallo-organic coordination. Hedley (1960) suggested similarly that in *Gromia oviformis* the iron was present bound to the carboxyl and/or sulfate groups of the protein-acid mucosubstances. In any event, it is improbable that the ferruginous arenaceous Foraminifera are actively secreting iron in the usual metabolic sense without the formation of some typical iron-proteins. Whether or not such iron-proteins are present in these animals awaits detailed histochemical study. Lacking these data the following hypothesis is tentatively suggested: Various mineralogically distinctive clastic particles (carbonates, quartz, micas, clay minerals, etc.) occur in the marine environment, each with its own surface chemistry, a reflection of the crystal chemistry and the local environment. Also a wide variety of organic materials—proteins, lipids, carbohydrates, amino acids, sugars, etc. exist in sea water as the result of biological activities. As the organic-inorganic components tend to approach a dynamic equilibrium, mineral grains will adsorb organic complexes. Indeed, certain minerals will preferentially adsorb certain organic compounds (see for example, Fripiat, 1965; Evans, 1965, Williams and Zirino, 1964, Bader *et al*, 1960; Whitehouse, 1955). The degree to which this takes place and the complexes involved are variable and a function of such factors as the mineral surface pH, surface charge and the steric configuration of the organic ligands. Furthermore, many organic compounds are capable of chelating iron and other cations (Smith, 1956). Bader *et al* (1960) and Kaurichev and Nozdrunova (1960) have demonstrated the effectiveness of the amino acids in this regard. The surface pH of quartz is between 6 and 7, (Keller, 1958; Stevens and Carron, 1948). The solubility of iron at pH 6 is dramatically greater (10^5 times) than at pH 8.5 (Mason, 1958). It seems possible that the surface chemistry of quartz is such that it can increase the solubility of iron (and aluminum) at the interface over that in seawater itself. Undoubtedly the mineral-iron-organic chelate reactions and the selectivity involved are very complex, but if it can be accepted that certain minerals have a tendency to adsorb certain organic compounds to which iron may or may not be chelated, then it can be a step towards understanding that some arenaceous Foraminifera prefer some minerals to the exclusion of others. The process would be essentially that of chemotaxis. The phagocytotic ingestion of such grains to provide the organism with a selective source of nutrient material is probable. Indeed, the presence of specific amino acids and proteins is often necessary in protozoa as "inducing substances" for intense pino- or phagocytotic activity (Pitelka, 1963; Holter, 1962). The actual source of the iron might well be independent of the adsorbed organic material. It could be from Fe^{++} reduced at or below the sediment-water interface or from particulate colloidal oxides ingested with the grains and dissolved within the vacuoles. In either case, however, it is eventually incorporated in the chamber wall as Fe^{+++} organically complexed. In the Foraminifera the storage of the mineral grains and accompanying vacuolized plasmalemma mucoid fluids could take place against a cyst membrane secreted during chamber formation. This "excretory step" could explain the extremely well-fitted nature of many arenaceous walls. The process would be one of closest packing of grains in a partially fluid medium by cytoplasmic pressure resulting in their rearrangement against the cyst membrane. Simultaneously the formation of peptides and polypeptides through carboxyl linkages would release the iron from its probable chelated position at the carboxyl groups. The ferric iron is then available to precipitate as an insoluble, colloidal, hydrated ferric oxide tending to stabilize the cementing clorox-insoluble mucosubstances. This process is not unlike that suggested by Schuylenborgh (1965) for the formation of similar iron oxides in soils. The process of incorporation of mineral grains might take place only during chamber formation. At other times the grains might be excreted back into the milieu.

This experimental model is hypothetical but it is not inconsistent with the limited data available. It is suggested as a working model which can be tested by subsequent culturing experiments and more detailed histological studies at both the light and electron microscopic level. It is offered as a possible physiological explanation for test construction, but it is not suggested as applicable to all other arenaceous Foraminifera.

The data presented here allow for clarification of some of the difficulties associated with earlier observations. Cushman (1950) indicated a belief that in the arenaceous Foraminifera a ferruginous cement could be largely replaced by a calcareous cement. This he concluded from observations on color changes taking place geographically as well as in single individuals. It is clear from the present study that such a conclusion is not necessarily warranted. As color of the test is not a reliable indicator of iron content (Hedley, 1963), so is it not a reliable indicator of calcareous cement. The transition that Cushman observed taking place in a single individual was that of a colorless iron-organic cement giving way to a reddish-brown iron-organic cement.

The complete absence of calcareous material in the test of *H. canariensis* results in an additional complication of taxonomic importance. Loeblich and Tappan (1964) indicate in their description of the Family Lituolidae that the wall is agglutinated, with calcareous cement or microgranular calcite. Inasmuch as there is no calcareous material of any kind in the test this would require either shifting the genus *Haplophragmoides* to some other family or modifying the family description to indicate the degree to which the cementing material can vary. The latter choice seems preferable.

ACKNOWLEDGEMENTS

The author is grateful for the criticisms and suggestions of M. A. Buzas, R. Cifelli, M. G. Gross, R. H. Hedley, and H. A. Lowenstam, all of whom read preliminary drafts of the manuscript. G. H. Hamilton provided valuable technical assistance.

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EXPLANATION OF PLATE 12

FIGS.	PAGE
Electron micrograph (single stage replica) of the surface of *H. canariensis* with quartz grains (Q), minor cement and large feldspar grain (F). (× 7000)	148

Towe: Wall of *Haplophragmoides canariensis*

Towe: Wall of *Haplophragmoides canariensis*

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EXPLANATION OF PLATE 13

FIGS.	PAGE
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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XVIII, PART 4, OCTOBER 1967

337. ORIGIN, DEVELOPMENT, AND GEOLOGIC SIGNIFICANCE OF *NEOGLOBOQUADRINA* BANDY, FRERICHS, AND VINCENT, GEN. NOV.*

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ABSTRACT

A new generic name, **Neogloboquadrina**, is proposed based upon the type species **"Globigerina" dutertrei** d'Orbigny, 1839. The type species arose in later Miocene time from **Globorotalia globorotaloidea** (Colom), developing toothlike umbilical flaps by later Pliocene time in tropical areas; umbilical flaps have not yet developed in temperate forms. The pitted non-spinose wall distinguishes this new genus from **Globigerina**; tropical forms with toothlike umbilical flaps are like **Globoquadrina** as a result of evolutionary convergence.

Evolution of umbilical flaps in tropical populations of the later Pliocene is a valid datum. Expansions of tropical populations during interglacial intervals of the Quaternary can produce the superposition of tropical populations (with flaps) over temperate populations (without flaps) in geographic areas marginal to the tropics; these cases may be confused with the actual evolutionary sequence of the later Pliocene.

INTRODUCTION

It is the purpose of this study to show the origin, development and geologic importance of the new genus *Neogloboquadrina* based upon a lineage study of the type species "*Globigerina*" *dutertrei* d'Orbigny, 1839. From a structural approach, this genus is essentially like *Globoquadrina* Finlay, 1947, as pointed out by Parker (1962); from a phylogenetic approach, it arose from a different set of ancestors and is therefore genetically unrelated to *Globoquadrina*.

It is not the purpose of this work to explore the classification of planktonic foraminifera. This subject has been reviewed and reconsidered in a number of recent studies (Bolli, Loeblich, and Tappan, 1957; Pokorny, 1958; Banner and Blow, 1959; Loeblich and Tappan, 1964; etc.). In keeping with Galloway (1933) and Cushman (1948), most authors have used wall, chamber arrangement, and basic position of the aperture as the primary basis of classification. Banner and Blow have emphasized the external structural modifications of the aperture in their work. Phylogeny, an important part of Galloway's classification, has assumed much importance in recent works by many authors such as Blow (1959), Wade (1964), etc. The stratigraphic occurrences of many planktonic forms is now so well documented that occurrence in geologic time is valid as a critical factor in classification. The case for *Neogloboquadrina* exemplifies the importance of the phylogenetic approach.

ACKNOWLEDGMENTS

The writers wish to express their grateful thanks and appreciation to the National Science Foundation for support (GP 2530) and for the opportunity of the senior author to undertake cruises of the R/V ANTON BRUUN in the Indian Ocean (Cruise 7, 1964) and the southeastern Pacific (Cruise 17, 1966). We wish to thank the scientists, officers, and crew of the BRUUN for their assistance and cooperation. Thanks are also due K. S. Rodolfo and the staff of the U.S.C. & G.S. PIONEER for collections made in the Andaman Sea; to Lamont Geological Observatory for making available samples from their core V 15-164; to officers and crew of the U.S.C. R/V VELERO IV for assisting with collections from basins of the continental borderland of southern Californa; to the scientists, officers, and crew of the USNS ELTANIN for collections made in the Antarctic; to Henriette M. Williston for typing and editorial service; and to Fritz Theyer for assistance in retouching the photographs.

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA

Superfamily GLOBIGERINACEA Carpenter

Genus **Neogloboquadrina** Bandy, Frerichs, and Vincent, gen. nov.

Plate 14, figures 2-12

Type species: *Globigerina dutertrei* D'ORBIGNY, 1839, *in* de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, Bertrand, Paris, p. 84 (plates published separately, vol. 8, pl. 4, figs. 19-21).—BANNER and BLOW, 1960, Cushman Found. Foram. Res., Contr., vol. 11, p. 11, pl. 2, fig. 1 (lectotype).

Test globose, trochospiral, multilocular, spire flat to rather high, chambers inflated. The umbilicus is deep and moderately broad. The aperture is interiomarginal, varying from umbilical to umbilical-extraumbilical, with toothlike umbilical flaps in tropical specimens, weakly developed flaps or none at all in specimens from temperate areas. Wall moderately and uniformly perforate, giving a pitted appearance with no spines or only a slight development of spines near the aperture. This genus is like *Globoquadrina* Finlay (1947), but it developed from a different lineage in the later Miocene and is therefore genetically unrelated. It differs from *Globig-*

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* This study was supported by a grant from the National Science Foundation (GP 2530).

erina d'Orbigny (1826, p. 277, model no. 76) in having a pitted mostly non-spinose wall structure.

DISCUSSION

Related or synonymous forms now assigned to *Neogloboquadrina* include "*Globigerina*" *eggeri* Rhumbler (1901) and "*Globigerina*" *subcretacea* Lomnicki (1901). Parker has shown convincing evidence (1962) of gradations between these species and she has placed them together in synonymy with "*Globoquadrina*" *dutertrei* (d'Orbigny, 1839). Other authors (Bandy, in press, *a*; Ingle, 1966a) in the past have preferred to refer to these forms as separate species because most of the members of any given population can often be assigned to one of these variants.

The original specimens of "*Globigerina*" *dutertrei* were from Cuba, Martinique and Guadalupe; the lectotype of Banner and Blow (1960) compares favorably with specimens in sand samples from the Gulf of Batabano (Bandy, 1964b), Cuba. Young or small Cuban specimens of *"G." dutertrei* compare rather well with the original illustration of d'Orbigny; larger forms of the species assume more chambers per whorl and have a larger and deeper umbilicus. About 99% of these specimens have toothlike umbilical flaps, or an indication of them on one or more chambers; this is essentially true of most other tropical populations. It is the opinion of the authors that Parker's conclusions are fully justified and that the various forms are no more than subspecies, if that, based upon the usual taxonomic principles.

Bradshaw (1959) considered the higher spired *eggeri* type to be most characteristic of a warm water fauna and the juvenile type, with smaller low spired tests, characteristic of the cool water environment. However, both small and large forms occur in both cool and warm water areas in bottom sediments and both high and low spired forms occur in tropical collections of this study. Further, those with umbilical flaps (typical *dutertrei*) show both high and low spired variants and from about 5 to about 7 chambers in the final whorl; those with no umbilical flaps show similar kinds of variations.

Tropical specimens referred to the subspecies *dutertrei* have about 10% more pores per unit area than those from cool waters, a relationship reported by Wiles (1965) for this same group under the name *eggeri* in his study of glacial and interglacial sections of deep-sea cores. In addition, the cool water subspecies *subcretacea* has a thicker wall associated with the decrease in pore concentration.

ORIGIN OF *NEOGLOBOQUADRINA*

In the later Miocene beds of Mallorca, Colom (1954) found populations of planktonic foraminifera which included a new species, "*Globigerina*" *globorotaloidea* Colom. In 1959, Blow described a new species of *Globorotalia* (*G. acostaensis* Blow) from the uppermost Miocene of Venezuela. Dr. G. Colom has kindly sent topotype specimens of "*Globigerina*" *globorotaloidea* to the senior author and comparisons of these with the specimens of *Globorotalia acostaensis* indicate that they are the same species. Parker (1964) noted the marked similarity of "*Globoquadrina*" *dutertrei*, *Globorotalia acostaensis,* and *Globorotalia globorotaloidea. Neogloboquadrina dutertrei* (d'Orbigny) may be separated from *Globorotalia globorotaloidea* by the enlargement of the umbilicus in the later Miocene and Pliocene (Plate 14, figs. 1-2).

The umbilical-extraumbilical apertural character and the wall structure suggest the genus *Globorotalia* could be used for *acostaensis*, *globorotaloidea*, and *dutertrei*. The latter (*dutertrei*) has been placed in *Globigerina* usually, in *Globoquadrina* (Parker, 1962, 1964; Ujiié, 1963; Ujiié and Kagawa, 1963), and in *Globorotalia* (Bolli, 1964; Reiss and Gvirtzman, 1964; Bolli and Bermudez, 1965; Bolli, 1966a, 1966b). Within the Miocene, there do appear to be gradational forms between these indicating a genetic relationship.

The highly variable character of the group in the later Miocene is well demonstrated in the detailed study of the Tortonian by Cita, Premoli Silva, and Rossi (1965). The forms illustrated there as "*Globigerina*" *globorotaloidea* Colom compare favorably with topotypes; and it should be noted that there is a suggestion of a lip along the base of the aperture in topotypes of the species and in the original illustrations by Colom (1954).

DEVELOPMENT AND GEOLOGIC SIGNIFICANCE OF *NEOGLOBOQUADRINA*

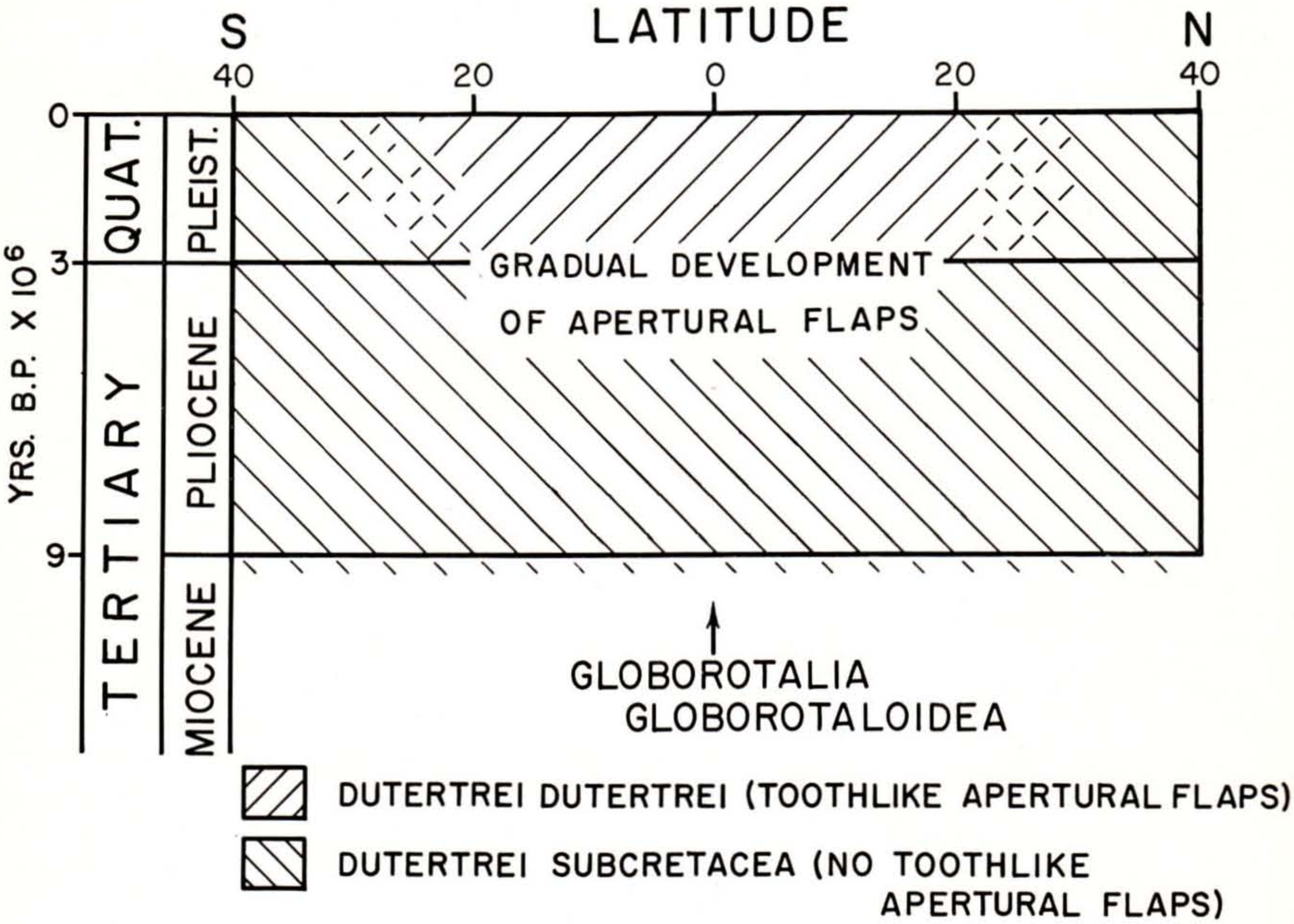
Expansion of the umbilicus was the initial stage of development of *N. dutertrei* (d'Orbigny) from *Globorotalia globorotaloidea* (Colom). This feature is shown by comparing the original illustrations of Colom (1954) with the lectotype of *Neogloboquadrina dutertrei* figured by Banner and Blow (1960). A topotype of *G. globorotaloidea* is illustrated on plate 14, fig. 1; a specimen of *N. dutertrei,* illustrated on plate 14, fig. 2, is from the Lower Pliocene of Panay (Bandy, 1962, 1963a, 1963b). In neither the ancestral form nor in the early representatives of *N. dutertrei* is there a suggestion of dental-like umbilical flaps.

It is suggested that "*Globigerina*" *subcretacea* Lomnicki be retained as a subspecies of *N. dutertrei* (d'Orbigny) for those populations which essentially lack apertural or umbilical flaps. Lomnicki (1901) studied specimens from the Upper Miocene of Wieliczka, Poland; these were in large part the basis for his species *subcretacea.* There is no indication of flaps in these upper Miocene forms. He included as a synonym the Recent form illustrated as "*Globigerina cretacea*" by Brady (1884); however, Brady's specimens were from off the Ki Islands and Parker has shown (1962) that populations from this locality are characterized by umbilical flaps. These with flaps are referred to *Neogloboquadrina dutertrei* subspecies *dutertrei.*

It is interesting to note that specimens of "*Globigerina eggeri*" from the type locality (Recent) appear to have umbilical flaps (Parker, 1962) in some cases and not in others. The location, near Juan Fernandez Island, far off the coast of Chile (33°42′S, 78°18′W), is near or in the transition area between the tropical populations of *dutertrei* (with umbilical flaps) on the north and those with no umbilical flaps on the south. Cruise 17 of the R/V ANTON BRUUN made a north-south transect to a point just south of Juan Fernandez in 1966. Collections obtained along this profile corroborate this transition from the tropical to temperate forms of *N. dutertrei.* Most of these forms near Juan Fernandez have a rather flat dorsal spire like the form of *subcretacea.* Most populations of the later Miocene-Pliocene interval noted have this form and usually about 5 chambers in the final whorl, like Lomnicki's species, justifying their retention as *Neogloboquadrina dutertrei* (d'Orbigny) subspecies *subcretacea* (Lomnicki).

Geologically, *Neogloboquadrina dutertrei* s. l. lacks toothlike apertural flaps in the later Miocene, during most of the Pliocene, and then the tropical populations began developing umbilical flaps toward the end of the Pliocene (text fig. 1). No flaps were noted in a re-examination of Pliocene specimens (Plate 14, fig. 2) of the Philippine samples studied earlier (Bandy, 1963a), none is present in the Pliocene populations of the Los Angeles Basin, none is noted in the Pliocene of Italy (Wezel, 1964), and they are not shown in the Pliocene form from the Mohole (Parker, 1964) or in sample fractions examined by the author from the Mohole.

Development of toothlike umbilical flaps in *N. dutertrei* is recorded in the Lower Pleistocene core segments of the tropical Atlantic (Plate 14, fig. 3),



TEXT FIGURE 1

Origin and development of *Neogloboquadrina dutertrei* (d'Orbigny) subspecies *subcretacea* (Lomnicki) without umbilical flaps in the later Miocene from *Globorotalia globorotaloidea* (Colom) and of the development of *Neogloboquadrina dutertrei* subspecies *dutertrei* with umbilical flaps in the later Pliocene of tropical areas. Radiometric age for the Quaternary is based upon the work of Obradovich (1965); the 9-million-year date for the Miocene-Pliocene boundary is based upon K-A dates (Yeats, 1965; Bandy, Ingle, and Frerichs, in press). One of these dates (9.9 million years) is from near the top of the Miocene at Malaga Cove, southern California (Geochron RO536), just below the SPHAEROIDINELLA DEHISCENS DATUM there (Bandy, in press, *b*; Ingle, 1966b).

in Pleistocene populations from the Naganuma Formation of Japan (Ujiié and Kagawa, 1963, pl. 46, fig. 9c), and in Pleistocene and Recent samples from many parts of tropical areas. Modern forms from Cuba, Panama, the Andaman Sea, and three from the Mozambique Channel (Plate 14, figs. 6-12) illustrate some of the variation in the development of umbilical flaps in these tropical forms referred to as *Neogloboquadrina dutertrei* subspecies *dutertrei*. Populations from these areas and from other tropical areas of the Atlantic and Pacific have umbilical toothlike flaps in more than 90 percent of the cases examined. From 50 to 100 specimens were examined in many samples and it is often difficult to find any tropical specimens with a complete lack of umbilical flaps on at least one of the chambers of the final whorl. The flaps do not appear fully developed on all of the chambers of the final whorl. In many tropical specimens there are well-developed flaps on the last two or three chambers of the final whorl; other specimens lack flaps on the final chamber or two, having one small toothlike flap on the antepenultimate chamber. It is necessary to examine carefully the umbilical margins of the last four chambers to determine the presence or absence of these toothlike features.

There are essentially no toothlike flaps in populations of *Neogloboquadrina dutertrei* subspecies *subcretacea* from the later Miocene of southern California, from the Pliocene of California, from the Pleistocene of California, or from the Recent core segments from the offshore basins studied recently (Bandy, in press, *a*). A specimen from the area of the cold Peru Current (Plate 14, fig. 4) in the southern hemisphere and one from the northern hemisphere in the area off southern California (Plate 14, fig. 5) are representative of these populations which have no umbilical toothlike flaps. Counts of 100 specimens show only one or two percent of specimens with faint indications of small flaps. A number of samples were examined from the collections of the USNS ELTANIN between 33 and about 45 degrees south latitude; 90 to 100% of the specimens of *Neogloboquadrina dutertrei* are without umbilical flaps, especially in the Peru Current. In the northern Pacific, the transition from tropical forms (with umbilical flaps) to temperate forms (without flaps) is off Baja California.

Regarding coiling characteristics, essentially all Pliocene and Quaternary populations of *Neogloboquadrina dutertrei* are dextrally coiled whether they are with or without umbilical flaps. Less than one percent are sinistrally coiled. However, sinistral populations occur in the later Miocene of southern California (Ingle, 1966b) and in the very basal Pliocene and upper Miocene of Venezuela (Bolli, 1964).

SUMMARY AND CONCLUSIONS

Globorotalia globorotaloidea (Colom) gave rise to *Neogloboquadrina dutertrei* (d'Orbigny) subspecies *subcretacea* (Lomnicki) in the later Miocene. This transition involved primarily the expansion of the umbilicus and the change from an extraumbilical aperture to one that is more umbilical in position. Forms figured as *dutertrei* from Early and Middle Miocene beds belong to other globorotaloids.

Near the end of the Pliocene, toothlike umbilical flaps began to appear in tropical populations but not in the cool temperate areas. This evolutionary dichotomy provides a valuable stratigraphic level, and the two populations now serve to identify different water masses. Development of umbilical flaps in *Neogloboquadrina* has produced an isomorph of the Eocene-to-Recent genus *Globoquadrina*; the two genera have different origins and exemplify evolutionary convergence.

A bioseries showing the development of umbilical flaps in tropical populations of *Neogloboquadrina dutertrei* in later Pliocene time is the basis for a datum; however, pseudobioseries may be demonstrated today from cool temperate areas toward the tropics. Further, at any time after the initial development of umbilical flaps in tropical areas, expansions of tropical conditions during interglacial times of the Quaternary could easily result in the superposition of tropical populations above cool-water populations, thus providing another type of pseudobioseries in these expanded geographic zones. Failure to recognize and distinguish between true and false cases of bioseries may contribute to serious errors in correlation.

It was noted by Wiles (1965) that there was a high pore concentration in "*Globigerina eggeri*" during interglacial ages and a low pore concentration in specimens of this species for the glacial ages. Similarly, *N. dutertrei dutertrei* has more than 10% more pores per unit area than most specimens of *N. dutertrei subcretacea*. The decrease in pore concentrations is usually associated with a thickening of the wall itself. Thus, temperature increase is correlated with the development of umbilical toothlike flaps, an increase in pore concentrations, and a thinning of the wall. Conversely, temperature decrease is correlated with a reduction in umbilical flaps, a decrease in pore concentrations, and an increase in the thickness of the wall. These criteria should be helpful in paleoclimatic analyses of Quaternary deep-sea cores.

Radiometric data (Bandy, in press, *b*) suggest that well-developed forms of *Neogloboquadrina* appeared somewhat over 9 million years ago, below the SPHAEROIDINELLA DEHISCENS DATUM (Bandy, 1963b, 1964a); tropical populations began developing umbilical flaps about 3 or 4 million years ago and are now characterized by these toothlike structures.

Phylogenetic evaluations of many foraminiferal stocks are needed to detect other cases of isomorphism.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XVIII, PART 4, OCTOBER 1967

338. NEW SPECIES OF UPPER CRETACEOUS FORAMINIFERA FROM THE LOWER ARIYALUR STAGE OF VRIDHACHALAM AND PONDICHERRY, INDIA

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ABSTRACT

The strata of the Lower Ariyalur Stage (Upper Cretaceous) of Vridhachalam and Pondicherry have yielded a rich assemblage of smaller Foraminifera. The present paper deals with the description and illustration of seven new benthonic species (arenaceous and calcareous types) recorded from this stage. These are: **Textularia ariyalurensis**, **Anomalina madraszi**, **Anomalina submadraszi**, **Anomalina vridhachalensis**, **Cibicides blanfordi**, **Cibicides purobi** and **Heterolepa pondi**. Their size variation in different biostratigraphic zones is also noted.

INTRODUCTION

The study of the Upper Cretaceous Foraminifera from the Lower Ariyalur Stage (?Upper Turonian-Coniacian to Lower Maestrichtian) of Vridhachalam and Pondicherry has largely been neglected in the recent literature. The author in 1960 undertook the detailed study of Foraminifera from this stage for the biostratigraphic interpretations of the Cretaceous deposits of Vridhachalam and adjoining areas of Pondicherry. Based on the vertical distribution of the planktonic and benthonic forms of Foraminifera, the Lower Ariyalur Stage, which was earlier described as a single uniform formation, is subdivided into five biostratigraphic Zones and two sub-Zones (Banerji, 1964, 1965). These zones and their geologic ages are:

E. *Globotruncana linneiana tricarinata* Zone
  (Upper Campanian to Lower Maestrichtian)
D. *Globotruncana globigerinoides* Zone
  Globotruncana ventricosa sub-Zone
    (Upper Campanian)
  Globotruncana marginata sub-Zone
    (Lower Campanian)
C. *Globotruncana concavata* Zone (Santonian)
B. *Globotruncana linneiana coronata* Zone
  (Coniacian)
A. Unfossiliferous Sandstone Zone
  (?Upper Turonian to Lower Coniacian)

Other biostratigraphic details have been published elsewhere (1966a, b).

This work was undertaken primarily for the purpose of contributing to the knowledge of the occurrence and distribution of the Upper Cretaceous Foraminifera in these areas. The study reveals the presence of a rich microfauna, consisting predominantly of smaller Foraminifera. Most of these forms were previously reported from the various Upper Cretaceous formations of North America, Trinidad, Europe, Middle East, Australia, and Tiruchirapalli district of India, but these are, by and large, new to these two areas under study. The present paper deals only with the systematic description and illustration of the following seven new benthonic species recorded from the Lower Ariyalur Stage of Vridhachalam and Pondicherry areas:

Textularia ariyalurensis
Anomalina madraszi
Anomalina submadraszi
Anomalina vridhachalensis
Cibicides blanfordi
Cibicides purobi
Heterolepa pondi

The genus *Heterolepa* is recorded for the first time from this part of the subcontinent and is represented by *Heterolepa pondi*, n. sp. One new planktonic species recorded from these areas, *Globotruncana vridhachalensis* Banerji, is described elsewhere along with another *Globotruncana* fauna (Banerji, 1966a).

SAMPLE LOCALITIES

The rock samples were collected by the author during the field seasons of 1960-61 and 1961-62 from an aggregate area covering approximately 130 sq. kms. north of Vridhachalam (11°31′ : 79°19′20″) and northwest of Pondicherry (11°56′ : 79°50′). In the Vridhachalam area, the Lower Ariyalur Stage, consisting of fossiliferous, hard, greyish to yellowish-brown arenaceous limestone, calcareous sandstone and sandy shale, lies unconformably over the Archaean gneisses and granitic gneisses, etc. It is, in turn, overlain by fine- to medium-grained white sandstone, sandy clay and calcareous nodules, without any megafossil, this constituting the Upper Ariyalur Stage (Middle to Upper Maestrichtian). In Pondicherry, the Lower Ariyalur Stage appears to be directly overlain by the Cuddalore Sandstone of Upper Miocene-?Pliocene age.

The rock samples which have yielded the Foraminifera and to which reference is made in this report have been collected from the following localities:

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A. Vridhachalam area
(11°31′N : 79°15′E and 11°46′N : 79°25′E)

Patti	(11°33′20″N : 79°15′30″E)
Adikaripatti	(11°30′00″N : 79°15′50″E)
Reddikuppam	(11°28′00″N : 79°16′30″E)
Killanur	(11°39′30″N : 79°18′40″E)
Chendamangalam	(11°44′30″N : 79°20′00″E)

B. Pondicherry Area
(11°55′N : 79°40′E and 12°05′N : 79°50′E)

Tutipet	(11°58′45″N : 79°43′30″E)
Karasur	(11°59′00″N : 79°44′30″E)
Royapudupakam	(12°02′00″N : 79°48′25″E)

ACKNOWLEDGMENTS

The author is indebted to Dr. T. C. Bagchi, Professor of Geology, Indian Institute of Technology, Kharagpur, for providing all facilities for the present study, guidance, and for reviewing the manuscript. Sincere thanks are due to Dr. Barun K. Sen Gupta for many critical suggestions and for checking the systematic position of some of the forms recorded from this stage. A research scholarship, other field grants and laboratory facilities provided by the authorities of the Institute are duly acknowledged.

SYSTEMATIC DESCRIPTIONS

The systematic classification of Foraminifera as adopted in this report is after Loeblich and Tappan (1964).

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Hérouard, 1896
Superfamily LITUOLACEA de Blainville, 1825
Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus **Textularia** Defrance, 1824
Genotype: *Textularia sagittula* Defrance, 1824, p. 177

Textularia ariyalurensis Banerji, n. sp.
Plate 15, figures 1, 2

Shape of the test.—Free, biserial, slightly longer than broad, compressed, initial end much compressed, later increasing rapidly in breadth at the apertural end, apertural face flattened, edge subacute, periphery subacute and slightly lobulate; chambers rather indistinct at the initial end, distinct in later parts, rapidly increasing in breadth rather than height towards the apertural end; sutures indistinct in early parts, distinct, depressed and straight in later parts; wall finely arenaceous to little agglutinated; aperture an elongate crescent-shaped opening at the middle of the inner margin of the last chamber, without any lip.

Dimensions.—The holotype measures 0.58 mm. in length, 0.18 mm. in thickness and 0.46 in width. Specimens from—

(a) *Globotruncana linneiana coronata* Zone measure: length from 0.54 mm. to 0.58 mm.; thickness from 0.16 mm. to 0.18 mm.; width from 0.44 mm. to 0.46 mm.; average length/thickness ratio: 3.29; average length/width ratio: 1.24.

(b) *Globotruncana concavata* Zone measure: length from 0.56 mm. to 0.62 mm.; thickness from 0.18 to 0.20 mm.; width from 0.48 mm. to 0.50 mm.; average length/thickness ratio: 3.10; length/width ratio: 1.20.

(c) *Globotruncana marginata* sub-Zone measure: length from 0.50 mm. to 0.54 mm.; thickness from 0.16 mm. to 0.18 mm.; width from 0.46 mm. to 0.48 mm.; average length/thickness ratio: 3.06; average length/width ratio: 1.10.

Remarks.—This species is characterized by the broad compressed test that increases rapidly in width with a corresponding increase in width of the chambers but with very little change in their height, flattened apertural face, depressed sutures and crescent-shaped aperture without any lip.

This species seems to be restricted to the Coniacian (*Globotruncana linneiana coronata* Zone), Santonian (*Globotruncana concavata* Zone) and Lower Campanian (*Globotruncana marginata* sub-Zone) of Vridhachalam. The forms of Santonian age are larger, those of Coniacian are more elongated in comparison to their width and thickness, as is evident from the form ratios. This species becomes more compressed and stout during the Lower Campanian times. The name of the species is after the town Ariyalur (Tiruchirapalli district), the type area for the Ariyalur Formation in India.

Occurrence.—The holotype (VFN 1/12/28) is from the *Globotruncana marginata* sub-Zone, exposed near (south of) the village of Patti, Vridhachalam. Other recorded specimens are from the *Globotruncana linneiana coronata* Zone and *Globotruncana concavata* Zone of Vridhachalam (locality-Chendamangalam). Not found at Pondicherry.

Suborder ROTALIINA Delage and Hérouard, 1896
Superfamily CASSIDULINACEA d'Orbigny, 1839
Family ANOMALINIDAE Cushman, 1927
Subfamily ANOMALININAE Cushman, 1927
Genus **Anomalina** d'Orbigny, 1826
Genotype: *Anomalina punctulata* d'Orbigny, 1826, p. 282

Anomalina madraszi Banerji, n. sp.
Plate 15, figures 3, 4, 5

Shape of the test.—Free, globular in outline, biconvex, planispiral in adult, depressed at center on both sides, periphery lobulate, edges smooth and rounded, only two whorls visible on the spiral side; chambers distinct, subspherical, last one more or less globular in shape, 7 to 9 in the last whorl, increasing fairly rapidly and uniformly in size as added, chambers of earlier whorl indistinct; sutures distinct in the last whorl, almost straight and depressed on the spiral side, little curved and tangential towards the periphery on the umbilical side, flush and indistinct in the early portion of the test; wall finely punctuate and granular in microstructure; aperture a very low arched slit with a distinct lip, at the base of the last chamber, extending about half the distance to the umbilicus on the umbilical side.

Dimensions.—The holotype measures 0.54 mm. in diameter and 0.36 in thickness.

Other specimens from—

(a) *Globotruncana ventricosa* sub-Zone measure: diameter from 0.50 mm. to 0.56 mm.; thickness from 0.36 mm. to 0.39 mm.; average diameter/thickness ratio 1.50.

(b) *Globotruncana linneiana tricarinata* Zone measure: diameter from 0.54 mm. to 0.62 mm.; thickness from 0.34 mm. to 0.37 mm.; with average diameter/thickness ratio: 1.68.

Remarks.—Diagnostic features of this species are the large test with semiglobular outline, subspherical chambers, slightly curved sutures and characteristic low arched slit as aperture, with a lip extending half the distance to the umbilicus. It is interesting to note that forms observed from the *Globotruncana linneiana tricarinata* Zone are more compressed than those of the *Globotruncana ventricosa* sub-Zone, as evident from the comparison of their average diameter/thickness ratios. The name of this species is from Madras State in India, the area of study.

Occurrence.—The holotype (VFN 1/17/83) is from the *Globotruncana linneiana tricarinata* Zone exposed half a kilometer south of village Patti. Other types are from the *Globotruncana ventricosa* sub-Zone of the Vridhachalam and Pondicherry areas; it appears to be restricted to Campanian horizons.

Anomalina submadraszi Banerji, n. sp.

Plate 15, figures 6, 7, 8

Shape of the test.—Free, trochospiral, unequally biconvex, umbilical side more convex, depressed at the center on the spiral side, periphery highly lobulate, globular in outline, edges rounded, only two whorls are seen on the spiral side, completely to semi-involute on the umbilical side, with a slightly raised umbilical boss surrounded by groove; chambers distinct, 9 in the last whorl, subspherical to globular in shape, increasing uniformly in size as added; sutures distinct in the last whorl, slightly curved and depressed on the umbilical side, almost straight and relatively flush to very little depressed on the spiral side, sutures of earlier chambers not distinct and flush with the surface; wall calcareous, coarsely perforate and granular; aperture a low, arched interiomarginal opening without a lip, extending very little towards the umbilicus.

Dimensions.—The holotype measures 0.56 mm. in diameter and 0.36 mm. in thickness.

Other paratypes and hypotypes range from 0.52 mm. to 0.68 mm. in diameter and 0.36 mm. to 0.46 mm. in thickness; average diameter/thickness ratio: 1.48.

Remarks.—This species is distinguished from *Anomalina madraszi* Banerji, in having a more globular, less compressed, semi-involute test, periphery highly lobulate, straight sutures on the spiral side and distinctly more coarsely perforate wall. The aperture is characterized by a low opening, without any lip, at the base of the last chamber, embracing the periphery and extending only slightly onto the umbilical side.

Occurrence.—Holotype (PFN 5/27/84) is from the *Globotruncana linneiana tricarinata* Zone as exposed in a dry well near (south of) the village of Royapudupakam in the Pondicherry area. Other specimens are from the same zone exposed in various wells at Killanur and Adikaripatti in the Vridhachalam area; some doubtful specimens are recorded from near (north of) the village of Karasur in the Pondicherry area.

Anomalina vridhachalensis Banerji, n. sp.

Plate 15, figures 9, 10, 15

Shape of the test.—Free, moderately large in size, almost equally biconvex, highly compressed, partially evolute, depressed at the umbilicus on both sides, edges acute to subacute, with a little sharp serrate margin formed as a result of the overlapping of chambers at the periphery, only two whorls visible; chambers of earlier whorl not very distinct, 8 to 10 in the last whorl, slightly inflated, increasing gradually but uniformly in size as added; sutures flush and relatively indistinct in the early portion, distinct, depressed and smoothly curved in the last whorl on both sides; wall granular and very finely perforated; aperture interiomarginal, an arched opening with a distinct lip at the base of the last chamber, extending onto the umbilical side.

Dimensions.—The holotype measures 0.56 mm. in diameter and 0.20 mm. in thickness.

Other specimens measure in diameter from 0.50 mm. to 0.64 mm., in thickness from 0.18 mm. to 0.25 mm.; average diameter/thickness ratio: 2.60.

Remarks.—This species is distinguished from all other forms in having a highly compressed, biconvex, semi-involute test with acute to subacute, slightly serrate margin, smoothly curved depressed sutures in adult and an interiomarginal *Anomalina* type of aperture with a distinct lip.

Occurrence.—The holotype (VFN 5/47/87) is from the *Globotruncana concavata* Zone, exposed north of the village of Chendamangalam. Other types are described from the same Zone, exposed near the village of Patti. This species seems to be restricted to beds of Santonian age in Vridhachalam. No record was obtained from the Pondicherry area except for a few broken and doubtful specimens, hence this species is named after Vridhachalam.

Genus **Heterolepa** Franzenau, 1884
Genotype: *Heterolepa simplex* Franzenau, 1884, p. 214
Heterolepa pondi Banerji, n. sp.
Plate 15, figures 14, 19, 20

Shape of the test.—Free, trochospiral, rather circular in outline, unequally biconvex to planoconvex, spiral side very little convex, evolute, composed of two and a half distinct, slowly enlarging whorls with the central portions slightly raised, umbilical side highly convex, pyramidal, involute, with a central umbo surrounded by a deep groove, periphery subacute with a fine distinct nonperforate keel; chambers distinct, numerous, 10 in the last whorl, increasing very gradually but uniformly in size as added, last chamber highly projecting on the umbilical side; sutures flush, limbate and rather indistinct in the early parts, depressed, distinct and slightly curved in the later parts of the spiral side and appear to be double in structure, radial, distinct, depressed and almost straight on the umbilical side; wall smooth, finely perforate, granular in microstructure; aperture interiomarginal, a low arched slit at the base of the last chamber, extending farther on the umbilical side and for some distance along the spiral side.

Dimensions.—The holotype measures 0.58 mm. in diameter and 0.32 mm. in thickness. Other types range up to 0.62 mm. in diameter, to 0.34 mm. in thickness; average diameter/thickness ratio: 1.90.

Remarks.—This species is characterized by its unequally biconvex, trochospiral test with a distinct nonperforate keel at the periphery, evolute spiral side with relatively numerous chambers, and involute umbilical side with radial and straight sutures. The aperture is typical of *Heterolepa*, as described by Loeblich and Tappan (1962, p. 72). The species is named after the town of Pondicherry from where the holotype is described.

Occurrence.—The holotype (PFN 3/16/87) is from the *Globotruncana concavata* Zone of Pondicherry, exposed near (west of) the village of Tutipet. In Vridhachalam, it appears to be common in the *Globotruncana linneiana coronata* Zone, *Globotruncana concavata* Zone and *Globotruncana linneiana tricarinata* Zone and rare in the *Globotruncana globigerinoides* Zone. This species appears to range from the Coniacian to Lower Maestrichtian in Vridhachalam (localities: Patti and Chendamangalam) and Pondicherry (localities: Tutipet and Karasur).

Superfamily ORBITOIDACEA Schwager, 1876
Family CIBICIDIDAE Cushman, 1927
Subfamily CIBICIDINAE Cushman, 1927
Genus **Cibicides** Montfort, 1808
Genotype: *Cibicides refulgens* De Montfort, 1808, p. 122
Cibicides blanfordi Banerji, n. sp.
Plate 15, figures 11, 12, 13

Shape of the test.—Free, trochospiral, circular and compressed, spiral side flattened to slightly convex, composed of three distinct whorls, slightly concave at the center, umbilical side involute, relatively more convex with a central low rounded umbilicus, periphery smooth and very little lobulate, edge rounded to subrounded; chambers distinct, 9 in the last whorl, inflated, increasing slowly in the early portion, relatively more rapidly in later portion of the last whorl; sutures distinct, smoothly curved and depressed on the spiral side, relatively less curved at the center and sweeping tangentially at the periphery on the umbilical side; wall perforate, radial in microstructure, aperture a restricted low interiomarginal opening with a distinct lip at the base of the last chamber, slightly extending across the periphery on the spiral side.

Dimensions.—The holotype measures 0.52 mm. in diameter and 0.22 mm. in thickness. Other specimens range from 0.50 mm. to 0.64 mm. in diameter and from 0.26 mm. to 0.30 mm. in thickness. The average diameter/thickness ratio of the forms recorded from the *Globotruncana marginata* sub-Zone is 2.08, those of the *Globotruncana ventricosa* sub-Zone 2.20, *i.e.*, the forms become more compressed in the latter sub-Zone. The variation in the diameter/thickness ratio (along with variations in the actual foraminiferal assemblage) may be helpful in establishing two sub-Zones within the *Globotruncana globigerinoides* Zone in the Vridhachalam and Pondicherry areas.

Remarks.—The distinguishing features of this new species are the compressed test with a low rounded umbilicus, curved and depressed sutures in the adult portion, and a small, restricted, typical *Cibicides* aperture that extends slightly onto the spiral side. The sutures on the umbilical side near the periphery are very characteristic of this species. The name of this species is in honor of the late H. F. Blanford of Geological Survey of India as a tribute to his outstanding work (1858-65) on the Upper Cretaceous rocks of southern India.

Occurrence.—The holotype (VFN 1/16/85) is from the uppermost part of the *Globotruncana ventricosa* sub-Zone, exposed near (south of) the village of Patti. This species is mostly recorded from the *Globotruncana globigerinoides* Zone of the Vridhachalam and Pondicherry areas, but a very few specimens were recovered from the *Globotruncana concavata* and *Globotruncana linneiana tricarinata* Zones of these areas. Important localities for this species are Patti and Chendamangalam in the Vridhachalam and Karasur in the Pondicherry area.

Cibicides purobi Banerji, n. sp.

Plate 15, figures 16, 17, 18

Cf. *Rosalina ammonoides* REUSS, 1884, Geog. Skizzen Böhm., vol. 2, p. 214.

Cf. *Cibicides ammonoides* (Reuss) TRUJILLO, 1960, Jour. Paleontology, vol. 34, p. 335, pl. 48, figs. 8a-c.

Shape of the test.—Free, trochospiral, slightly oblong in shape, compressed near the periphery, almost planoconvex, spiral side flat to very little convex, composed of three distinct whorls, umbilical side more convex, with a very low umbonal boss, periphery smooth in the early parts and slightly lobulate in the later parts of the test, edge smooth and rounded; chambers distinct, 10 in the last whorl, inflated, increasing gradually but uniformly in size as added, last-formed chamber distinctly lobulate; sutures flush and limbate in the early portion of the test, distinct, depressed and curved in the later portion, distinct, relatively less depressed and less curved on the umbilical side; wall coarsely perforate, radial in microstructure; aperture a low opening at the base of the last formed chamber, extending for some distance on the spiral side.

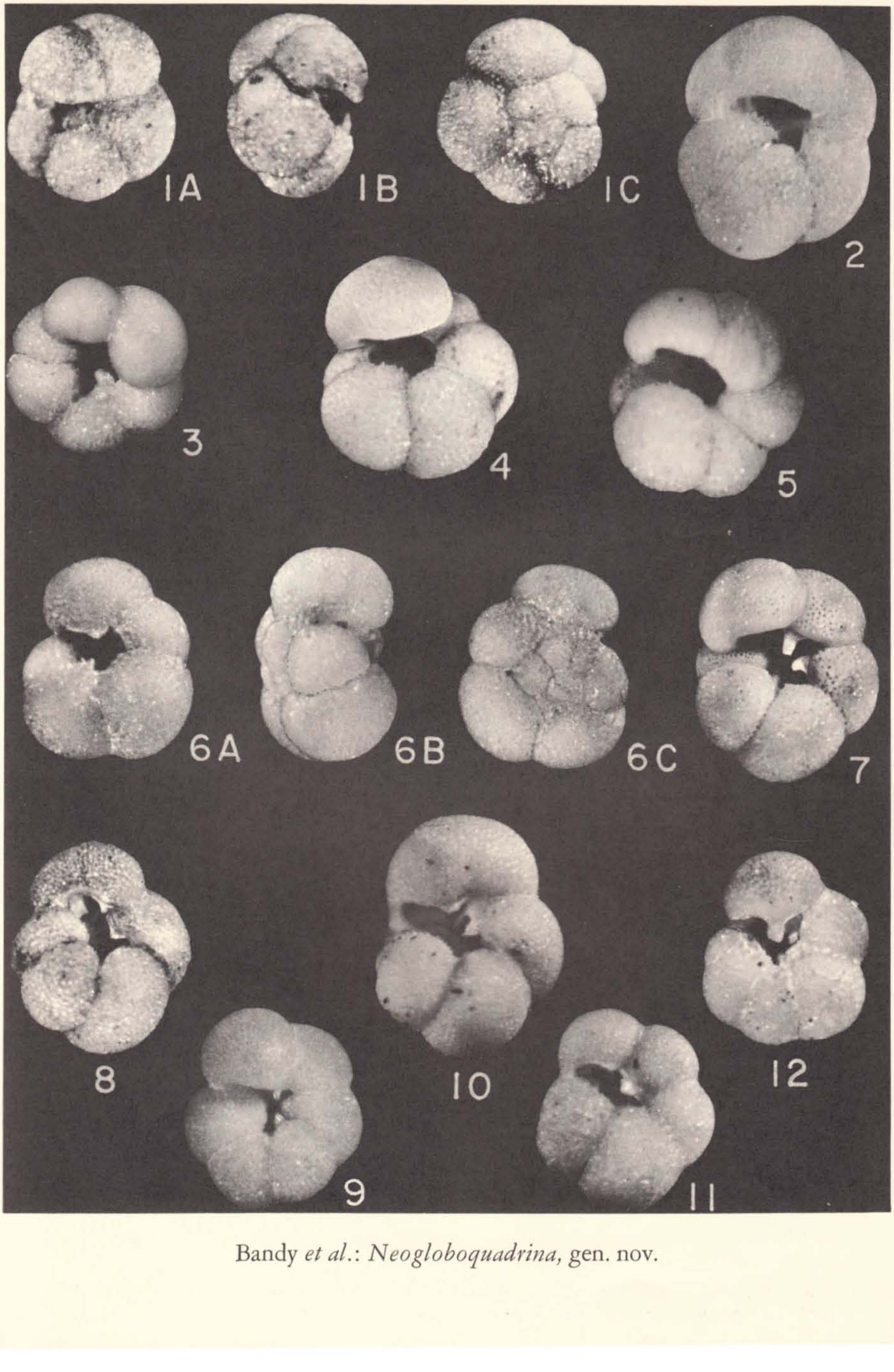
Dimensions.—The holotype measures 0.45 mm. in diameter and 0.24 mm. in thickness. Other studied specimens range up to 0.65 mm. in diameter and 0.37 mm. in thickness; average diameter/thickness ratio: 1.86.

Remarks.—This species is characterized by a compressed planoconvex test with the last chamber distinctly lobulate, a low umbonal mass on the umbilical side and characteristic interiomarginal *Cib-*

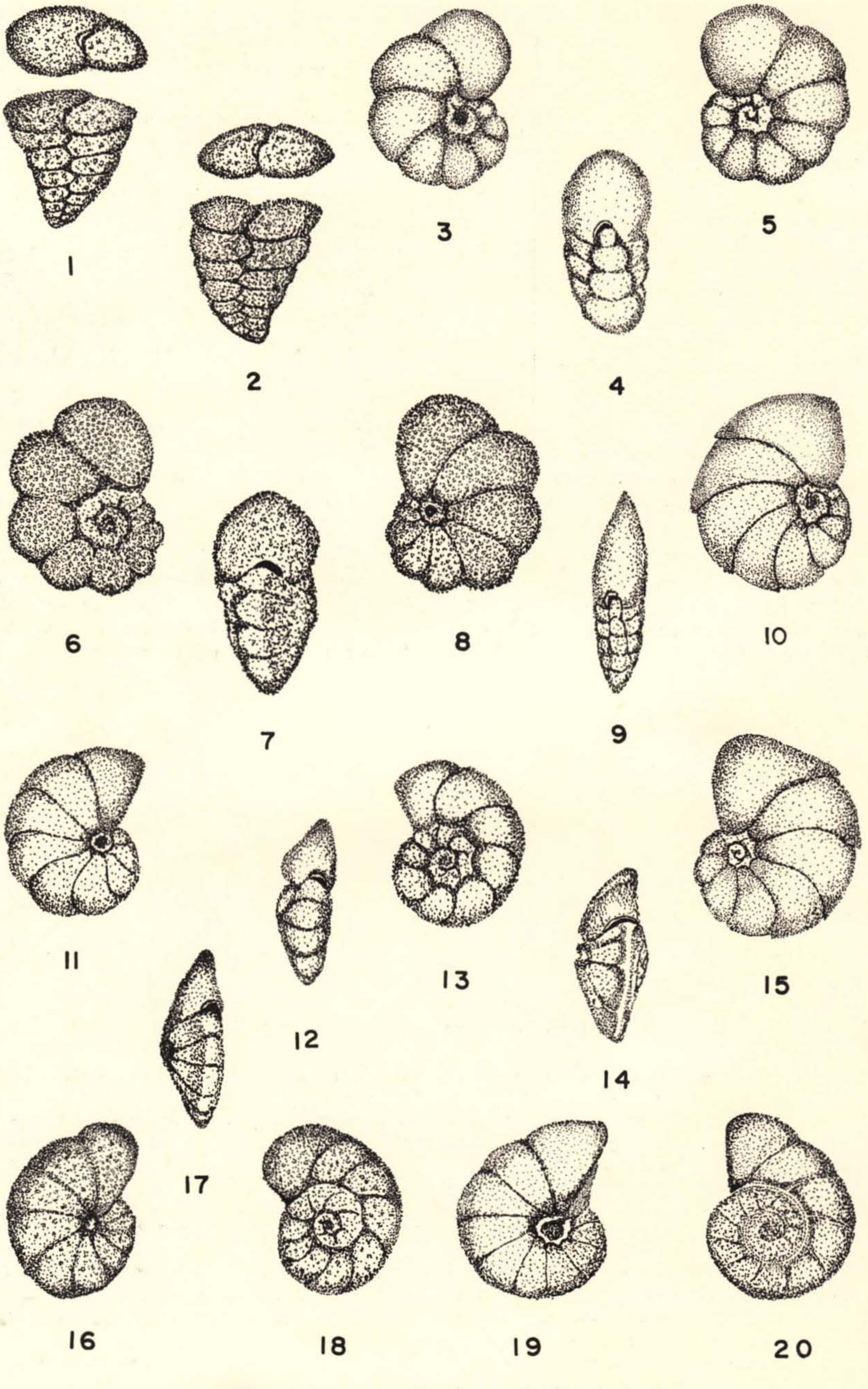
EXPLANATION OF PLATE 14

FIGS. PAGE

1. *Globorotalia globorotaloidea* (Colom), × 68. 1A, Ventral view; 1B, edge view; 1C, dorsal view. This is a topotype submitted by Dr. Colom from the Upper Miocene of Mallorca. 152
2. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *subcretacea* (Lomnicki), × 60. Ventral view. Specimen from the Lower Pliocene of Panay, Philippines, sample 3-1443 (Bandy, 1963a, 1963b). Note the absence of apertural or umbilical flaps. 152
3. *Neogloboquadrina dutertrei* (d'Orbigny) subsp *dutertrei* (d'Orbigny), × 44. Ventral view. Specimen from Lower Pleistocene of Vema core V 15-64 (134 cm.) in the Atlantic Ocean off Brazil (Ericson, Ewing, and Wollin, 1963). Umbilical flap present on third from the last chamber. 152
4. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *subcretacea* (Lomnicki) × 59. Ventral view. Recent specimen from a depth of 473 fathoms, USNS ELTANIN Petterson Grab 4-4 (32°48′S; 71°51′W). Note the lack of umbilical flaps on the chambers. 152
5. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *subcretacea* (Lomnicki), × 68. Ventral view. Recent specimen from off southern California, AHF Station 4674 (10-15″), depth of water 872 fathoms (32°16.5′N; 119°19.5′W). Note the lack of umbilical flaps. 152
6. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *dutertrei* (d'Orbigny), × 60. 6A, Ventral view; 6B, edge view; 6C, dorsal view. Recent specimen from core 12B off Cuba (Bandy, 1964b). Portions of umbilical toothlike flaps occur on the last chamber and on the fourth from the last chamber. 152
7. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *dutertrei* (d'Orbigny), × 51. Ventral view. Recent specimen from the Gulf of Panama, USNS ELTANIN Station 25 (4°51′N; 80°27′W). Note prominent umbilical flaps on last two chambers and weakly developed flaps on the earlier chambers. 152
8. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *dutertrei* (d'Orbigny), × 51. Ventral view. slightly oblique. Recent specimen from the Gulf of Panama (Bandy and Arnal, 1957, H 139). Note the small apertural toothlike flaps on the last two chambers. 152
9. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *dutertrei* (d'Orbigny), × 55. Ventral view. Recent specimen from the Andaman Sea (9°54′N; 94°55′E). Note the toothlike umbilical flaps on the last three chambers. 152
10. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *dutertrei* (d'Orbigny), × 76. Ventral view. Recent specimen from the southwestern Indian Ocean, R/V ANTON BRUUN Station 361J, Cruise 7, International Indian Ocean Expedition. Umbilical flaps occur on the last two chambers. 152
11. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *dutertrei* (d'Orbigny), × 68. Ventral view. Same station as figure 10. Note the umbilical flap on the next to the last chamber. 152
12. *Neogloboquadrina dutertrei* (d'Orbigny) subsp. *dutertrei* (d'Orbigny), × 76. Ventral view. Recent specimen from the southwestern Indian Ocean, R/V ANTON BRUUN Station 385B, Cruise 7, International Indian Ocean Expedition. Umbilical toothlike flap on the last chamber. 152



Bandy *et al.*: *Neogloboquadrina,* gen. nov.



Banerji: New species from Vridhachalam

icides type of aperture. This species is very similar to *Cibicides ammonoides* (Reuss) in shape, but differs essentially from the latter in the above mentioned characters and also in having a large number of chambers with a coarsely perforate wall in the last whorl.

Occurrence.—This species seems to be most abundantly distributed in all the zones and subzones of the Vridhachalam and Pondicherry areas. The holotype (VFN 1/19/86) is from the upper part of the *Globotruncana ventricosa* sub-Zone, exposed near (south of) the village of Patti. The geological range of this species appears to be from the Coniacian to Lower Maestrichtian in the Vridhachalam and Pondicherry areas of southern India.

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EXPLANATION OF PLATE 15

FIGS.		PAGE
1.	*Textularia ariyalurensis* Banerji, n. sp. Hypotype, side and apertural views, from *Globotruncana linneiana coronata* Zone, Chendamangalam, Vridhachalam. × 35.	159
2.	*Textularia ariyalurensis* Banerji, n. sp. Holotype, side and apertural views, from *Globotruncana marginata* sub-Zone, Patti, Vridhachalam. × 35.	159
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6, 7, 8.	*Anomalina submadraszi* Banerji, n. sp. Holotype. 6, spiral view. 7, edge view. 8, umbonal view; from *Globotruncana linneiana tricarinata* Zone, Royapudupakam, Pondicherry. × 40.	160
9, 10, 15.	*Anomalina vridhachalensis* Banerji, n. sp. Holotype. 9, edge view. 10, umbonal view. 15, spiral view; from *Globotruncana concavata* Zone, Chendamangalam. × 42.	160
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14, 19, 20.	*Heterolepa pondi* Banerji, n. sp. Holotype. 14, edge view. 19, umbonal view. 20, spiral view; from *Globotruncana concavata* Zone, Tutipet, Pondicherry. × 35.	161

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XVIII, PART 4, OCTOBER 1967

339. A REVISED CLASSIFICATION OF THE FAMILY DISCOCYCLINIDAE GALLOWAY

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ABSTRACT

Four genera—**Discocyclina**, **Asterocyclina**, **Pseudophragmina** and **Asterophragmina**—are recognised in the family Discocyclinidae Galloway. Subgeneric division of any of these genera is shown to be not practicable.

CLASSIFICATORY CONSIDERATIONS

The classification proposed here is a modified form of that presented by Cole in the *Treatise on Invertebrate Paleontology*. *Asterophragmina* Rao is raised to the generic rank on the postulation that the difference between *Pseudophragmina* and *Asterophragmina* is essentially the same as that between *Discocyclina* and *Asterocyclina*. Subgeneric division of any of the four genera recognized here—*Discocyclina*, *Asterocyclina*, *Pseudophragmina* and *Asterophragmina*—is found to be impracticable. Distinguishing features and distribution of the family Discocyclinidae and its four genera are presented below.

Order FORAMINIFERA

Family DISCOCYCLINIDAE Galloway, 1928

Type genus.—Discocyclina Gümbel, 1868.

The test is discoidal, lenticular, biconvex, thin or inflated, flat or curved. The outline is circular, polygonal or stellate in plan view. The chambers are arranged in an equatorial layer which may become multiple in parts of the shell. The equatorial layer is covered on both sides by layers of lateral chambers which vary in shape, size and arrangement.

The Discocyclinidae are dimorphic. In microspheric forms the small subcircular initial chamber is followed by a planispirally coiled nepionic stage. In some cases the nepiont consists of only a short spiral of arcuate chambers while in others these arcuate chambers are followed by a spiral of rows of tangentially elongate chambers with or without an enveloping tendency during growth.

The megalospheric embryonic apparatuses are bilocular, multilocular or multiple. The bilocular embryonic apparatus consists of a subcircular first chamber partly or completely embraced by a large second chamber. In case of multilocular embryonic apparatuses, the increase in number of the embryonic chambers arises by the subdivision of either the deuteroconch or the protoconch. The periembryonic equatorial chambers may or may not differ from the later formed equatorial chambers.

In the neanic stage of both the microspheric and the megalospheric forms the equatorial chambers are arranged in concentric annuli which are either circular or stellate in outline. The radial walls of the equatorial chambers may be complete, incomplete, absent or indistinct. When the radial chamber walls are well developed, the chambers in equatorial section may have rectangular, spatulate, or hexagonal shape, but usually the rectangular chamber form dominates. Pseudopillars, formed by thickening of the walls of the lateral chambers, as well as true pillars are present. Usually they project above the surface of the test as papillae or granules.

The chambers of the same annulus communicate by means of annular stolons which in pairs penetrate each radial chamber wall either proximally or distally, one below the roof and the other above the floor of the equatorial chamber. Each equatorial chamber is connected by radial stolons with adjacent chambers in the next inner and the next outer annulus. There are usually four such radial stolons in each equatorial chamber. Increase in number of radial stolons depends on the increase in the height of the chambers. Vertical stolons connect the equatorial chambers with the lateral chambers. There are radial, vertical and oblique stolons between the lateral chambers. The roofs and floors of both the equatorial and the lateral chambers are finely perforated. A canal system may or may not be present. There is no marginal cord.

Distribution.—The representatives of the family Discocyclinidae are known to occur in tropic and temperate regions throughout the world. They range in age from Middle Palaeocene (Danian is regarded as belonging to Lower Palaeocene) to Uppermost Eocene.

Remarks.—The origin of the Discocyclinidae is not known. The postulation of a Nummulitid ancestor based on the superficial resemblance with the heterosteginine group of forms is not supported by any known phyletic link. Workers, who do not accept the presence of canals in the representatives of this family, suggest the derivation of the Discocyclinidae from a non-canaliculate ancestor belonging to the Discorbidea.

Genus **Discocyclina** Gümbel, 1868

Type species.—*Orbitulites pratti* Michelin, 1846.

The outline of the test is circular or quadrate in plan view. The equatorial chambers are single-layered throughout the test. The radial chamber walls are well developed and those in adjacent annuli are either in alignment or alternate. The annular stolons are mostly situated at the proximal side of the chambers.

Distribution.—Discocyclina is the most widely distributed and best represented genus of the family. It ranges from Middle Palaeocene to Uppermost Eocene and occurs throughout the tropic and temperate regions of the world. In the region between southern Europe and India, the genus is represented by fewer species in the Palaeocene and Lower Eocene but becomes abundant in the Middle and Upper Eocene. In the Americas the genus ranges from Palaeocene to Middle Eocene. It occurs in Middle to Upper Eocene beds in the Indonesian region, while in the Central Pacific Islands it appears to be recorded only in Upper Eocene beds. In general, *Discocyclina* is better represented in the region between southern Europe and India than in the Americas.

Remarks.—The synonymy presented by Cole is accepted here. The subgeneric division into *Discocyclina* s.s. and *Aktinocyclina* has already been indicated as not tenable (Samanta, 1965a, b).

Comments will be made here regarding Brönnimann's (1946) attempt to retain *Orbitoclypeus* Silvestri as a valid genus. According to Brönnimann, the type species, *O. himerensis* Silvestri, is distinguished in having a circular protoconch completely surrounded by the larger deuteroconch and spatulate to more or less rectangular equatorial chambers in a centered horizontal section. It was further added that in thick horizontal section and in tangential section of the equatorial chamber layer the equatorial chambers are prominently hexagonal in form. However, in the discocyclinids both these features, namely, the character of the megalospheric embryonic apparatus and the shape of the equatorial chambers, are well-known to be too variable to be used in supraspecific classification. Accordingly, the morphological features of the megalospheric generation of Silvestri's form are not diagnostic enough to permit its separation from *Discocyclina*. Again, species of *Discocyclina* whose megalospheric forms are similar to *D. himerensis* are found to possess microspheric nepionts different from those of *D. himerensis*. Since in the discocyclinids the difference in the structure of the microspheric nepiont is not reflected in the morphology of the megalospheric generation, the use of the structure of the microspheric nepiont alone in supraspecific grouping is not practicable. It is important to point out here that in the representatives of the genus *Discocyclina* the structure of the microspheric nepionts is found to vary from the *D. papyracea* (Boubée) type to the *Asterocyclina stellaris* (Brunner) type.

Genus **Asterocyclina** Gümbel, 1868

Type species.—Calcarina (?) *stellata* d'Archiac, 1846.

In plan view, the test is circular, polygonal or stellate in outline. The rays are either prominent, extending from the centre to beyond the general periphery of the test, or faint to absent on the surface, but always distinct in equatorial sections, at least in its inner part. A multiplication of the equatorial chamber layer occurs along the rays. The radial chamber walls are well developed and alternate in adjacent annuli. The annular stolons are situated at the proximal side of the equatorial chambers.

Distribution.—Asterocyclina ranges from Middle Palaeocene to Upper Eocene. It is poorly represented in Palaeocene to Lower Eocene beds. Its occurrence in an horizon lower than Middle Eocene appears to be restricted to the region between the Mediterranean area and Western Pakistan. It is widely distributed in the Middle and Upper Eocene rocks of Europe, Africa, Middle East, Pakistan, India, East Indies and the Americas. In central Pacific Islands the genus is restricted to Upper Eocene. In number of species it is more abundantly represented in the Americas than in the region between southern Europe and India.

Remarks.—As the type of microspheric nepiont recorded in *Asterocyclina stellaris* (Brunner) occurs also in representatives of the genus *Discocyclina* (see Schweighauser, 1953; Cole, 1964), there is no need for the postulation that the two genera differ from each other in the general structure of the equatorial chamber layer; *i.e.*, they belong to two different suprageneric groups.

The microspheric nepionts of only a very few species of *Asterocyclina* are known. As in *Discocyclina*, the microspheric nepionts in representatives of the genus *Asterocyclina* are also likely to vary in structure; in some species it may be quite different from the *A. stellaris* (Brunner) type. To check this the microspheric form of a species of *Asterocyclina* such as *A. mariannensis* (Cushman), whose megalospheric form differs markedly from that of *A. stellaris* (Brunner), should be examined.

Genus **Pseudophragmina** Douvillé, 1923

Type species.—Orthophragmina floridana Cushman, 1917.

In plan view, the test is circular or quadrate in outline. The equatorial chambers are single-layered throughout the test. The radial walls of equatorial chambers may be complete, incomplete, absent or indistinct. The annular stolons are situated at the distal side of the chambers.

Distribution.—The genus occurs in the Palaeocene to Upper Eocene beds of the Americas. According to Cole (1950, p. 371), the Palaeocene determination is not absolutely established and may represent Lower Eocene. The occurrence of the genus in Upper Eocene beds of Western India was recently reported (Mohan, 1962), but this has not yet been supported by illustration or description.

Remarks.—*Asterophragmina* Rao, which is included under *Pseudophragmina* with doubt (Cole, 1964, p. c 715), is here raised to generic rank. As concerns the subgeneric division of *Pseudophragmina* into *Proporocyclina*, *Pseudophragmina* s.s., and *Athecocyclina*, it follows clearly from the statement made by Vaughan (1945, p. 68) that the degree of degeneration of the radial chamber walls cannot serve as a satisfactory basis for subgeneric separation. A complete intergradation between these three subgenera of *Pseudophragmina* indicates that this subgeneric division should not be retained.

Genus **Asterophragmina** Rao, 1942

Type species.—*Pseudophragmina* (*Asterophragmina*) *pagoda* Rao, 1942.

In plan view, the test is stellate in outline, with rays radiating from the centre to the periphery. The rays are distinct in equatorial sections and are regarded to be produced by the equatorial chambers, as in *Asterocyclina*. The radial walls of the equatorial chambers are poorly developed and are mostly indistinct or absent. When complete, the radial walls alternate in adjacent annuli. The annular stolons are situated on the distal side of the chambers.

Distribution.—The genus *Asterophragmina* Rao is so far recorded from the Upper Eocene of Burma only.

Remarks.—In the Treatise, Cole (1964, p. c 715) remarked that *Asterophragmina* Rao was "Possibly a defective specimen of *Asterocyclina*." The only reason for expressing this doubt about the validity of *Asterophragmina* Rao seems to be the coexistence of distally situated annular stolons and alternating radial chamber walls in adjacent annuli in Rao's form. According to both Vaughan (1945, p. 69) and Cole (1950, p. 372) these two features do not coexist in the representatives of the family *Discocyclinidae*. Two points should be mentioned in this conection. Firstly, *Asterophragmina* Rao was not based on a single specimen, but upon 19 specimens. Both centered equatorial and vertical sections were examined, and two centered equatorial sections were illustrated (Rao, *op. cit.*, pl. 1, fig. 3, and pl. 2, fig. 1). Although the writer feels that a more thorough study of Rao's form is required for better understanding of this interesting genus, up to now there is no evidence to support Cole's remark. Secondly, in 1942, when Rao created *Asterophragmina*, the position of the annular stolons was regarded by Vaughan and Cole (1940, pp. 327-328) to be the *only* distinguishing feature between *Discocyclina* s.l. and *Pseudophragmina* s.l. The position of radial chamber walls in adjacent annuli was not considered at that time by these authors to be of any taxonomic significance. Earlier, Vaughan (1928, pp. 341-342) wrote: "I have had many specimens of *Discocyclina floridana* prepared to show the embryonic and equatorial chambers. . . . There is variation in the relation of the chamber walls of adjacent rings, they may alternate or they may be in alignment. I examined many specimens and figures of *Discocyclina* with reference to this feature. Even the original figures of Grümbel (*op. sup. cit.*) show variation."

It is interesting to point out here that Vaughan and Cole have frequently changed their opinion regarding the genus *Pseudophragmina* Douvillé. In 1928, Vaughan argued that the features mentioned by Douvillé, *i.e.*, the degeneration of the radial chamber walls and their position in adjacent annuli, are not sufficiently diagnostic for the erection of the genus *Pseudophragmina*. Then, in 1940, Vaughan and Cole recognised it as a valid genus and postulated that the basic difference between *Discocyclina* and *Pseudophragmina* lies in the position of the annular stolons. In 1945 Vaughan changed his opinion and stated that the difference in the position of the radial walls of equatorial chambers in adjacent annuli constitutes the basic difference between the *Discocyclina* s.l. and *Pseudophragmina* s.l. This presented difficulty in recognising *Asterophragmina* (with alternating chamber walls) as a subgenus of *Pseudophragmina*. The distal position of the annular stolons and the degeneration of the radial walls in *Asterophragmina*, on the other hand, do not permit its inclusion under *Discocyclina* s.l. In other words, *Asterophragmina* does not fit satisfactorily in their scheme of classification. This resulted in Cole's suggestion that *Asterophragmina* Rao is based on defective specimens of *Asterocyclina*.

In the opinion of the writer, the position of radial chamber walls varies considerably in the representatives of Discocyclinidae and so cannot serve as a reliable basis for supraspecific grouping in this family. The position of the annular stolons is a more stable feature and is found to be most useful in distinguishing the *Discocyclina* and *Asterocyclina* group (with proximal annular stolons) from the *Pseudophragmina* and *Asterophragmina* group (with distal annular stolons).

ACKNOWLEDGMENT

Thanks are due to Dr. John R. Haynes of the University College of Wales for reading the manuscript.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XVIII, PART 4, OCTOBER 1967

340. *GLOBIGERINA NEPENTHES* TODD OF PLIOCENE AGE FROM THE GULF COAST

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ABSTRACT

Globigerina nepenthes Todd is reported from Middle Pliocene rocks of the Louisiana Gulf Coast. An historical survey is given of previously reported occurrences of **G. nepenthes.** Taxonomic notes and stratigraphic ranges are provided for some diagnostic planktonic species which establish the relative stratigraphic position of **G. nepenthes** in Gulf Coast sediments.

INTRODUCTION

Globigerina nepenthes Todd has been found in numerous well samples (both sidewall cores and ditch samples) from the northern Gulf of Mexico, offshore Louisiana. The extinction horizon for this species must be regarded at least as young as Middle Pliocene in age. The writers use a Pliocene-Pleistocene boundary defined by the major extinction of the genus *Discoaster* (calcareous nannoplankton) and the accompanying change in the foraminiferal assemblage as proposed by Ericson et al. (1963). This horizon may, however, be of Nebraskan to Aftonian age (Akers, 1965). Bandy's (1964) Miocene-Pliocene boundary is accepted tentatively. Bandy's boundary is based primarily on the lowermost range of *Sphaeroidinella dehiscens* and *Globorotalia truncatulinoides.*

NORTHERN GULF COAST STRATIGRAPHIC SEQUENCE

Globigerina nepenthes is found in the lower two-thirds of the Gulf Coast Pliocene sedimentary column where it is accompanied by *Globorotalia truncatulinoides*, *Globigerina inflata*, and *Sphaeroidinella dehiscens* (text fig. 1). Its final occurrence here is recognized as its true extinction horizon since several thousand feet of sediments overlying this horizon contain foraminifera which accumulated in deep marine conditions (200-1000 meters). The possibility that some ecological factor other than water depth may have caused migration rather than extinction is considered to be remote.

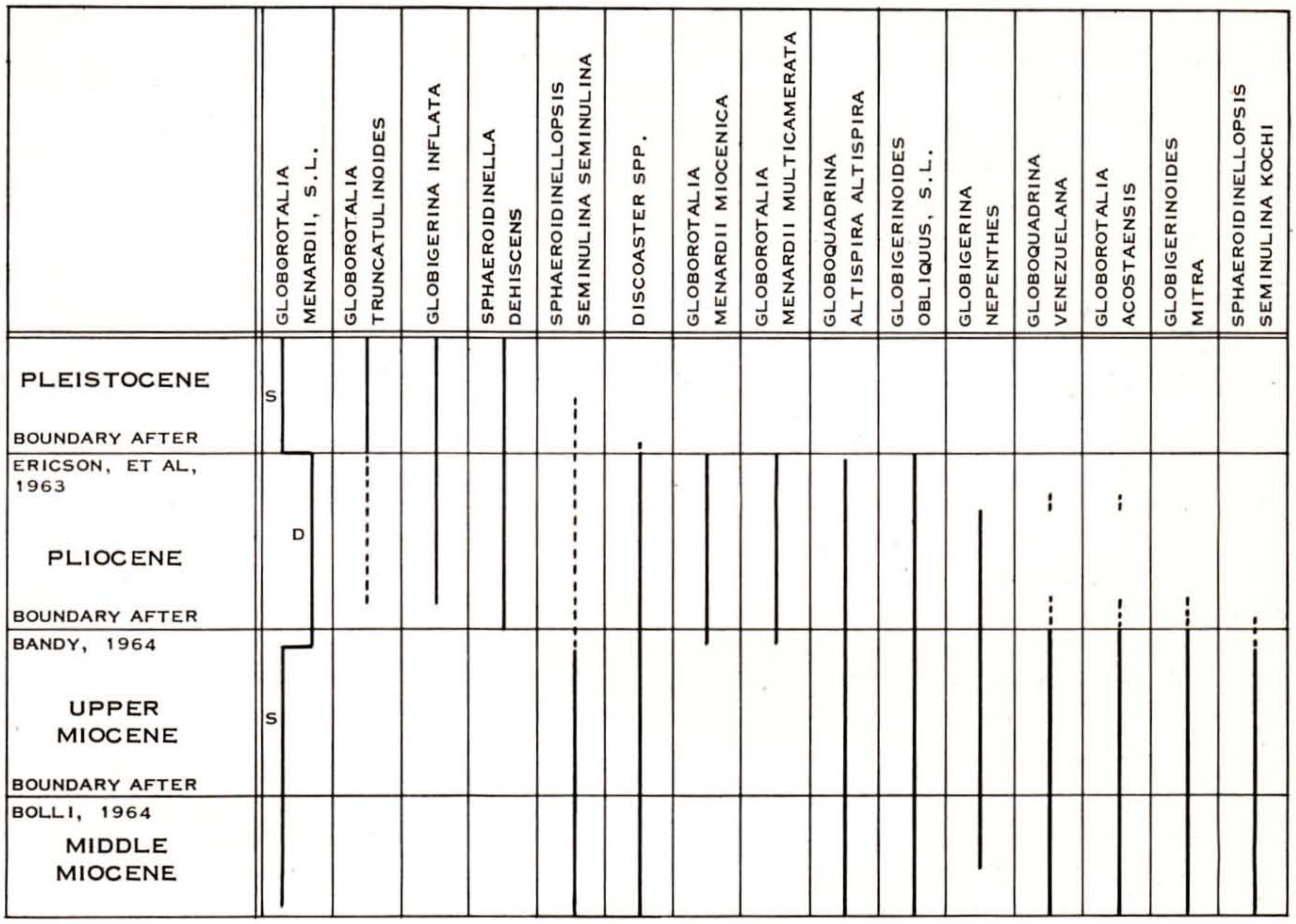
A typical well in the subject area penetrates youngest Miocene sediments approximately 2000 feet below the *G. nepenthes* extinction horizon. In some wells this interval is as much as 5000 feet. This young Miocene is characterized by the frequent occurrence of *Globigerinoides mitra*, *Sphaeroidinellopsis seminulina seminulina*, *Sphaeroidinellopsis seminulina kochi*, *Globoquadrina venezuelana*, and *Globorotalia acostaensis* (text fig. 1). These same species have been found in low frequencies also in the Gulf Coast Pliocene section. *Sphaeroidinellopsis seminulina seminulina* has been identified in beds as young as Lower Pleistocene in age (above *Discoaster* extinction). *Discoaster hamatus* and *D. bollii* (of Miocene age according to Martini and Bramlette, 1963) are also found with *G. nepenthes* in our Miocene samples. Banner and Blow (1967, text-figure 14) find, as do we, that the upper portion of the range of *Globigerina nepenthes* overlaps the lower portion of the range of *Sphaeroidinella dehiscens dehiscens*, *Globorotalia multicamerata*, and *Globorotalia miocenica*. These authors place the termination of *G. nepenthes* in the Lower Pliocene.

Several species which occur in the Upper Miocene range upward to, or nearly to, the Pliocene-Pleistocene boundary. These include *Globoquadrina altispira altispira*, *Globorotalia menardii miocenica, Globorotalia menardii multicamerata*, and *Globigerinoides obliquus* s.l. (text fig. 1).

Pulleniatina obliquiloculata, a species whose stratigraphic range permits definition of the Miocene-Pliocene boundary in some areas (Bandy, 1964; Bolli, 1964), is present in our Pliocene material but is of such low frequency that its precise range here is at present not clear.

PREVIOUS RECORD OF *GLOBIGERINA NEPENTHES*

Globigerina nepenthes has been reported authoritatively from beds of Middle to Upper Miocene age from Trinidad (Bolli, 1957), Venezuela (Blow, 1959; Bolli, 1964; Bolli and Bermúdez, 1965), the Dominican Republic (Bermúdez, 1961), Cuba (Bermúdez, 1961), Italy (Saito, 1962; Cita, Premoli Silva, and Rossi, 1965), Israel (Reiss and Gvirtzman, 1964), Pacific cores (Riedel, Bramlette, and Parker, 1963), Saipan (Todd, 1957; Saito, 1962), the Philippines (Bandy, 1963), New Zealand (Geiger, 1962; Jenkins, 1964), Taiwan (Huang, 1963), Japan (Saito, 1962; Asano, 1962; Takayanagi and Saito, 1962), and Java (Bolli, 1964). According to Bolli (1964), the beds in Japan from which the species is reported by Takayanagi and Saito (1962) may be of Pliocene age. The writers agree with this opinion since the fauna contains *Globorotalia truncatulinoides* (= *G. tosaensis* of Takayanagi and Saito) and *Globigerina inflata* (= cf. *G. oceanica* of Takayanagi and Saito). In addition to the Miocene occurrences enumerated above, the writers confirm *G. nepenthes* in the Up-



TEXT FIGURE 1

Ranges of some planktonic foraminifera in the Louisiana Gulf Coast.
—— = common occurrence; - - - - = rare occurrence; S = sinistral coiling; D = dextral coiling.

per Miocene of Louisiana and from the lower part of the section at the type locality for the Buff Bay Formation of Jamaica.

Our observations are not the first report of *Globigerina nepenthes* in sediments of Pliocene age, but they do confirm the opinion of others that this species became extinct during Pliocene time. Geiger (1962) reports the species in early Pliocene rocks of New Zealand, and this is confirmed by Jenkins (1964). Ericson, Ewing, and Wollin (1963, figure 5) report the species in Pliocene cores from the Atlantic. Riedel, Bramlette, and Parker (1963) report *G. nepenthes* in a core of Pliocene age from the Pacific.

Bryant and Pyle (1965) have listed an assemblage of discoasters and planktonic foraminifera obtained from a piston-core on the crest of one of the Sigsbee Knolls in the Gulf of Mexico. They suggest on the basis of the incorporated assemblage, which includes *G. nepenthes,* that the sediments near the bottom of the core are of "Tortonian age (*Globorotalia menardii menardii*/*Globigerina nepenthes* zone)." This may be an overestimate of the age of these sediments, since every species listed occurs in rocks of Pliocene age. *Globigerina nepenthes* has also been seen by the writers in a core, V3-48, 490 cm., raised from 677 fathoms in the Gulf of Mexico by Lamont Geological Observatory's oceanographic ship *Vema*. Here, as in our Louisiana Pliocene material, this species is in association with *Sphaeroidinella dehiscens*, *Globorotalia truncatulinoides*, and *Globigerina inflata*.

Saito, Burckle, and Ewing (1966, p. 1174) have assigned an Upper-Middle Miocene (Tortonian) age to a portion of Core V 21-229 from the vicinity of the Blake Plateau on the presence of *Globigerina nepenthes*, *Globigerinoides obliquus*, *Sphaeroidinellopsis seminula* and *Globoquadrina altispira.* All of these species occur in Pliocene sediments of the Gulf of Mexico region, and they have all been reported elsewhere from beds younger than Miocene. This portion of Core V 21-229, therefore, may be of Middle Pliocene age.

Globigerina nepenthes has not been found in the Pliocene Manchioneal Formation of Jamaica which contains a rich planktonic assemblage. Thus, it may be that the final extinction of *G. nepenthes* occurred previous to deposition of the Manchioneal beds. So far, *G. nepenthes* has not been reported in the Pliocene of Italy, nor have the writers observed it in their Pliocene material from that region. Neither do Calabrian samples furnished by M. B. Cita contain the species.

It is interesting that *G. nepenthes* was not reported in the Pliocene sediments of the Cubagua-1 well off northeastern Venezuela, by means of which Bolli and Bermúdez (1965) have extended the ranges of several "Miocene" planktonic species into the Pliocene. The writers consider the Gulf Coast Pliocene section containing the *G. nepenthes* extinction horizon to be approximately equivalent to the *Globoquadrina altispira altispira/Globorotalia crassaformis* zone of Bolli and Bermúdez (1965; see below). This zone comprises the upper 849 feet of the Cubagua-1 well. Bold (1966) suggests, on the basis of the ostracode fauna, that the upper 800 feet of sediments in the Cubagua-1 well were deposited at a maximum depth of 40 meters. Bolli and Bermúdez (1965) also note a shallowing in the higher part of the Cubagua Formation. This shallow bathymetry would very likely have excluded *G. nepenthes*. This species apparently is more responsive to slight changes in ecological conditions, such as water depth, than many planktonic species, as can be inferred from its varied morphology (see Saito, 1962).

BIOSTRATIGRAPHIC IMPLICATIONS

As Bolli and Bermúdez state (1965, p. 136), the Pliocene-Pleistocene boundary of Ericson *et al.* (1963) (= Poag and Akers, this paper) falls between the *Globorotalia truncatulinoides/Globorotalia inflata* zone and the *Globoquadrina altispira altispira/Globorotalia truncatulinoides* zone of the former authors. In addition, Bandy's (1964) Miocene-Pliocene boundary (= Poag and Akers, this paper) falls in the middle of the *Globorotalia margaritae* zone of Bolli and Bermúdez (1965). With this in mind, a comparison of the ranges of *Globoquadrina altispira altispira*, *Globorotalia acostaensis*, *Globigerinoides obliquus extremus*, *Globorotalia truncatulinoides*, and *Globigerina inflata* listed by Bolli and Bermúdez (1965, table 1) with the ranges of the same species in the Louisiana Gulf Coast (text fig. 1) reveals that they are very similar. If inferred paleoecological influences had not affected the ranges of some species (*e.g.*, *Globigerina inflata* in Venezuela, Java, and Jamaica) the compared ranges would no doubt be identical.

The upper range of *G. nepenthes* is stratigraphically higher in the Louisiana Gulf Coast than has been reported in the Caribbean, a fact which introduces a need for redefinition of some presently recognized biostratigraphic zones based on the range of *G. nepenthes*. It also points out that any present biostratigraphic zonation for world-wide correlations based on planktonic foraminifera must be used only as a temporary guide. Much more information is required regarding the ranges of species in little known areas such as the northern Gulf of Mexico.

TAXONOMIC NOTES

Globigerina inflata d'Orbigny

Plate 16, figures 13-15

Globigerina inflata D'ORBIGNY, 1839, p. 134, pl. 2, figs. 7-9.

Turborotalia inflata (d'Orbigny), BERMÚDEZ, 1961, p. 1323, pl. 18, figs. 2a-b.

Globorotalia cf. *G. oceanica* Cushman and Bermúdez, TAKAYANAGI and SAITO, 1962, p. 79, pl. 27, figs. 6a-12c.

Globorotalia inflata (d'Orbigny), PARKER, 1962, p. 236, pl. 5, figs. 6a-9.

Globigerina inflata d'Orbigny, AKERS and DORMAN, 1964, p. 16, pl. 13, figs. 17-19.

Remarks.—Our specimens are identical to Recent specimens. Morphological variation is similar to that described by Parker, 1962. Saito (1963, p. 176) implies that *Globorotalia* cf. *G. oceanica* identified by Takayanagi and Saito from the Nobori Formation (1962) belongs to the species *Globorotalia inflata* (= *Globigerina inflata* of Poag and Akers, this paper).

Globigerina nepenthes Todd

Plate 16, figures 1-12

Globigerina nepenthes TODD, 1957, p. 301, pl. 78, figs. 7a, b.

Sphaeroidinellopsis nepenthes (Todd) var. *constricta* BERMÚDEZ, 1961, p. 1278, pl. 10, figs. 2a, b.

Globigerina nepenthes Todd, SAITO, 1962, pp. 332-335, pl. 51, figs. 1a-4c, pl. 52, figs. 1-8.

Remarks.—Our specimens have been compared to topotypes of *G. nepenthes* and are identical. Morphological variation is similar to that described in detail by Saito (1962). Both elongate five-chambered types (Plate 16, figs. 1-9) and spherical four-chambered types (Plate 16, figs. 10-12) are present at its highest stratigraphic occurrence. A thickened lip is present in nearly all specimens, and the test is thickly calcified, a feature which often obscures the early chamber arrangement. The adumbilical end of the chamber which lies symmetrically under the arch of the aperture, typically protrudes into the umbilicus. Figure 10 (Plate 16) shows the characteristic somewhat elongate aperture and the depression of one side of the apertural face which are normally present in our four-chambered specimens. Figure 7 (Plate 16) shows a specimen in which the final (5th) chamber has been broken away, revealing the apertures of the previous three chambers in the umbilicus. The aperture of the penultimate chamber can be seen within the apertural opening of the final chamber in figures 3 and 4, (Plate 16).

Specimens resembling Bermúdez's (1961) variety *constricta* are included in our material. Some specimens are identical to specimens from Trinidad, sent to W. H. Akers by H. M. Bolli.

Globigerinoides mitra Todd

Plate 16, figures 19-21

Globigerinoides mitra TODD, 1957, p. 302, pl. 78, figs. 3, 6.

Globigerinoides mitra Todd, BOLLI, 1957, p. 114, pl. 26, figs. 1a-4.

Globigerinoides mitra Todd, BLOW, 1959, p. 191, pl. 13, fig. 67.

Remarks.—Our specimens are identical to Trinidad specimens sent to W. H. Akers by H. M. Bolli.

Globigerinoides obliquus Bolli

Plate 16, figures 16-18

Globigerinoides obliqua BOLLI, 1957, p. 113, pl. 25, figs. 9a-10c; text-fig. 21, nos. 5a-b.

Globigerinoides obliquus extremus BOLLI and BERMÚDEZ, 1965, p. 139, pl. 1, figs. 10-12.

Remarks.—Our specimens have been compared with specimens identified by H. M. Bolli from Trinidad and are identical. Our specimens also include forms which have the characteristics of *G. obliquus extremus.*

Globorotalia acostaensis Blow

Plate 16, figures 22-24

Globorotalia acostaensis BLOW, 1959, pp. 208-210, pl. 17, figs. 106a-c, 107.

Globorotalia acostaensis Blow, TAKAYANAGI and SAITO, 1962, pp. 75-76, pl. 24, figs. 2a-c.

Globorotalia acostaensis Blow, CITA, PRIMOLI SILVA and ROSSI, 1965, pp. 225-226, pl. 18, figs. 6a-c, text-fig. 5, figs. a-b.

Remarks.—Our specimens agree with figures and descriptions of the above listed authors and with topotypes from Venezuela. The more highly arched aperture, more lobate peripheral outline and more inflated chambers distinguish it from our five-chambered specimens of *Globigerina pachyderma incompta* Cifelli. The degree to which the aperture reaches the periphery is not constant in our specimens.

Globorotalia menardii miocenica Palmer

Plate 17, figures 1-3

Globorotalia menardii (d'Orbigny) var. *miocenica* PALMER, 1945, p. 70, pl. 1, figs. 10a-c.

Globorotalia menardii miocenica Palmer, BLOW, 1959, p. 216, pl. 19, figs. 121a-c.

Globorotalia menardii miocenica Palmer, AKERS and DORMAN, 1964, p. 18, pl. 14, figs. 1-5, 19-21.

Remarks.—Our specimens have been compared with topotypes from the Bowden Formation of Jamaica and are identical.

Globorotalia menardii multicamerata Cushman and Jarvis

Plate 17, figures 4-6

Globorotalia menardii (d'Orbigny) var. *multicamerata* CUSHMAN and JARVIS, 1930, p. 367, pl. 34, figs. 8a-c.

Globorotalia menardii multicamerata Cushman and Jarvis, AKERS and DORMAN, 1964, p. 19, pl. 14, figs. 22-25.

Remarks.—Our specimens have been compared with topotypes from the Bowden Formation of Jamaica, and are identical. Banner and Blow (1965) have stated that specimens identified as this species from Recent sediments belong to *G. cultrata* (s.l.) (= *Globorotalia menardii menardii* of present writers). The writers also believe that this is probably correct.

Globorotalia truncatulinoides (d'Orbigny)

Plate 17, figures 7-9

Rotalina truncatulinoides D'ORBIGNY, 1839, p. 132, pl. 2, figs. 25-27.

?*Globorotalia tosaensis* TAKAYANAGI and SAITO, 1962, p. 81, pl. 28, figs. 11a-12c.

Globorotalia truncatulinoides (d'Orbigny), AKERS and DORMAN, 1964, p. 20, pl. 14, figs. 16-18.

Remarks.—Our specimens are identical to Recent specimens of this species. Some specimens are heavily calcified, a feature which gives them close resemblance to *G. tosaensis.* The writers, however, are not sure that *G. tosaensis* is a species distinct from *G. truncatulinoides.* Takayanagi and Saito (1962) state that *G. tosaensis* has no keel and has fewer chambers per whorl than *G. truncatulinoides.* However, their type figures (figs. 11a-c, 12a-c, pl. 28) show a distinct keel and 4½ chambers in the final whorl, which are typical of *G. truncatulinoides.* Moreover, Bolli and Bermúdez (1965), although apparently recognizing it as separate from *G. truncatulinoides,* feel that it corresponds to the type with thickened walls representing a late life cycle from deeper water.

Globoquadrina altispira altispira (Cushman and Jarvis)

Plate 17, figures 10-11

Globigerina altispira CUSHMAN and JARVIS, 1936, p. 5, pl. 1, figs. 13a-c, 14.

Globoquadrina altispira altispira (Cushman and Jarvis), BOLLI, 1957, p. 111, pl. 24, figs. 7a-8b.

Globigerina altispira altispira Cushman and Jarvis, AKERS and DORMAN, 1964, p. 14, pl. 12, figs. 3-5.

Remarks.—Our specimens are identical to high-spired Trinidad specimens identified by H. M. Bolli and sent to W. H. Akers.

Globoquadrina venezuelana (Hedberg)

Plate 17, figures 12-14

Globigerina venezuelana HEDBERG, 1937, p. 681, pl. 92, figs. 7a-b.

Globigerina venezuelana Hedberg, BOLLI, 1957, p. 110, pl. 23, figs. 6a-8b.

Globoquadrina venezuelana (Hedberg), BLOW, 1959, p. 186, pl. 11, figs. 58a-59.

Remarks.—Our specimens are identical to specimens identified by H. M. Bolli from Trinidad and sent to W. H. Akers.

Sphaeroidinella dehiscens (Parker and Jones)

Plate 17, figures 15-17

Sphaeroidina bulloides d'Orbigny var. *dehiscens* PARKER and JONES, 1865, p. 369, pl. 19, figs. 5a-c.

Sphaeroidinella dehiscens (Parker and Jones), CUSHMAN, 1927, p. 90, pl. 19, fig. 2.

Sphaeroidinella dehiscens (Parker and Jones), AKERS and DORMAN, 1964, p. 20, pl. 13, figs. 13, 14.

Remarks.—Our specimens are identical to Recent specimens.

Sphaeroidinellopsis seminulina seminulina (Schwager)

Plate 17, figures 18-20

Globigerina seminulina SCHWAGER, 1866, p. 256, pl. 7, fig. 112.

Sphaeroidinella seminulina (Schwager), GALLOWAY and HEMINWAY, 1941, p. 415, pl. 30, figs. 4a-b.

Sphaeroidinella rutschi CUSHMAN and RENZ, 1941, p. 25, pl. 4, figs. 5a-c.

Sphaeroidinella grimsdalei (Keijzer), BOLLI, 1957, p. 114, pl. 26, figs. 9-11.

Sphaeroidinella seminulina seminulina (Schwager), BLOW, 1959, p. 197, pl. 12, figs. 74-77c.

Sphaeroidinellopsis seminulina seminulina (Schwager), BANNER and BLOW, 1959, p. 15.

Sphaeroidinellopsis seminulina (Schwager), BANNER and BLOW, 1960, p. 24, pl. 7, figs. 2a-b.

Remarks.—We restrict to this species those specimens having four chambers in the final whorl, an umbilical aperture, and a lobate periphery. Many three-chambered specimens have been encountered, but these generally have the more elongate sutural aperture characteristic of *Sphaeroidinellopsis subdehiscens* (Blow), and we place them there.

Sphaeroidinellopsis seminulina kochi (Caudri)

Plate 17, figures 21-23

Globigerina sp. KOCH, 1923, p. 355, text-figs. 8a-b.

Globigerina kochi CAUDRI, 1934, p. 144.

Sphaeroidinella kochi (Caudri), GLAESSNER, 1934, p. 69, list.

Globigerina grimsdalei KEIJZER, 1945, p. 205, text-figs. 33a-d.

Sphaeroidinella grimsdalei (Keijzer), BOLLI, 1957, p. 114, pl. 26, figs. 12a-c.

Sphaeroidinella seminulina kochi (Caudri), BLOW, 1959, p. 198, pl. 12, figs. 78, 79.

Sphaeroidinellopsis seminulina kochi (Caudri), BANNER and BLOW, 1959, p. 15.

Remarks.—We have restricted our identification of this form to specimens containing five or more chambers, an umbilical aperture, and a highly lobate periphery. Our specimens are identical to five-chambered specimens identified as *Sphaeroidinella grimsdalei* by H. M. Bolli from Trinidad and sent to W. H. Akers. They are also identical to specimens of *Sphaeroidinellopsis seminulina kochi* from the Pozón Formation of Venezuela.

SUMMARY AND CONCLUSIONS

The association of *Globigerina nepenthes* with *Globorotalia truncatulinoides*, *Globigerina inflata*, and *Sphaeroidinella dehiscens* in the lower two-thirds of the thick marine Pliocene sedimentary column of the Gulf Coast indicates a Middle Pliocene age for the extinction horizon of *G. nepenthes*. This Middle Pliocene occurrence generates a need for redefinition of some Tertiary planktonic foraminiferal biostratigraphic zones which have been based on the belief that the range of *G. nepenthes* is limited to the Miocene Epoch. Additional information is needed in order to establish the complete stratigraphic ranges of planktonic foraminifera in the Upper Cenozoic. The thick sediments of the northern Gulf of Mexico offer data which are apparently lacking in most areas studied to date.

ACKNOWLEDGMENTS

This paper is published with permission of Chevron Oil Company. G. S. Robinson and W. P. S. Ventress reviewed the manuscript. A. D. Warren supplied topotypes of *Globigerina nepenthes*. H. M. Bolli provided W. H. Akers with numerous specimens of planktonic foraminifera from the Cipero and Lengua Formations of Trinidad. M. B. Cita furnished many foraminiferal samples from the Tertiary and Calabrian of Italy. E. Robinson of the Geological Survey of Jamaica assisted in collecting the Buff Bay, Bowden, and Manchioneal Formations.

The writers acknowledge the research of all those listed in our bibliography. It is only through the data supplied by these specialists that we are beginning to understand the distribution of the subject species in time and space.

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EXPLANATION OF PLATE 16

FIGS. PAGE

All illustrations on this plate and the following plate are camera lucida drawings by C. W. Poag.

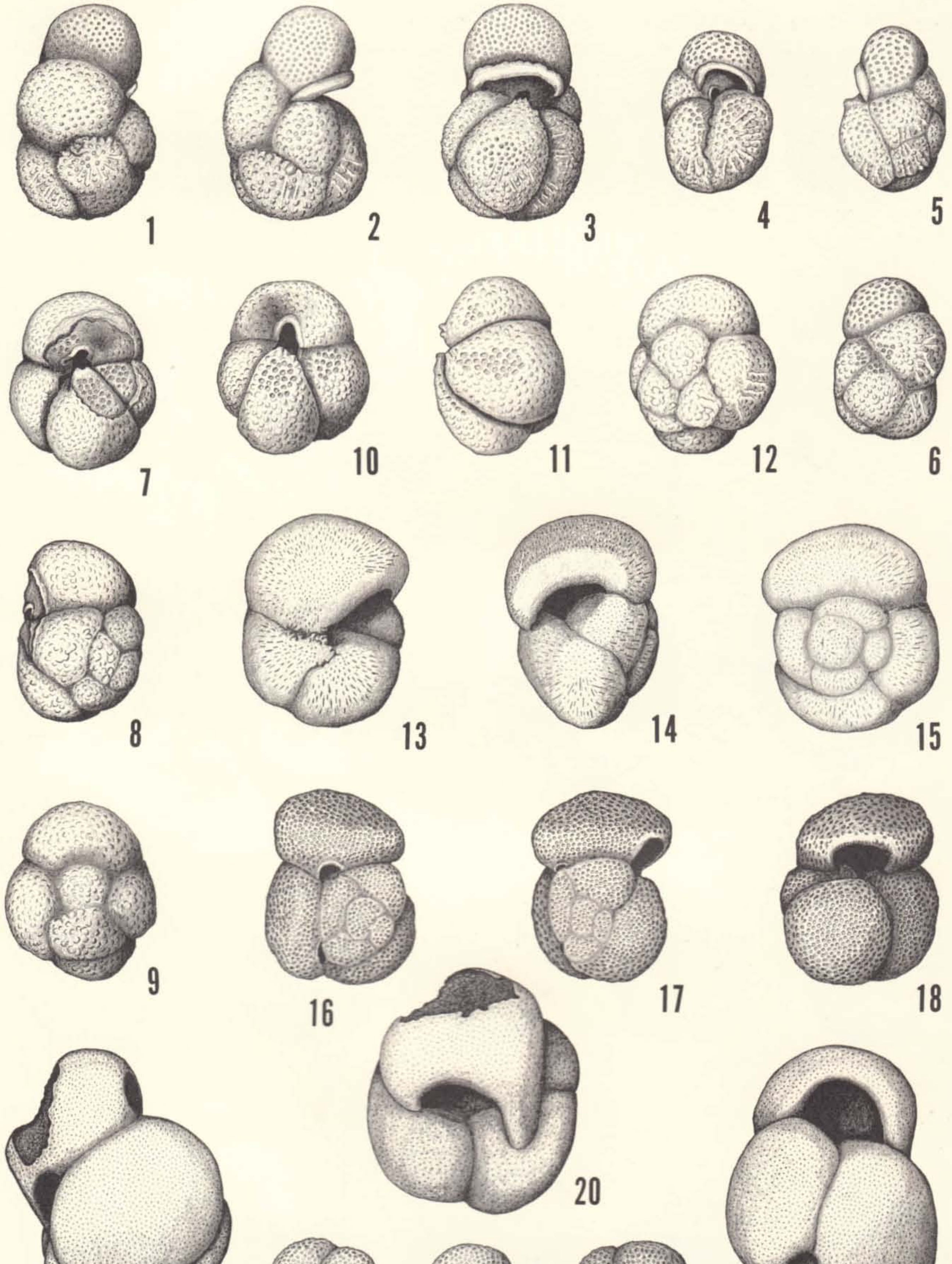
1-12. *Globigerina nepenthes* Todd. × 78. 170
- 1-3. Typical five-chambered form showing thin-walled fifth chamber; aperture of penultimate chamber showing in fig. 3.
- 4-6. Small five-chambered form.
- 7-9. Five-chambered form with fifth chamber broken away; apertures of 3 chambers visible in umbilicus; right side of apertural face depressed.
- 10-12. Typical four-chambered form; elongate aperture and depression of left side of apertural face shown in fig. 10; all figured specimens Middle Pliocene, ditch samples.

13-15. *Globigerina inflata* d'Orbigny. × 78. 170
13, umbilical view; 14, peripheral view; 15, spiral view; Lower Pliocene, sidewall core.

16-18. *Globigerinoides obliquus* Bolli. × 78. 171
16, spiral view; 17, peripheral view; 18, umbilical view; uppermost Pliocene, ditch sample.

19-21. *Globigerinoides mitra* Todd. × 42. 171
19, side view with final chamber broken; 20, umbilical view; 21, apertural view; Upper Miocene, ditch sample.

22-24. *Globorotalia acostaensis* Blow. × 78. 171
22, umbilical view; 23, peripheral view; 24, spiral view; lowermost Pliocene, ditch sample.



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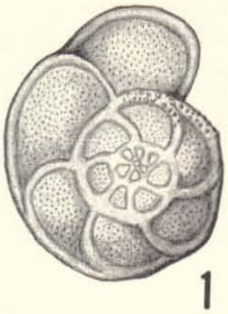
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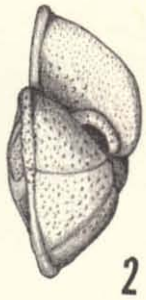
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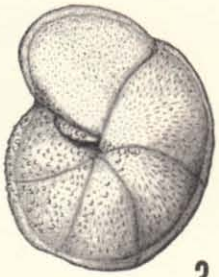
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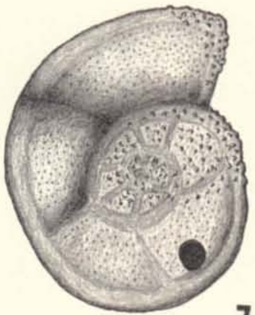
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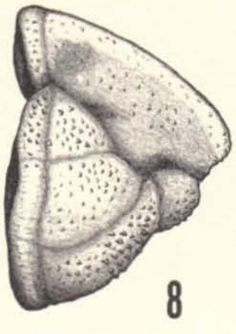
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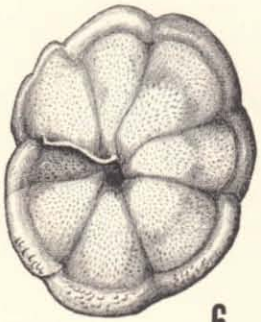
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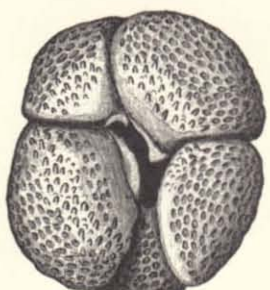
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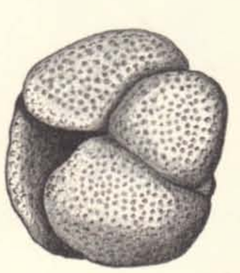
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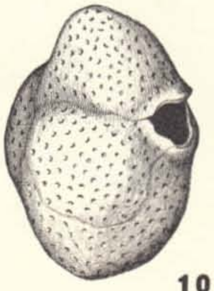
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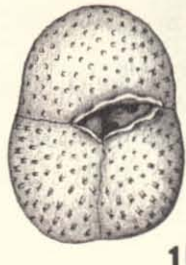
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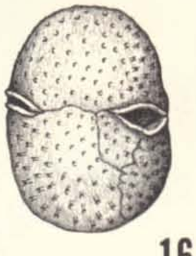
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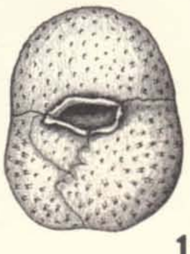
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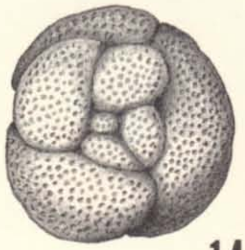
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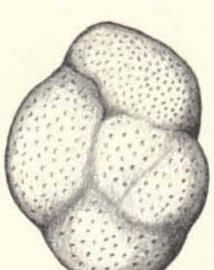
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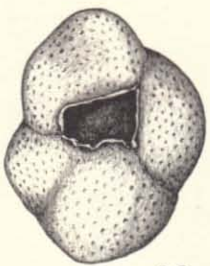
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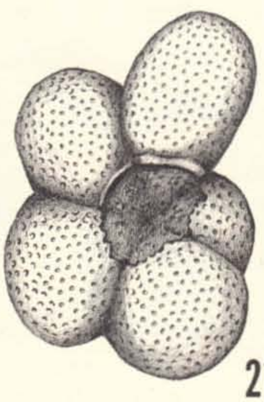
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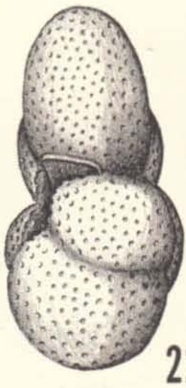
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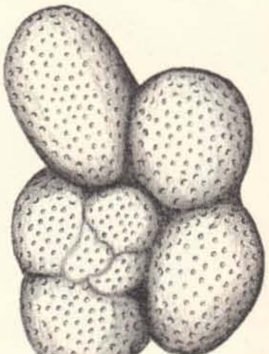
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Addendum: While this manuscript was in press, the authors identified a typical 4-chambered specimen of *Globigerina nepenthes* in a core representing the interval 1237-1249 feet from the Cubagua 1 well (Bolli and Bermúdez, 1965; Bermúdez, 1966). This is a considerably younger occurrence than previously reported from this well.

EXPLANATION OF PLATE 17

FIGS.		PAGE
1-3.	*Globorotalia menardii miocenica* Palmer. × 78. 1, spiral view; 2, peripheral view; 3, umbilical view; uppermost Pliocene, ditch sample.	171
4-6.	*Globorotalia menardii multicamerata* Cushman and Jarvis. × 42. 4, spiral view; 5, peripheral view; 6, umbilical view; Upper Pliocene, ditch sample.	171
7-9.	*Globorotalia truncatulinoides* (d'Orbigny). × 78. 7, spiral view; 8, peripheral view; 9, umbilical view; Lower Pliocene, sidewall core.	171
10-11.	*Globoquadrina altispira altispira* (Cushman and Jarvis). × 78. 10, umbilical view; 11, side view; Upper Pliocene, ditch sample.	171
12-14.	*Globoquadrina venezuelana* (Hedberg). × 42. 12, umbilical view; 13, peripheral view; 14, spiral view; Upper Miocene, ditch sample.	172
15-17.	*Sphaeroidinella dehiscens* (Parker and Jones). × 42. 15, primary apertural view; 16, peripheral view; 17, secondary apertural view; Lower Pliocene, sidewall core.	172
18-20.	*Sphaeroidinellopsis seminulina seminulina* (Schwager). × 42. 18, peripheral view; 19, spiral view; 20, umbilical view; Lower Pliocene, ditch sample.	172
21-23.	*Sphaeroidinellopsis seminulina kochi* (Caudri). × 42. 21, umbilical view; 22, peripheral view; 23, spiral view; Upper Miocene, ditch sample.	172

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XVIII, PART 4, OCTOBER 1967

341. TEST RECALCIFICATION IN *ROSALINA FLORIDANA* (CUSHMAN)

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ABSTRACT

The foraminifer **Rosalina floridana** is capable of recalcifying its test after decalcification in acidified sea water. Recalcification occurs during chamber formation, when a new layer of calcite is deposited over the entire exterior of the test while the new chamber is being calcified. No calcification mechanism independent of chamber formation was observed. It is suggested that all foraminiferal species that deposit a calcite layer over the entire exterior of the test every time a chamber is added are able to recalcify.

INTRODUCTION

During an investigation of the process of chamber formation in the foraminifer *Rosalina floridana* (Cushman), experiments were conducted to determine the ability of this species to recalcify the test after it was decalcified by artificial means. The objective of this work was to find a method that would enable one to study the calcification processes in foraminifera.

PREVIOUS WORK

During experiments on environmental factors affecting foraminifera, Bradshaw (1961) found that *Ammonia beccarii tepida* and *Spirillina vivipara* could survive being placed in sea water with a pH of 2.0 for periods of time long enough to completely decalcify the test. Three days after being returned to sea water of normal pH one specimen of *A. beccarii tepida* had recalcified its test and others did so later. There is no mention of recalcification in *S. vivipara*.

METHODS

Specimens of *R. floridana* from laboratory cultures were decalcified by immersion in sea water acidified to a pH of 5.0 with HCl. Total decalcification of the test usually occurred within sixty minutes. Upon completion, the specimens were transferred through at least three changes of normal sea water before being placed in small petri dishes containing sea water with *Chlamydomonas sp.*, a food organism. The activity of the specimens was checked at frequent intervals for several days until recalcification of the tests had occurred.

Specimens of *Spiroloculina hyalina* were also decalcified and treated in a similar manner.

RESULTS

After a brief period of inactivity, usually less than three hours, the decalcified specimens of *R. floridana* developed pseudopodia and began feeding in a normal manner. On all the specimens the terminal chamber collapsed either immediately after decalcification or soon after feeding began. In the case of the larger specimens, the last two or three chambers of the whorl usually became detached because the organic lining, the only part of the test left after decalcification, was too delicate to withstand the strains placed on it as the animal moved about. The cytoplasm from within these chambers often remained with the foraminifer and formed an external mass that could not be retracted into the test. Usually much of this was blebbed off as small cytoplasmic spheres during the following days. This displaced internal cytoplasm could be identified by the orange-colored lipid droplets it contained. The cytoplasm normally found outside the test, such as that composing the pseudopodia, is colorless.

Three to five days after decalcification most of the foraminifers recalcified their tests. No attempt was made to quantify these observations, but of the several hundred specimens used in this study only a very few calcified before three days and only a slightly greater number took longer than five days. Recalcification occurred as a result of adding a new chamber to the test.

During chamber formation the new chamber is calcified and, in addition, a layer of calcite is deposited over the whole exterior surface of the test. This results in a laminated calcite wall structure in all but the newest chamber. The reader is referred to two papers by the author (1967, and in press) for an explanation of this process and diagrams of the wall structure of *R. floridana*. In the case of decalcified specimens, the result is a new, calcified chamber and the recalcification of the organic lining of the test with a single layer of calcite. The laminated wall structure existing before decalcification is not restored. The new chambers are often malformed and smaller than normal, while many of the tests are distorted by a partial uncoiling of the whorl or a displacement of the spiral arrangement of the chambers. The cytoplasmic sheath that covers the dorsal surface of the test during calcification often has an abnormal appearance in specimens that have lost chambers as a result of the presence of the external mass of lipid-containing cytoplasm derived from them, as mentioned above.

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Decalcification and subsequent recalcification do not seem to change or hinder the normal behavior of the foraminifers, and all that reproduced during the course of this project had viable young.

There was no recalcification of the test in *S. hyalina*. Within a few hours after decalcification, the outer chambers began to uncouple from the rest of the test, and the process continued until the animal was reduced to a number of detached individual chambers. The cytoplasm in the detached chambers formed minute pseudopodia, fed on *Chlamydomonas* and survived for periods as long as two weeks before degenerating. None of the specimens remained intact long enough for any recalcification to occur.

DISCUSSION

The normal chamber-building processes of *R. floridana* have been investigated (in press) by the author, and the present study was started in an effort to find another calcifying mechanism that was independent of chamber formation. However, the ability of this foraminifer to calcify its test after decalcification appears to be an integral part of a normal chamber-forming process and cannot be independently initiated. The foraminifer always deposits a layer of calcite over the whole test while a newly formed chamber is being calcified. Thus, there is no recalcification in the sense of restoring the destroyed calcite wall structure; there is simply new calcite deposition that would have occurred even if the test had not been experimentally decalcified.

From Bradshaw's observations on *A. beccarii tepida* and the results reported here, there appears reason to believe that recalcification is possible in all species that add a calcite layer to the test as each new chamber is added, *i.e.*, all species with a lamellar wall structure. Unless a calcification mechanism not integrally associated with chamber formation is functional in other types of foraminifera, they probably do not possess the ability to recalcify the test. Some of the miliolids, such as *Quinqueloculina*, may be able to recalcify, because the deposition of calcite crystals on and in the matrix of the chamber walls appears to be a continuous process and is not restricted to the time when a new chamber is being built. An investigation now in progress on chamber formation and calcification in *S. hyalina* may provide more information on this question.

This study was supported by Public Health Service Training Grant 5TI DE 92-05 from the National Institute of Dental Research, National Institute of Health.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XVIII, PART 4, OCTOBER 1967

RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the Foraminifera that have come to hand.

BANERJI, RANJIT K. The genus *Globotruncana* and biostratigraphy of the Lower Ariyalur stage (Upper Cretaceous) of Vridhachalam, South India.—Journ. Geol. Soc. India, v. 7, 1966, p. 51-69, pls. 3-5, text figs. 1-3 (range charts, graph), table 1 (zonal chart).—Eight species (1 new) and 2 subspecies from 4 zones between Coniacian and lower Maestrichtian.

BANNER, F. T., and BLOW, W. H. The origin, evolution and taxonomy of the foraminiferal genus *Pulleniatina* Cushman, 1927.—Micropaleontology, v. 13, No. 2, April 1967, p. 133-162, pls. 1-4, text figs. 1-14 (diagrams, range chart).—The genus originated from *Globorotalia acostaensis* and 2 evolutionary lines are known, both commencing with *P. primalis* n. sp. One line includes *P. obliquiloculata* and 2 new subspecies; the other includes *P. spectabilis* n. sp. having a short range in the lower Pliocene of the Indo-Pacific. Two unrelated forms are studied: a neotype is proposed for *Globigerina inflata*, and *Rotaliatinopsis* n. gen. (type species ?*Pulleniatina semi-involuta* Germeraad) is erected in the Alabaminidae.

BARBIERI, FRANCESCO. Segnalazione dei generi *Gabonella* e *Grimsdaleinella* (Foraminiferi) nel Cretacico dell' Appennino settentrionale.—Boll. Soc. Geol. Ital., v. 85, fasc. 1, 1966, p. 13-20, 2 pls.—Illustrations of associated species (mostly in *Gabonella, Grimsdaleinella, Schackoina,* and *Hedbergella*) from Cenomanian-Turonian rocks.

BARR, F. T., and GOHRBANDT, K. H. A. *Thomasinella punica*, a Tethyan foraminifer from the Cenomanian of central Tunisia.—Guidebook to the Geology and History of Tunisia, Petrol. Explor. Soc. Libya, 9th Field Conf., Amsterdam, April 1967, p. 153-158, text figs. 1-4 (maps, photomicrographs, drawings).—Thin beds composed almost exclusively of this species indicate a quiet, shallow, and protected marine environment.

BERGER, WOLFGANG H., and SOUTAR, ANDREW. Planktonic Foraminifera: Field experiment on production rate.—Science, v. 156, No. 3781, June 16, 1967, p. 1495-1497, text fig. 1 (graph), table 1.—In the Santa Barbara Basin use of a sediment trap to catch sinking empty shells and open-closed net tows to determine standing crops permits an estimate of turnover times between 27 and 77 days for the 4 commoner globigerines. Hence, life spans of these species are of the order of a month.

BERMUDEZ, PEDRO J., and GAMEZ, HECTOR A. Estudio Paleontologico de una seccion del Eoceno. Grupo Punta Carnero de la Isla Margarita, Venezuela.—Mem. Soc. Ciencias Nat. La Salle, v. 26, No. 75, Sept.-Dec. 1966, p. 205-259, pls. 1-11, map, geol. section, correl. chart, check lists.—Illustrated catalog includes 89 species, 1 new. Age is middle Eocene.

BLONDEAU, A. Decouverte de *Nummulites* au Cameroon.—Proc. 2nd West African Micropaleont. Colloquium, Ibadan, Nigeria, June 18-July 1, 1965, J. E. van Hinte, ed., 1966, p. 24-26, pl. 1.—*Nummulites* (*Operculinoides*) *furoni* n. sp. from upper Paleocene or lower Eocene.

BOGDANOVICH, A. K. A new *Articulina* from the Maeotian of Kuban (in Russian).—Paleont. Zhurnal, 1967, no. 1, p. 131, 132, text figs.

BUGROVA, E. M. Occurrence of foraminifers of the genus *Lockhartia* in the Paleocene of USSR.—Internat. Geol. Review, v. 9, No. 3, March 1967, p. 278-281, text figs. a-f (drawings).—*Lockhartia luppovi* sp. nov.

BULATOVA, Z. I. On finds of Foraminifera in Senonian deposits of North Sosva River (in Russian).—Akad. Nauk SSSR, Sibirskoe Otdel., Geol. i Geofiz., No. 2 (86), 1967, p. 86-91, 1 pl.

CATENACCI, ENZO, and MOLINARI, VIVIANA. Sull' età dei conglomerati di Minturno (Lazio Meridionale).—Boll. Serv. Geol. Italia, v. 86, Anno 1965 (1966), p. 27-41, pls. 1, 2 (geol. map, photomicrographs of Foraminifera).—Illustrations and lists of lower Pliocene species.

CHANTON, NICOLE. A propos de la présence de Lasiodiscidae (Foraminifères) dans le Viséen terminal du bassin houiller de Djerada (Maroc).—C. R. S. Soc. Géol. France, fasc. 4, May 8, 1967, p. 166-167, text figs. 1-4 (photomicrographs).

COLEMAN, P. J., and MCTAVISH, R. A. Association of Early Miocene planktonic and larger Foraminifera from the Solomon Islands, southwest Pacific.—Australian Journ. Sci., Melbourne Congress, Proc., v. 29, No. 10, April 1967, p. 373-375, text figs. 1, 2 (maps).—Larger Foraminifera typical of upper Tertiary *e* and planktonics of the *Catapsydrax dissimilis* zone, both indicative of Aquitanian age.

CRESCENTI, UBERTO. Sulla biostratigrafia del Miocene affiorante al confine marchigiano-abruzzese.—Geologica Romana, v. 5, 1966, p. 1-54, pls. 1, 2, text figs. 1-9 (correl. diagram, columnar sections, drawings), tables 1-4 (correl. charts, range charts).—Four cenozones (Aquitanian, Langhian, Helvetian, and Tortonian) and the Messinian thanatocenosis zone. Forty species and 5 subspecies of planktonics described and illustrated, 2 species new.

CUTBILL, J. L., and FORBES, C. L. Graphical aids for the description and analysis of variation in fusuline Foraminifera.—Palaeontology, v. 10, pt. 2, June 1967, p. 322-337, text figs. 1-13 (drawings, graphs).

DELISE, KNOXIE C. Biostratigraphy of the San Emigdio formation, Kern County, California. —Univ. Calif. Publ. Geol. Sci., v. 68, May 5, 1967, p. 1-67, pls. 1-7, text figs. 1-8 (maps, columnar section, check lists).—Includes illustrated systematic catalog of 123 species and varieties, 1 species new, from the Tejon formation and lower part of the Emigdio formation of late Eocene age.

DE ZANCHE, VITTORIO. Osservazioni sulla patologia di Nummuliti ed Assiline e sul singolare stato di conservazione di Alveoline nei pressi di Albanello in Valle del Chiampo (Vicenza). —Mem. Istit. Geol. Min. Univ. Padova, v. 25, 1965-66, 1966, p. 1-17, pls. 1, 2, text figs. 1-15 (map, outcrop photo, drawings).—Examples of abnormal growth and healing of breaks and other examples of calcination from volcanism.

DROOGER, C. W. Zonation of the Miocene by means of planktonic Foraminifera—a review and some comments.—Internat. Union Geol. Sci., Proc. 3rd Sess. in Berne 8-13 June 1964, 1966, p. 40-50, table 8.—Review of development of planktonic zonation in various parts of the world with comments by others introducing different opinions and points of view.

Notes on *Miogypsina* of Cameroon.—Proc. 2nd West African Micropaleont. Colloquium, Ibadan, Nigeria, June 18-July 1, 1965, J. E. van Hinte, ed., 1966, p. 44-48.—Association, in a well, of *M.* (*Miogypsinoides*) *bantamensis* Tan and *M.* (*Miolepidocyclina*) *burdigalensis* (Gümbel) indicates Burdigalian age.

DUTKEVICH, G. A. A new *Yabeina* from the Upper Permian of the south-eastern Pamirs (in Russian).—Paleont. Zhurnal, 1967, no. 1, p. 18-21, pl. 1.

EAMES, F. E., and CLARKE, W. J. A Palaeocene *Heterostegina*.—Palaeontology, v. 10, pt. 2, June 1967, p. 314-316, pl. 51 (part), text fig. 1 (distrib. diagram).—*Heterostegina adamsi* sp. nov. from the upper Palaeocene of Somalia.

EL-NAGGAR, Z. R. Planktonic Foraminifera in the Thanet sands of England, and the position of the Thanetian in Paleocene stratigraphy.—Journ. Paleontology, v. 41, No. 3, May 1967, p. 575-586, text fig. 1 (check list).—Forty-nine species and subspecies include some specimens reworked from late Senonian and early and middle Paleocene. The indigenous species permit correlation with the beginning of late Paleocene.

GEROCH, STANISLAW. Lower Cretaceous small Foraminifera of the Silesian Series, Polish Carpathians (English summary of Polish text).—Ann. Soc. Geol. Pologne, v. 36, fasc. 4, Année 1966, p. 413-480, text figs. 1-14 (map, columnar sections, graphs, 9 plates of fossils).—Lists, descriptions, and illustrations of species; 2 species and 1 subspecies new. Ages are Tithonian to Albian, ?Cenomanian.

GIBSON, THOMAS G. Stratigraphy and paleoenvironment of the phosphatic Miocene strata of North Carolina.—Bull. Geol. Soc. America, v. 78, No. 5, May 1967, p. 631-650, pls. 1, 2, text figs. 1-4 (maps, correl. chart, columnar section).—The Pungo River Formation is correlated with the Calvert Formation of Maryland by means of the *Globigerinatella insueta* zone. Depth of deposition is determined from quantitative analysis of benthonics and the depth ranged in different parts of the section from 100-200 meters to less than 70 meters. Deposition of the overlying Yorktown Formation occurred under conditions that gradually shallowed from 100 to less than 15 meters and probably became brackish and that warmed from cool-temperate to subtropical.

HANSEN, HANS JORGEN. Description of seven type specimens of Foraminifera designated by d'Orbigny, 1826.—Biol. Medd. Kon. Dan. Vidensk. Selsk., Bind 23, nr. 16, 1967, p. 1-11, pls. 1-3. —Seven lectotypes based on specimens recently discovered in the Museum in Copenhagen, and representing species missing from the d'Orbigny collection in Paris. *Gyroidina* is emended.

HANZAWA, SHOSHIRO. Three new Tertiary foraminiferal genera from Florida, Saipan and Guam.—Trans. Proc. Paleont. Soc. Japan, n. ser., No. 65, April 10, 1967, p. 19-25, pls. 3, 4.—*Quasiborelis* nov. (type species *Borelis gunteri* Cole), *Tayamaia* nov. (type species *Gypsina marianensis* Hanzawa), and *Quasirotalia* nov. (type species *Q. guamensis* nov.).

HIGUCHI, YU. *Eponides bosoensis* new name for *Eponides asanoi* Higuchi, preoccupied.—Trans. Proc. Paleont. Soc. Japan, n. ser., No. 65, April 10, 1967, p. 26.

VAN HINTE, J. E. *Bolivinoides* from the Campanian type section.—Proc. Kon. Nederl. Akad. Wetenschappen, ser. B, v. 70, No. 3, 1967, p. 254-263, pl. 1, text figs. 1-4 (graphs, correl. diagram, range chart), table 1.—Zonation by *Bolivinoides* compared with correlation by *Globotruncana.*

HOFKER, JAN, JR. Primitive *Orbitoides* from Spain. —Micropaleontology, v. 13, No. 2, April 1967, p. 243-249, pls. 1, 2, text figs. 1-5 (map, drawings, graph).—Two species from the upper Santonian.

HOFMANN, GERHARD W. Über *Suggrunda porosa* Hoffmeister & Berry (Foram.) aus der ostbayerischen Molasse.—Neues Jahrb. Geol. Paläont. Mh., Band 6, June 1967, p. 342-349, text figs. 1-5 (range chart, drawings, graphs).—Found in Oligocene and Miocene well material of the Molasse Basin in environments of reduced oxygen content.

HOTTINGER, L. *Heterostegina, Grzybowskia* et *Spiroclypeus* Néogènes du Maroc.—Internat. Union Geol. Sci., Proc. 3rd Sess. in Berne 8-13 June 1964, 1966, p. 61-69, pls. 13-15, table 16 (range chart).—Illustrations of closely related evolutionary forms in the 3 genera, with their respective stratigraphic ranges indicated.

Les *Ammonia* dans le Miocène Supérieur et Pliocène Marocain.—Internat. Union Geol. Sci., Proc. 3rd Sess. in Berne 8-13 June 1964, 1966, p. 117-123, pls. 35-37, table 16 (range chart). —Illustrations of 4 species-groups in *Ammonia* (i.e. *beccarii, punctato-granosa, inflata,* and *papillosa*), with their respective stratigraphic ranges indicated.

IGO, HISAYOSHI. Some Permian Fusulinids from Pahang, Malaya, *in* Geology and Paleontology of Southeast Asia, vol. 3, compiled and edited by TEICHI KOBAYASHI and RYUZO TORIYAMA. —Univ. Tokyo Press, Tokyo, 1966, p. 30-38, pls. 4-9, text figs. 1, 2 (map, outcrop photo), tables 1, 2.—Four species, 1 new: *Pseudofusulina gobbetti.*

JENKINS, D. GRAHAM. Two lineages from the Neogene planktonic Foraminifera of the Australasian region.—Internat. Union Geol. Sci., Proc. 3rd Sess. in Berne 8-13 June 1964, 1966, p. 23-29, pls. 2, 3, table 4 (range chart).—The *Globigerina woodi-Orbulina universa* lineage and the *Globorotalia barisanensis-G. opima continuosa* lineage.

Recent distribution, origin, and coiling ratio changes in *Globorotalia pachyderma* (Ehrenberg).—Micropaleontology, v. 13, No. 2, April 1967, p. 195-203, text figs. 1-8 (map, drawings, graphs), tables 1-3.—In Recent seas *Globigerina pachyderma* is coiled sinistrally in cold water and dextrally in warm. In New Zealand the coiling of specimens in the upper Miocene, Pliocene, and Pleistocene reveal 10 alternations which are interpreted as indicating alternations of cold and warm temperatures.

KANE, HENRY E. Recent microfaunal biofacies in Sabine Lake and environs, Texas and Louisiana.—Journ. Paleontology, v. 41, No. 4, July 1967, p. 947-964, text figs. 1-30 (maps, check lists), tables 1-3.—Present-day biofacies in Sabine Lake are *Haplophragmoides-Miliammina* and *Ammobaculites,* with *Streblus-Elphidium* near the narrow pass to the Gulf of Mexico and Miliolidae in the neritic zone of the Gulf. Cores from the lake bottom reveal the previous existence of the two latter biofacies within Sabine Lake, denoting a former freer communication with the Gulf.

KRIJNEN, J. P. Pseudorbitoid Foraminifera from Curaçao. I and II.—Proc. Kon. Nederl. Akad. Wetenschappen, ser. B, v. 70, No. 2, 1967, p. 144-164, pls. 1-6, text figs. 1-7 (map, drawings, graphs), tables 1-4.—Three species, 1 new.

LEE, JOHN J., FREUDENTHAL, HUGO D., KOSSOY, VICTOR, and BÉ, ALLAN. Cytological observations on two planktonic Foraminifera, *Globigerina bulloides* d'Orbigny, 1826, and *Globigerinoides ruber* (d'Orbigny, 1839) Cushman, 1927.—Journ. Protozoology, v. 12, No. 4, 1965, p. 531-542, pls. 1-5.

LIPPS, JERE H. Planktonic Foraminifera, intercontinental correlation and age of California mid-Cenozoic microfaunal stages.—Journ. Paleontology, v. 41, No. 4, July 1967, p. 994-999, text figs. 1-4 (map, range charts, correl. chart). —Charts show correlation between European and California stages and the tropical planktonic zonation. Ranges of 29 planktonic species in California, as compared with their ranges in tropical areas, are in most instances more restricted.

LUDBROOK, NELLY HOOPER. Correlation of Tertiary rocks of the Australasian region.—Tertiary Correlations and Climatic Changes in the Pacific, Feb. 28, 1967, p. 7-19, text figs. 1-3 (map, range chart, correl. table).—Ranges of 28 significant species of planktonics indicated between Paleocene and Pliocene.

MATEU, GUILLERMO MATEU. Contribución al conocimiento de los Foraminíferos vivientes. Estudio sistemático y bioecológico de los Foraminíferos vivientes del litoral catalano-balear.

—Univ. Barcelona, tesis doctoral, 1966, p. 1-19, text figs. 1-5 (maps, graph, photomicrographs), table (showing occur. and abund.).—Quantitative analysis according to habitat (algae; leaves, stems or sediment of *Posidonia* beds; mud or sand) and depth (25, 50, 75, or 100 meters). Occurrence of about 150 species is recorded.

MOHAN, MADAN, and SOODAN, K. S. *Inordinatosphaera*—a new genus of Globigerinidae.—Geol. Soc. India Bull., v. 4, No. 1, Jan. 1967, p. 22-25, 1 pl.—*Inordinatosphaera indica* n. gen., n. sp. from the middle Eocene of Kutch superficially resembles *Globigerinatella* but differs in lacking areal apertures.

MOSTARDINI, F., PIERI, M., and PIRINI, C. Stratigrafia del Foglio 212, Montalbano Ionico.—Boll. Serv. Geol. Italia, v. 87, 1966, p. 57-143, text figs. 1-57 (maps, columnar sections, geol. sections, outcrop photos, photomicrographs of foram assemblages and of thin sections).—*Bolivina lucana* sp. n. is described from the lower Pliocene. Several Foraminifera assemblages are illustrated from formations between Upper Cretaceous and Quaternary.

MURRAY, J. W. Transparent and opaque foraminiferid tests.—Journ. Paleontology, v. 41, No. 3, May 1967, p. 791.—Lowered pH causes transparent tests to turn opaque.

MUYLAERT, J. Le genre *Cyclammina* au Maroc Septentrional.—Internat. Union Geol. Sci., Proc. 3rd Sess. in Berne 8-13 June 1964, 1966, p. 127-133, pls. 40-43.—Illustrations of 5 species in the Eocene, Oligocene, and Miocene.

PAPP, A. Evolution von Nannoplankton und Foraminiferen im mittleren Neogen Mitteleuropas.—Internat. Union Geol. Sci., Proc. 3rd Sess. in Berne 8-13 June 1964, 1966, p. 70-77, pls. 17-21 (range chart, drawings).—Illustrations of evolutionary series in *Heterostegina* and 3 groups of *Uvigerina*.

PARKER, FRANCES L. Late Tertiary biostratigraphy (planktonic Foraminifera) of tropical Indo-Pacific deep-sea cores.—Bull. Am. Paleontology, v. 52, No. 235, June 30, 1967, p. 111-208, pls. 17-32, text figs. 1-5 (correl. chart, range chart, core diagrams, drawings), tables 1-4 (local. data, check lists).—Important study based on 18 deep-sea cores, 1 dredge sample, and 5 outcrop samples from Fiji and encompassing zones N.16 (of the middle Miocene) to N.23 (upper part of the Quaternary) of the Banner and Blow zonation. Fifty-seven species (4 new) are described and illustrated and their classification is discussed.

PROTO DECIMA, FRANCA, and ZORZI, PAOLO. Studio micropaleontologico-stratigrafico della serie Cretaceo-Terziaria del Molinetto di Pederobba (Trevigiano occidentale).—Mem. Istit. Geol. Min. Univ. Padova, v. 25, 1965-66, 1966, p. 1-44, pls. 1-5, table 1 (range chart).—Illustrated systematic catalog of 37 planktonic species. Six West Indian zones—one in the upper Maestrichtian and 5 in the Ilerdian and Cuisian—are recognized.

RAINWATER, E. H. Miocene of the Gulf Coastal Plain of the United States of America.—Proc. 2nd West African Micropaleont. Colloquium, Ibadan, Nigeria, June 18-July 1, 1965, J. E. van Hinte, ed., 1966, p. 141-161, text figs. 1-14 (correl. chart, outcrop and structure maps, geol. sections, strat. range chart, columnar sections).—A review of the thick deltaic sedimentation and the use of Foraminifera in working out the history of transgressions and regressions.

REYMENT, R. A. Procedures of quantitative evaluation of variability in foraminifers.—Proc. 2nd West African Micropaleont. Colloquium, Ibadan, Nigeria, June 18-July 1, 1965, J. E. van Hinte, ed., 1966, p. 176-203, tables 1-13.—Using a Paleocene species of *Afrobolivina*.

Excursion to the Ewekoro area, western Nigeria.—Proc. 2nd West African Micropaleont. Colloquium, Ibadan, Nigeria, June 18-July 1, 1965, J. E. van Hinte, ed., 1966, p. 275-291, pls. 1, 2, text figs. 1-3 (map, columnar sections), table 1 (correl. table).—Illustrated check list includes 46 species of smaller Foraminifera (9 new and 13 indeterminate) from the Upper Cretaceous and Paleocene.

ROSS, CHARLES A. Late Paleozoic Fusulinacea from northern Yukon Territory.—Journ. Paleontology, v. 41, No. 3, May 1967, p. 709-725, pls. 79-86, text figs. 1, 2 (map, diagram), table 1.—Nineteen species (9 new and 6 indeterminate).

Eoparafusulina from the Neal Ranch Formation (Lower Permian), west Texas.—Journ. Paleontology, v. 41, No. 4, July 1967, p. 943-946, pl. 124, text fig. 1 (phylogenetic diagram).—A new species and a new subgenus.

SABINS, FLOYD F., JR., and ROSS, CHARLES A. Stratigraphy and fusulinids of Naco Group in Chiricahua and Dos Cabezas Mountains, Arizona.—New Mexico Geol. Soc., Guidebook, 16th Field Conf., Oct. 15-17, 1965, p. 148-157, text figs. 1-5 (columnar sections, map, drawings of fusulinid sections, range charts).

SALAJ, JOZEF, BIELY, ANTON, and BYSTRICKY, JAN. Die Foraminiferen in der Trias der Westkarpaten.—Archives des Sci., v. 19, fasc. 2, May-Aug. 1966, p. 211-218, pls. 1, 2.—Fifteen species illustrated in thin sections of rock.

SAMANTA, BIMAL K. *Discocyclina* from the early Tertiary sediments of Pondicherry, south India. —Micropaleontology, v. 13, No. 2, April 1967, p. 233-242, pl. 1, text figs. 1-5 (map, outlines, graph, drawings), tables 1-6.—*D. ramaraoi* n. sp. from upper Paleocene and lower Eocene.

SANDERSON, G. A. A bibliography of the family Fusulinidae, addendum 4.—Journ. Paleontology, v. 41, No. 4, July 1967, p. 1006-1012.

SASTRI, V. V. A note on the Foraminifera and Ostracoda from the Inter-trappean beds near Rajahmundry.—Records Geol. Survey India, v. 92, pt. 2, 1963, p. 299-310, pl. 35.—Four species of Foraminifera, 2 new, from the lower Eocene.

SASTRI, V. V., CHANDRA, A., and PANT, S. C. Foraminifera from the Raghavapuram shales near Tirupati, Andhra Pradesh.—Records Geol. Survey India, v. 92, pt. 2, 1963, p. 311-314, pl. 36.—An arenaceous assemblage from the Lower Cretaceous: 2 species and a new variety.

SCOTT, G. H. Description of an experimental class within the Globigerinidae (Foraminifera)—2. —New Zealand Journ. Geol. Geophysics, v. 10, No. 1, March 1967, p. 55-73, text figs. 1-16 (graphs and drawings), table 1.

SEIGLIE, GEORGE A., and BERMUDEZ, PEDRO J. Notes on genus *Tosaia* Takayanagi in America and description of a new species.—Caribbean Journ. Sci., v. 6, No. 1 & 2, March-June 1966, p. 65-69, pl. 1, text figs. 1, 2 (drawing, graph). —Recent off Venezuela and in the Miocene of Venezuela and Panama.

SINNI, ELENA LUPERTO. Presenza di Foraminiferi Giurassici nei Calcari con selce di S. Fele.—Boll. Soc. Geol. Ital., v. 85, fasc. 2, 1966, p. 275-285, text figs. 1-7 (photomicrographs).—Mainly *Protopeneroplis*, *Labyrinthina*, and *Involutina*.

SKINNER, JOHN W., and WILDE, GARNER L. *Eowaeringella*, new generic designation for fusulinids of the group of *Wedekindellina ultimata* Newell and Keroher.—Journ. Paleontology, v. 41, No. 4, July 1967, p. 1004-1005.

STEHLI, F. G. Some applications of foraminiferal ecology.—Proc. 2nd West African Micropaleont. Colloquium, Ibadan, Nigeria, June 18-July 1, 1965, J. E. van Hinte, ed., 1966, p. 223-239, text figs. 1-14 (graphs, maps).—Models based on environmental responses in modern forms can be used in determining past features, such as bathymetry, oceanic circulation, polar wandering, etc.

TODD, RUTH, and LOW, DORIS. Recent Foraminifera from the Gulf of Alaska and southeastern Alaska.—U. S. Geol. Survey Prof. Paper 573-A, June 26, 1967, p. 1-46, pls. 1-5, text fig. 1 (map), tables 1, 2.—Illustrated systematic catalog includes 140 species, 3 indeterminate, none new.

TOWE, KENNETH M., and CIFELLI, RICHARD. Wall ultrastructure in the calcareous Foraminifera: crystallographic aspects and a model for calcification.—Journ. Paleontology, v. 41, No. 3, May 1967, p. 742-762, pls. 87-99.—Electron microscopic study based on 3 radial, 3 granular, and 3 porcellaneous species, illustrated by 33 electron photomicrographs. A major taxonomic division into radial and granular types is not supported but the porcellaneous group is distinct from the other two.

TURENKO, T. V. On Upper Cretaceous foraminifers of Naiba River in southern Sakhalin (English abstract of Russian text).—Akad. Nauk SSSR, Sibirskoe Otdel., Geol. i Geofiz., No. 12, 1966, p. 72-78, range and abund. chart.—Occurrence and abundance plotted for about 20 species in a section from Cenomanian to Paleocene.

ZERNETSKY, B. F., and SELIN, Y. I. Significance of finding *Nummulites litoralis* Zern. of the Boltysh depression for the stratigraphy of shallow Paleogene sediments (English abstract of Ukrainian text).—Dopovidi Akad. Nauk Ukrains'koj RSR, ser. geol., geofiz., khim., biol., 1967, No. 4, p. 302-305, text figs. 1-5.

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