

CONTRIBUTIONS
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254. THE MORPHOLOGY AND STRUCTURE OF *AMMONIA BECCARII* (LINNÉ)

By

RICHARD CIFELLI¹

U. S. National Museum, Washington, D. C.

ABSTRACT

This paper presents the results of an analysis of the external features, development of size and chambers, internal structure and nature of the wall of *Ammonia beccarii* (Linné). The specimens used for study are from the beach sands of Rimini. The following aspects of this species are of particular interest: 1) Growth is essentially uniform, but individuals differ in the relative rates of increase in number of chambers, size of diameter and degrees of whorl. 2) An imperforate plate, distinct in structure from the radial wall, covers the axial region of all but the final chamber. 3) The septa are single. 4) The components of the test wall are composed of both radially built and granular parts. 5) The radial wall is weakly laminated. The laminae do not envelop all of the previously formed part of the test with the addition of each chamber.

INTRODUCTION

Ammonia beccarii (Linné) is a species of unusual interest. Characteristically found in the littoral zones of the Recent seas, it has been recorded from the coastal areas in most parts of the world. The type area is in the Mediterranean, but records of the species include regions as remotely situated from each other as Iceland, Australia and South Georgia. Geologically, *Ammonia beccarii* is reported to range as far back in time as the Late Cretaceous. This distribution in time and space is truly remarkable for a species of benthonic Foraminifera and, if real, is a matter of considerable biogeographic importance. The fact is, however, that *Ammonia beccarii* is imperfectly known. The figures given in the literature vary considerably and the relationships of all the forms included in this species are not clear.

As a first step towards understanding the complex variety of forms included in *Ammonia beccarii* it is necessary to analyze in detail the test features of the species as it occurs in its type area. The present study includes an analysis of the internal structure and nature of the wall as well as the external features. The material examined is from the beach sands of Rimini, Italy, on the shores of the Adriatic Sea, which is in the region from which the species was originally described. Although only a single population of this species was examined, the results, even now, are of interest. The wall and test structure are, in some important respects, unlike what one would expect to find in a "typical" species of Rotaliidae such as *Ammonia beccarii*. The wall is composed of both radial and granular calcite and the structure of the test differs from *Rotalia trochidiformis* Lamarck, type species of *Rotalia*, in several

features which are currently used in the definition of superfamilies (Smout, 1954; Reiss and Merling, 1958; Loeblich and Tappan, 1961). The differences in wall and structure clearly point to a generic distinction between these two species but their relationships above the generic level cannot be determined until the wall and structure of many more species of Rotaliidae and Discorbidae have been examined.

I wish to thank the following persons for their advice on various aspects of this study and for their critical comments: Dr. George Switzer, Dr. David P. Raup, Dr. Raymond C. Douglass, Dr. Norman F. Sohl, Miss Ruth Todd, and Dr. Emile A. Pessagno, Jr. The drawings were prepared by Mr. Lawrence B. Isham, scientific illustrator, U. S. National Museum, and the thin sections were photographed by Mr. Jack Scott, photographer, U. S. National Museum.

THE PROBLEM OF THE GENERIC NAME

The species described here, originally designated *Nautilus beccarii* Linné, is most familiarly known as *Rotalia beccarii* (Linné). The type species of *Rotalia*, however, is *R. trochidiformis* Lamarck. The available genera which include *N. beccarii* as the type species are, according to Frizzell and Keen (1949): *Ammonia* Brünnich, 1771; *Hammonium* Fichtel and Moll, 1798; *Streblus* Fischer, 1817; *Turbinulina* Risso, 1826. Workers recognizing a generic distinction from *Rotalia* have most frequently used *Streblus*, although *Ammonia* is the oldest name. The reason is that there is doubt about the validity of *Ammonia*. That genus first appeared, in a post-Linnean sense, along with other genera in a work by Brünnich published in 1771. The International Commission on Zoological Nomenclature (1950, p. 313), acting on appeal from Winckworth for clarification of the genera, ruled that Brünnich's work was a valid publication for zoological purposes, with the acceptance or rejection of each genus to be decided on its individual merits. Later, the Commission (1954, Opinion 236) directed the insertion of Brünnich's work on the Official List of Works Approved as Available for Zoological Nomenclature. To my knowledge no specific action was ever taken on *Ammonia* and its position still remains unclarified. *Ammonia* has not been placed on either the "Official List" or the "Official Index." The problem in the case of *Ammonia* was that the genus originally included 2 species, *Nautilus beccarii* and *Nautilus spirula*, a cephalopod. This obstacle was removed, however, by Frizzell and Keen (1949, p. 106) who designated *N. beccarii* as the type

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species. Therefore, there do not appear to be any grounds for challenging the validity of *Ammonia*, and, as the oldest name, it has, nomenclaturally, a clear title to *Nautilus beccarii*. It is true that *Streblus* has been used considerably more frequently than *Ammonia*, but that usage has become common only in the last 15 years or so and would not seem well enough established to support an appeal for the conservation of the former name.

EXTERNAL FEATURES

Surface

This species has been well illustrated by Cushman (1928). The test is large, over one millimeter in most fully grown individuals, and the chambers are arranged in a low spire that is either slightly biconvex or planoconvex. The periphery is lobulate. The color of the test is light brown or tan. The surface is porous except for imperforate parts which include the septa, the base of the chambers on the ventral side (chamber flaps), and the fillings of clear calcite that occur in the sutures and in the umbonal area. On the dorsal side the clear calcite uniformly fills the sutural depressions so that the sutures are flush and the surface is smooth. The ventral sutures are incised and V-shaped. At the edges of the chambers are transverse shallow grooves which extend into the sutural areas. On the last chamber the grooves can be seen on the surface of the septum. Beads and knobs of calcareous fillings stud the sutural areas, and, in the lower part, connect with the chamber flaps. The accumulation of calcareous filling is greater in the early than in the late part of the test. The sutures between the earlier chambers tend to be completely filled, while those of the last few chambers are mostly open and deeply incised.

The umbonal cavity is a deep, rather wide opening centrally located on the ventral side. It is partially filled with a central plug and, occasionally, one or more smaller accessory plugs. Extending into the umbonal cavity are the chamber flaps, wedges of clear calcite, which originate from the base of the chambers.

Size

The data on the dimensions of the test given below are based on the measurements of 50 specimens. All of the specimens used were entire and there were no indications on any of them of breakage or loss of the final chambers. The specimens chosen do not represent a growth series; only specimens having at least 20 chambers were selected. The maximum number of chambers observed in an individual was 34. Within this observed range, the distribution was bimodal, with most specimens having either 23 or 27 chambers. In the measurements shown below, the mean refers to the specimens within the observed range.

	Observed range	Mean
Maximum diameter	.62 - 1.69 mm.	1.09 mm.
Minimum diameter	.50 - 1.52 mm.	.88 mm.
Ratio of maximum to minimum diameter	1.06 - 1.26	1.22
Thickness	.29 - .50 mm.	.39 mm.

The maximum and minimum diameters are almost equal and the test is nearly equidimensional. The ratio between the diameters varies within small limits and the shape of the test is consistently subrounded, with a slight elongation in the direction of the long diameter. The thickness is rather small relative to the greater diameter and the test is low spired.

Umbo

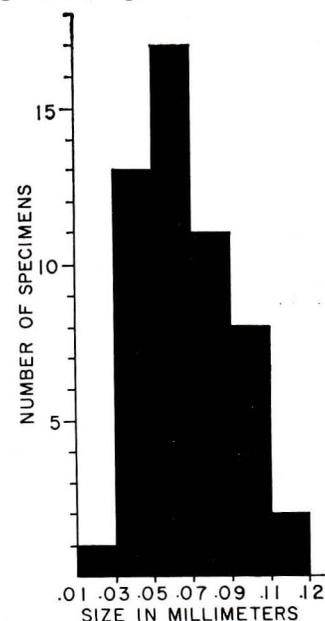
The umbonal area is partially filled with a plug of clear calcite in the center. The plug is an irregularly shaped solid mass that is often scalloped by shallow grooves. The size of the plug, though often large, is highly variable, and there are often one or more subsidiary plugs around the margin of the umbonal area. On occasional specimens the plug is completely absent and the umbonal area is an empty depression.

	Observed range	Mean
Size of umbonal plug	0 - .34 mm.	.17 mm.

THE CHAMBERS

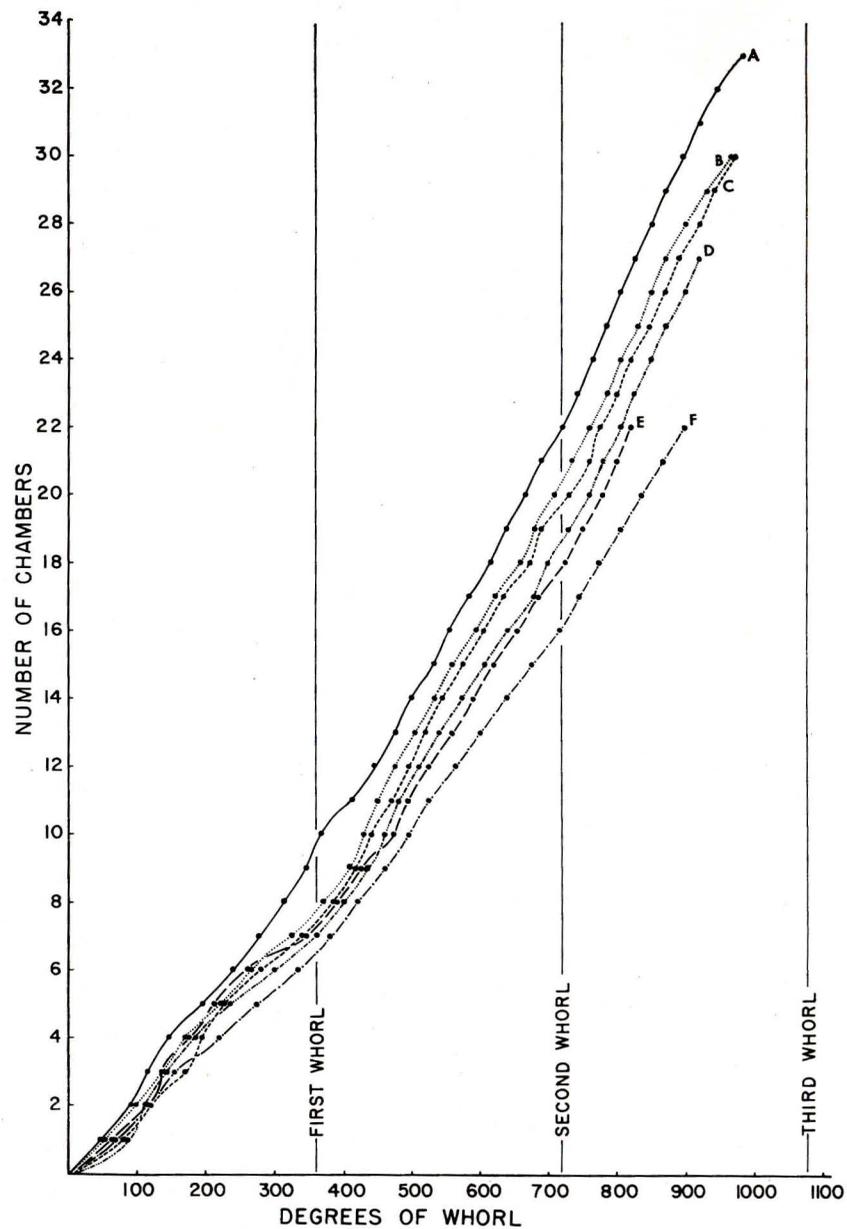
Proloculus

The proloculus is small compared to the total size of the test and no correlation was observed between prolocular size and total number of chambers, test size, or any other test feature which would indicate morphologic dimorphism. In the specimens studied there were no discontinuities and only a single mode in the frequency distribution of prolocular sizes within the observed range (text fig. 1).



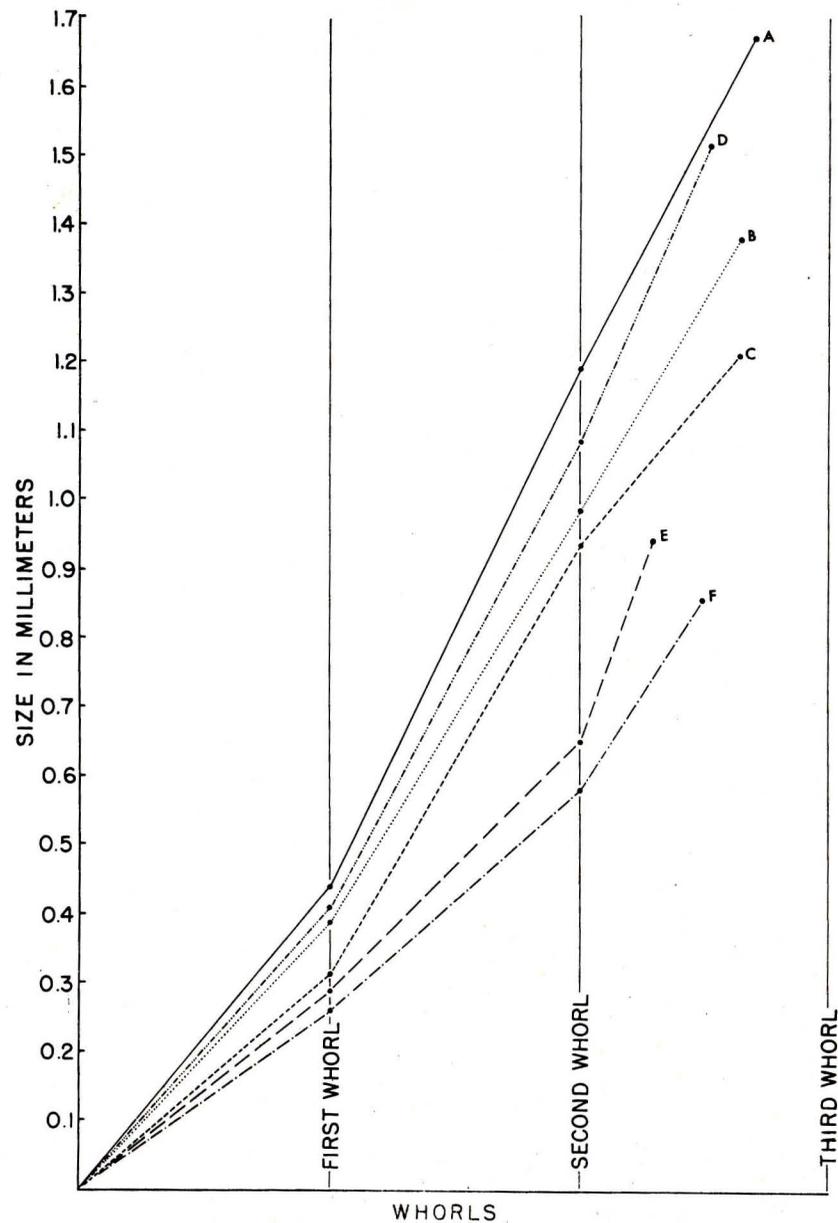
TEXT FIGURE 1

Prolocular sizes of 50 specimens of *Ammonia beccarii*.



TEXT FIGURE 2

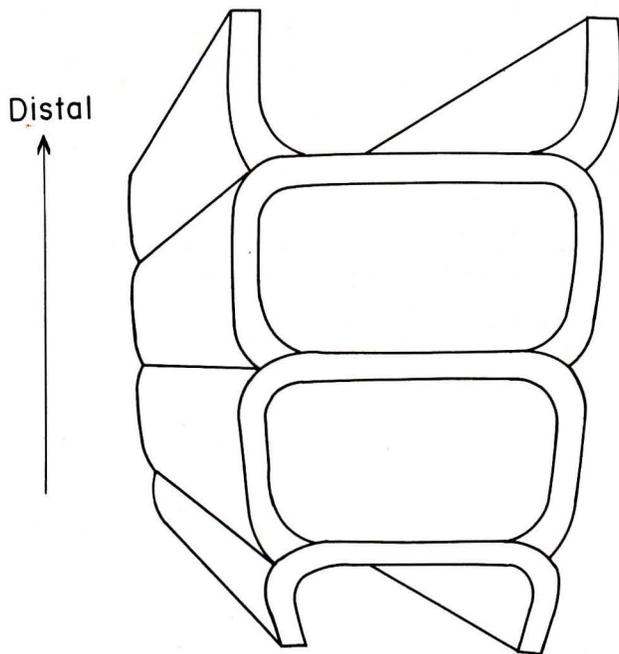
Growth curves of six specimens of *Ammonia beccarii*, showing rate of increase in number of chambers with respect to rate of increase in degrees of whorl.



TEXT FIGURE 3

Growth lines of the same six specimens as those used in text figure 2, showing rate of increase in size of diameter with rate of increase in whorls.

chamber. There are no enveloping laminae, so that the radial wall of each chamber is separate and distinct from the radial walls of other chambers. The radial wall of a new chamber is attached to the septum of the preceding chamber. The area of attachment is indented a short distance from the margin on the ventral side and extends along the septum, near the periphery, to the dorsal margin. The junction of the chambers is shown in text figure 4. It will be noted



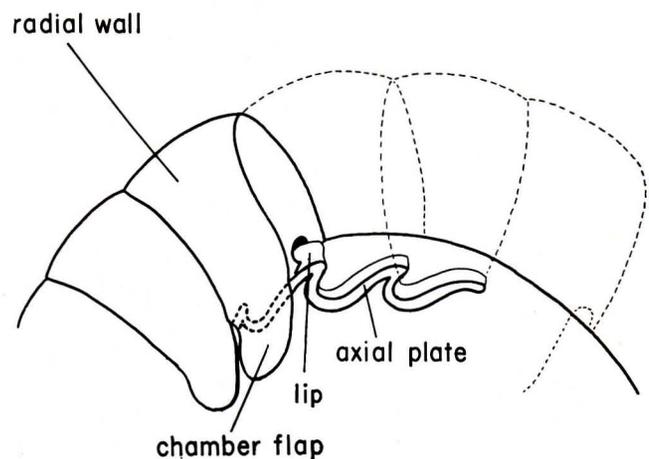
TEXT FIGURE 4
Sub-axial view through chambers of *Ammonia beccarii*.

that the septa are single, and that there is no doubling of the septal wall except along the area of attachment of the new chamber. On broken specimens a remnant of the radial wall can often be seen on the last whole chamber. It appears as a slight ridge on the septal face, indented from the ventral margin and periphery. The radial wall curves outward from where it joins the septum, and the suture on the ventral side and periphery is deeply depressed and V-shaped. In the last few chambers the depression is broad, but it narrows in the early part of the test, so that the beginning chambers are appressed and there is no space between them.

The junction of the chambers and the relationship between the radial wall and septum can be clearly observed in thin section. Under crossed nicols the radial wall exhibits radial extinction. When the stage is rotated the extinction shadow passes along the wall, but cuts out abruptly at the junction with the new chamber and continues down towards the septum. In the new chamber the extinction shadow stops at the junction and does not continue down towards the septum, except in portions of the section that have been cut through the part of the wall that is joined to the septum. The boundary between the chambers is sharp (pl. 22, figs. 3, 6). Occasionally, a wedge of cal-

careous filling is found in the suture which separates the radial walls of the chambers (pl. 22, fig. 3).

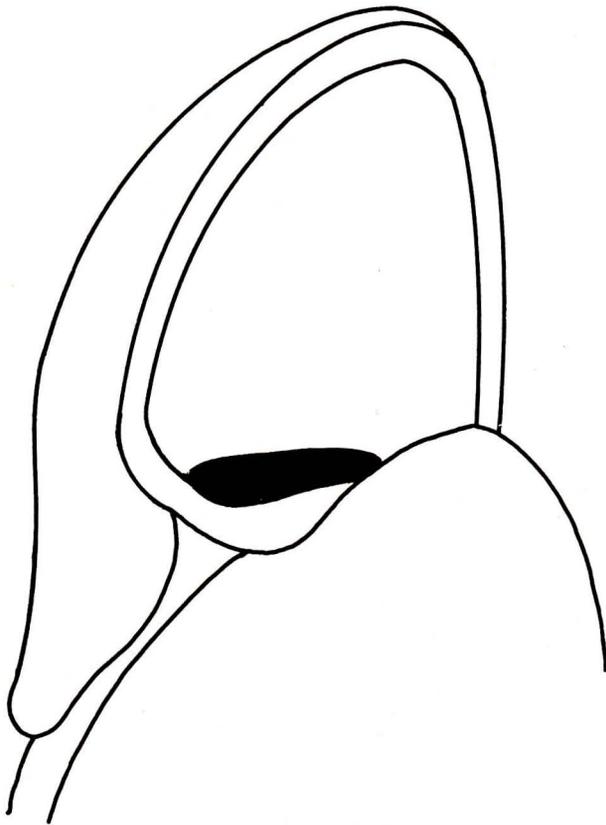
An important aspect of this species that may be easily overlooked, because complete specimens seldom occur, is that there is no wall in the axial region of the final chamber. In all of the remaining chambers there is an axial wall, but it is in the form of an imperforate plate (axial plate) and is distinct in structure from the radial wall. The axial plate corresponds to the toothplate of Reiss and Merling (1958). However, the axial plate, which in effect forms the axial wall of all but the last chamber in this species, bears so little resemblance to the toothplates described by Hofker (1951) that the latter term does not seem appropriate. The attachment of the axial plate and its relationship to the chamber are shown in text figure 5. On the ventral side the plate is connected in the



TEXT FIGURE 5
Perspective view of *Ammonia beccarii* with sides of chambers removed.

area where the radial wall passes into the chamber flap. The junction of these 3 wall parts form a solid, much thickened area, and, therefore, in all but the final chamber there is no opening into the umbilical area. The axial plate curves from the ventral side and extends dorsally where it abuts against the wall of the previous whorl. The axial plate projects anteriorly through the aperture at the bottom of the septum and forms a lip at the base of the aperture (text fig. 6). The apertural lip seen on septa of all chambers except the final one is the anterior projection of the axial plate. The posterior part of the axial plate of the next succeeding chamber is attached to the base of the lip of the previous chamber. In thin section the lip and axial plate, when preserved, appear as hook shaped structures (pl. 22, fig. 1).

The axial plate is the only structure to be seen inside of the chambers of dissected or sectioned specimens. The chambers are simple and there are no additional accessory plates or chamberlets, nor are there any internal passages or canals which would result from contortions of the axial plate. Since the axial plate is absent in the final chamber, it must form later than the remaining part of the wall in a chamber.



TEXT FIGURE 6
Apertural view of penultimate
chamber in *Ammonia beccarii*.

There is a lag of one chamber in the time of development of the axial plate as compared to the radial wall.

Aperture

Owing to the absence of the axial plate, the aperture of the final chamber differs from the apertures of all the remaining chambers. In the final chamber the aperture is an opening at the base of the septum that extends continuously beneath the chamber flap to the septum of the preceding chamber. Therefore, the chamber and the umbonal area beneath the chamber flap form a single open area. The shape of the aperture differs among specimens (text fig. 7), but some of the difference is probably due to breakage of the septum which, in the final chamber, is fragile.

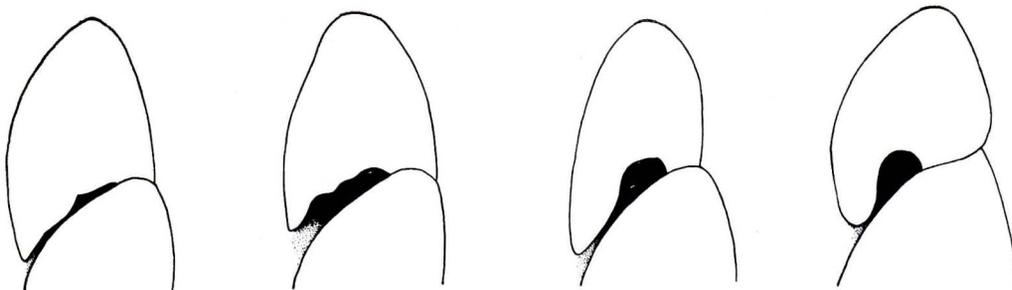
All of the remaining chambers are separated without communication from the umbonal area by the axial plate. The aperture in these chambers is a rather broad slit with a well-defined lip on the distal side of the base of the septum. As discussed above, this lip is actually the anterior projection of the axial plate of the preceding chamber.

Small, irregular openings are sometimes visible in the walls along the ventral sutures of the last few chambers. These openings are commonly interpreted as sutural pores of primary origin which provide this species with a means of communication between the chamber and the umbilical area. The primary origin of these pores, however, is questionable. They are sporadic in occurrence and irregular in size, position and shape; they do not have the appearance of pores, and are likely of secondary origin. The wall is thin and fragile in the last few chambers, particularly in that area where it folds into the suture and connects with the septum of the previous chamber. These sutural openings are probably formed by breakage of the wall.

NATURE OF THE WALL

The test wall, though composed entirely of calcite, is of a complex nature, consisting of both radial and granular parts. There is a sharp contrast between the radial wall which is finely perforate and composed of radial fibers and the septa which are imperforate and built of minute interlocking grains. The calcareous fillings are also imperforate and granular, although the umbo is coarsely crystalline.

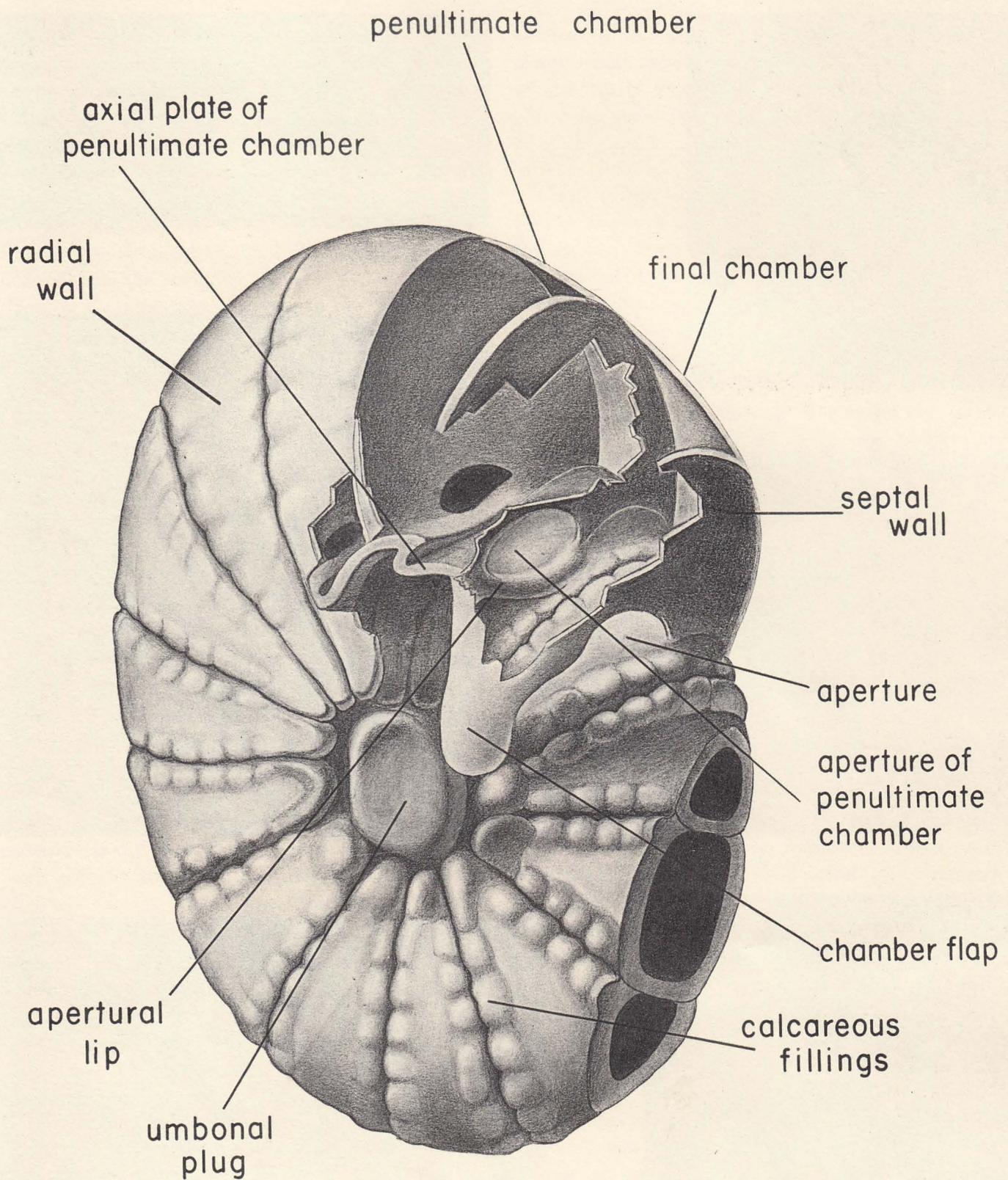
The calcite fibers in the radial wall are very slender and, in the material studied, could not be resolved under the microscope for measurement. The fibers extend throughout the thickness of the wall without apparent discontinuity. They are arranged mostly perpendicular to the surface of the wall, although in thin section they appear to bend and curve somewhat along their length. When viewed under crossed nicols, sections cut perpendicular to the wall surface exhibit a well-defined radial extinction pattern as the stage is



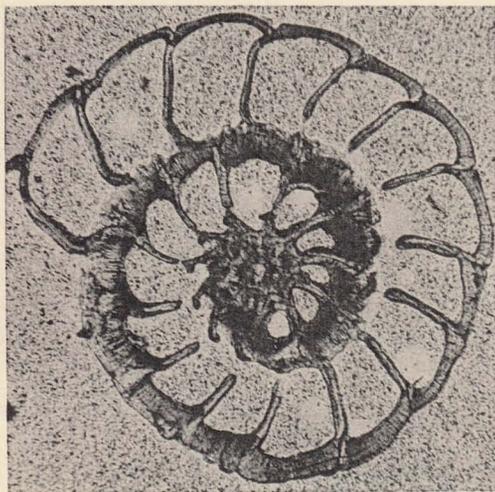
TEXT FIGURE 7
Apertural views of final chambers in *Ammonia beccarii*.

EXPLANATION OF PLATE 21

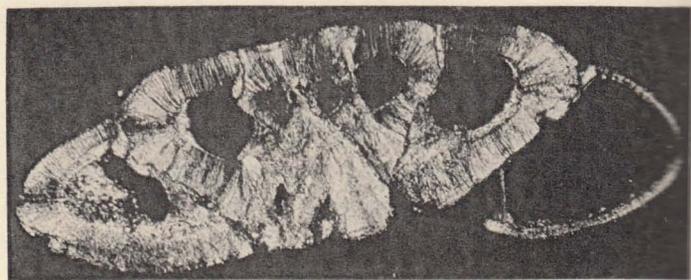
Cut away, perspective view of *Ammonia beccarii* (Linné) showing the components of the test.



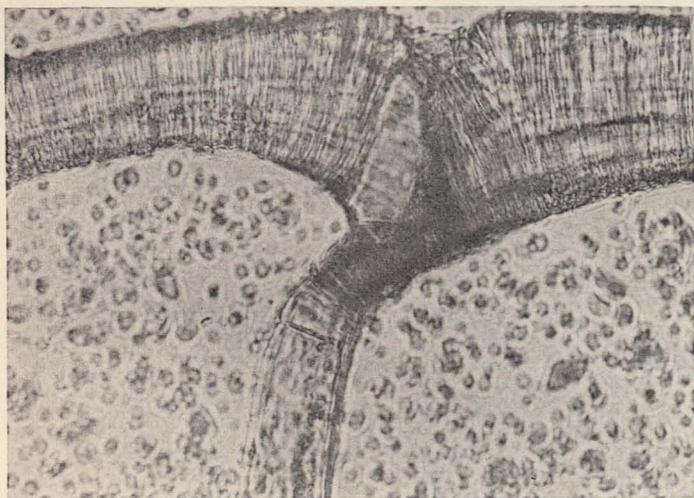
Cifelli: *Ammonia beccarii* (Linné)



1



2



3



4



5



6

rotated (pl. 22, fig. 6) while the surface of the wall shows a black cross (pl. 22, fig. 5).

The pores in the radial wall are fine and densely packed. They are circular in outline and have a diameter observed to range from .001 mm. to .0025 mm. The spacing between the pores is uniform, with the individual pores being about .003 mm. to .006 mm. apart. The pores are distributed throughout the radial wall, but stop abruptly at the boundary between the radial wall and the septum.

There is a considerable decrease in the thickness of the radial wall from the early to the late part of the test, with most of the decrease occurring in the final whorl. The thickening in the early part of the test is probably due to the addition of successive laminations to the radial walls of the chambers as the animal grew. This process was observed by Myers (1943, p. 16) in a living *Tretomphalus*. However, the laminations in *Ammonia beccarii* are often obscure, and in many sections they cannot be observed at all. Distinguishing them is made difficult by the fractures that develop in the wall as the section is being ground. The fractures are often aligned subparallel to the surface of the wall and have the appearance of laminations. Pessagno (personal communication, 1960) has noted that laminations are best seen in transverse section, under ordinary light without the condenser. At any rate, the laminations are poorly defined in this species. The laminations are confined to the individual chambers and there is no envelopment of laminae over the previously formed part of the test with the addition of each new chamber, such as is found in *Rotalia trochidiformis* (Smout, 1954; Reiss and Merling, 1958).

The radial wall is continuous with the septum but the boundary where the nature of the wall changes from radial-perforate to granular-imperforate is rather sharp (pl. 22, fig. 6). The grains in the septum are interlocking and variable in shape and size. Most of the grains are less than 10 microns, but some are much larger, observed to reach 75 microns. The surface of the septum has a rough, mottled appearance. No laminations were observed in the septum, but the grains appear to be aligned roughly parallel to the surface of the septum.

The chamber flap and calcareous fillings, like the septum, are imperforate and granular. There are dif-

ferences in details of the grain, however, that are still obscure and require further study. The umbo is a solid, coarsely crystalline mass (pl. 22, fig. 2). The grains are interlocking and are about .08 mm. in size.

DISCUSSION

Wood (1949) discussed the importance of the nature of the wall in the classification of Foraminifera. He showed that the hyaline Foraminifera included both radial and granular walled forms, although he did not imply that these forms necessarily represented separate natural groupings. In fact, Wood (1949, p. 242) stated, "the only thing that is certain is that when we know the minute wall-structure of all foraminifera we shall have the use of another character of importance which must be given due weight when building up evolutionary schemes." Later workers have been considerably less reserved than Wood about the significance of wall microstructure. In the recent literature it is not uncommon to find genera placed in separate families, or even superfamilies, for no other apparent reason than that one form has a radially built wall and another a granular one. *Ammonia beccarii* contains, in a single individual, both radial and granular parts. Clearly, the nature of the wall, at least as it is presently understood, cannot alone provide a natural basis for classifying the hyaline Foraminifera.

Ammonia beccarii has always been considered a close relative of *Rotalia trochidiformis* and, in fact, the two species are still sometimes regarded as congeners. *Rotalia trochidiformis* is an important species as it is the type species of the genus *Rotalia*. Its structure has been described by Davies (1932), Smout (1954) and Reiss and Merling (1958).

The most important features that the above species have in common are the well-developed rotalid form of the test and the occurrence on the test of imperforate parts. The imperforate parts appear as pustules and fillings in the sutural areas and as plugs in the umbonal area. There are also wedges of imperforate calcite at the bases of the chambers which extend into the umbonal area (chamber flaps). Moreover, in both species an imperforate plate, distinct from the radial wall, appears in the axial region of the chambers.

There are, however, important differences in the structures of these two species. First, the imperforate

EXPLANATION OF PLATE 22

FIGS.

Ammonia beccarii (Linné)

1. Axial section. $\times 36$.
2. Transverse section. $\times 36$. Under crossed nicols. Note the coarse crystals in the umbonal plug which have passed into extinction.
3. Tangential section. $\times 720$. Under crossed nicols. A mass of calcareous filling intervenes in the sutural area between the two chambers.
4. Surface of a portion of the septal wall. $\times 280$. Under crossed nicols. At the top of the photo the septal wall passes into the radial wall which is slightly out of focus.
5. Surface of a portion of the radial wall. $\times 280$. Under crossed nicols.
6. Tangential section. $\times 280$. Under crossed nicols.

plate in the axial region of the chamber is, in *Ammonia beccarii*, simple and confined to the axial wall of the chamber. In *Rotalia trochidiformis*, the plate is much more complex. According to Reiss and Merling (1958, p. 7), it is a contorted plate which extends along the lateral walls and posteriorly to the septum where it bends up and covers the septal face of the previous chamber, forming a double septum. The septum of *A. beccarii* is single, except near the margins where it is joined by the radial wall of the succeeding chamber.

The wall of *Rotalia trochidiformis* is strongly laminated. In *Ammonia beccarii* the laminations are poorly defined and are not always visible in thin section. Moreover, in *R. trochidiformis* the laminations extend into the umbo, but in *A. beccarii* the umbo is unlaminated. The most significant difference in laminations is that in *R. trochidiformis* the laminations are enveloping, and at each chamber they cover all of the previous part of the test. In *A. beccarii* there is no envelopment of the early part of the test and the wall is discrete for each chamber.

Another difference in the structure of the walls between the two species is in pore size. In *Ammonia beccarii* the pores are very fine, but in *Rotalia trochidiformis* they are extremely coarse (Davies, 1932, pl. 4, figs. 6, 9).

The differences between the two species discussed above are clearly sufficient to place these species in separate genera. The question about their degree of relationship above the generic level is problematic. Although there are resemblances which suggest close relationship, the differences involve characters which have been used in recent years to separate the rotaliform Foraminifera into separate superfamilies. *A. beccarii* does not fit the structural model of the Rotaliidae (Smout, 1954, Reiss and Merling, 1958) in that it has a single septum and does not have overlapping laminae. In these respects it is more like species of genera assigned to the Discorbidae. The structure and nature of the wall in most species of Foraminifera are still poorly known, however, and at present it is not possible to evaluate the relative importance of these resemblances and differences in the taxonomy of the rotaliform Foraminifera.

BIBLIOGRAPHY

- BROTZEN, FRITZ, 1942, Die Foraminiferengattung *Gavelinella* nov. gen. und die Systematik der Rotaliformes: Sver. Geolog. Undersökning, ser. C, no. 451, pp. 1-60, pl. 1, text figs. 1-18.
- CUSHMAN, J. A., 1928, On *Rotalia beccarii* (Linné), Contr. Cushman Lab. Foramin. Research, vol. 4, pt. 4, pp. 103-107, pl. 15.
- DAVIES, L. M., 1932, The genera *Dictyoconoides* Nuttall, *Lockhartia* nov., and *Rotalia* Lamarck: their type species, generic differences, and fundamental distinction from the *Dictyoconus* group of forms: Trans. Roy. Soc. Edinburgh, vol. 57, pt. 2 (no. 13), pp. 397-428, pls. 1-4, text figs. 1-10.
- FRIZZELL, D. L. and KEEN, M. A., 1949, On the nomenclature and generic position of *Nautilus beccarii* Linné (Foraminifera, "Rotaliidae"): Jour. Paleontology, vol. 23, no. 1, pp. 106-109.
- HOFKER, J., 1951, The toothplate - Foraminifera: Archives Néerlandaises Zool., vol. 8, 4 e livr; pp. 353-373, text figs. 1-30.
- International Commission on Zoological Nomenclature, 1950, Conclusions of the twelfth meeting: Bull. Zool. Nomenclature, vol. 4, pts. 10-12, pp. 255-350.
- LOEBLICH, A. R., JR. and TAPPAN, HELEN, 1961, Suprageneric classification of the Rhizopodea: Jour. Paleontology, vol. 35, no. 2, pp. 245-330.
- MYERS, E. H., 1943, Biology, ecology and morphogenesis of a pelagic foraminifer: Stanford Univ. publ., Univ. Ser., Biol. Sci., vol. 9, no. 1, pp. 1-30, pls. 1-4.
- REISS, Z. and MERLING, P., 1958, The structure of some Rotaliidea. Ministry of Develop., Geol. Survey, State of Israel, Bull. no. 21, pp. 1-19, pls. 1-5.
- SMOUT, A. H., 1954, Lower Tertiary Foraminifera of the Qatar Peninsula: British Museum (Natural History), London, 96 pp., 15 pls., 44 text figs.
- WOOD, ALAN, 1949, The structure of the wall of the test in the Foraminifera; its value in classification: Quart. Jour. Geol. Soc., London, vol. 104, pp. 229-255, pls. 13-15.

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255. DISTRIBUTION OF RECENT FORAMINIFERA
IN UPPER FLORIDA BAY AND ASSOCIATED SOUNDS

GEORGE W. LYNTS

Department of Geology, University of Wisconsin

ABSTRACT

The distribution of the total population and standing crop from upper Florida Bay and associated sounds was investigated for distributional factors. A total of 68 samples were collected and investigated for foraminiferal content and analyzed for per cent of sand, silt and clay. The total population was used to divide the area into four faunal provinces: upper Florida Bay, Blackwater Sound, Barnes Sound and Card Sound, and to further subdivide these provinces into brackish and more marine biotopes. The relative abundance of the Miliolidae, *Quinqueloculina lamarckiana* d'Orbigny and *Discorbis floridana* Cushman showed a direct relationship with salinity while that of *Streblus beccarii* (Linnaeus) and *Elphidium galvestonense* Kornfeld showed an inverse relationship. The whole area was characterized by the Miliolidae and was considered to be in the porcelaneous zone. The relationship between Foraminifera and sediment distribution was quantitatively analyzed and the results indicate that sediment size may be a factor controlling the distribution of certain Foraminifera. The quantitative considerations also indicate that the Foraminifera were not on the whole wave- or current-sorted. The study of the standing crop indicated that most of the families identified in the total population have living representatives in the area.

INTRODUCTION

This investigation is part of a project being undertaken to expand the knowledge of the ecology of benthonic Foraminifera in Florida Bay and its adjacent waters. The primary purpose of this report is to describe the foraminiferal distribution in upper Florida Bay and to discuss some of its ecologic implications. Upper Florida Bay is quite shallow, with depths ranging from less than a foot to about thirteen feet. The shallowness of the water makes this an ideal location for ecologic study, since essentially it makes the depth factor constant and allows for easier study of the other factors affecting Foraminifera. The correlation between faunal distribution and sediment distribution is quantitatively investigated.

Sixty-eight samples were collected in 1958 and 1960. Traverses F, G and H were collected during the summer of 1958 by Mr. James I. Jones and Mr. Thomas G. Gibson. Traverse S60 was collected during the winter of 1960 by the writer, Mr. James I. Jones and Mr. Wayne D. Bock. The majority of the samples were collected by dredging over a short distance and a few were collected by grab. Notation was made of the bottom type, and, when present, the type of plant life growing in the sampling area.

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation for the invaluable guidance and inspiration provided

by Dr. Roger L. Batten. Others who contributed to various aspects of the study are: Dr. Tj. H. van Andel and Dr. John B. Hayes who made suggestions regarding the sediment analysis; Mr. James I. Jones, Mr. Thomas G. Gibson, Mr. Wayne D. Bock and Miss Sally Scholz who assisted in the collection and preparation of the samples. Dr. James H. Torrie and Mr. J. Michael Widmier made valuable contributions to the study of the quantitative data.

The U. S. National Museum made available type specimens for comparison. I wish to thank the Institute of Marine Science, University of Miami, for the use of their facilities during various aspects of the study. The investigation could not have been undertaken without the funds provided by the Wisconsin Alumni Research Foundation.

PREVIOUS WORK

Vaughan (1918) compared shallow-water bottom samples from Murray Island, Australia, with samples from Florida and the Bahamas. This study included five samples from the Florida Keys, including the Tortugas. Cushman identified the species of Foraminifera present in the samples and found *Orbiculina adunca* (Fichtel and Moll) to be the most abundant species in the Florida Keys.

Cushman (1922) investigated the shallow-water Foraminifera of the Dry Tortugas. The study was primarily ecological and included observations of living Foraminifera.

Norton (1930) made an ecological study of Foraminifera from the waters of Australia and the Florida-Bahama region. He divided the Foraminifera into several ecological zones based on depth and temperature. The Peneroplidae and Miliolidae were found to be most abundant in the shallowest and warmest waters. He noted that these families decreased in abundance with depth.

Thorp (1939) made a study of calcareous marine deposits from the Florida and Bahama region. He stated that the Foraminifera were widely distributed and comprised about nine per cent of the deposits. The most abundant genera of Foraminifera found were: *Archaias*, *Peneroplis*, *Quinqueloculina*, *Clavulina* and *Valvulina*. He also found that occasionally pelagic forms would be swept into the shallow waters by waves and currents and contaminate the shallow-water deposits.

Stubbs (1940) made an investigation of the Foraminifera from the vicinity of Biscayne Bay. He described

23 genera and 61 species of which the Miliolidae and Peneroplidae were the predominant families. *Archaias angulatus* (Fichtel and Moll) was found to be the most abundant species.

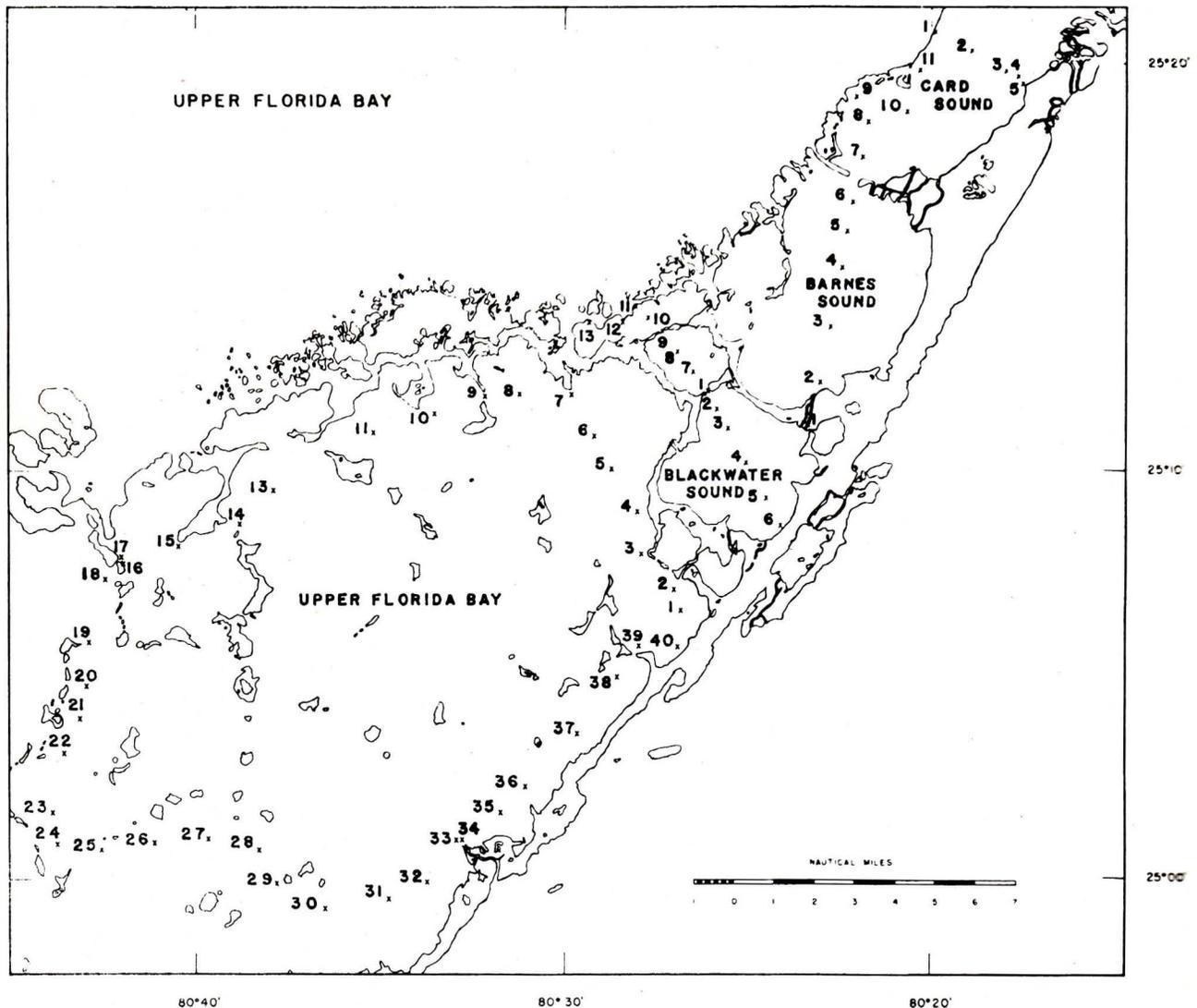
Bush (1949, 1958) made two studies of the distribution of Foraminifera in Biscayne Bay. The first described the general distribution of the Foraminifera. The second, a more comprehensive study, described the sediments and ecological distribution of the Foraminifera. He recognized thirteen biotopes in Biscayne Bay. These biotopes were predominated by porcelaneous species, but some contained a significant number of agglutinate and perforate species.

Moore (1957) made an ecological study of the Foraminifera in the northern Florida Keys. He divided the Foraminifera into four faunal provinces: Florida Bay, back-reef, reef and fore-reef. He found the Flor-

ida Bay environment dominated by the Peneroplidae, Miliolidae and Nonionidae. The families Amphisteginidae, Textulariidae, Lagenidae and Buliminidae were absent. *Rotalia beccarii* and *Cornuspiramia antillarum* (Cushman) were restricted to the Florida Bay environment. He stated that only species of the family Miliolidae were living in the Florida Bay environment and that the Florida Bay fauna was wave- or current-sorted.

LOCATION OF STATIONS

Upper Florida Bay is located south of the Peninsula of Florida. It lies between the Florida mainland and the Florida Keys. The area investigated lies between 25°21-59' North Latitude and 80°17-44' West Longitude. Text figure 1 shows the location of the stations, and Table 1 gives the geographic position and depth, in feet, of the stations.



TEXT FIGURE 1
Location of stations

TABLE 1. Location of stations, giving depth.

Station	N. Latitude	W. Longitude	Depth in feet	Station	N. Latitude	W. Longitude	Depth in feet
S60-1	25°06.5'	80°26.8'	5	S60-36	25°02.2'	80°31.1'	10
S60-2	25°07.1'	80°27.0'	4	S60-37	25°03.5'	80°29.6'	7
S60-3	25°07.9'	80°27.8'	5	S60-38	25°04.9'	80°28.6'	7
S60-4	25°08.9'	80°27.9'	3	S60-39	25°05.6'	80°28.0'	7
S60-5	25°10.0'	80°28.7'	4	S60-40	25°05.6'	80°26.9'	7
S60-6	25°10.7'	80°29.1'	5	F-1	25°11.8'	80°26.1'	3
S60-7	25°11.8'	80°29.7'	1	F-2	25°11.4'	80°25.8'	8
S60-8	25°11.8'	80°31.2'	3	F-3	25°11.0'	80°25.5'	10
S60-9	25°11.7'	80°32.2'	3	F-4	25°10.2'	80°25.0'	10
S60-10	25°11.4'	80°33.4'	3	F-5	25°09.3'	80°24.5'	9
S60-11	25°10.9'	80°35.1'	5	F-6	25°08.1'	80°24.0'	5
S60-13	25°09.5'	80°37.9'	3	F-7	25°12.4'	80°26.4'	5
S60-14	25°08.7'	80°38.8'	3	F-8	25°12.9'	80°26.9'	5
S60-15	25°08.2'	80°40.5'	3	F-9	25°13.4'	80°27.4'	5½
S60-16	25°07.8'	80°42.0'	3	F-10	25°13.7'	80°27.7'	5
S60-17	25°07.8'	80°42.0'	1	F-11	25°14.0'	80°28.0'	2
S60-18	25°07.3'	80°42.5'	6	F-12	25°13.6'	80°28.3'	3½
S60-19	25°05.8'	80°42.9'	2	F-13	25°13.6'	80°29.3'	3
S60-20	25°04.7'	80°43.0'	4	G-1	25°11.1'	80°23.3'	11
S60-21	25°04.0'	80°43.1'	6	G-2	25°12.1'	80°23.0'	8½
S60-22	25°03.5'	80°43.5'	5	G-3	25°13.5'	80°22.7'	13
S60-23	25°01.6'	80°43.9'	7	G-4	25°14.9'	80°22.4'	10
S60-24	25°00.9'	80°43.7'	8	G-5	25°15.8'	80°22.2'	10½
S60-25	25°00.7'	80°42.5'	4	G-6	25°16.6'	80°22.1'	10
S60-26	25°00.9'	80°41.1'	8	G-7	25°17.7'	80°21.9'	9
S60-27	25°01.0'	80°40.4'	4	G-8	25°18.5'	80°21.7'	8
S60-28	25°00.7'	80°38.3'	8	G-9	25°19.2'	80°22.0'	3
S60-29	24°59.9'	80°37.8'	6	G-10	25°18.8'	80°20.7'	10
S60-30	24°59.3'	80°36.5'	6	G-11	25°19.8'	80°20.3'	9½
S60-31	24°59.5'	80°34.8'	8	H-1	25°20.7'	80°19.9'	8
S60-32	24°59.9'	80°33.7'	6	H-2	25°20.3'	80°18.9'	11
S60-33	25°00.9'	80°32.8'	6	H-3	25°19.8'	80°17.9'	11
S60-34	25°00.9'	80°32.8'	3	H-4	25°19.7'	80°17.6'	7
S60-35	25°01.6'	80°31.7'	9	H-5	25°19.4'	80°17.4'	3

The stations have been divided into four traverses: Traverse S60, stations 1-40, upper Florida Bay, depth from one to ten feet; Traverse F, stations 1-13, Blackwater Sound, depth from two to ten feet; Traverse G, stations 1-6, Barnes Sound, depth from eight to thirteen feet, stations 7-11, Card Sound, depth from three to ten feet; and Traverse H, stations 1-5, Card Sound, depth from three to eleven feet.

METHOD OF STUDY

Neutralized formalin was added to the samples shortly after collection to preserve the protoplasm, so that the standing crop could be investigated. Formalin buffered with hexamethylenetetramine was used to produce a mildly alkaline solution. This buffered formalin must be tested periodically as it will become acidic with time, causing the loss of the calcium carbonate tests.

A protoplasm stain, rose Bengal (Walton, 1952),

was added to the samples, and they were allowed to stand for several hours. Rose Bengal stains protoplasm dark red, the intensity of color depending upon the length of time allowed to set, and makes possible the identification of the standing crop. The sediment was washed and sieved through a two millimeter screen. The sediment was then divided into two unequal portions. The larger portion was returned to bottles and buffered formalin added. The smaller portion was dried.

A microsplitter was used to divide the dried sediment to assure a random sample. Then, 0.25 gram of sediment was weighed and bottled. These 0.25 gram samples were spread onto a picking tray and picked of all Foraminifera; notation was made of all other organisms present. Counts of the total population and standing crop were then made. In the majority of the samples studied, between 200 and 1,300 specimens were counted.

Percentages of the total population, Table 2, are used to indicate the relative importance of the different species at each station, since they are accurate and easily comparable (Bandy, 1954). The standing crop, because of the small number of specimens present, is indicated by the absolute number of specimens found in each station, Table 3. This method of presentation compensates for the criticism of Said (1950), in that the size of the sample is given and does not give a misleading impression of abundance.

The larger portion of sediment, to which buffered formalin had been added, was then used in a wet sediment analysis, so the per cent of clay would not be obscured. The reader is referred to Krumbein and Pettijohn (1938) for the detailed procedure of sediment analysis. Percentages of sand, silt and clay are recorded in Figures 2, 3, 4 and 5.

OCEANOGRAPHY

There is a paucity of oceanographic work in upper Florida Bay, with articles by Davis (1940), Ginsburg (1956) and Goodell and Gorsline (1961) giving most of the known information. The following discussion is after Ginsburg (1956).

The oceanographic environment is quite rigorous, with widely fluctuating temperatures and salinities. The temperature varies from 19-38°C in the shallow water and from 20-30°C in the deeper water. The salinity fluctuates from 10-40 ‰, with the lowest salinities being found adjacent to the mainland. The most important changes in the level of upper Florida Bay are caused by the wind either blowing the water into or out of the bay. This steady wind also keeps the waters of the bay quite turbid throughout the year.

SEDIMENTS

This discussion of the sediments of upper Florida Bay is from Trask (*in* Thorp, 1939), unless otherwise noted. The sediments of upper Florida Bay are calcareous muds. It was found that the shoals consisted of sediment with a median diameter of approximately five microns, were poorly sorted and contained a few embedded shells. The sediment of the basins was found to consist largely of a shell breccia embedded in a marl matrix. Dr. H. Lowenstam (personal communication) suggests a probable sorting agent in *Thalassia*, which traps the fine sediments very effectively, giving areas of fine and coarse sediment. Trask and Ginsburg (1956) both found that the sediment in the basins was usually less than a foot thick and Trask stated that an underlying limestone apparently controls the depth of the basins.

The 68 samples studied are mainly calcareous muds, containing a little quartz at about half of the stations. Most of the stations containing quartz are in Blackwater, Barnes and Card Sounds. The coarser portion of the sediment is composed of shell detritus, the main constituents being mollusks, Foraminifera and ostra-

cods. The striking feature in the sediment analysis is the small amount of silt-size particles in the majority of samples (Text figs. 2-5). In upper Florida Bay, the majority of samples contain 60 per cent, or more, of sand-size particles. The sediment in Blackwater Sound contains varying amounts of sand- and clay-size particles. Both Barnes and Card Sounds have a sandy or sandy-clay sediment.

QUANTITATIVE CONSIDERATIONS OF FORAMINIFERA - SEDIMENT DISTRIBUTION

A quantitative analysis of the correlation between the distribution of the Foraminifera and the distribution of the sediments was undertaken. The analysis was made to investigate the possibility that the distribution of Foraminifera might be controlled by sediment size and also to determine whether the Foraminifera could have been wave- or current-sorted.

The quantitative methods used in the analysis were a test of correlation and a test of significance. Standard formulae were used to obtain the values of correlation (r) and of significant difference (t).

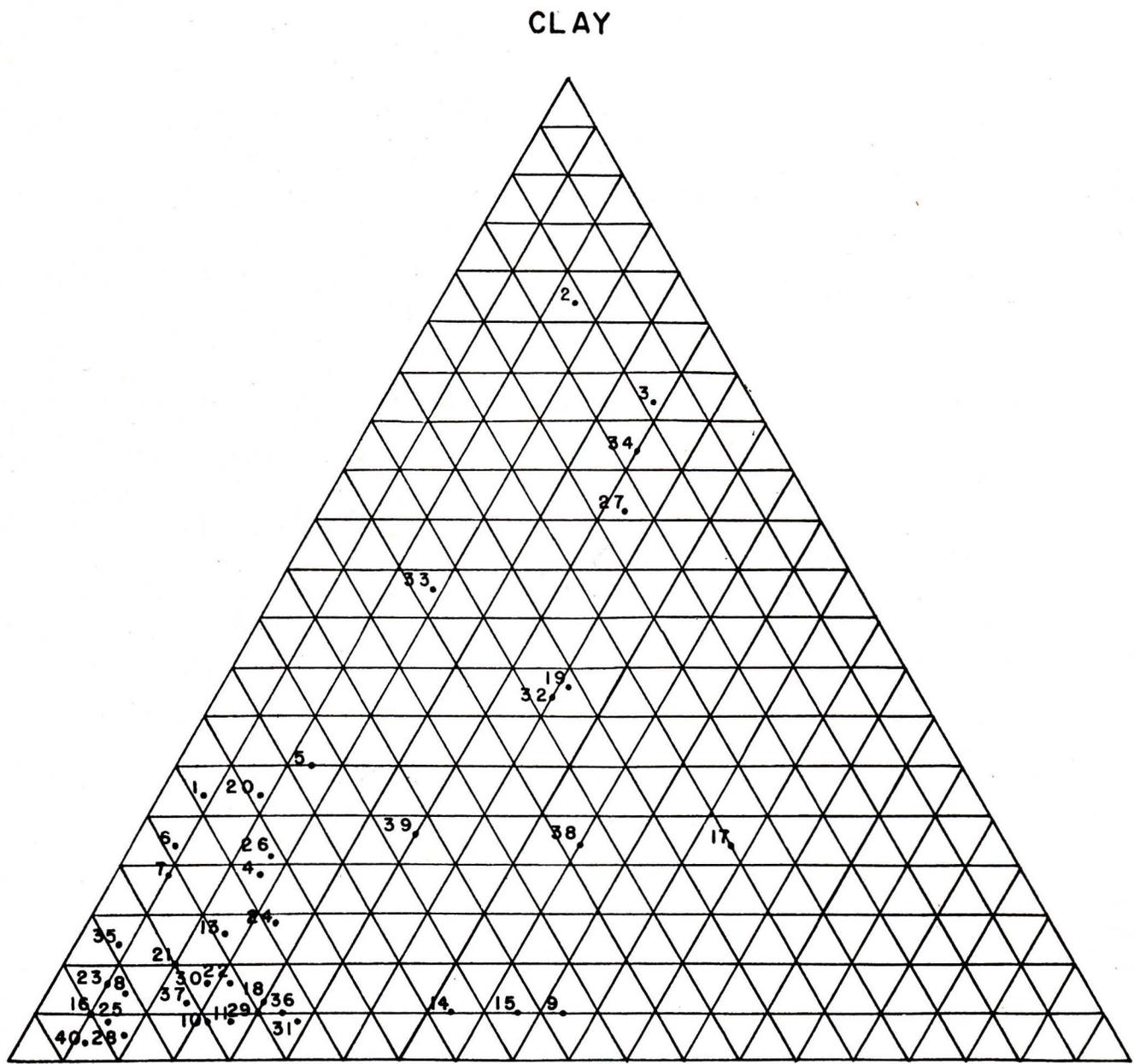
In order for correlation to be used, there must be a normal distribution. If the variable y is not present in more than 10-15 per cent of the observations, a normal distribution is not proved and correlation can not be performed (Torrie, personal communication).

In the investigation of the relationship between the distribution of the Foraminifera and the distribution of the sediment, all of the observations, in this instance all of the stations occupied, must be considered. It is necessary to consider the sediment at the stations without occurrence of the Foraminifera, as the sediment size may be the ecological factor prohibiting successful occurrence.

The groups that meet the above qualification are investigated by correlation. These results show the direct relationship between Foraminifera-sediment distribution. The groups which do not meet the above qualification are analyzed by the use of the t statistic. The t test is used to show whether or not there is a significant difference between the sediments in which the group is found and those where it is absent. The information gained by the use of the t test is therefore only an indication of correlation.

The quantitative analysis was performed on the family, generic and specific levels, and the results are recorded in Tables 4, 5 and 6. The taxonomic units which were analyzed by means of correlation did not indicate a high relationship between faunal-sediment distribution and therefore their distribution was not controlled by the sediments. Some of the units which were investigated by the t test did show a significant difference which indicated that their distribution was influenced by the sediments.

Table 4 shows that there is some indication of correlation between Foraminifera-sediment distribution in



SAND

TEXT FIGURE 2

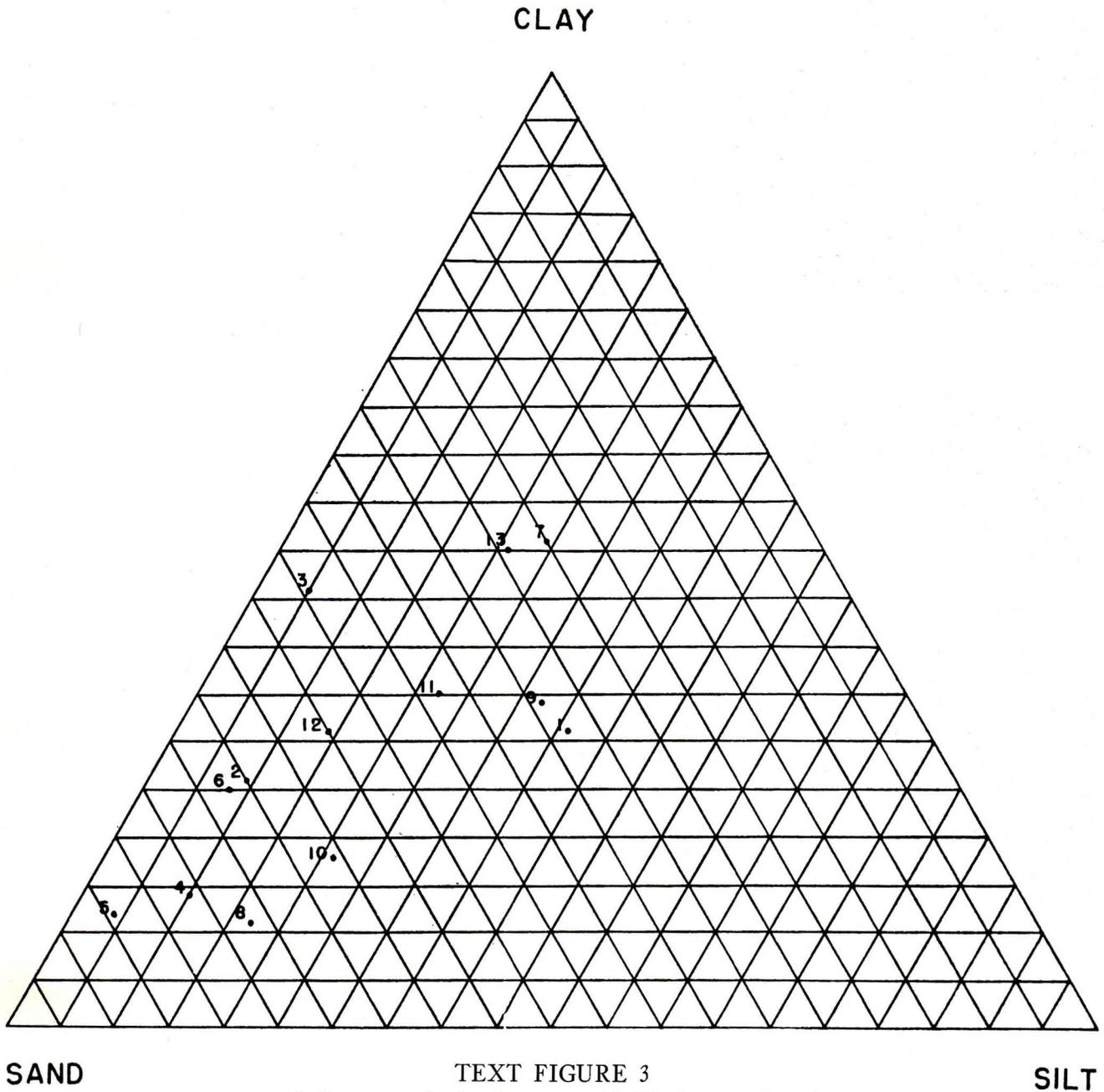
SILT

Sediment analysis of traverse S60, upper Florida Bay

TABLE 4. Relationship between family-sediment distribution.

Family	t, df ¹ 67			r		
	Sand	Silt	Clay	Sand	Silt	Clay
Rzehakinidae	0.965	0.883	0.595			
Ataxophragmiidae	2.127*	3.692**	0.437	+	-	
Nubeculariidae	1.907	1.535	3.418**			+
Miliolidae				-0.029	-0.132	0.110
Soritidae				0.406	-0.355	-0.264
Turriliniidae	0.481	0.064	0.528			
Bolivinitidae	2.462*	0.942	2.298*	-		+
Discorbidae	2.079*	3.064**	0.636	+		
Rotaliidae				-0.122	0.255	-0.010
Elphidiidae				-0.148	0.384	-0.061
Nonionidae	3.019**	0.142	3.809**	-		+
Cibicididae	0.109	0.990	0.465			
Spirillinidae	0.705	0.469	0.406			

1 df is the degrees of freedom
 * indicates significance to the 95 per cent level
 ** indicates significance to the 99 per cent level
 + indicates a direct relationship between variables
 - indicates an inverse relationship between variables



TEXT FIGURE 3
Sediment analysis of traverse F, Blackwater Sound

the families Ataxophragmiidae, Nubeculariidae, Bolivinitidae, Discorbidae and Nonionidae.*

Table 5 shows an indication toward correlation in the following genera:

- Schenckiella*
- Valvulina*
- Cornuspiroides*
- Nodobaculariella*

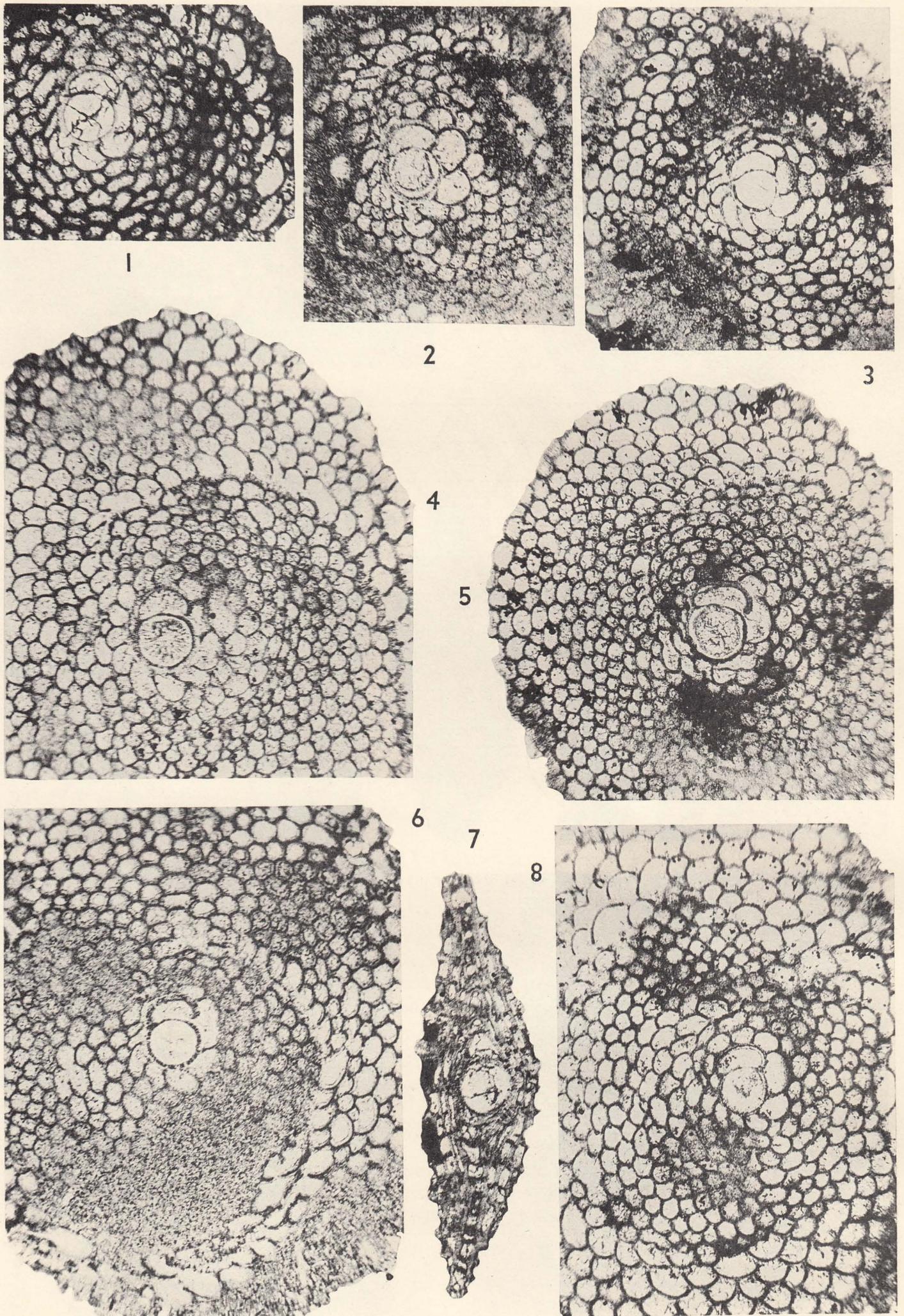
- Schlumbergerina*
- Bolivina*
- Discorbis*
- Rotalia*
- Nonion*

On the specific level, Table 6 shows that not all of the species of the above genera have the same relationship, or even a relationship, to Foraminifera-sediment distribution. It is interesting to note that while there

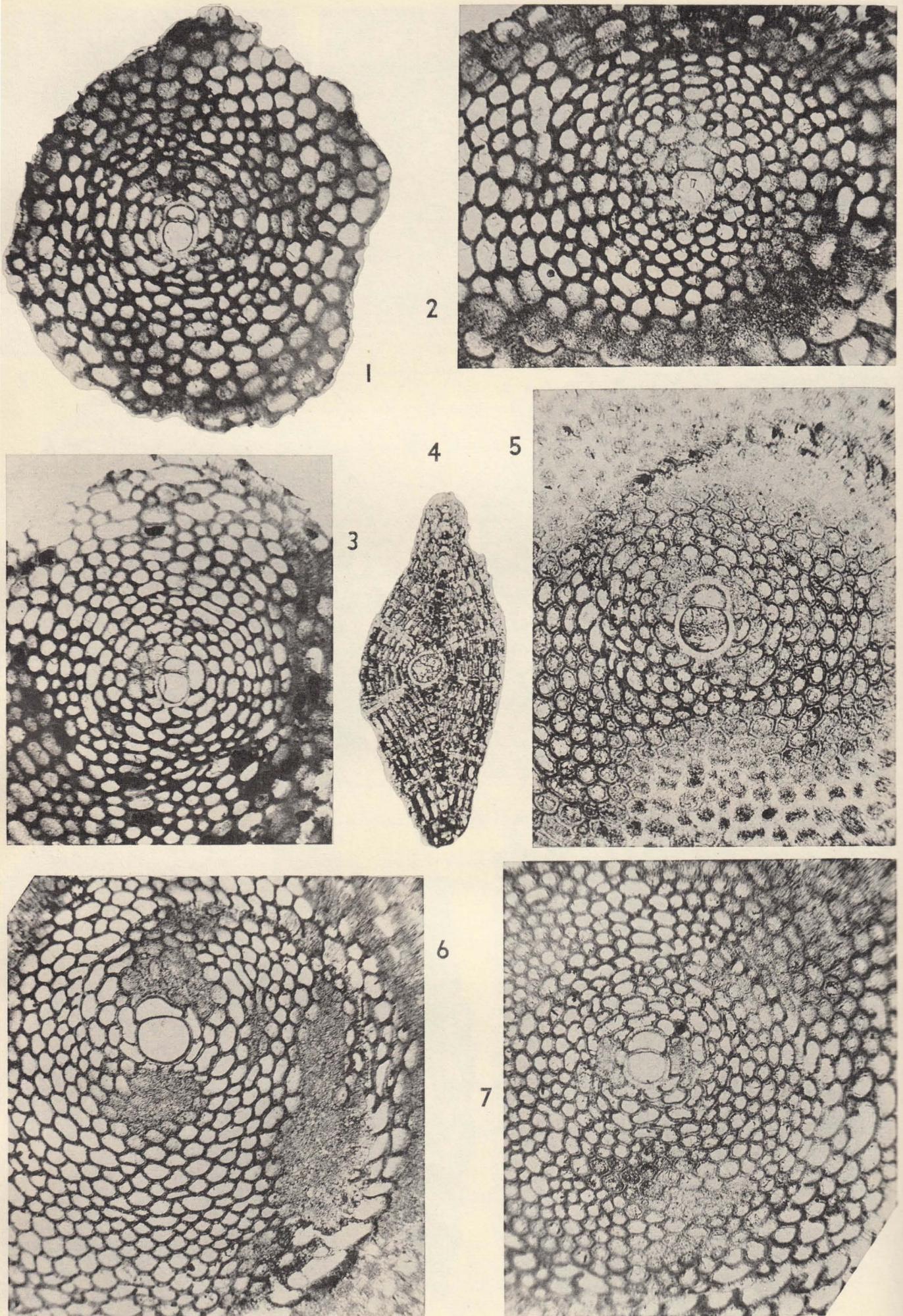
* Classification proposed by Loeblich and Tappan (1961).

EXPLANATION OF PLATE 23

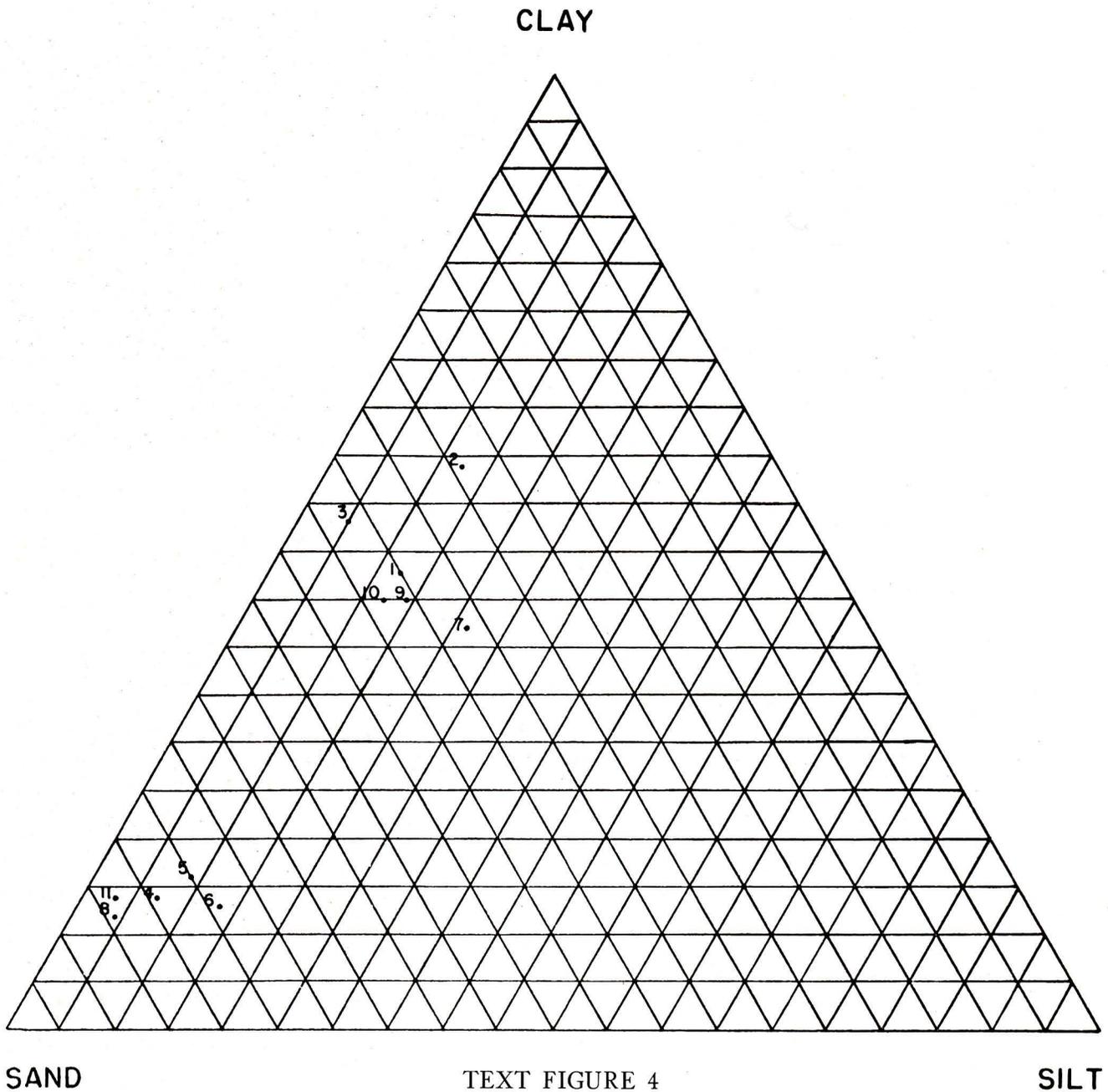
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| <p>FIGS.</p> <p>1-8. <i>Helicolepidina spiralis</i> Tobler</p> <p>1-6, 8. Parts of equatorial sections, $\times 40$; 1-5, 8, loc. 1; 6, loc. 2; for enlargements of the central part of fig. 1, see pl. 25, fig. 1, and for fig. 3, see pl. 25, fig. 2; figs. 3, 6 are Type I specimens; figs. 1, 2, 4 are Type II specimens; fig. 8 is a Type IIIa specimen; and fig. 5 is a Type IIIb specimen.</p> <p>7. Vertical section, $\times 40$; loc. 1.</p> | <p>PAGE</p> <p>146-9</p> |
|--|--------------------------|



Cole: Periechial chambers in *Helicolepidina*



Cole: Periembrionic chambers in *Helicolepidina*



TEXT FIGURE 4
Sediment analysis of traverse G, Barnes Sound

is a relationship on the generic level of *Bolivina*, none of its species show any relationship to Foraminifera-sediment distribution. Species showing an indication toward correlation to Foraminifera-sediment distribution, other than those of the above genera, are:

- Quinqueloculina polygona* d'Orbigny
- Quinqueloculina rhodiensis* Parker
- Triloculina rotunda* d'Orbigny
- Triloculina sidebottomi* (Martinotti)
- Elphidium crispum* (Linnaeus)

If the Foraminifera of upper Florida Bay are wave-

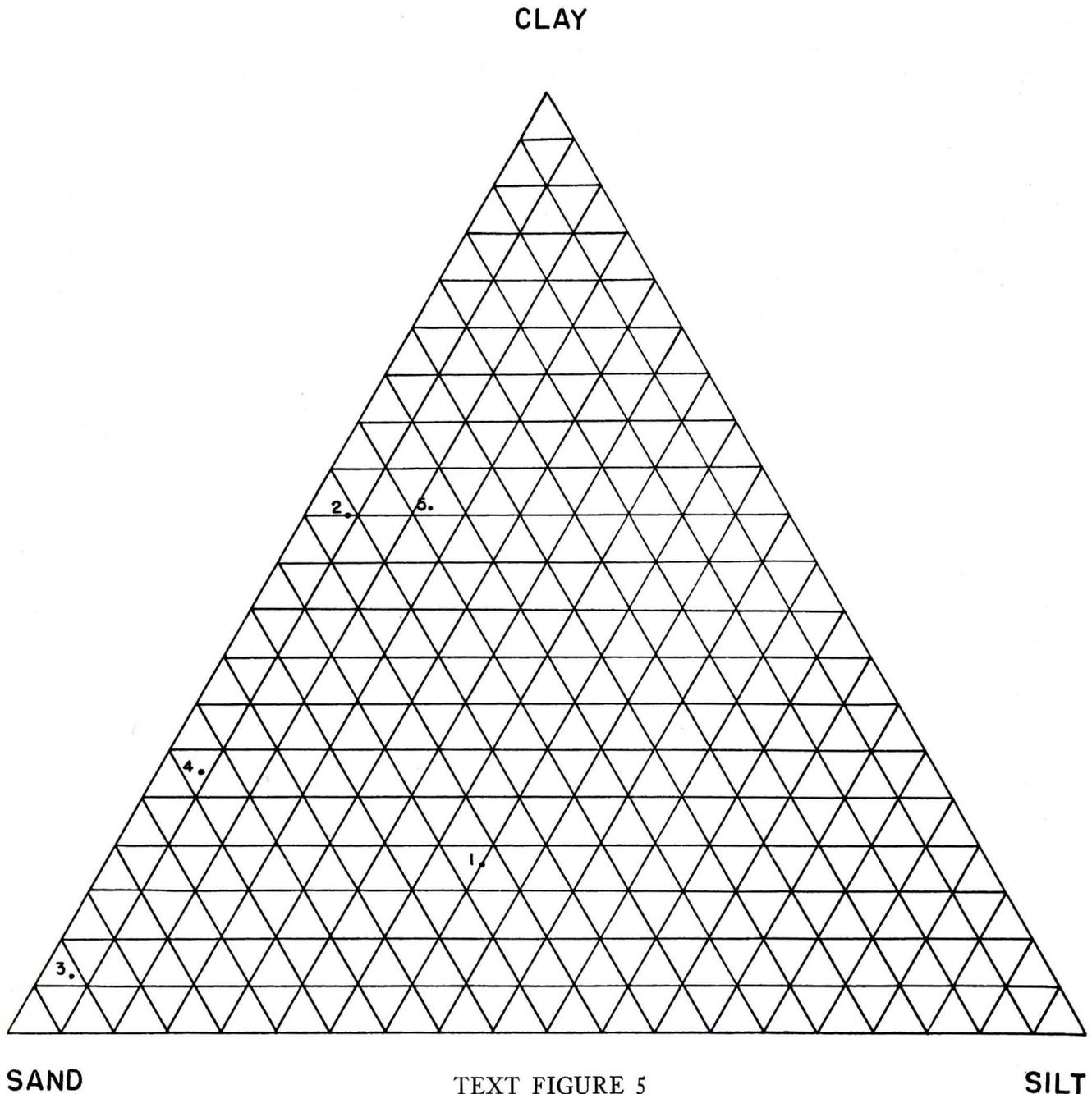
or current-sorted, as Moore (1957) suggested, it seems reasonable to assume that the majority of the species would show a high correlation to Foraminifera-sediment distribution. The results of the quantitative analysis performed on samples from upper Florida Bay and associated sounds do not show such a correlation.

FAUNAL ANALYSIS

The fauna of south Florida was stated to be Indo-Pacific by Cushman (1922); this is supported by the fact that most of the species identified in the Puerto

EXPLANATION OF PLATE 24

FIGS.	PAGE
1-7. <i>Helicolepidina spiralis</i> Tobler	147
1-3, 5-7. Parts of equatorial sections, X 40; 1-3, loc. 4; 5-7, loc. 3; for enlargement of the central part of fig 3, see pl. 27, fig. 1; all figures represent Type IIIb specimens; 1-3 are topotypes of <i>H. nortoni</i> Vaughan.	
4. Vertical section, X 20, loc. 3.	



Galera area, northern Mindoro, Philippines, by Graham and Militante (1959) occur in Florida Bay. This would suggest that the Florida Bay Foraminifera are a part of a cosmopolitan fauna.

Upper Florida Bay and its associated sounds have a maximum depth of about thirteen feet and therefore lie within the porcelaneous zone (Phleger, 1960). The fauna of the area is dominated by the Miliolidae, which occur abundantly (11-93%) at all of the stations. There is also a significant number of Rotaliidae and Elphidiidae occurring at most of the stations. The most commonly occurring species are:

Miliolinella circularis (Bornemann)
Quinqueloculina agglutinans d'Orbigny
Quinqueloculina lamarckiana d'Orbigny
Quinqueloculina poeyana d'Orbigny
Quinqueloculina sabulosa Cushman
Quinqueloculina seminulum (Linnaeus)

Quinqueloculina subpoeyana Cushman
Triloculina bassensis Parr
Triloculina bermudezi Acosta
Triloculina linneiana d'Orbigny
Triloculina oblonga (Montagu)
Triloculina trigonula (Lamarck)
Hauerina bradyi Cushman
Discorbis floridana Cushman
Streblus beccarii (Linnaeus)
Elphidium galvestonense Kornfeld

The area under investigation may be divided into four provinces for convenience. The provinces approximate the traverses (Text fig. 1): Traverse S60, upper Florida Bay; Traverse F, Blackwater Sound; Traverse G, stations 1-6, Barnes Sound; Traverses G, stations 7-11, and H, Card Sound. Table 2 gives the distribution of the total population.

The fauna of upper Florida Bay is distinguished by

TABLE 5. Relationship between genus-sediment distribution.

Genus	t, df 67			r		
	Sand	Silt	Clay	Sand	Silt	Clay
<i>Miliammina</i>	0.965	0.883	0.595			
<i>Schenckiella</i>	1.657	0.216	2.620*			+
<i>Clavulina</i>	0.106	1.778	1.000			
<i>Valvulina</i>	3.157**	4.680**	0.956	+	-	
<i>Cornuspiroides</i>	1.747	1.163	2.935**			+
<i>Cyclogyra</i>	1.626	0.764	1.456			
<i>Nodobaculariella</i>	0.945	1.343	2.054*			+
<i>Miliolinella</i>				-0.059	0.053	0.040
<i>Massilina</i>	0.357	0.861	0.101			
<i>Pyrgo</i>	0.581	1.813	0.402			
<i>Quinqueloculina</i>				-0.109	-0.170	0.238
<i>Spiroloculina</i>	0.105	0.976	0.350			
<i>Triloculina</i>				-0.053	-0.014	0.197
<i>Hauerina</i>				0.298	-0.089	0.291
<i>Schlumbergerina</i>	1.563	1.102	2.601*			+
<i>Articulina</i>	0.902	0.945	1.683			
<i>Peneroplis</i>	1.629	1.142	1.239			
<i>Spirolina</i>	0.659	0.955	1.392			
<i>Archaias</i>				0.457	-0.329	-0.326
<i>Sorites</i>	1.481	0.579	1.419			
<i>Buliminella</i>	0.481	0.064	0.528			
<i>Bolivina</i>	2.462*	0.942	2.298*	-		+
<i>Discorbis</i>	2.079*	3.064**	0.636	+	-	
<i>Rotalia</i>	0.714	2.923**	0.765			
<i>Streblus</i>				0.032	0.334	0.076
<i>Elphidium</i>				-0.148	0.384	-0.061
<i>Fursenkoia</i>	1.270	0.115	1.455			
<i>Nonion</i>	3.019**	0.142	3.809**	-		+
<i>Cibicides</i>	1.175	0.795	1.888			
<i>Gyroidinoides</i>	1.810	0.521	1.810			
<i>Spirillina</i>	0.705	0.469	0.406			

TABLE 6. Relationship between species-sediment distribution.

Species	t, df 67			r		
	Sand	Silt	Clay	Sand	Silt	Clay
<i>Miliammina fusca</i>	0.965	0.883	0.595			
<i>Schenckiella occidentalis</i>	1.657	0.216	2.620*			+
<i>Clavulina tricarinata</i>	0.106	1.778	1.000			
<i>Valvulina oviedoia</i> (Group 1)	2.407*	3.423**	0.829	+	-	
<i>Valvulina oviedoia</i> (Group 2)	2.132*	4.360**	0.063	+	-	
<i>Cornuspiroides foliacea</i>	1.747	1.163	2.935**			+
<i>Cyclogyra involvens</i>	1.626	0.764	1.456			
<i>Nodobaculariella cassis</i>	0.945	1.343	2.054*			+
<i>Miliolinella circularis</i>				-0.041	0.057	0.026
<i>Miliolinella fichteliana</i>	1.026	0.263	1.063			
<i>Miliolinella labiosa</i>	0.880	0.605	1.419			
<i>Massilina secans</i>	0.357	0.861	0.101			
<i>Pyrgo denticulata</i>	0.071	1.958	1.098			
<i>Quinqueloculina agglutinans</i>				0.391	-0.215	-0.193
<i>Quinqueloculina bidentata</i>	0.692	1.733	0.207			
<i>Quinqueloculina boschiana</i>				-0.364	0.083	0.373
<i>Quinqueloculina laevigata</i>	1.155	0.827	0.857			
<i>Quinqueloculina lamarckiana</i>	0.447	0.441	0.321			
<i>Quinqueloculina poeyana</i>				0.042	-0.002	-0.041
<i>Quinqueloculina polygona</i>	2.796**	0.310	3.155**	+		-
<i>Quinqueloculina rhodiensis</i>	0.322	2.033*	0.826			
<i>Quinqueloculina sabulosa</i>				-0.388	-0.088	0.521
<i>Quinqueloculina seminulum</i>				0.488	0.330	0.392
<i>Quinqueloculina subpoeyana</i>				0.050	-0.121	-0.010
<i>Quinqueloculina species</i>	1.809	0.651	1.704			
<i>Spiroloculina antillarum</i>	0.292	1.339	0.483			
<i>Spiroloculina arenata</i>	1.085	0.033	1.336			
<i>Triloculina bassensis</i>				0.413	-0.392	-0.249
<i>Triloculina bermudezi</i>				-0.017	0.015	0.026

TABLE 6 (cont.). Relationship between species-sediment distribution.

Species	t, df 67			r		
	Sand	Silt	Clay	Sand	Silt	Clay
<i>Triloculina carinata</i>	0.873	1.102	1.747			
<i>Triloculina linneiana</i>				-0.057	-0.066	0.109
<i>Triloculina oblonga</i>	0.500	0.171	0.491			
<i>Triloculina planciana</i>	0.640	1.105	0.079			
<i>Triloculina rotunda</i>	2.363*	0.043	2.833**	-		+
<i>Triloculina sidebottomi</i>	1.267	0.766	2.041*			-
<i>Triloculina trigonula</i>				-0.415	0.180	0.367
<i>Hauerina bradyi</i>				0.298	-0.089	0.291
<i>Schlumbergerina</i>						
<i>alveoliniformis occidentalis</i>	1.563	1.102	2.601*			+
<i>Articulina sagra</i>	0.902	0.945	1.683			
<i>Peneroplis carinatus</i>	1.527	0.535	1.239			
<i>Spirolina arietinus</i>	0.659	0.955	1.392			
<i>Archaias angulatus</i>				0.457	-0.329	-0.326
<i>Sorites marginalis</i>	1.481	0.579	1.419			
<i>Buliminella elegantissima</i>	0.481	0.064	0.528			
<i>Bolivina lowmani</i>	1.816	0.918	1.583			
<i>Discorbis floridana</i>	1.881	3.068**	0.411		-	
<i>Discorbis nitida</i>	0.767	1.107	0.255			
<i>Discorbis rosacea</i>	2.214*	2.571*	1.041	+	-	
<i>Rotalia translucens</i>	0.714	2.777**	0.765		-	
<i>Streblus beccarii</i>				0.032	0.334	0.076
<i>Elphidium advena</i>	1.033	0.800	1.620			
<i>Elphidium crispum</i>	1.690	0.833	2.562*			+
<i>Elphidium galvestonense</i>				0.166	0.292	-0.380
<i>Elphidium poeyanum</i>				-0.473	0.160	0.466
<i>Nonion depressulum</i>	2.942**	0.285	3.809**	-		+
<i>Nonion grateloupi</i>	1.026	0.116	1.306			
<i>Cibicides robertsonianus</i>	1.175	0.795	1.887			
<i>Gyroidinoides soldanii altiformis</i>	1.810	0.521	1.810			
<i>Spirillina vivipara</i>	0.705	0.469	0.406			

the rare occurrence of *Triloculina sidebottomi* (Martinotti). It may be possible to subdivide upper Florida Bay into two biotopes, brackish and more marine, on the basis of several species. The brackish biotope is located adjacent to the mainland, where drainage of fresh water from the mainland decreases the salinity, while the more marine biotope is located adjacent to the keys.

The Blackwater Sound fauna is distinguished by the rare occurrence of:

- Miliolinella fichteliana* (d'Orbigny)
- Miliolinella labiosa* (d'Orbigny)
- Quinqueloculina bidentata* d'Orbigny
- Quinqueloculina* sp.

The brackish biotope is recognized adjacent to the mainland in Blackwater Sound.

Barnes Sound may be distinguished by the lack of the Soritidae, which are quite abundant elsewhere in the area (Table 2). The two most common soritids, *Archaias angulatus* and *Peneroplis carinatus* d'Orbigny, occur at only one station. The stations in Barnes Sound appear to be in the more marine biotope.

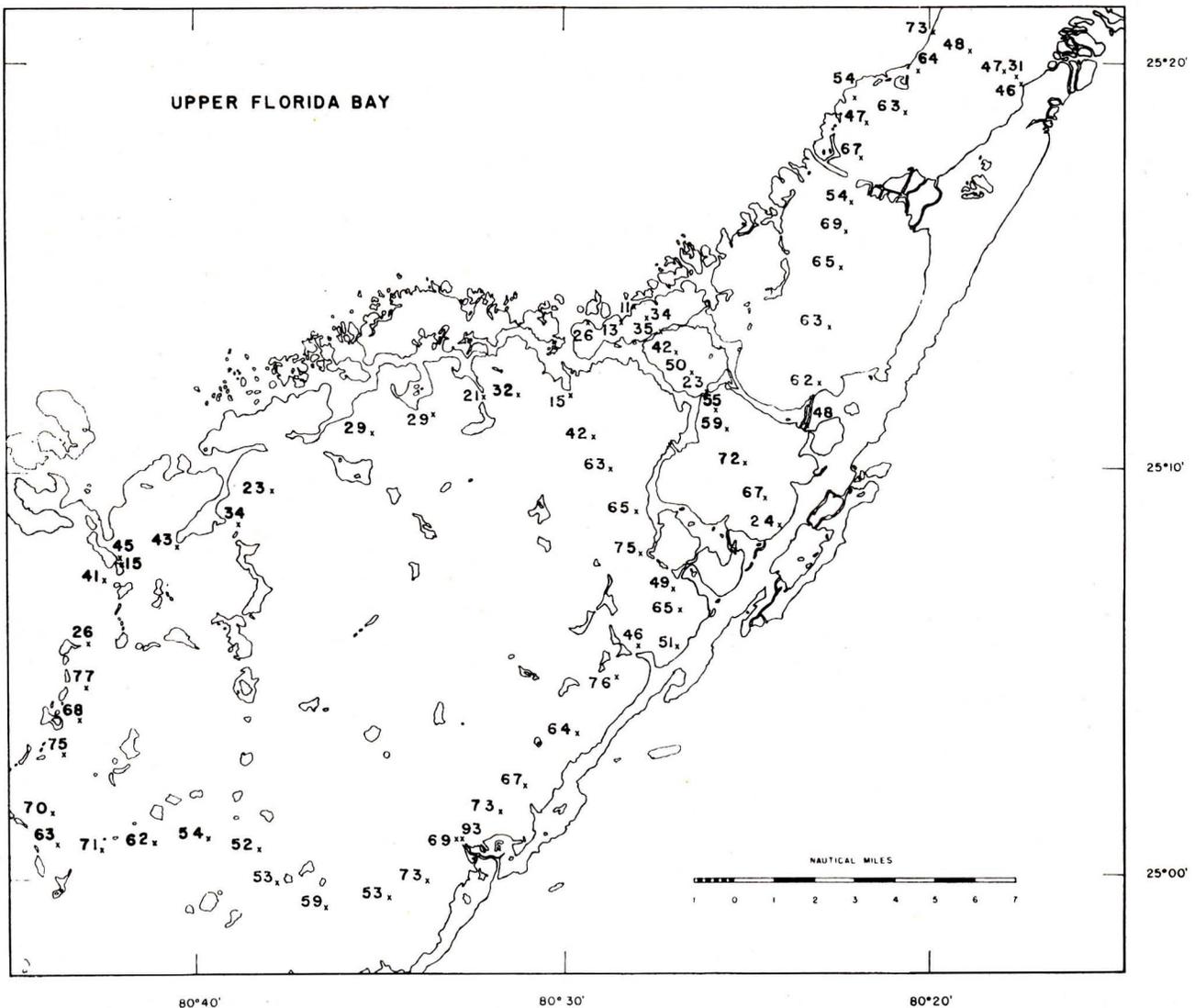
The fauna of Card Sound indicates a more marine biotope and is distinguished by the occurrence of *Articulina sagra* d'Orbigny at most stations. This species has rare occurrences outside of the sound.

The family Miliolidae (Text fig. 6) which occurs

abundantly at all of the stations, increases in per cent away from the mainland toward waters of increasing salinity. *Quinqueloculina lamarckiana* (Text fig. 7) and *Discorbis floridana* (Text fig. 8) also show this same relationship. *Streblus beccarii* (Text fig. 9) and *Elphidium galvestonense* (Text fig. 10) both of which occur commonly throughout the area, show an increase in per cent toward the mainland.

The distribution of the standing crop is presented in Table 3, which records the number of specimens present at each station. This table indicates a scarcity of living species throughout the area, but this is misleading due to the method of collection. The living Foraminifera occurs mainly in the top centimeter of the bottom sediment (Phleger, 1960); with the types of sampling used in this investigation, dredging and grab, the top centimeter would be mixed with much other sediment masking the per cent of living specimens at the station. The results of the study of the standing crop do not support Moore's (1957) findings, that only the Miliolidae are found living in Florida Bay. The families which are represented in the standing crop are:

- Ataxophragmiidae
- Nubeculariidae
- Miliolidae
- Soritidae



TEXT FIGURE 6
Distribution of the Family Miliolidae

Turrilinae
Bolivinitidae
Discorbidae
Rotaliidae
Elphidiidae
Nonionidae
Cibicididae

of which the Miliolidae are the most abundant. *Quinqueloculina bosciiana* d'Orbigny and *Quinqueloculina seminulum* (Linnaeus) are the most widely occurring living species, being present at 25 stations.

CONCLUSIONS

1. Upper Florida Bay is an area of rigorous ecological conditions. There are quite large fluctuations in salinity and temperature. The currents are complex within the area and the water is turbid throughout the year.

2. The sediments of upper Florida Bay and associated sounds are calcareous muds with little quartz. The sediment consists of sand- and clay-size particles with only a small amount of silt-size particles.

3. The foraminiferal fauna does not show a high

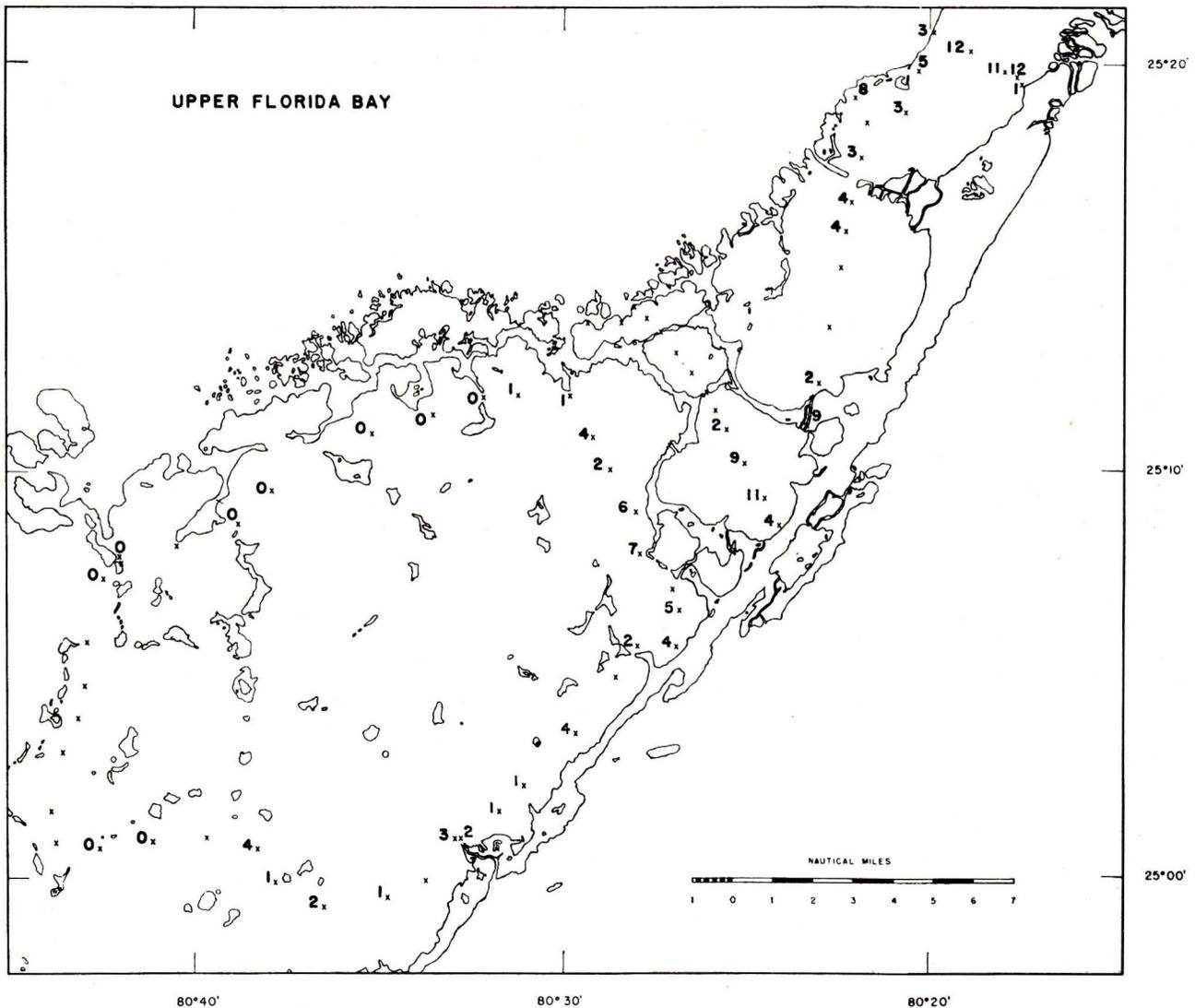
relationship to Foraminifera-sediment distribution. This is interpreted as indicating that the Foraminifera are not wave- or current-sorted.

4. Several species show an indication toward correlation to Foraminifera-sediment distribution. This suggests that sediment size may be an ecological factor influencing distribution in some species of Foraminifera.

5. Upper Florida Bay and associated sounds lie within the porcelaneous zone and may have a cosmopolitan foraminiferal fauna. The area can be divided into four faunal provinces distinguished by the presence of relatively rare species or lack of quite abundant species.

6. The faunal provinces can be further subdivided into brackish and more marine biotopes on the relative abundance of several species. *Streblus beccarii* and *Elphidium galvestonense* show an inverse relationship with salinity, while the family Miliolidae, *Quinqueloculina lamarckiana* and *Discorbis floridana* show a direct relationship with salinity.

7. Most of the families identified in the area have living representatives.



TEXT FIGURE 7

Distribution of *Quinqueloculina lamarckiana*

FAUNAL REFERENCE LIST

The original references to the species found in this study are listed in an order in which they would appear in the classification proposed by Loeblich and Tappan (1961). A complete taxonomy is given in Lynts (1961).

Miliammina fusca (Brady) = *Quinqueloculina fusca* Brady, 1870, Ann. Mag. Nat. Hist., vol. 6, p. 47, pl. 11, figs. 2a-c, 3.

Schenckiella occidentalis (Cushman) = *Clavulina occidentalis* Cushman, 1922, U. S. Natl. Mus., Bull. 104, pt. 3, p. 87, pl. 17, figs. 1, 2.

Clavulina tricarinata d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 111, pl. 2, figs. 16-18.

Valvulina oviedoiana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 103, pl. 2, figs. 21, 22.

Cornuspiroides foliacea (Philippi) = *Orbis foliaceus* Philippi, 1844, Enum. Moll. Sicil., vol. 2, p. 147, pl. 24, fig. 26.

Cyclogyra involvens (Reuss) = *Operculina involvens* Reuss, 1850, Denschr. Akad. Wiss. Wien, vol. 1, p. 370, pl. 46, fig. 30.

Nodobaculariella cassis (d'Orbigny) = *Vertebralina cassis* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 51, pl. 7, figs. 14, 15.

Miliolinella circularis (Bornemann) = *Triloculina circularis* Bornemann, 1855, Zeitschr. deutsch. geol. Ges., vol. 7, pt. 2, p. 349, pl. 19, figs. 4a-c.

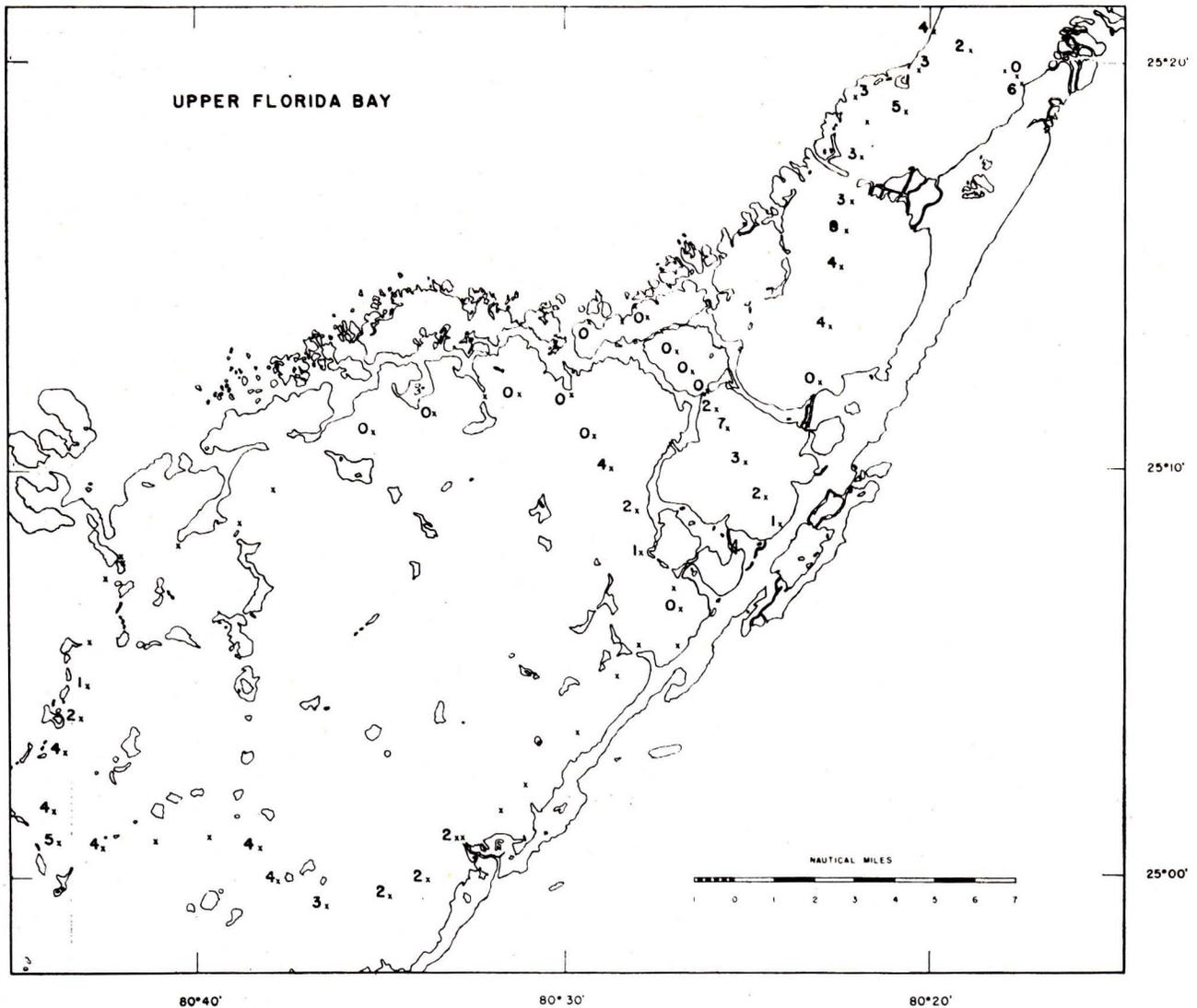
Miliolinella fichteliana (d'Orbigny) = *Triloculina fichteliana* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 171, pl. 9, figs. 8-10.

Miliolinella labiosa (d'Orbigny) = *Triloculina labiosa* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 157, pl. 10, figs. 12-14.

Massilina secans (d'Orbigny) = *Quinqueloculina secans* d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 303, No. 43, Modèles, No. 96.

Pyrgo denticulata (Brady) = *Biloculina ringens* Lamarck, var. *denticulata* Brady, 1884, Rep. Voy. Challenger, vol. 9, p. 143, pl. 3, figs. 4, 5.

Pyrgo subsphaerica (d'Orbigny) = *Biloculina subsphaerica* d'Orbigny, 1839, in de la Sagra, Hist.



TEXT FIGURE 8
Distribution of *Discorbis floridana*

Phys. Pol. Nat. Cuba, "Foraminifères," p. 162, pl. 8, figs. 25-29.

Quinqueloculina agglutinans d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 195, pl. 12, figs. 11-13.

Quinqueloculina bicornis (Walker and Jacob) = *Serpula bicornis* Walker and Jacob, 1798, in Adam's Essays Micr., Kanmacher's ed., p. 633, pl. 14, fig. 2.

Quinqueloculina bidentata d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 197, pl. 12, figs. 18-20.

Quinqueloculina boschiana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 190, pl. 11, figs. 22-24.

Quinqueloculina dilatata d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 192, pl. 11, figs. 28-30.

Quinqueloculina horrida Cushman, 1947, Contr. Cush. Lab. Foram. Research, vol. 23, pt. 4, p. 88, pl. 19, fig. 1.

Quinqueloculina laevigata d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 301, No. 6.

Quinqueloculina lamarckiana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 189, pl. 11, figs. 14, 15.

Quinqueloculina poeyana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 191, pl. 11, figs. 25-27.

Quinqueloculina polygona d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 198, pl. 12, figs. 21-23.

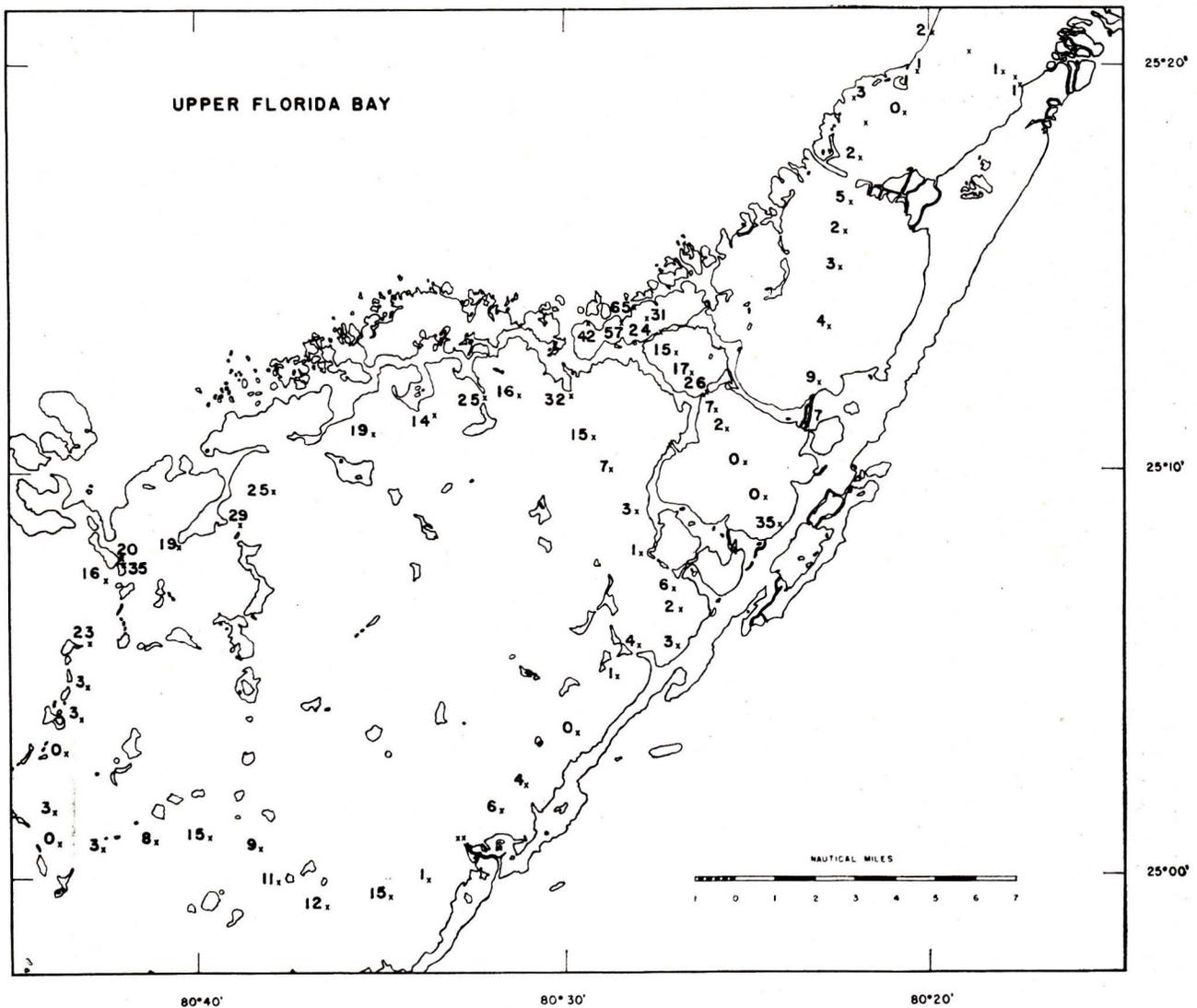
Quinqueloculina aff. *Q. reticulata* (d'Orbigny) = *Triloculina reticulata* d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 208.

Quinqueloculina rhodiensis Parker, 1953, in Parker, Phleger and Peirson, 1953, Cush. Found. Foram. Research, Spec. Publ. 2, p. 12, pl. 2, figs. 15-17.

Quinqueloculina sabulosa Cushman, 1947, Contr. Cush. Lab. Foram. Research, vol. 23, pt. 4, p. 87, pl. 18, fig. 22.

Quinqueloculina seminulum (Linnaeus) = *Serpula seminulum* Linnaeus, 1767, Syst. Nat., ed. 12, p. 1264.

Quinqueloculina subpoeyana Cushman, 1922, Publ. 311, Carnegie Instit., Washington, p. 66.



TEXT FIGURE 9
Distribution of *Streblus beccarii*

Spiroloculina antillarum d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 166, pl. 9, figs. 3, 4.

Spiroloculina arenata Cushman, 1921, Proc. U. S. Nat. Mus., vol. 59, p. 63, pl. 14, fig. 17.

Spiroloculina ornata d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 167, pl. 12, figs. 7, 7a.

Triloculina bassensis Parr, 1945, Roy. Soc. Victoria Proc., vol. 56 (n. ser.), pt. 2, p. 198, pl. 8, figs. 7a-c.

Triloculina bermudezi Acosta, 1940, Soc. Cubana Hist. Nat., Mem., vol. 14, no. 1, p. 37, pl. 4, figs. 1-5.

Triloculina carinata d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 179, pl. 10, figs. 15-17.

Triloculina linneiana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 172, pl. 9, figs. 11-13.

Triloculina oblonga (Montagu) = *Vermiculum oblonga* Montagu, 1803, Test. Brit., p. 522, pl. 14, fig. 9.

Triloculina planciana d'Orbigny, 1839, in de la Sagra,

Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 173, pl. 9, figs. 17-19.

Triloculina rotunda d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 299, No. 4.

Triloculina sidebottomi (Martinotti) = *Sigmoilina sidebottomi* Martinotti, 1920, Atti. Soc. Ital. Sci. Nat., vol. 59, pl. 2, fig. 29, text figs. 59-61.

Triloculina squamosa Terquem, 1878, Soc. Géol. France, Mém., sér. 3, tome 1, no. 3, p. 59, pl. 5, fig. 26.

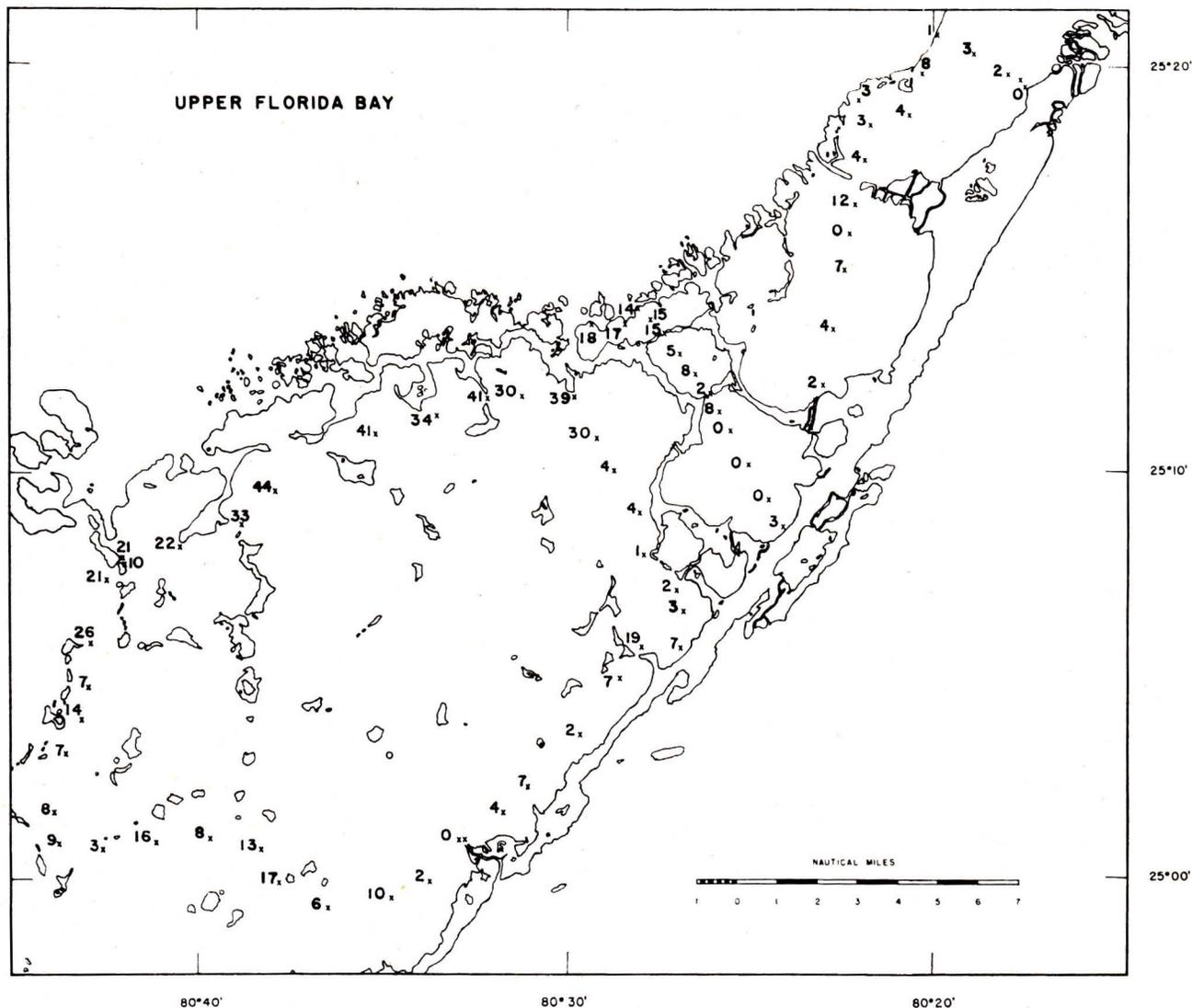
Triloculina trigonula (Lamarck) = *Miliola trigonula* Lamarck, 1804, Ann. Mus., vol. 5, p. 351, No. 3.

Hauerina bradyi Cushman, 1917, U. S. Natl. Mus., Bull. 71, pt. 6, p. 62, pl. 23, fig. 2.

Schlumbergerina alveoliniformis (Brady) var. *occidentalis* Cushman, 1929, U. S. Natl. Mus., Bull. 104, pt. 6, p. 36, pl. 7, fig. 2.

Articulina mucronata (d'Orbigny) = *Vertebralina mucronata* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 52, pl. 7, figs. 16-19.

Articulina sagra d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 160, pl. 9, figs. 23-26.



TEXT FIGURE 10

Distribution of *Elphidium galvestonense*

Peneroplis carinatus d'Orbigny, 1839, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères," p. 33, pl. 3, figs. 7, 8.

Peneroplis pertusus (Forskål) = *Nautilus pertusus* Forskål, 1775, Descr. Anim., p. 125, No. 65.

Peneroplis proteus d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 60, pl. 7, figs. 7-11.

Monalysidium politum Chapman = *Peneroplis* (*Monalysidium*) *polita* Chapman, 1900, Jour. Linn. Soc. London, Zool., vol. 28, p. 4, pl. 1, fig. 5.

Spirolina arietinus (Batsch) = *Nautilus* (*Lituus*) *arietinus* Batsch (part), 1791, Conch., Seesandes, p. 4, pl. 6, fig. 15c.

Archaias angulatus (Fichtel and Moll) = *Nautilus angulatus* Fichtel and Moll, 1803, Test. Micr., p. 112, pl. 21.

Sorites marginalis (Lamarck) = *Orbulites marginalis* Lamarck, 1816, Syst. Anim. sans Vert., vol. 2, p. 196, No. 1.

Buliminella elegantissima (d'Orbigny) = *Bulimina elegantissima* d'Orbigny, 1839, Voy. Amér. Mérid.,

vol. 5, pt. 5, "Foraminifères," p. 51, pl. 7, figs. 13, 14.

Bolivina hastata Phleger and Parker, 1951, Mem. Geol. Soc. America, vol. 46, pt. 2, p. 13, pl. 6, figs. 18a, b, 19.

Bolivina lowmani Phleger and Parker, 1951, Mem. Geol. Soc. America, vol. 46, pt. 2, p. 13, pl. 6, figs. 20a, b, 21.

Uvigerina auberiana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 106, pl. 2, figs. 23, 24.

Uvigerina peregrina Cushman, 1923, U. S. Natl. Mus., Bull., vol. 104, pt. 4, p. 166, pl. 42, figs. 7-10.

Discorbis floridana Cushman, 1922, Publ. 311, Carnegie Instit., Washington, p. 39, pl. 5, figs. 11, 12.

Discorbis nitida (Williamson) = *Rotalina nitida* Williamson, 1858, Rec. Foram. Gt. Britain, p. 54, pl. 4, figs. 106-108.

Discorbis rosacea (d'Orbigny) = *Rotalina rosacea* d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 273, No. 15, Modèles No. 39.

Planorbulina mediterraneensis d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 280, No. 2, pl. 14, figs. 4-6.

- Rotalia pauciloculata* Phleger and Parker, 1951, Mem. Geol. Soc. America, vol. 46, pt. 2, p. 23, pl. 12, figs. 8a, b, 9a, b.
- Rotalia translucens* Phleger and Parker, 1951, Mem. Geol. Soc. America, vol. 46, pt. 2, p. 24, pl. 12, figs. 11a, b.
- Streblus beccarii* (Linnaeus) = *Nautilus beccarii* Linnaeus, 1758, Syst. Nat., ed. 10, p. 710, pl. 1, figs. 1a-c, pl. 19, figs. h, i.
- Elphidium advena* (Cushman) = *Polystomella advena* Cushman, 1922, Publ. 311, Carnegie Instit., Washington, p. 56, pl. 9, figs. 11, 12.
- Elphidium crispum* (Linnaeus) = *Nautilus crispum* Linnaeus, 1758, Syst. Nat., ed. 10, p. 709.
- Elphidium galvestonense* Kornfeld = *Elphidium gunteri* Cole var. *galvestonensis* Kornfeld (part), 1931, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 3, p. 87, pl. 15, figs. 1a, b (not 2a, b, 3a).
- Elphidium poeyanum* (d'Orbigny) = *Polystomella poeyana* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 55, pl. 6, figs. 25, 26.
- Fursenkoina complanata* (Egger) = *Virgulina schreibersiana* Czjzek var. *complanata* Egger, 1893, Abhandl. K. bay, Akad. Wiss. München, vol. 18, pt. 2, p. 292, pl. 8, figs. 91, 92.
- Fursenkoina pontoni* (Cushman) = *Virgulina pontoni* Cushman, 1932, Contr. Cushman Lab. Foram. Research, vol. 8, pt. 1, p. 17, pl. 3, fig. 7.
- Nonion depressulum* (Walker and Jacob) = *Nautilus depressulus* Walker and Jacob, 1798, in Adam's Essays, Kanmacher's ed., p. 641, pl. 14, fig. 33.
- Nonion grateloupi* (d'Orbigny) = *Nonionina grateloupi* d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 294, No. 19.
- Cibicides io* Cushman = *Cibicides pseudoungeriana* (Cushman) var. *io* Cushman (part), 1931, U. S. Natl. Mus., Bull., vol. 104, pt. 8, p. 125, pl. 23, fig. 1 (not fig. 2).
- Cibicides robertsonianus* (Brady) = *Truncatulina robertsonianus* Brady, 1881, Quart. Jour. Micr. Sci., vol. 21, p. 65.
- Gyroidenoides soldanii altiformis* (R. E. and K. C. Stewart) = *Gyroidina soldanii* d'Orbigny var. *altiformis* R. E. and K. C. Stewart, 1930, Jour. Paleontology, vol. 4, p. 67, pl. 9, figs. 2a-c.
- Spirillina vivipara* Ehrenberg, 1841, Abhandl. K. Akad. Wiss. Berlin, Theil 1, p. 422, pl. 3, sec. 7, fig. 41.
- , (1958), The Foraminifera and sediments of Biscayne Bay, Florida and their ecology: Unpublished Ph.D thesis, University of Washington.
- CUSHMAN, J. A., 1922, Shallow-water Foraminifera of the Tortugas region: Publ. 311, Carnegie Instit., Washington, vol. 17, p. 1-88.
- DAVIS, J. H., 1940, The ecology and geologic role of mangroves: Publ. 517, Carnegie Instit., Washington, vol. 32, p. 307-409.
- GINSBURG, R. N., 1956, Environmental relationships of grain size and constituent particles in some south Florida carbonate sediments: Am. Assoc. Petroleum Geologists, Bull., vol. 40, p. 2384-2436.
- GOODELL, H. G., and GORSLINE, D. S., 1961, Data report — the hydrography of Apalachicola and Florida Bays, Florida: The Sedimentological Research Laboratory, Dept. Geology, Florida State Univ., Contribution no. 1, p. i-vi, 3-316.
- GRAHAM, J. J., and MILITANTE, P. J., 1959, Recent Foraminifera from the Puerto Galera area, northern Mindoro, Philippines: Stanford Univ. Publ., Geol. Sci., vol. 6, no. 2, p. 1-171.
- KRUMBEIN, W. C., and PETTIJOHN, F. J., 1938, Manual of sedimentary petrography: Appleton-Century-Crofts, Inc.; New York, 549 p.
- LOEBLICH, A. R., JR., and TAPPAN, HELEN, 1961, Suprageneric classification of the Rhizopodea: Jour. Paleontology, vol. 35, no. 2, p. 245-330.
- LYNTS, G. W., (1961), Distribution of Recent Foraminifera in upper Florida Bay and associated sounds: Unpublished master's thesis, University of Wisconsin.
- MOORE, W. E., 1957, Ecology of recent Foraminifera in northern Florida Keys: Am. Assoc. Petroleum Geologists, Bull., vol. 41, no. 4, p. 727-741.
- NORTON, R. D., 1930, Ecologic relation of some Foraminifera: Scripps Instit. Oceanography, Bull., tech. ser., vol. 2, p. 331-388.
- PHLEGER, F. B., 1960, Ecology of Recent Foraminifera: Johns Hopkins Press; Baltimore, 297 p.
- SAID, RUSHDI, 1950, The distribution of Foraminifera in the northern Red Sea: Contr. Cushman Found. Foram. Research, vol. 1, pts. 1 and 2, p. 9-29.
- STUBBS, SIDNEY, 1940, Studies of Foraminifera from seven stations in the vicinity of Biscayne Bay: Florida Acad. Sci., Proc., vol. 4, p. 225-230.
- THORP, E. M., 1939, Florida and Bahama calcareous deposits: Am. Assoc. Petroleum Geologists, A Symposium — Recent Marine Sediments, p. 283-297.
- VAUGHAN, T. W., 1918, Some shoal-water bottom samples from Murray Island, Australia, and comparisons of them with samples from Florida and the Bahamas: Publ. 213, Carnegie Instit., Washington, p. 235-288.
- WALTON, W. R., 1952, Techniques for recognition of living Foraminifera: Contr. Cushman Found. Foram. Research, vol. 3, no. 2, p. 56-60.

REFERENCES CITED

- BANDY, O. L., 1954, Distribution of some shallow-water Foraminifera in the Gulf of Mexico: U. S. Geol. Surv. Prof. Paper 254-F, p. iii, 125-141.
- BUSH, JAMES, (1949), A preliminary report of the Foraminifera of Biscayne Bay, Florida, and their ecological relations: Unpublished master's thesis, Indiana University.

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256. PERIEMBRYONIC CHAMBERS IN *HELICOLEPIDINA**

W. STORRS COLE

Cornell University, Ithaca, New York

ABSTRACT

Analysis of the number and arrangement of the periembryonic chambers in the genus *Helicolepidina* demonstrates that the variation is produced by non-genetic fluctuation in periembryonic development in individuals of a single population. Therefore, the postulate of Raadshooven (1951, p. 486) that the developmental sequence of the periembryonic chambers is an evolutionary one with stratigraphic significance is questionable. The species, *Helicolepidina spiralis* Tobler, 1922, ranging from middle through late Eocene, is the only valid species of this genus known to date.

INTRODUCTION

Although a recent study (Cole, 1960, p. 59) proved that *Helicolepidina polygyralis* Barker, 1932, should be transferred to the genus *Helicostegina*, two species were retained in the genus *Helicolepidina*. These species were separated by the presence of one principal periembryonic chamber in *Helicolepidina spiralis* Tobler, 1922, and by the occurrence of two principal periembryonic chambers in *Helicolepidina nortoni* Vaughan, 1936.

The recognition of two species of *Helicolepidina* rather than one was influenced by a study made by Raadshooven (1951, p. 487) in which he concluded ". . . a division of the Younger Eocene into upper Middle and Upper Eocene based on the differences in nepionic development within the '*Helicolepidina spiralis*' group proved to be satisfactory."

Earlier, Tan (1932) proved without question that there is a progressive reduction in the number of heterostegine chambers developed in species of *Cycloclypeus* from older to younger, stratigraphically arranged, populations. Moreover, he emphasized that by statistical methods a large number of species and varieties could be delineated. He (Tan, 1932, p. 127) concluded ". . . the frequency of the various nepionic mutants in the cycloclypean populations is a function of their stratigraphic age."

A number of papers have been published since the one in which Tan stressed not only the importance of the periembryonic chambers, but also the statistical analysis of the species within a given genus. However, objections have been raised concerning this approach. Cole (1957, p. 318) wrote: "Drooger's statistical approach was sound, but he allowed himself to be overinfluenced by minor variations which occur in all the larger Foraminifera. These minor variations which occur within a single population must be evaluated

carefully or the statistical results will be overbalanced in the direction of undue complexity."

Vaughan (1933, p. 6) recognized at the beginning of the precise study of American species of larger Foraminifera that "The amount of variation in many species of orbitoids is bewildering." Moreover, it should be recognized that concepts concerning the amount of variation allowable and the importance to be placed upon certain internal structures which have been used to define species must be changed as data accumulate.

It was not too long ago that the presence or absence of pillars was accepted as a major criterion to separate individuals into distinct species. However, studies of kinds made by Cole (1961a) demonstrate that such structures are too variable to be used to define a species.

If a sufficient number of specimens of any species of larger Foraminifera from a given population are examined, it will be found that there is variation within limits in all of the internal structures upon which the definition of a species could be based. It is necessary, therefore, in defining a species to be certain that the maximum variation which occurs between the individuals which compose the species are understood.

If the variation which occurs between specimens of a given species is not properly interpreted, numerous specific and varietal names will be given, either to groups of individuals from a given population or to other groups of individuals from related stratigraphic situations which are not separated from each other by an appreciable time interval.

The variation which occurs within individuals all of which are associated in a given population presents those who desire to approach taxonomy from the statistical viewpoint with a splendid opportunity to develop an artificial classification. Numerous specific names may be given because of minor variation in the number of nepionic chambers or some other internal structure which may be selected for analysis.

Moreover, an evolutionary-stratigraphic sequence may be developed on the percentage of variants in populations on the assumption that these variants are the result of evolutionary development. In some cases, however, these variants may be the result of non-genetic fluctuations in individuals, but because of their dominance in certain populations they are interpreted as evolutionary in origin, thus having stratigraphic significance.

Incidental to a study of the internal structure of *Lepidocyclina* (Cole, 1962, p. 37) a number of specimens of *Helicolepidina* were sectioned. Although these

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specimens were identified as *Helicolepidina nortoni* Vaughan (Cole, 1962, p. 38), it was recognized that certain of these specimens had only one principal periebryonic chamber, a morphological arrangement which supposedly characterizes *H. spiralis*.

Inasmuch as Raadshooven (1951, p. 487) had emphasized the possibility of the use of variation in the number and arrangement of the periebryonic chambers in *Helicolepidina* in making stratigraphic determinations, the specimens already sectioned and additional ones were studied to test this possibility. The results obtained are summarized in this discourse.

LOCALITIES

Trinidad

Loc. 1 — K3692, Soldado Rock; upper Eocene; H. G. Kugler, collector; for exact location, see map in Kugler, 1938, or pl. 2 in Vaughan and Cole, 1941 (reference: Cole, 1962, p. 30).

Loc. 2 — Vista Bella, San Fernando; upper Eocene; H. G. Kugler, collector, May 1932 (reference: Cole, 1960a, p. 133; 1961, p. 137; 1962, p. 30).

Loc. 3 — Steep bank on east (waiting rooms) side of San Fernando Railway Station; upper Eocene; JS899, John B. Saunders, collector; JS899 represents the same locality as KR25684, the type locality of the *Globorotalia cerroazulensis* zone (upper Eocene) in Trinidad (references: Bolli, 1957, p. 160; Cole, 1960, p. 57; 1961, p. 137).

Louisiana

Loc. 4 — Core sample at a depth of 3,611-3,612 feet from well drilled in sec. 20, T. 6 S., R. 5 E., St. Landry Parish, Louisiana; type locality of *Helicolepidina nortoni* Vaughan; gift of the late T. Wayland Vaughan (references: Vaughan, 1936, p. 248; Cole, 1952, p. 30).

PERIEMBRYONIC DEVELOPMENT IN *HELICOLEPIDINA*

In *Helicolepidina* principal periebryonic chambers develop from the extrusion of protoplasm through stolons in the wall of the second embryonic chamber just above the dividing wall between the two embryonic chambers. If only one stolon develops, a single principal (or initial) periebryonic chamber will develop. Specimens with only the initial periebryonic chamber are designated Type I (Pl. 25, fig. 2). (Note: all the illustrations are arranged so that the initial periebryonic chamber is on the right side of the embryonic chambers).

In every specimen regardless of other developments two coils of periebryonic chambers are generated from the initial periebryonic chamber, a minor coil which develops in a counter clockwise direction around the periphery of the second embryonic chamber, and a major coil which embraces the initial embryonic chamber in a clockwise direction. This major coil is designated the spiral coil as it eventually continues in

an open spiral through the equatorial chambers to the periphery of the test (Pl. 25, fig. 4).

If a stolon develops on the opposite side of the second embryonic chamber, another principal (second) periebryonic chamber will form (Pl. 25, fig. 1). This second periebryonic chamber is usually smaller than the initial one. Specimens with this development are assigned to Type II.

If, however, a coil of periebryonic chambers develops from the second periebryonic chamber, the specimens are placed in Type III (Pl. 27, fig. 6).

In Type I specimens the spiral coil advances clockwise from its generating point around the initial embryonic chamber and continues along the side of the second embryonic chamber until it encounters the counter clockwise coil of periebryonic chambers which also have developed from the initial periebryonic chamber (Pl. 23, fig. 3).

At the point of encounter the spiral coil is deflected from its position adjacent to the wall of the embryonic chambers, and thereafter continues its course through the equatorial chambers. Thus, in Type I specimens the spiral coil not only encircles the base of the initial embryonic chamber, but also is in contact with one side of the second embryonic chamber.

Type II specimens (Pl. 23, fig. 1) are similar to those of Type I, except a second stolon occurs from which is generated a single principal periebryonic chamber. In Type II specimens the continuity of the contact of the spiral coil with the left side of the embryonic chambers is interrupted for a short distance by the single, second principal periebryonic chamber.

Type III specimens are similar to Type II specimens in the development of two stolons in the second embryonic chamber. This Type is subdivided into two subtypes. In Type IIIa specimens the counter clockwise coil from the initial principal periebryonic chamber completely encircles the second embryonic chamber, and joins the principal periebryonic chamber formed by the second stolon (Pl. 23, fig. 8). Thus, the spiral coil is deflected from its position adjacent to the wall of the embryonic chambers opposite the second principal periebryonic chamber.

Type IIIb specimens (Pl. 26, fig. 2) are similar to Type IIIa specimens except that several periebryonic chambers develop from the second principal periebryonic chamber in a counter clockwise direction. The spiral coil is thus deflected from the wall of the initial embryonic chamber at the base of this chamber.

The illustrations show that the major difference between specimens is whether one or two stolons develop in the wall of the second embryonic chamber. If two stolons develop, two principal periebryonic chambers develop. But if the stolon on the left side is small, the second principal periebryonic chamber developed from the extrusion of protoplasm from this stolon will be small, and other chambers will not develop from it. Therefore, the clockwise major periebryonic coil is

not deflected from its course around the embryonic chambers (Pl. 23, fig. 1).

However, if the stolon on the left side of the second embryonic chamber is large, not only will a second principal periembrionic chamber be formed, but also the protoplasm from this chamber will generate other chambers. As these chambers develop, the spiral coil is deflected away from the embryonic chambers (Pl. 26, fig. 5) at the base of the initial embryonic chamber.

Raadshooven (1951, p. 485) interpreted the development of the periembrionic coils as an evolutionary development in which specimens of Type I (Pl. 23, fig. 1) are the most primitive. This kind is supposedly confined to the middle Eocene. Type IIIa (Pl. 23, fig. 8) is more advanced and supposedly marks transitional beds between the upper middle and upper Eocene. Finally, Type IIIb characterizes the upper Eocene (Pl. 26, fig. 2).

Type I (Pl. 23, fig. 1; pl. 25, fig. 4) is similar to *Helicolepidina spiralis* Tobler, 1922, whereas Type IIIb (Pl. 26, fig. 2) is identical with *H. nortoni* Vaughan, 1936 (Pl. 24, figs. 1-3), of which *H. spiralis trinitatensis* Brönnimann, 1944 (Pl. 24, figs. 5-7), is a synonym (Cole, 1960, p. 60). Type II and Type IIIa are intermediate between Types I and IIIb. Morphologically, however, Types II and IIIa are nearer Type IIIb than Type I as Type I has only one stolon and one principal periembrionic chamber, whereas the others have two stolons.

SIGNIFICANCE OF THE PERIEMBRYONIC DEVELOPMENT IN *HELICOLEPIDINA*

If Types I, II, and III occur in the same sample regardless of the dominance of one kind over the others, the most logical interpretation is that only one species is represented. A certain number of individuals develop only one stolon in the wall of the second embryonic chamber, whereas other individuals develop two stolons. The number of periembrionic coils varies from two to three in response to the number of stolons, and secondly to size of the stolon from which the second principal periembrionic chamber is developed. If this stolon is large, the protoplasmic flow is great enough not only to cause the formation of an additional periembrionic coil, but also this coil will form before the spiral coil can be developed on the left side of the embryonic chambers. Thus, the spiral coil will be deflected from the left wall of the embryonic chambers sooner than it is in Type I and II specimens.

Type I, II and III specimens occur in a single population, and these specimens in every respect are identical, except, as emphasized previously, certain ones develop one stolon in the wall of the second embryonic chamber, whereas others develop two stolons.

Although it is possible to recognize two species, one consisting of Type I specimens, and the other consisting of Type II and III specimens, the question might logically be asked whether two would be sufficient?

Should not Type II be separated from Types IIIa and b so that there will be four species? If this concept is carried to its logical end, one might separate Type IIIa and IIIb into several species, depending on the complexity of periembrionic coils developed from the principal periembrionic chambers. Thus, from one population a minimum of six species of *Helicolepidina* could be named.

It seems more logical to recognize that these specimens represent one gradational series of individuals, and that only one species is represented. This species would be *Helicolepidina spiralis* Tobler of which *H. nortoni* Vaughan would be a synonym. *H. spiralis* would have a stratigraphic range from middle into upper Eocene.

Table 1 demonstrates that the stratigraphic separation based upon the periembrionic development suggested by Raadshooven (1951, p. 486) in *Helicolepidina* is misleading. It would be impossible to decide whether locality 1 should be placed in the middle Eocene, in transitional beds between the upper middle and upper Eocene, or in the upper Eocene by an analysis of the periembrionic chambers of *Helicolepidina*.

TABLE 1. Comparison of specimens from one sample (loc. 1) with those illustrated by Raadshooven (1951) from different localities in Venezuela.

Specimen	Type	Compare with Raadshooven's illustrations	Stratigraphic position assigned by Raadshooven
Pl. 23, fig. 3; Pl. 25, fig. 4; Pl. 27, fig. 2.	I	pl. 3, fig. 4; text-fig. C	Upper middle Eocene
Pl. 23, fig. 8; Pl. 26, fig. 9; Pl. 27, fig. 5.	IIIa	pl. 3, fig. 5; text-fig. E	Transitional beds between upper middle and upper Eocene
Pl. 23, fig. 5; Pl. 25, fig. 3; Pl. 26, figs. 2, 4, 5.	IIIb	Text-fig. F	Upper Eocene

Most, if not all, the illustrations which have been published of *Helicolepidina* with the exception of the type illustration of *H. spiralis* are Type III specimens. After the specimens at locality 1 had been studied in which Types I, II, and III were found in association, other localities at which only Type III specimens had been reported were studied. The assumption was made that if a sufficient number of specimens were sectioned, Type I and II specimens would be found at these localities. This proved to be the case (Pl. 23, fig. 6; Pl. 26, fig. 3).

Unfortunately, it was not possible to examine middle Eocene samples which should contain according to

the theory established by Raadshooven (1951, p. 487) only Type I specimens. However, it seems probable from the evidence available that all the Types would be found in the middle Eocene if a sufficient number of specimens were examined.

EVOLUTION OF THE *HELICOLEPIDINA* LINEAGE

There is abundant evidence to demonstrate that in species in which either a planispiral or a rotaloid coil of chambers completely encircles the embryonic chambers only one stolon develops in the wall of the second embryonic chamber. However, in species in which the spiral coil of chambers does not completely encircle the embryonic chambers an additional stolon may develop through the wall of the second embryonic chamber. Individuals of the same species may have either one or two stolons develop without causing a marked change in the morphology of the test. Finally, in species in which a spiral coil does not develop several stolons form in the wall of the second embryonic chamber.

The thesis of Barker and Grimsdale (1936, p. 245) is accepted that *Helicostegina* was derived by the mutation of an *Amphistegina*-like species, and *Helicolepidina* and the first subgenus, *Polylepidina*, of the genus, *Lepidocyclina*, were mutants of the *Helicostegina* lineage. In this sequence *Helicostegina* maintains one stolon and a distinct spiral coil developed from this stolon.

In *Helicolepidina* individual specimens may have either one or two stolons and the spiral coil is reduced in importance. The same morphological arrangement occurs in *Polylepidina*. *Polylepidina* generated the subgenus *Pliolepidina* of *Lepidocyclina*. In this subgenus the spiral coil is completely eliminated. *Helicolepidina*, on the other hand, seemingly does not give rise to any other genus or subgenus, and this lineage became extinct at the end of the late Eocene.

It is postulated that in stratigraphic order from older to younger populations within the lineages generated from an *Amphistegina*-like ancestor there are three evolutionary stages which can be recognized. They are: 1) a one stolon system from which a distinct and strongly developed spiral coil is generated; 2) a one or two stolon system in which the initial principal stolon generates a moderately developed spiral coil; and, 3) a multiple stolon system without the development of a spiral coil.

Helicostegina, the ancestor of *Helicolepidina* and of the lepidocyclines, developed in the middle Eocene, but ranges upward through the upper Eocene. *Helicolepidina* was generated in the late middle Eocene and continued to the end of the late Eocene. *Polylepidina* is restricted to the middle Eocene, but from it by the late middle Eocene *Pliolepidina* had developed. This subgenus continued through the late Eocene.

FAUNAS AT THE LOCALITIES

Vaughan and Cole (1941, p. 42, 62) reported *Operculinoides soldadensis* Vaughan and Cole [= *Camerina floridensis* (Heilprin)] (Cole, 1958, p. 272; 1960b, p. 196) and *Pseudophragmina* (*Proporocyclina*) *tobleri* Vaughan and Cole from locality 1 (K3692) which they located as ". . . the top of bed no. 10 of Kugler's structure section of Soldado Rock. . ." Vaughan and Cole wrote that "*Operculinoides soldadensis* is an abundant species in the lower part of bed no. 11, at several places in bed no. 10 of Kugler's structure section of Soldado Rock, and at Mt. Moriah."

Pseudophragmina (*Proporocyclina*) *tobleri* Vaughan and Cole (1941, p. 62) was found at five localities (K3691, K3692, K3693, K3696, and K3878). Vaughan and Cole (1941, p. 27) noted "at Soldado Rock *Discocyclina* (*Discocyclina*) *bullbrookii* and *Pseudophragmina* (*Proporocyclina*) *tobleri* occur at a horizon above the typical 'Jacksonian' of Kugler's section. They were not recognized at other localities."

Caudri (1944, p. 386) wrote concerning the occurrence of *D. (D.) bullbrookii* and *Pseudophragmina* (*Proporocyclina*) *tobleri*: "From a palaeontological point of view it is highly improbable that this peculiar fauna should succeed the rich Mount Moriah fauna in normal sequence and the most acceptable explanation seems to be that it originated from a high-Paleocene (or perhaps lower or middle (?) Eocene) marl that was up to now never found *in situ* at this locality, and that it was re-deposited as a whole in a high, in itself barren, transgression niveau of the upper Eocene (Kugler's bed 11). Scattered specimens from this fauna are also found mixed with the upper Eocene fauna in the immediate neighborhood, especially in the upper part of the underlying bed 10 (e. g., K3691, K3692)."

Cole (1959, p. 380) restudied specimens from K3878 and E1 1440, concluding that *Discocyclina* (*Discocyclina*) *bullbrookii* Vaughan and Cole was the microspheric form of *D. (D.) anconensis* Barker, and that *D. (D.) anconensis* and *Pseudophragmina* (*Proporocyclina*) *tobleri* were middle Eocene species, thus strengthening the deduction by Caudri that these were reworked specimens.

The following species were found in the reexamination of a sample from locality 1 (K3692):

- Asterocyclina asterisca* (Guppy) — common
- Camerina floridensis* (Heilprin) — common
- trinitatensis* (Nuttall) — rare
- Helicolepidina spiralis* Tobler — abundant
- Lepidocyclina* (*Pliolepidina*) *pustulosa*
H. Douvillé — abundant
- Pseudophragmina* (*Proporocyclina*) *tobleri*
Vaughan and Cole — extremely rare

Dr. Raymond C. Douglass kindly listed the species from this locality (loc. 1) identified by Vaughan and Cole. The list he sent me is identical with the one given above. There is in the collection of the U. S.

National Museum only one specimen from this locality identified by Vaughan and Cole as *Pseudophragmina* (*Proporocyclina*) *tobleri*.

In addition, a number of specimens identified as *Cycloloculina jarvisi* Cushman (1929, p. 5) were found. The type locality of this species is from the Eocene of the Lothian Estate, Trinidad. Later, Coryell and Embich (1937, p. 301) reported the European species *C. annulata* Heron-Allen and Earland to be common in samples from the upper Eocene of Panama. It seems probable that the specimens from Trinidad and those from Panama represent the same species. This species (Pl. 26, figs. 7, 8) was not studied in detail.

In a previous study (Cole, 1962, p. 38) it was reported that specimens of *Lepidocyclina* (*Pliolepidina*) *pustulosa* with multilocular embryonic chambers were not found at K3692 (loc. 1 of this article). However, as additional specimens were sectioned for this study a specimen with two distinct sets of embryonic chambers (Pl. 27, fig. 3) was found. The occurrence of *Lepidocyclina* with multiple embryonic chambers at this locality is similar to that reported from locality K903 (Cole, 1962, p. 37, pl. 7, fig. 6) at which only one specimen with multiple embryonic chambers was found in the 38 specimens examined.

Although the sample from locality 1 (K3692) contains a few reworked middle Eocene specimens of *Pseudophragmina tobleri*, no other species of larger Foraminifera which have been reported from the middle Eocene were found. As Type I specimens of *Helicolepidina spiralis* Tobler were assumed to be characteristic of the middle Eocene (Raadshooven, 1951, p. 485), these specimens were examined especially to discover if they showed any evidence of reworking. Type I, II, and III specimens of *H. spiralis* from locality 1 have the same external appearance, color, and calcitic filled chambers, and it was impossible to separate them. Moreover, in appearance they were entirely similar to the associated species with the exception of the one specimen of *P. (P.) tobleri* which had a slightly different color and showed evidence of slight abrasion.

The faunas at Vista Bella quarry and at the San Fernando Railway Station have been recorded by Vaughan and Cole (1941, p. 27) and Cole (1960, p. 57). Table I presents the occurrence of species of larger Foraminifera at three localities, all assigned to the late Eocene, in only one of which (loc. 1) have been found specimens which might be reworked.

Raadshooven (1951, p. 487) stated "as far as could be checked from available palaeontological and stratigraphic evidence in western Venezuela the biserial types (*Type I of this article*) occur only in strata which are definitely older than the beds containing the quadriserial types (*Type IIIb of this article*) and a division of the Younger Eocene into upper Middle and Upper Eocene based on the differences in nepionic

TABLE 2. Faunas of larger Foraminifera

Species	Loc. 1	Loc. 3	Loc. 2
<i>Asterocyclina asterisca</i> (Guppy)	X	X	X
<i>Camerina floridensis</i> (Heilprin)	X	X	X
<i>striatoreticulata</i> (Rutten)		X	
<i>trinitatensis</i> (Nuttall)	X	X	X
<i>Helicolepidina spiralis</i> Tobler	X	X	X
<i>Helicostegina polygyralis</i> (Barker)		X	X
<i>Lepidocyclina</i> (<i>Pliolepidina</i>)			
<i>pustulosa</i> H. Douvillé	X	X	X
(<i>Eulepidina</i>) <i>chaperi</i> Lem.			
and R. Douvillé		X	
<i>Pseudophragmina</i> (<i>Proporocyclina</i>)			
<i>flintensis</i> (Cushman)		X	X
<i>tobleri</i> Vaughan and Cole*	X		

* One reworked specimen.

development within the '*Helicolepidina spiralis*' group proved to be satisfactory."

At locality 1 of the thirty thin sections available 6 or 20% were Type I (biserial), 5 or 16.6% were Type II (not recognized by Raadshooven), 7 or 23.3% were of Type IIIa (biserial) and 12 or 40% represented Type IIIb (triserial). At the two other localities Type IIIb specimens predominated, but at each of these localities Type I and II specimens (Pl. 23, fig. 6; Pl. 26, fig. 3) were found by sectioning a sufficient number of specimens.

The percentages of the different Types of *Helicolepidina* from this one sample might be interpreted to reflect a late Eocene age because of predominance of Type IIIb specimens. However, it has been demonstrated that three types heretofore regarded as representing three distinct stratigraphic horizons occur together, therefore a different conclusion might be reached.

It is just as logical to interpret the predominance of Type IIIb as a fortuitous occurrence controlled by variation within the individual specimens. If this is correct, certain middle Eocene localities may have a predominance of Type IIIa or IIIb specimens. Thus, until many more studies are made the percentage method must be viewed with caution.

The larger Foraminifera at localities 1, 2, and 3 (Table 2) are ones which characterize the upper Eocene. Bolli (1957, p. 160) has dated locality 3 by planktonic Foraminifera as the *Globorotalia cerroazulensis* (his *G. cocoaensis*) zone of the San Fernando Formation, latest Eocene, of Trinidad, B.W.I.

As the sample from locality 1 contained rather numerous planktonic Foraminifera, an attempt was made to identify these to determine, if possible, the zone to which this locality should be assigned. Preliminary analysis of the planktonic Foraminifera by the writer suggested that locality 1 represented a lower zone in

the Navet Formation to which Bolli (1957, p. 159) assigned a middle Eocene age.

At my request Miss Ruth Todd of the U. S. Geological Survey examined the planktonic Foraminifera from locality 1.

She (letter, dated 1 May 1962) wrote that the sample sent her contained ten species, as follows:

- Globigerina yeguaensis* Weinzierl and Applin
- **Globigerapsis kugleri* Bolli, Loeblich and Tappan
- Catapsydrax dissimilis* (Cushman and Bermudez)
- **Globorotalia aspensis* (Colom)
- bolivariana* (Petters)
- **bullbrooki* Bolli
- centralis* Cushman and Bermudez
- Globorotaloides suteri* Bolli
- **Truncorotaloides rohri* Brönnimann and Bermudez
- topilensis* (Cushman)

The four species which are starred are the ones with the shortest stratigraphic ranges, and seemingly indicate that this planktonic fauna represents the *Globigerapsis kugleri* zone (Bolli, 1957, p. 158) of Trinidad. Her assistance in identifying these specimens by direct comparison with the type specimens in the collection of the U. S. National Museum is gratefully acknowledged.

The result of this attempt to check the stratigraphic position of this locality by means of the faunas of planktonic Foraminifera is similar to that obtained by a previous study of the faunas of planktonic and larger Foraminifera on Yap, Caroline Islands (Cole, Todd, Johnson, 1960). The planktonic Foraminifera in the samples from Yap indicated an older stratigraphic position than the larger Foraminifera did.

Inasmuch as locality 1 has a few worn specimens of *Pseudophragmina* (*Proporocyclina*) *tobleri* which seemingly are not indigenous, the most logical explanation for the conflicting ages suggested by the two kinds of Foraminifera is that the planktonic kind are reworked.

CONCLUSIONS

It has been demonstrated that perieembryonic development in *Helicolepidina* is produced by non-genetic fluctuation in individuals in a single population. This kind of variation is non-evolutionary, and occurs in other genera of larger Foraminifera. Therefore, caution should be used in developing stratigraphic zonation upon assumed evolutionary progressions which later may prove to be the result of individual variation.

Although reworking may be an adequate explanation

in certain situations to resolve the conflicting age determinations between planktonic and larger Foraminifera, it does not necessarily follow that reworking can be invoked promiscuously.

All the evidence from the analysis of the entire foraminiferal population found at locality 1 demonstrates that reworking has occurred. A few specimens of larger Foraminifera and many specimens of planktonic Foraminifera from an identifiable older zone occur with an indigenous population of larger Foraminifera, all of which except *Pseudophragmina* (*Proporocyclina*) *tobleri* are known to be associated at many localities. Moreover, the indigenous specimens have identical preservation and do not show any evidence of abrasion.

Recently, Eames *et al* (1962, p. 42) have extended the concept of reworking to explain the occurrence of certain lepidocyclines with multilocular embryonic chambers in association with other species of larger Foraminifera of unquestioned Eocene age. They regard these lepidocyclines with multilocular embryonic chambers as always marking the Miocene.

If all lepidocyclines with multilocular embryonic chambers are confined to the Miocene, it is remarkable that the kind which Cole (1960a, p. 136; 1961, p. 136; 1962, p. 37) defined as one development within the *Pliolepidina pustulosa* series always occurs with unquestioned species of late Eocene larger Foraminifera. Cole (1961, p. 137) wrote: ". . . the species with the irregular, multilocular embryonic chambers would be the only indigenous species present at all of the localities from which it is known in the vast Caribbean area."

The fact that smaller and larger Foraminifera at certain localities are reworked is not questioned. But, each situation at which reworking is postulated must be examined critically to be certain that reworking can be proven. The evidence from the analysis of the faunas at locality 1 seemingly demonstrates that reworking did occur during the deposition of the sediments at this locality.

However, at locality 3 the evidence is just as convincing that reworking did not occur. The planktonic and larger Foraminifera at this locality are in agreement regarding the late Eocene age of this sample.

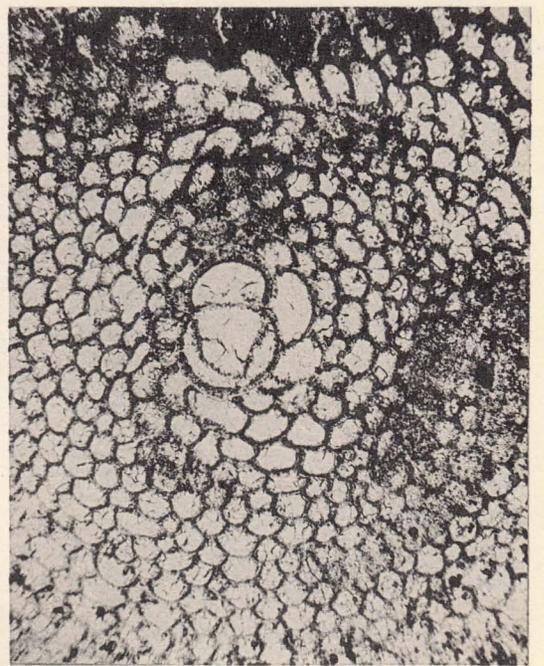
It should be emphasized that at both localities 1 and 3 specimens of *Lepidocyclina* with multilocular embryonic chambers were found. These are indigenous specimens, and do not demonstrate that the localities have a younger age than late Eocene.

EXPLANATION OF PLATE 25

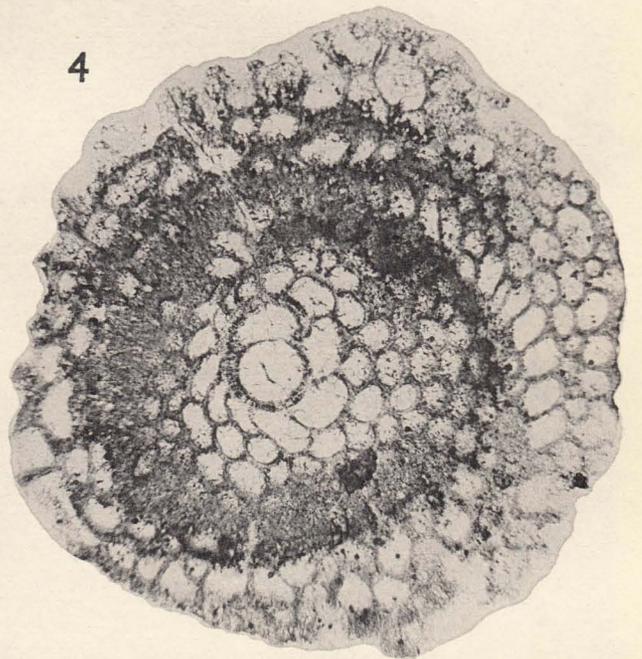
FIGS.	PAGE
1-5. <i>Helicolepidina spiralis</i> Tobler	146, 7
1-5. Parts of equatorial sections; 1, 2, $\times 230$; 3-5, $\times 40$; loc. 1; 1, 2, enlargement of embryonic and perieembryonic chambers; 1, see: pl. 23, fig. 1; 2, see: plate 23, fig. 3; 2, 4, are Type I specimens; 1, 5 are Type II specimens; and, fig. 3 is a Type IIIb specimen.	



1



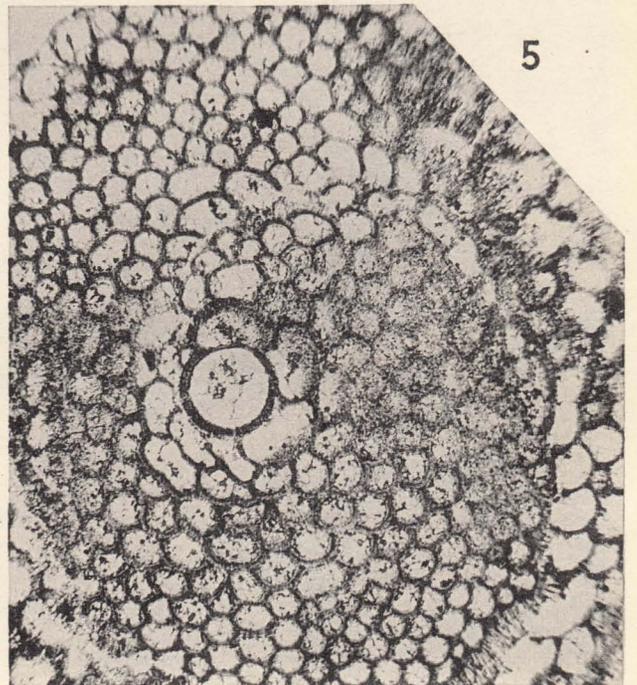
3



4

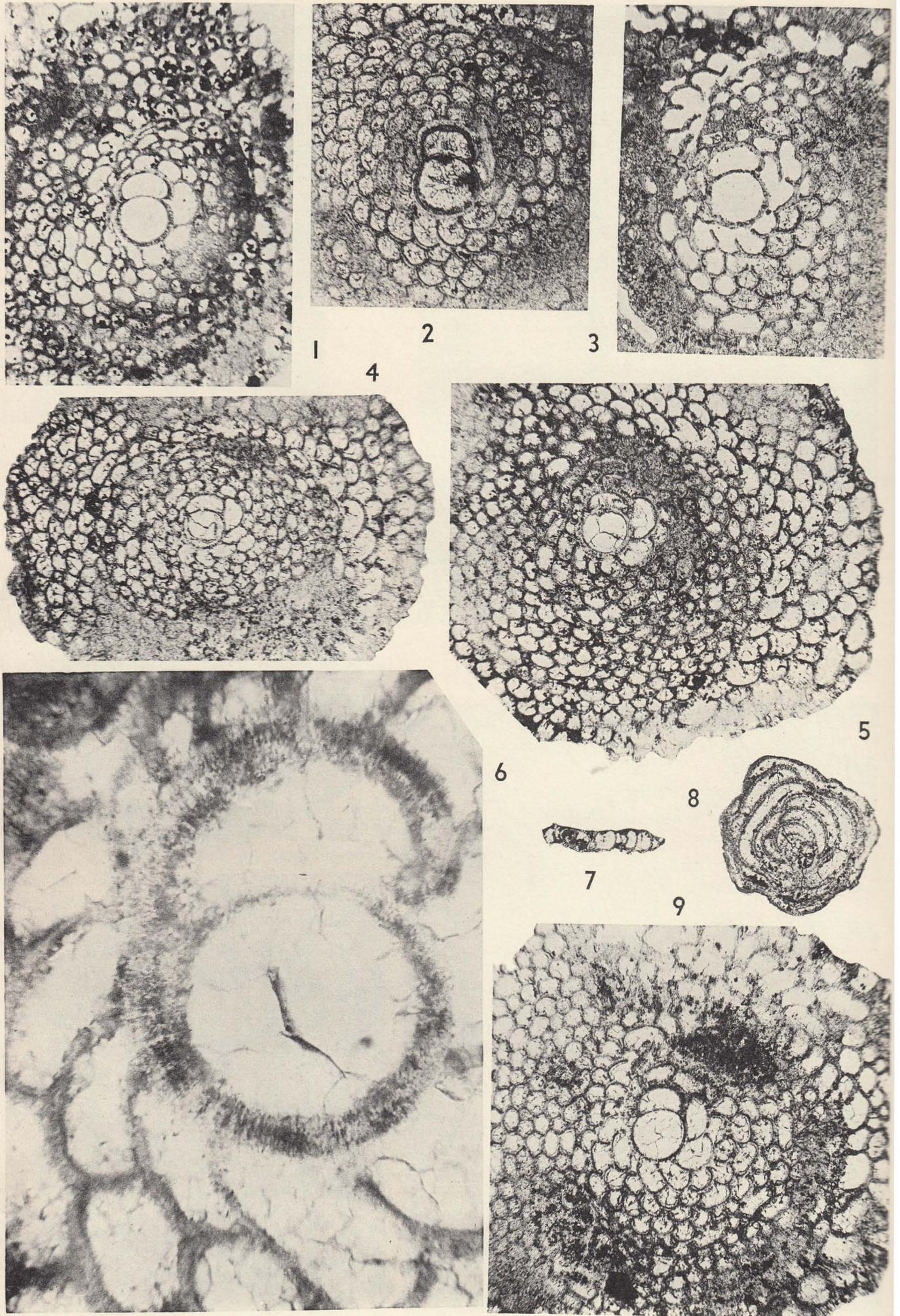


2



5

Cole: Periembrionic chambers in *Helicolepidina*



Cole: Periembrionic chambers in *Helicolepidina*

LITERATURE CITED

- BARKER, R. W., and GRIMSDALE, T. F., 1936, A contribution to the phylogeny of the orbitoidal Foraminifera with descriptions of new forms from the Eocene of Mexico: *Jour. Paleontology*, v. 10, no. 4, p. 231-247, pls. 30-38, 4 text figs.
- BOLLI, HANS, 1957, Planktonic Foraminifera from the Eocene Navet and San Fernando Formations of Trinidad, B.W.I.: *U. S. Natl. Museum Bull.* 215, p. 155-198, pls. 35-39, text figs. 27, 28.
- BRÖNNIMANN, P., 1944, Ein neues Subgenus von *Orbitocyclina* aus Iran nebst Bemerkungen über *Helicolepidina* Tobler und verwandte Formen: *Schweizer. Palaeont. Abhand.*, v. 64, p. 1-42, 3 pls., 15 text figs.
- CAUDRI, C. M. B., 1944, The larger Foraminifera from San Juan de los Morros, State of Guarico, Venezuela: *Bull. Am. Paleontology*, v. 28, no. 114, p. 355-404, pls. 30-34, 2 text figs., chart.
- COLE, W. S., 1952, Eocene and Oligocene larger Foraminifera from the Panama Canal Zone and vicinity: *U. S. Geol. Survey Prof. Paper* 244, p. 1-41, pls. 1-28, 2 text figs. (1953).
- , 1957, Late Oligocene larger Foraminifera from Barro Colorado Island, Panama Canal Zone: *Bull. Am. Paleontology*, v. 37, no. 163, p. 313-338, pls. 24-30.
- , 1958, Names of and variation in certain American larger Foraminifera, particularly the camerinids - No. 2: *Bull. Am. Paleontology*, v. 38, no. 173, p. 261-284, pls. 32-34.
- , 1959, Faunal associations and the stratigraphic position of certain American Paleocene and Eocene larger Foraminifera: *Bull. Am. Paleontology*, v. 39, no. 182, p. 377-393, pls. 32, 33, 1 table.
- , 1960, Revision of *Helicostegina*, *Helicolepidina* and *Lepidocyclina* (*Polylepidina*): *Contrib. Cushman Found. Foram. Research*, v. 11, pt. 2, p. 57-62, pls. 10-13.
- , 1960a, Variability in embryonic chambers of *Lepidocyclina*: *Micropaleontology*, v. 6, no. 2, p. 133-140, pls. 1-4.
- , 1960b, The genus *Camerina*: *Bull. Am. Paleontology*, v. 41, no. 190, p. 189-205, pls. 23-26.
- , 1961, Some nomenclatural and stratigraphic problems involving larger Foraminifera: *Contrib. Cushman Found. Foram. Research*, v. 12, pt. 4, p. 136-147, pls. 8-17.
- , 1961a, An analysis of certain taxonomic problems in the larger Foraminifera: *Bull. Am. Paleontology*, v. 43, no. 197, p. 373-407, pls. 28-39.
- , 1962, Embryonic chambers and the subgenera of *Lepidocyclina*: *Bull. Am. Paleontology*, v. 44, no. 200, p. 29-60, pls. 4-8.
- , TODD, R., and JOHNSON, C. G., 1960, Conflicting age determinations suggested by Foraminifera on Yap, Caroline Islands: *Bull. Am. Paleontology*, v. 41, no. 186, p. 77-112, pls. 11-13, 3 tables, 1 text fig.
- CORYELL, H. N., and EMBICH, J. R., 1937, The Tranquilla shale (upper Eocene) of Panama and its foraminiferal fauna: *Jour. Paleontology*, v. 11, no. 4, p. 289-305, pls. 41-43, 1 text fig.
- CUSHMAN, J. A., 1929, *Cycloloculina* in the western hemisphere: *Contrib. Cushman Lab. Foram. Research*, v. 5, pt. 1, p. 4, 5, pl. 1, figs. 8-10.
- EAMES, F. E., BANNER, F. T., BLOW, W. H., and CLARKE, W. J., 1962, Fundamentals of mid-Tertiary stratigraphical correlation: Cambridge University Press, p. 1-163, 17 pls., 20 text figs.
- KUGLER, H. G., 1938, The Eocene of the Soldado Rock near Trinidad: *Bol. Geol. Minería*, v. 2, Nos. 2-4, p. 1-24, map, geol. sect., 3 text figs.
- RAADSHOOVEN, B., VAN, 1951, On some Paleocene and Eocene larger Foraminifera of Venezuela: Third World Petrol. Congress, Proc., sec. 1, E. J. Brill, The Hague, p. 476-489, 3 pls., map, text figs.
- TAN SIN HOK, 1932, On the genus *Cycloclypeus* Carpenter: *Dienst van den Mijnb. in Nederlandsch-Indie, Wetensch. Meded.* No. 19, p. 1-194, 24 pls., text figs., numerous charts and tables.
- TOBLER, A., 1922, *Helicolepidina*, ein neues Subgenus von *Lepidocyclina*: *Eclogae Geol. Helvetiae*, v. 17, no. 3, p. 380-384, 3 text figs.
- VAUGHAN, T. W., 1933, Studies of American species of Foraminifera of the genus *Lepidocyclina*: *Smithsonian Miscell. Coll.*, v. 89, no. 10, p. 1-53, pls. 1-32.
- , 1936, *Helicolepidina nortoni*, a new species of Foraminifera from a deep well in St. Landry Parish, Louisiana: *Jour. Paleontology*, v. 10, no. 4, p. 248-252, pls. 39, 40.
- , and COLE, W. S., 1941, Preliminary report on the Cretaceous and Tertiary Larger Foraminifera of Trinidad, British West Indies: *Geol. Soc. America, Special Paper* 30, p. 1-137, 46 pls., 2 text figs.

EXPLANATION OF PLATE 26

FIGS.	PAGE
1-6, 9. <i>Helicolepidina spiralis</i> Tobler	146, 7
1-6, 9. Parts of equatorial sections; 1-5, 9, $\times 40$; 6, $\times 230$; 1, 2, 4-6, 9, loc. 1; 3, loc. 2; for enlargement of fig. 4 see: pl. 27, fig. 6; 6, see: pl. 25, fig. 4; 1, 2, 4, 5 are Type IIIb specimens; 6 is a Type I specimen; and, 3, 9 are Type IIIa specimens.	
7, 8. <i>Cycloloculina jarvisi</i> Cushman	149
7. Vertical section, $\times 40$; loc. 1.	
8. Equatorial section, $\times 40$; loc. 1.	

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XIII, PART 4, OCTOBER, 1962

CORRECTIONS

In our article, "The type specimens of *Globigerina quadrilobata* d'Orbigny, *Globigerina sacculifera* Brady, *Rotalina cultrata* d'Orbigny and *Rotalia menardii* Parker, Jones and Brady," which appeared in these Contributions (vol. 13, pt. 3, p. 98) in July of this year, the word *not* was omitted from the first line of the final paragraph of page 98. Since this omission alters the entire sense of this paragraph and the one following, these paragraphs are reprinted here.

"2. *Rotalina cultrata* d'Orbigny, 1839.

"We do not see why the neotype of *R. cultrata* d'Orbigny cannot reasonably be said to conform with either d'Orbigny's description or his intentions. Todd (*op. cit.*, p. 122) quotes d'Orbigny (1839, p. 76) in the belief that his vernacular "légèrement pointillée" means either "a punctate or hispid wall surface." As d'Orbigny (*loc. cit.*) had already given the formal diagnosis "Testa ovali, depressissima, punctata . . ." with no mention of hispidity or surface rugosity, the fact that the test of *R. cultrata* was believed by d'Orbigny to be perforate (probably weakly so) but not markedly hispid seems very likely. This agrees with the neotype (Banner and Blow, 1960, pp. 34-5). When d'Orbigny believed that a test was rugose he said so (d'Orbigny, 1839, p. 97, for *Rosalina candeina*: "rugosa"; "rugueuse," "tuberculées") and when he described *Truncatulina advena* (which, as Todd says, is illustrated in a manner which suggests it has a wall similar to that of *Rotalina cultrata*) he stated (p. 87) that the test was marked by "très petits points" — which, to us, means "very finely perforate." It is clear, however, from the examples quoted by Todd, that d'Orbigny's illustrations are not always wholly reliable, for his figures of *Rotalina sagra* (1839, pl. 5, figs. 13-15) show no perforations at all, even though authors have assigned this species to the perforate genus *Cancriis* (see Barker, 1960, p. 218).

"The neotype is bigger than the specimen measured by d'Orbigny as Todd points out (*op. cit.*, *loc. cit.*). The samples from the Recent sands off Cuba, from amongst which the neotype was selected, show, as do many other Recent samples, that specimens identical in their structure and proportions range in size from 0.3 mm. or less to 1.0 mm. or more in diameter. From study of both fossil and Recent assemblages, we concluded that a relatively large test, probably representing a fully-grown individual, would more fully and clearly represent the characteristic morphology of the species for which the neotype was intended — for which, we believe, a name was intended by d'Orbigny. The neotype conforms fully with d'Orbigny's formal diagnosis, which continues: "carinata, cultrata, supra subcomplanata, subtus convexiuscula; spira subplana, anfractibus duobus limbatis; loculis sex ovatis, contectis, supra limbatis" (d'Orbigny, 1839, p. 76); it also, we believe, agrees well with the original illustrations (*op. cit.*, pl. 5, figs. 7-9), and we know of no other Recent species which does so."

F. T. BANNER and W. H. BLOW

The following corrections should be made in Table 1 of my paper, "A review of the planktonic Foraminifera from the Upper Cretaceous of California," published in July of this year (vol. 13, pt. 3, p. 104):

1. In column IX opposite #15 *Globotruncana ventricosa* White, delete "15."
2. In column IX opposite #16 *Gublerina ornatisima* (Cushman and Church), add "16."
3. In column V under Coniacian and opposite #19 *Heterohelix globulosa* (Ehrenberg), add "19."

JOSEPH J. GRAHAM

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XIII, PART 4, OCTOBER, 1962
RECENT LITERATURE ON THE FORAMINIFERA

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

- ADAMS, C. G. Calcareous adherent Foraminifera from the British Jurassic and Cretaceous and the French Eocene.—*Palaeontology*, v. 5, pt. 2, June 1962, p. 149-170, pls. 21-24, text fig. 1 (line drawings).—Descriptions and illustrations of 9 species and 5 varieties (2 new) in 4 genera, with discussion of the status of 3 other genera. Accurate identification of adherent species and genera is possible only of individuals showing unobscured juvenile stages and having space for normal growth.
- ASANO, KIYOSHI. Tertiary globigerinids from Kyushu, Japan.—*Sci. Repts. Tohoku Univ., 2nd Ser. (Geol.) Spec. Vol. No. 5 (Kon'no Mem. Vol.)*, March 1962, p. 49-65, pls. 19-23.—Twenty-nine species (4 new) from Eocene, Oligocene, and Miocene.
- Faunal change of planktonic Foraminifera through the Neogene of Japan.—*Proc. Kon. Nederl. Akad. Wetenschappen, ser. B*, v. 65, No. 1, 1962, p. 114-129, text fig. 1 (map), tables 1, 2.—Important paper summarizes correlations with planktonic zonation of West Indian region.
- BACH, ILSE. Bemerkungen zur Mikrofauna des Eocène (in German with English summary).—*Geologie, Berlin, Jahrg. 11, heft 1*, Jan. 1962, p. 98-117, pls. 1, 2.—Systematic catalog of 45 species and subspecies from well drillings, none new; a few illustrated.
- BELFORD, D. J. Miocene and Pliocene planktonic Foraminifera, Papua-New Guinea.—*Australia Bur. Min. Res., Geol. and Geophysics, Bull. No. 62-1*, 1962, p. 1-51, pls. 1-8, text figs. 1-3 (outline drawings).—Descriptions and illustrations of 27 species and 7 subspecies (1 new).
- BERMUDEZ, PEDRO J., and FUENMAYOR, ANGEL N. Notas sobre los foraminiferos del grupo Cabo Blanco, Venezuela.—*Boletin Informativo, Asoc. Venez. Geol. Min. Petr.*, v. 5, No. 1, Jan. 1962, p. 1-16, text fig. 1 (map).—Species listed from 2 formations, 1 in upper Pliocene, the other in lower Pleistocene.
- BIGNOT, G. Première idée de la microfaune Albienne des environs du Havre.—*Bull. Soc. Géol. Normandie et Amis Mus. Havre*, tome 51, 1961, p. 13-16, 1 pl.—List and illustrations of species.
- BOLTOVSKOY, ESTEBAN. Planktonic foraminifera as indicators of different water masses in the South Atlantic.—*Micropaleontology*, v. 8, No. 3, July 1962, p. 403-408, text fig. 1 (map).—Subtropical, subantarctic, and transitional water masses are distinguished from one another by means of their characteristic species, by slight morphological differences in species, and by salinity and temperature.
- BOMBITA, G. Biostratigraficheskoe Revizionnoe Issledovanie Paleogenovogo Flisha Vostochnykh Karpat.—*Acad. Répub. Pop. Roumaine, Rev. Géol. et Géog.*, tom. 5, No. 2, 1961, p. 211-237, text figs. 1-88 (maps, section, photos, line drawings).—Nummulites in thin section.
- BRAGA, J. M. Foraminíferos da Costa de Moçambique.—*Publ. Institut. Zool. "Dr. Augusto Nobre," Fac. Ciencias Porto*, No. 77, 1961, p. 1-208, pls. 1-21.—Illustrated systematic catalog includes 270 species and subspecies, none new. Study based on 65 bottom samples from the coast of southern Mozambique.
- BRENNER, GILBERT J. A zoogeographic analysis of some shallow-water Foraminifera in the Gulf of California, No. 14, *in* Results of the Puritan-American Museum of Natural History Exped. to Western Mexico.—*Bull. Amer. Mus. Nat. Hist.*, v. 123: Art. 5, April 9, 1962, p. 249-298, pl. 40, text figs. 1-4 (map, graphs), table 1 (occurrence chart).—Qualitative and quantitative analysis is based on 81 bottom samples ranging in depth from 0.8 to 79.4 meters. Occurrence and abundance of 139 species and varieties, 3 species new, are recorded. The population change from north to south in the Gulf is evaluated.
- BROUWER, J. Age determinations of some rock samples from the Star Mountains region, Appendix II of Geological Results of the Star Mountains ("Sterrengebergte") Expedition, by C. B. BÄR, J. H. CORTEL, and A. E. ESCHER.—*Nova Guinea (Contr. to the Anthropology, Botany, Geology, and Zoology of the Papuan Region)*, Geology, No. 4, Nov. 15, 1961, p. 97-99, table 1.—Ages based on planktonic and larger Foraminifera.
- BYSTRICKA, HEDVIGA. Die Mikrofauna der Buntens Schichten des Beckens von Zilina (German summary of Czech text).—*Acta Geol. Geogr. Univ. Comen., Bratislava, Geologica* No. 5, Nov. 1961, p. 109-176, pls. 15-27, occurrence table.—Illustrated systematic catalog of about 100 species, none new, from an assemblage interpreted as of middle Eocene age.
- CASTELAIN, J., FAULKNER, J. S., DE KLASZ, I., MEIJER,

- M., and RÉRAT, D. Répartition stratigraphique d'*Afrobolivina afra* Reyment dans quelques bassins côtiers de l'Afrique occidentale.—*Revue de Micropaléontologie*, v. 5, No. 1, June 1962, p. 54-58, pl. 1, range chart.—The range of this Upper Cretaceous species, found in 8 coastal basins from Senegal to Angola, does not coincide from basin to basin but varies from Coniacian to upper Maestrichtian.
- CHANG, LI-SHO. A biostratigraphic study of Oligocene in northern Taiwan based on smaller Foraminifera.—*Proc. Geol. Soc. China*, No. 5, April 1962, p. 47-64, pls. 1-5, text figs. 1-5 (maps), tables 1-7.—Over 100 species and subspecies (3 new) are illustrated and their occurrence and abundance indicated in several sections. Zonation by smaller Foraminifera is refined.
- Some planktonic Foraminifera from the Suo and Urai Groups of Taiwan and their stratigraphic significance.—*Proc. Geol. Soc. China*, No. 5, April 1962, p. 127-133, pl. 1, text fig. 1 (map).—Ages of the two groups are stated in terms of the West Indian planktonic sequence.
- CHRISTODOULOU, G. Berichtigung des Namens *Vaginulina compressa* (Costa) *carinata* Christodoulou zu *Vaginulina compressa* (Costa) *melidonisi* n. ssp.—*Paläont. Zeitschr.*, v. 36, Nos. 1/2, April 1962, p. 134.
- COLE, W. STORRS. Embryonic chambers and the subgenera of *Lepidocyclina*.—*Bull. Amer. Pal.*, v. 44, No. 200, May 18, 1962, p. 25-60, pls. 4-8, tables 1-4.—Multilocular embryonic chambers are interpreted as a result of development of the shell from a cytoplasmic mass containing two or more nuclei.
- CRESPIN, IRENE. *Lacazinella*, a new genus of trematophore foraminifera.—*Micropaleontology*, v. 8, No. 3, July 1962, p. 337-342, pls. 1, 2, text figs. 1, 2 (map, drawings).—A large upper Eocene miliolid (type species *Lacazina wichmanni* Schlumberger, 1894) of New Guinea.
- CURRY, DENNIS. A lower Tertiary outlier in the central English Channel, with notes on the beds surrounding it.—*Quart. Jour. Geol. Soc. London*, v. 118, pt. 2, June 29, 1962, p. 177-205, text figs. 1, 2 (range chart, geol. map), tables 1-10.—Foraminifera used in identifying the beds of the outlier and the surrounding Chalk.
- CZUDEK, TADEAS, and CICHA, IVAN. The distribution of the Tortonian in the eastern part of the Nizky Jeseník Mts. (German summary of Czech text).—*Vestník Ustred. ustavu geol.*, roc. 37, cislo 3, 1962, p. 183-190, pls. 1, 2 (landscape and foram photos), text fig. 1 (map).
- DELEAU, P., and MARIE, P. Les Fusulinidés du Westphalien C du Bassin d'Abadla et quelques autres Foraminifères du Carbonifère Algérien (Région de Colomb-Béchar).—*Publ. Serv. Carte Géol. Algérie*, n. ser., Bull. No. 25, Travaux des Collaborateurs, 1958 (1959), p. 45-160, pls. 1-12.—In the descriptive part, are included 46 species (7 new) and 2 varieties, all illustrated in section. Seven new genera are erected: *Conicocornuspira* (type species *C. conica* n. sp.), *Hemigordiella* (type species *Hemigordius calcarea* Cushman and Waters), *Hemigordiellina* (type species *Glomospira diversa* Cushman and Waters), and *Ondogordius* (type species *O. campanula* n. sp.) in the Ophthalmitidae; *Tolypamminella* (type species *T. vermiculare* n. sp.) in the Ammodiscidae; and *Pseudotetrataxis* (type species *Tetrataxis planolocola* Lee and Chen) and *Falsotetrataxis* (type species *Tetrataxis scutella* Cushman and Waters) in the Trochamminidae.
- DIDKOVSK'KYI, V. JA. Miliolidy Neogenovykh Vidkladiv Pivdenno-zakhidnoi Chastini Rosiis'koi Platformy. Tom I, Rody *Quinqueloculina* ta *Triloculina*.—*Akad. Nauk Ukrain. RSR, Kiev, Instyt. geol. nauk Trudy*, ser. strat. paleo., vyp. 39, 1961, p. 1-122, pls. 1-23, map, table.—Illustrated catalog includes 78 species (44 new) and 29 varieties (20 new), nearly all from upper Tortonian or middle Sarmatian.
- O mikrofaune Srednego Sarmata Prichernomorskoj Vpadiny v Predelakh USSR.—*Akad. Nauk Ukrain. RSR, Geol. Zhurnal*, tom 22, vyp. 1, 1962, p. 51-58, map, occurrence chart.—Middle Sarmatian species listed.
- DROOGER, C. W., and BATJES, D. A. J. Miocene planktonische Foraminiferen des Nordseebeckens.—*Meyniana, Geol. Instit. Kiel, Band 10*, April 1961, p. 18-20, pl. 1, tables 1, 2 (range chart, occurrence and abundance chart).—Includes illustrations of planktonics from Oligocene and Miocene.
- EAMES, F. E., BANNER, F. T., BLOW, W. H., CLARKE, W. J., and SMOUT, A. H. Morphology, taxonomy, and stratigraphic occurrence of the Lepidocyclininae.—*Micropaleontology*, v. 8, No. 3, July 1962, p. 289-322, pls. 1-8, text figs. 1-5 (schematic diagrams of sections).
- EDGEELL, H. S. A record of *Globotruncana concavata* (Brotzen) in North-west Australia.—*Revue de Micropaléontologie*, v. 5, No. 1, June 1962, p. 41-50, pl. 1, tables 1, 2.—Other Tethyan records are discussed and the distinctions from *G. ventricosa* are set forth. The subspecies *carinata* occurs in the Santonian of the Carnavon Basin.
- ELLERMANN, C. Bemerkungen zu *Asterigerina gürichi* (Franke).—*Meyniana, Geol. Instit. Kiel, Band 10*, April 1961, p. 13, 14.
- EMERY, K. O., and HÜLSEMANN, JOBST. The relation-

- ships of sediments, life and water in a marine basin.—Deep-Sea Research, v. 8, 1962, p. 165-180, text figs. 1-10 (maps, core log, photographs, graphs).—In the deep and nearly barren parts of the Santa Barbara basin *Bolivina seminuda* and *Suggrunda eckisi* are tolerant of low oxygen conditions. *Bolivina argentea* and *Loxostoma pseudobeyrichi* dominate in the shallower basin depths where oxygen concentrations are greater.
- FISCHER, ALFRED G. Fossilien aus Riffkomplexen der alpinen Trias: *Cheilosporites* Wöhner, eine Foraminifere? (with English abstract of German text).—Paläont. Zeitschr., v. 36, Nos. 1/2, April 1962, p. 118-124, pls. 13, 14.—A colonial form consisting of uniserial chambers in branching rows, forming a colony up to 5 cm. high.
- FUNNELL, BRIAN MICHAEL, and WEST, RICHARD GILBERT. The early Pleistocene of Easton Barents, Suffolk.—Quart. Jour. Geol. Soc. London, v. 118, pt. 2, June 29, 1962, p. 125-141, text fig. 1 (pollen diagram), tables 1, 2.—Quantitative analysis of 2 Foraminifera samples coinciding with or closely related to pollen zones.
- GERKE, A. A. Foraminifery Permskikh, Triasov'kh i Lejasov'kh Otlozhenij Neftenosn'kh Rajonov Severa Thentral'noj Sibiri.—Russia Nauchno-issl. instit. geol. Arktiki, Trudy, tom 120, 1961, p. 1-518, pls. 1-122, text figs. 1-4 (maps, columnar sections), tables 1-4.—A partial systematic catalog (only through *Dentalina*) accompanied by illustrations and tables of distribution and abundance that encompass the entire group of smaller Foraminifera from the Permian, Triassic and Liassic of central Siberia. Many new species and varieties are erected and new names assigned to the illustrated forms.
- HAGN, H. Die Gliederung der Oberen Meeresmolasse nördlich vom Überlinger See (Bodensee) in mikropaläontologischer Sicht.—Jahreshefte Geol. Landes. Baden-Württemberg, Band 5, Dec. 1, 1961, p. 293-321, text figs. 27-30 (map, columnar sections, drawings of fossils), table 19 (occurrence chart).
- HEDLEY, R. H., and BERTAUD, W. S. Electron-microscopic observations of *Gromia oviformis* (Sarcodina).—Jour. Protozoology, v. 9, No. 1, 1962, p. 79-87, text figs. 1-15.—Electron photographs showing wall canals, honeycomb membranes, and cytoplasmic inclusions.
- HERRICK, STEPHEN M. Marginal sea of middle Eocene age in New Jersey.—U. S. Geol. Survey Prof. Paper 450-B, Apr. 27, 1962, p. B56-B58, text figs. 21.1, 21.2.—Foraminifera listed from Manasquan formation in a test well.
- HILTERMANN, H. Die Bedeutung der Foraminiferen für die Miocän-Stratigraphie im Nordseebecken.—Meyniana, Geol. Institut. Kiel, Band 10, April 1961, p. 15-17.
- HORNIBROOK, N. DE B. Tertiary Foraminifera from Oamaru District (N. Z.). Part 1—Systematics and Distribution.—New Zealand Geol. Survey, Pal. Bull. 34 (1), Sept. 1961, p. 1-192, pls. 1-28, text figs. 1-5 (maps, drawings), tables 1-7.—Illustrated systematic catalog contains nearly 400 species (100 new). Four new genera are described: *Semirosalina* (type species *S. inflata* n. sp.) and *Nummodiscorbis* (type species *N. novozealandica* n. sp.) in the Discorbidae and *Cribrorotalia* (type species *Notorotalia tainuia* Dorreen) and *Discorotalia* (type species *Polystomella tenuissima* Karrer) in the new subfamily Notorotaliinae of the Elphidiidae. Sixty samples, covering the interval from Danian-Paleocene to lower Miocene, form the basis of the monograph. Distribution, abundance, and stratigraphic range in New Zealand are graphically shown.
- HUSS, FELICJA. Distribution of benthonic and planktonic Foraminifera in the Upper Cretaceous sediments of NW Poland (English summary of Polish text).—Acta Geol. Polonica, v. 12, No. 1, 1962, p. 113-157, text figs. 1-11 (graphs, diagrams, map), tables 1, 2.—Quantitative analyses of boring samples indicate that sea depth gradually decreased from over 1,500 meters in the Turonian to 50-100 meters in the Maestrichtian.
- ISHII, KEN-ICHI, and NOGAMI, YASUO. On the new genus *Metadololina*.—Trans. Proc. Pal. Soc. Japan, n. ser., No. 44, Dec. 15, 1961, p. 161-166, pl. 25.—Type species is *Pseudodololina pseudolepida gravitesta* Kanmera, 1954.
- ISHIZAKI, KUNIHIRO. A new locality and faunal assemblage of fusulinids from the limestone in the area west of Ryoseki, Kochi Prefecture.—Sci. Repts. Tohoku Univ., 2nd Ser. (Geol.), Spec. Vol. No. 5 (Kon'no Mem. Vol.), March 1962, p. 107-118, pl. 29, tables 1-6.—Six species of Fusulinidae.
- IVANOVA, L. V. Microfaunal complexes from the Galicka Series of the Dashava-Zhidachev area in the Fore Carpathians (English summary of Ukrainian text).—Dopovidi Akad. Nauk Ukrain. RSR, Kiev, No. 4, 1962, p. 520-523.—Smaller Foraminifera zones in the upper Tortonian and lower Sarmatian.
- JARKE, JOACHIM. Die Beziehungen zwischen hydrographischen Verhältnissen, Faziesentwicklung und Foraminiferenverbreitung in der heutigen Nordsee als Vorbild für die Verhältnisse während der Miocän-Zeit.—Meyniana, Geol. Institut. Kiel, Band 10, April 1961, p. 21-36, pls. 1-4, maps 1-9.—A summary of quantitative analysis of numerous samples from the North Sea in which 12 "Foraminifera provinces" are recognized. Thirty-six species and subspecies are illustrated.
- JORDAN, ROBERT R. Planktonic Foraminifera and the

- Cretaceous-Tertiary boundary in central Delaware.—Delaware Geol. Survey, Rept. of Investig. No. 5, Feb. 1962, p. 1-13, pls. 1, 2, text figs. 1, 2 (map, distrib. chart).—Nine Maestrichtian species and 6 Danian ones are illustrated from below and above the Cretaceous-Tertiary boundary at about 980 feet in a deep well.
- KANE, HENRY E. The distribution of the Foraminifera of Sabine Lake and Sabine Pass, Texas and Louisiana, and the nearshore area of the Gulf of Mexico.—*Jour. Paleontology*, v. 36, No. 4, July 1962, p. 834-836.—Concentrations (as percentages) of 36 species and varieties.
- KAVANAU, J. LEE. Countercurrent streaming in liquid surfaces and its relevance to protoplasmic movements.—*Science*, v. 136, No. 3516, May 18, 1962, p. 652-653.—An explanation of the filament streaming already observed in *Allogromia*, in which feeding could occur during both the extending and the withdrawing of pseudopodia.
- KHAN, MOHSIN H. Lower Cretaceous index foraminifera from northwestern Germany and England.—*Micropaleontology*, v. 8, No. 3, July 1962, p. 385-390, text figs. 1, 2 (correl. chart, range chart).—Six zones are recognized between Valanginian and Barremian, and ranges of 26 species in NW Germany and England are compared.
- LEONOV, G. P., and ALIMARINA, V. P. Stratigraphy and planktonic Foraminifera of Cretaceous-Paleogene "transition" beds of the central part of the North Caucasus (English summary of Russian text).—*Sbornik trudov geologicheskogo fakul'teta Moskovskogo Universiteta* (K 21 sess. mezhdunarodnogo geol. kongressa), 1961, p. 29-60, pls. 1-7, tables 1, 2.—Three zones, one in Danian and two in Montian, the upper two subdivided into 2 sub-zones. Correlations are shown with zonations of the American section.
- LLOYD, ADRIAN J. Polymorphinid, miliolid and rotaliform foraminifera from the type Kimmeridgian.—*Micropaleontology*, v. 8, No. 3, July 1962, p. 369-383, pls. 1, 2, text figs. 1-7 (map, line drawings), table 1 (range chart).—Describes and illustrates 18 species (4 new) of common calcareous forms (excluding Nodosariidae). Study of variability in species of *Eoguttulina* indicates that such features as test shape in side view, degree of overlap of chambers, nature of sutures, size and disposition of pores, etc., serve better in classification than does chamber arrangement.
- LOEBLICH, ALFRED R., JR., and TAPPAN, HELEN. On terminations used in suprageneric classification of the Rhizopoda: a reply.—*Jour. Paleontology*, v. 36, No. 4, July 1962, p. 839-840.
- Lys, M. Études paléontologiques et géologiques sur les falaises de Fresco, (Cote d'Ivoire). 3. Foraminifères.—*Univ. Dakar, Ann. Fac. Sci., Année 1961, tome 6, 1962, p. 47-80, pls. 1-7.*—Well illustrated systematic catalog of about 80 species, 7 new. The fauna is correlated with Bolli's *Globorotalia pseudomenardii* zone of the Paleocene.
- MAMEDOV, T. A. Novye Vidy Krupnykh Foraminifer iz Eothenovykh Otlozhenij Nakhichevanskoj ASSR.—*Doklady Akad. Nauk Azerbaidzh. SSR, tom 17, No. 10, 1961, p. 925-930, pl. 1.*—Two new species, 1 *Assilina* and 1 *Nummulites*.
- Karakter Raspredelenija Nummulitovoj Fauny v Razreze Eothenovykh Otlozhenij Nakhichevanskoj ASSR.—*Izvest. Akad. Nauk Azerbaidzh. SSR, ser. geol.-geogr. nauk nefti, 1961, No. 5, p. 73-84, text figs. 1, 2, charts 1, 2.*—Zonation by nummulites.
- MAMONTOVA, E. V. Orbitolinidy in Problema Neftegazonosnosti Srednej Azii.—*Russia Vses. geol. instit. Trudy, n. ser., tom 51, 1961, p. 72-92, pls. 1-5, text figs. 8-12.*—Descriptions and illustrations of 6 species of *Orbitolina* (3 new) and 2 of *Dictyoconus*.
- MARTINIS, B. Notizie geologiche e paleontologiche sui terreni dei dintorni di Corigliano d'Otranto.—*Riv. Ital. Pal. Stratig., v. 68, No. 1, 1962, p. 67-96, pls. 6, 7, text figs. 1-3* (map, sections).—Includes photographs and descriptions of the most typical smaller Foraminifera of the Helvetian beds.
- MASLAKOVA, N. I. Foraminifery Verkhnemelovykh Otlozhenij Dagestana.—*Voprosy Stratigrafii i Regional'noj Geologii, vyp. 192, 1961, p. 58-88, pls. 1-5, 1 table* (range chart).—Includes descriptions and illustrations of 28 species, 3 new. Ranges for these and other species between Cenomanian and Danian are indicated.
- MAYER, E. M. Novye Vidy Foraminifer Melkovodij Kandalakshskogo Zaliva in Biology of the White Sea (in Russian), edit. by L. A. ZENKEWITCH.—*Repts. White Sea Biol. Station of State Univ. Moscow, v. 1, 1961, p. 70-87, text figs. (pls.) 1-3.*—Includes systematic list of 76 species from Kandalak Bay. Six new species are described.
- MERCUS, D. Contribution à la connaissance de la lithologie des Couche de Nadanova.—*Acad. Répub. Pop. Roumaine, Rev. Géol. et Géog., tom. 5, No. 2, 1961, p. 239-273, pls. 1-11* (line drawings and thin sections), 2 columnar sections.—Cretaceous planktonics in thin section.
- MISIK, MILAN. Die mikrofazies mit *Involutina liasica* (Jones) aus dem Lias der Velka Fatra (Westkarpaten) (German summary of Czech text).—*Acta Geol. Geog. Univ. Comeniana (Bratislava), Geologica, No. 5, 1961, p. 177-191, pls. 28-30.*
- MISTRETTA, F. Foraminiferi planctonici del Pliocene inferiore di Altavilla Milicia (Palermo, Sicilia).—

- Riv. Ital. Pal. Stratig., v. 68, No. 1, 1962, p. 97-114, pls. 8-11, text fig. 1 (line drawings).—Twelve species, 1 new and 1 indeterminate. Neotype of *Globigerina gomitulus* Seguenza is designated and placed in synonymy with *Globigerinoides elongatus*.
- MORIKAWA, ROKURO, and ISOMI, HIROSHI. Studies of Permian Fusulinids in the east of Lake Biwa, central Japan.—Geol. Survey Japan, Rept. No. 191, 1961, p. 1-29, pls. 1-21, text figs. 1, 2 (maps), tables 1-29.—Descriptions and illustrations of 33 species, 7 new and 3 indeterminate.
- NOGAMI, YASUO. Permische Fusuliniden aus dem Atetsu-Plateau Südwestjapans. Teil 2. Verbeekinae, Neoschwagerinae u. a.—Mem. College Sci., Univ. Kyoto, ser. B, v. 28, No. 2, Geol. Min., Nov. 1961, p. 159-242, pls. 1-7, text figs. 1, 2 (map, range chart).—Descriptions and illustrations of 23 species (10 indeterminate).
- OERTLI, H. J. Sur la rédaction d'études paléontologiques. Règles de nomenclature et "attitude morale."—Revue de Micropaléontologie, v. 5, No. 1, June 1962, p. 59-61.
- PESAGNO, EMILE A., JR. The Upper Cretaceous stratigraphy and micropaleontology of south-central Puerto Rico.—Micropaleontology, v. 8, No. 3, July 1962, p. 349-368, pls. 1-6, text figs. 1-4 (maps, correl. chart, line drawing), charts 1-4 (distrib. and abund. tables).—Includes systematic catalog of 60 species and subspecies with illustrations of the planktonic ones, of which 1 species and 2 subspecies are new.
- PIRINI, SOCIA C. Contributo paleontologico allo studio dell'Appennino Settentrionale.—Boll. Soc. Geol. Ital., v. 80, fasc. 1, 1961, p. 111-138, pls. 1-6, map, correlated columnar sections.—Includes photographs of typical assemblages of smaller Foraminifera from formations between Cenomanian and lower Miocene.
- POIGNANT, ARMELLE. A propos de *Miogypsinoides complanata* (Schlumberger).—Revue de Micropaléontologie, v. 5, No. 1, June 1962, p. 62-64.—Specimens with a long embryonic spire are not specifically separable from those with a short one. Both kinds have an analogous polymorphism of external characters.
- PRONINA, M. T. Novye Predstaviteli *Streblus* v otlozhenijakh Miothena Nakhichevanskoj ASSR.—Izvest. Akad. Nauk Azerbaidzh. SSR, ser. geol.-geogr. nauk nefti, 1961, No. 5, p. 55-61, pl. 1.—Five new varieties of *Streblus beccarii*.
- Kharakter Mikrofauny Miothenovykh Otlozhenij Nakhichevanskoj ASSR.—Doklady Akad. Nauk Azerbaidzh. SSR, tom 17, No. 10, 1961, p. 931-935.
- ROSS, CHARLES A. Permian Foraminifera from British Honduras.—Palaeontology, v. 5, pt. 2, June 1962, p. 297-306, pl. 46, text figs. 1, 2 (map, columnar sections).—Fusulinids indicating late Wolfcampian age.
- SACHS, K. N., JR., and GORDON, W. A. Stratigraphic distribution of Middle Tertiary larger Foraminifera from southern Puerto Rico.—Bull. Amer. Pal., v. 44, No. 199, May 10, 1962, p. 1-24, pls. 1-3, text fig. 1 (map), tables 1, 2.—Includes 9 species.
- SAITO, TSUNEMASA. Eocene planktonic Foraminifera from Hahajima (Hillsborough Island).—Trans. Proc. Pal. Soc. Japan, n. ser., No. 45, April 10, 1962, p. 209-225, pls. 32-34.—Well-illustrated systematic catalog includes 18 species, 1 new. The fauna is correlated with the "*Porticulasphaera mexicana* zone" of Trinidad and regarded as of Lutetian age. The new species includes as synonyms *Porticulasphaera mexicana* of Beckmann and of Bolli, Loeblich, and Tappan. The original *Globigerina mexicana* is transferred to *Globigerapsis*.
- SANDER, N. J. Aperçu paléontologique et stratigraphique du Paléogène en Arabie Séoudite orientale.—Revue de Micropaléontologie, v. 5, No. 1, June 1962, p. 3-40, pls. 1-5, text figs. 1-8 (map, correl. charts, range charts, occurrence tables, evolution diagrams).—Includes descriptions and illustrations of 15 species characteristic of the shallow epicontinental sea of eastern Arabia during the Montian to Lutetian. Eleven new species, 4 new varieties, and 1 new genus are described: *Miscellanoides* (genotype *M. bramkampii* n. sp.).
- SCHEIBNER, ERVIN, and SCHEIBNEROVA, VIERA. On the occurrence of Danian in the Klippen Belt of West Carpathians at Slovakia (English summary of Czech text).—Acta Geol. Geog. Univ. Comenianae (Bratislava), Geologica No. 5, 1961, p. 193-201, text figs. 1, 2 (geol. section).
- SCHEIBNEROVA, VIERA. Microfauna of the Middle and Upper Cretaceous of the Klippen Belt of West Carpathians in Slovakia (English summary of Czech text).—Acta Geol. Geog. Univ. Comenianae (Bratislava), Geologica No. 5, 1961, p. 11-108, pls. 1-14.—Includes illustrated systematic catalog of 72 species and subspecies, none new.
- SEMINA, S. A. Stratigrafija i Foraminifery (Fuzulinidy) Shvagerinovogo Gorizonta Oksko-thninskogo Podnjatija.—Akad. Nauk SSSR, Geol. instit., Trudy, vyp. 57, 1961, p. 1-73, pls. 1-5, text figs. 1-5 (map, columnar sections), distrib. table.—Twenty-one species (11 new) and 2 new species and 1 new variety.
- SHENG, J. C. Some fusulinids from the Maokou Limestone of Chinghai Province, northwestern China (English translation of Chinese text).—Acta Pal-

- aeont. Sinica, v. 6, No. 3, Aug. 1958, p. 268-292, pls. 1-4, text fig. 1 (map).—Eleven species (6 new) and 2 new varieties.
- SHENG, J. C., and CHANG, L. H. Fusulinids from the type-locality of the Changhsing Limestone (English translation of Chinese text).—Acta Palaeont. Sinica, v. 6, No. 2, May 1958, p. 205-214, pl. 1, text fig. 1 (columnar section).—Four species, 3 new.
- SOUAYA, F. J. Contribution to the study of *Miogypsina* s. l. from Egypt. I-III.—Proc. Kon. Nederl. Akad. Wetenschappen, ser. B, v. 64, No. 5, 1961, p. 665-705, pls. I-IV (line drawings, thin sections), pls. 1-9 (map, columnar sections, drawings, graphs); tables 1-14.—Includes biometric analyses of the 3 species found and paleoecologic conclusions about them.
- STSCHEDRINA, Z. G. Foraminifery Zalivov Belogo Morja in Biology of the White Sea (in Russian), edit. by L. A. ZENKEWITCH.—Repts. White Sea Biol. Station of State Univ. Moscow, v. 1, 1961, p. 51-69, text figs. 1-10.—Includes systematic list of 72 species with depth ranges. Four species (3 new) are described and illustrated, and 2 new genera are erected in the subfamily Webbinellinae: *Pseudowebbinella* (type species *Crithionina goësi* Höglund) and *Iridiella* (type species *I. maris-albi* sp. n.).
- SULLIVAN, FRANK R. Foraminifera from the type section of the San Lorenzo Formation, Santa Cruz County, California.—Univ. Calif. Publ. Geol. Sci., v. 37, No. 4, March 30, 1962, p. 233-352, pls. 1-23, text figs. 1-5 (maps, strat. column, distrib. and abund. chart).—Study based on 50 samples covering an interval of continuous deposition from late Eocene (early Narizian, Butano formation) to "Oligo-Miocene" (early Zemorrian, lower Vaqueros formation). Illustrated systematic catalog includes 213 species and varieties, 3 species and 1 variety new.
- SUYARI, KAZUMI. Geological and paleontological studies in central and eastern Shikoku, Japan. Part I. Geology.—Jour. Gakugei, Tokushima Univ., v. 11, 1961, p. 11-76, text figs. 1-6 (correl. charts, columnar sections).
- Part II. Paleontology.—Jour. Gakugei, Tokushima Univ., v. 12, 1962, p. 1-64, pls. 1-12.—These 2 papers include zonation by fusulinids and systematic descriptions and illustrations of 69 species and subspecies (12 new).
- TAKAYANAGI, YOKICHI. Some new names for the Cretaceous Foraminifera from Hokkaido, Japan.—Sci. Repts. Tohoku Univ., 2nd ser. (Geol.), v. 33, No. 1, Nov. 1961, 1 p.—Correction of 3 homonyms.
- TAKAYANAGI, YOKICHI, and IWAMOTO, HISAICHI. Cretaceous Planktonic Foraminifera from the Middle Yezo Group of the Ikushumbetsu, Miruto, and Hatonosu areas, Hokkaido.—Trans. Proc. Palaeont. Soc. Japan, n. ser., No. 45, April 10, 1962, p. 183-196, pl. 28, table 1.—Four species and a new subspecies indicating correlation with the Albanian.
- TAKAYANAGI, YOKICHI, and SAITO, TSUNEMASA. Planktonic Foraminifera from the Nobori Formation, Shikoku, Japan.—Sci. Repts. Tohoku Univ., 2nd ser. (Geol.), Spec. Vol. No. 5 (Kon'no Mem. Vol.), March 1962, p. 67-105, pls. 24-28, text figs. 1-3 (map, range chart, outline drawings), table 1 (distrib. chart).—Descriptions and illustrations of 44 species (3 new) and 5 subspecies (1 new) and 2 varieties. Fauna is correlated with the *Globorotalia menardii menardii*/*Globigerina nepenthes* zone of Venezuela and interpreted as probably Tortonian.
- TAPPAN, HELEN. Foraminifera from the Arctic slope of Alaska. Part 3, Cretaceous Foraminifera.—U. S. Geol. Survey Prof. Paper 236-C, July 13, 1962, p. 91-209, pls. 29-58, text figs. 10-18 (diagrams, maps, correl. charts).—Descriptions and illustrations of about 150 species from formations between Valanginian and Senonian. The faunas are impoverished and consist mostly of agglutinated specimens. Intertonguing marine, nearshore, and nonmarine beds have distinct facies, but some of the more tolerant species are used in inter-regional correlation.
- TASNADI-KUBACSKA, A. Paläopathologie.—Veb Gustav Fischer Verlag, Jena, 1962, 269 p., 293 text figs.—Includes a section "Die Paläopathologie der Foraminiferen," p. 25-38, text figs. 14-37.
- TEDESCHI, SOCI D., and COCOCETTA, V. Stratigrafia della serie di Costa Merlassino.—Boll. Soc. Geol. Ital., v. 80, fasc. 1, 1961, p. 139-153, pls. 1-4.—Includes photographs of typical assemblages of smaller Foraminifera from upper Eocene.
- VANGEROW, E. F. Über *Ammodiscus* aus dem Zechstein.—Paläont. Zeitschr., v. 36, Nos. 1/2, April 1962, p. 125-133, text figs. 1-9 (diagrams, photographs, line drawings).—Two species, 1 new.
- VENGLINSKY, I. V. New data on the paleontological characteristics of the Helvetian strata of Podolia (English summary of Ukrainian text).—Dopovidi Akad. Nauk Ukrain. RSR, Kiev, No. 1, 1962, p. 99-104, distrib. table.—Foraminifera listed.
- VLERK, I. M. VAN DER. *Lepidocyclina radiata* (K. Martin), 1880.—Proc. Kon. Nederl. Akad. Wetenschappen, ser. B, v. 64, No. 5, 1961, p. 620-626, pls. 1, 2.—Further description and additional illustrations of Martin's original specimen. The species is interpreted as having been one of the

last-occurring species in this genus, marking latest Tertiary f.

- WAGNER, FRANCES J. E. Faunal report, Submarine Geology Program, Polar Continental Shelf Project, Isachsen, District of Franklin.—Geol. Survey Canada, Dept. Mines and Tech. Surveys, Paper 61-27, 1962, p. 1-10, figs. 1, 2 (maps), tables 1, 2. —Recent organisms (60 species of Foraminifera predominating) are tabulated from 15 sea bottom samples at depths between 143 and 1,239 meters.

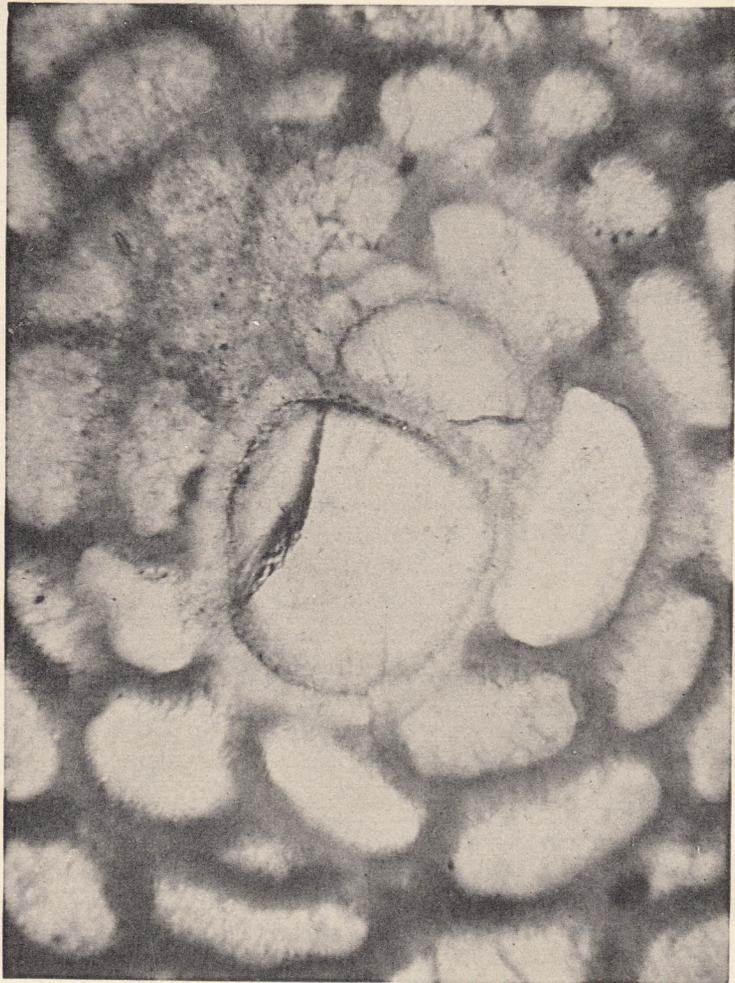
WEAVER, DONALD W. Eocene Foraminifera from west of Refugio Pass, California.—Univ. Calif. Publ. Geol. Sci., v. 37, No. 5, April 30, 1962, p. 353-399, pls. 1-9, text figs. 1-4 (maps, columnar section, occurrence and abund. chart).—Illustrated systematic catalog of about 125 species from a middle and upper Eocene sequence.

RUTH TODD

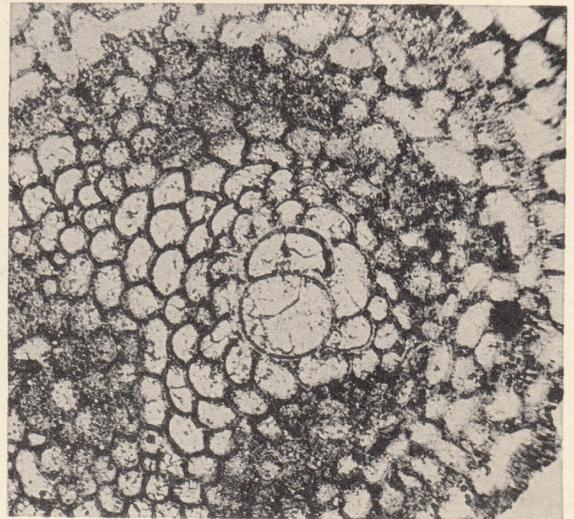
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EXPLANATION OF PLATE 27

FIGS.		PAGE
1, 2, 4-6.	<i>Helicolepidina spiralis</i> Tobler	146, 7
1, 2, 4-6.	Parts of equatorial sections; 1, 6, \times 230; 2, 4, 5, \times 40; 1, loc. 4; 2, 5, 6, loc. 1; 4, loc. 3; 1, see: pl. 24, fig. 3; 6, see: pl. 26, fig. 4; 1, 4, 6 are Type III <i>b</i> specimens; 2 is a Type I specimen; and, 5, is a Type III <i>a</i> , specimen.	
3.	<i>Lepidocyclina (Pliolepidina) pustulosa</i> H. Douvillé	149
	Part of an equatorial section, \times 40, of a specimen with two sets of embryonic chambers; loc. 1.	



1

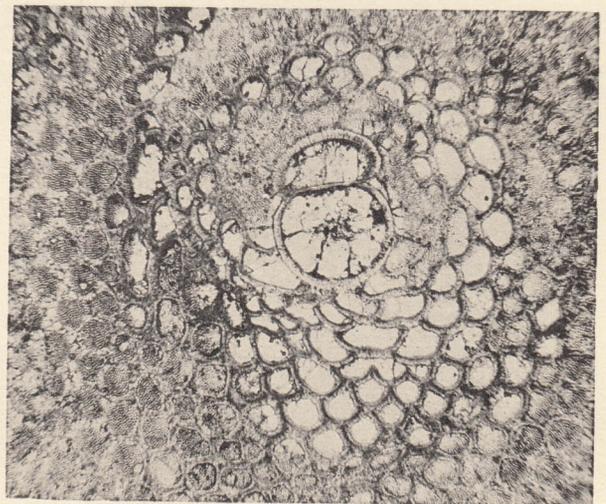


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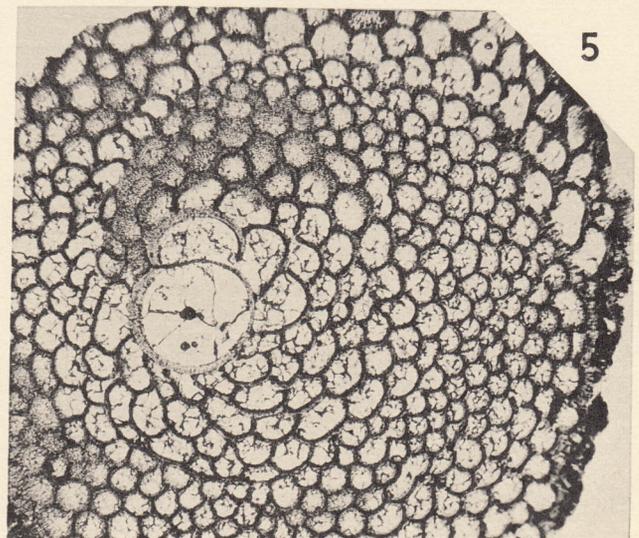


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6



5

Cole: Periembryonic chambers in *Helicolepidina*