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30. FORAMINIFERA OF NARRAGANSETT BAY[1]

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ABSTRACT—Results are given of a quantitative study of the Foraminifera of Narragansett Bay in an attempt to decipher the ecologic conditions which determine the appearance of the species in the area. Two foraminiferal populations are noticed: the first is characteristic of the southern and more saline waters and the second thrives in the northern brackish areas. The topography of the bottom and the type of sediment exert control on the appearance of the species, while salinity is a dominant factor in their distribution. Foraminiferal numbers in the Bay are lower than those in the continental shelf and larger numbers are observed in the interior brackish areas of the Bay.

INTRODUCTION

Narragansett Bay includes the intercommunicating system of water ways that discharge into the Atlantic Ocean through the navigable entrances between Point ~~Judith and~~ Sakonnet Point in the state of Rhode Island. Conanicut Island and Rhode Island separate the southern portion of this water area into three passages known as Western Passage, Eastern Passage and Sakonnet River. A number of smaller islands are distributed over the Bay, and many small bays and river entrances indent its shores. Of the tributary streams the two most important are Providence River and Taunton River which flow into the northern and eastern parts of the Bay respectively. The various passages serve as highways for water-borne traffic to and from the numerous towns situated on the Bay. Of major importance are the ports of Newport, about three miles inside the entrance to Eastern Passage; Providence, at the head of Providence River about twenty-seven miles from the ocean; and Fall River, at the mouth of Taunton River about eighteen miles from Newport.

In spite of the fact that Narragansett Bay is one of the important fishing centers of the East Coast of the United States, very little work has been done on its hydrography. As far as the author is aware, Haight's work (1938) is the only study on the hydrography of the area. This work is particularly concerned with the tidal currents which regularly sweep into the Bay. The results of Haight's calculations are reproduced in condensed chart form by the U. S. Coast and Geodetic Survey (1945). Narragansett Bay is subjected to tidal currents which move freely in and out of the Bay and make possible the mixing of all water bodies.

The salinity and temperature distribution of the Bay has not been observed in detail, although the general pattern is known (Riley 1948; Sumner, Osborn and Cole 1913). The salinity distribution in the numerous bays that indent the East Coast of America is subjected to great variations and the pattern is complex and varied. Fresh water enters Narragansett Bay through the two main rivers and runoff and the surface water is likely to have very low salinities. In general salinities between 25 and 28 o/oo may be expected at the bottom waters even near the rivers. Although no complete data is available, it is almost certain that these salinities do increase gradually by approaching the open ocean. Saline waters are known to penetrate the rivers as far as the tidal currents are effective.

The bottom configuration of Narragansett Bay is very irregular. Apparently little change in bottom topography occurred after the inundation of the area in post-glacial time. The Eastern Passage is a deep irregular basin of some 150 feet in maximum depth and with an average depth of 80 feet. The Western Passage is a shallow flat with a maximum depth of some 50 feet and an average depth of 25 feet. The Sakonnet River is a shallow and slightly irregular waterway with a maximum depth of 50 feet and an average of 25 feet in depth. The northern areas of both the Eastern and Western Passages around Prudence Island are shallower flats with some irregularity and an average depth of 30 feet.

Sediments vary from gravels, which are common in the Eastern Passage, to sand and silt. The sediments on the whole are not well sorted, although they become better sorted near the river mouths. The results of mechanical analyses of some samples are given in table I in terms of median diameter and sorting coefficient. Mechanical analyses were carried out by sieving and pipette methods (Krumbein and Pettijohn 1938). Wentworth size classification is used in designating the names of the sediments except for the coarse sediments where gravel was preferred to pebble as the former name appears in the charts of the U. S. Coast and Geodetic Survey. The "muds" which the charts of the Survey show are probably silts (in the Wentworth sense).

No data are available on the nitrogen percentage of the sediments of Narragansett Bay, but the analyses of four samples show that the sediments of the Bay possess high organic content. The result of these analyses is given in table I. The determination of nitrogen was made by the Kjeldahl method and the procedure of analysis followed was that described by Trask and Patnode (1942, pp. 36-38).

Acknowledgments: The writer is much indebted to Dr. Charles J. Fish, Director of Narragansett Marine

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[1] Contribution No. 491 from the Woods Hole Oceanographic Institution.

TABLE I

Sample No.	Depth (in ft.)	Location		Md (in mm)	So	N %	Remarks
		Lat.	Long.				
1	70	41°25′40″	71°25′10″	.04	1.72		Core
2	76	41 25 40	71 22 40				Grab
3	89	41 25 30	71 19 40				Core
4	76	41 26 20	71 17 00				Grab
5	42	41 29 20	71 13 30	.38	1.12		Grab
6	33	41 34 10	71 13 00				Core
7	38	41 37 00	71 13 40	.02	1.81		Core
8	20	41 39 30	71 14 50	.02	1.95		Core
9	27	41 36 25	71 23 00				Grab
10	16	41 38 30	71 22 00	.51	1.71	.16	Grab
11	21	41 38 30	71 23 40				Core
12	14	41 40 40	71 25 00			.18	Core
13	4	41 40 50	71 25 00	.14	1.08		Grab
14	20	41 41 00	71 18 00	.07	1.31		Core
15	16	41 41 20	71 21 20	.18	1.11		Grab
16	10	41 42 40	71 20 00	.20	1.12		Grab
17	22	41 38 30	71 19 40				Core
18	25	41 38 30	71 17 00				Core
19	75	41 36 00	71 17 30	.19	1.09		Grab
20	95	41 34 30	71 18 00				Core
21	90	41 31 40	71 20 00				Core
22	78	41 31 40	71 21 30				Core
23	55	41 31 40	71 23 40	.17	1.07		Grab
24	24	41 31 40	71 24 00	.17	1.13	.22	Grab
25	26	41 30 20	71 23 30	.18	1.10		Grab
26	30	41 27 30	71 25 10	.31	1.40		Grab
27	47	41 27 50	71 24 20				Core
28	100	41 27 30	71 22 30	.17	1.13		Grab
29	128	41 20 30	71 20 30	1.62	1.88		Grab
30	131	41 30 40	71 20 40	2.20	1.97		Grab
31	43	41 33 30	71 20 40	.07	1.62		Core
32	32	41 34 30	71 21 30				Core
33	26	41 34 30	71 23 00				Core
34	20	41 34 30	71 24 40	.04	1.59	.21	Core

Biological Laboratory for allowing the full use of one of the ships of his laboratory for the collection of samples. He is also indebted to Professor Henry C. Stetson for his keen interest in the problem and for the help he has so generously given during the progress of this work. Sincere thanks are offered to Dr. Alfred R. Loeblich, Jr., and to Miss Ruth Todd for checking some of the foraminiferal identifications.

Collection of samples: Thirty-four samples (eighteen cores and sixteen grabs) were collected from Narragansett Bay during the summer of 1950. Core samples were collected by a Hough coring tube and the grab samples were obtained by an "orange peel" (for the description of these devices, see Hough, 1939). Only the top parts of cores were examined. Table I gives the locations, the median grain size diameter, the sorting coefficient and the nitrogen percentage of the different samples. Figure 1 shows the areal distribution of the samples collected.

SYSTEMATIC WORK

Fifty-five species of Foraminifera observed in Narragansett Bay are arranged systematically below according to Cushman's classification.

ASTRORHIZIDAE

Rhabdammina cf. **R. linearis** H. B. Brady

SACCAMMINIDAE

Psammosphaera fusca F. E. Schultze
Proteonina atlantica Cushman
Armorella sphaerica Heron-Allen and Earland
Tholosina bulla (H. B. Brady)
Thurammina papillata H. B. Brady

HYPERAMMINIDAE

Saccorhiza ramosa (H. B. Brady)

REOPHACIDAE

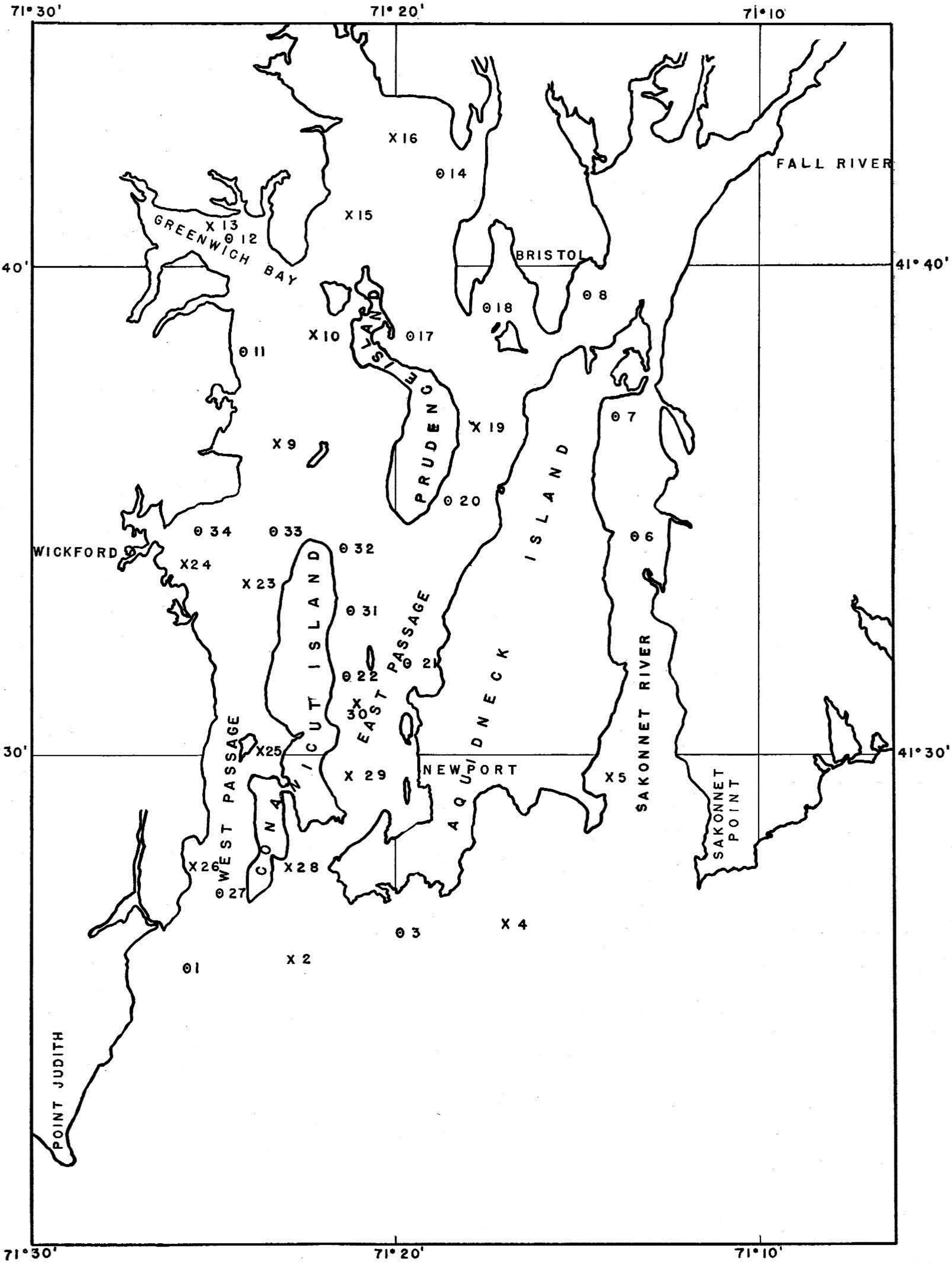
Reophax dentaliniformis H. B. Brady
R. nana Rhumbler

LITUOLIDAE

Haplophragmoides columbiense Cushman

TEXTULARIIDAE

Textularia cf. **T. tenuissima** Earland



X Grab ⊖ Core

Figure 1: Map of Narragansett Bay showing Sample Locations

VALVULINIDAE

Eggerella advena (Cushman)

MILIOLIDAE

Quinqueloculina seminula (Linné)
Q. seminula (Linné) var. **jugosa** Cushman
Q. disciformis (Macgillivray)
Q. vulgaris d'Orbigny
Miliolinella sp.
Triloculina tricarinata d'Orbigny
Pyrgo subsphaerica (d'Orbigny)

SILICINIDAE

Miliammina fusca (H. B. Brady)

OPHTHALMIDIDAE

Cornuspira planorbis Schultze

TROCHAMMINIDAE

Trochammina lobata Cushman
T. inflata (Montagu)
T. squamata Parker and Jones

LAGENIDAE

Lagena gracillima (Seguenza) var. **mollis** Cushman

POLYMORPHINIDAE

Guttulina lactea (Walker and Jacob)
Globulina glacialis Cushman and Ozawa
Pseudopolymorphina novangliae (Cushman)

NONIONIDAE

Nonion pauciloculum Cushman
N. tisburyensis Butcher
Nonionella atlantica Cushman
Elphidium advenum (Cushman)
E. advenum (Cushman) var. **margaritaceum** Cushman
E. discoidale (d'Orbigny)
E. excavatum (Terquem)
E. frigidum Cushman
E. incertum (Williamson)
E. incertum (Williamson) var. **clavatum** Cushman
E. subarcticum Cushman

BULIMINIDAE

Buliminella elegantissima (d'Orbigny)
Bulimina elegans d'Orbigny
B. marginata d'Orbigny
Fissurina laevigata Reuss
F. globosa (Montagu)
Virgulina fusiformis (Williamson)
Bolivina pseudoplicata Heron-Allen and Earland
Hopkinsina pacifica Cushman var. **atlantica** Cushman

ROTALIIDAE

Discorbis bertheloti (d'Orbigny) var. **floridensis** Cushman
D. subaraucana Cushman
Eponides frigidus (Cushman) var. **calidus** Cushman and Cole
Poroeponides lateralis (Terquem)
Rotalia beccarii (Linne)
R. beccarii (Linne) var. **tepida** Cushman

ANOMALINIDAE

Cibicides lobatulus (Walker and Jacob)
C. concentricus (Cushman)

All species recorded in the area have been described and figured by Cushman (1944) with the exception of the following: *Rhabdammina* cf. *R. linearis*, *Thurammina papillata*, *Textularia tenuissima*, *Miliolinella* sp., *Nonion tisburyensis*, *Nonionella atlantica*, *Elphidium frigidum*, *Bulimina elegans*, *Virgulina fusiformis*, and *Rotalia beccarii tepida*.

It is possible that *Nonion orbiculare* (H. B. Brady) of Cushman (1944, p. 24, pl. 3, fig. 24) is conspecific with *Elphidium frigidum* of this paper. Cushman (1944, p. 24) notes that some of the specimens tend "to develop what seem like very primitive retral processes and possibly this could be placed in *Elphidium*." *E. frigidum* is an obiquitous species in Narragansett Bay, occurring in both the northern and southern areas of the Bay in more or less equal abundance. The species is characterized by poorly developed retral processes. The two genera *Elphidium* and *Nonion* grade into one another in the Narragansett material and the problem is further complicated because some species of *Elphidium* (e. g. *E. incertum clavatum*) pass through an early *Nonion*-like stage without retral processes in their ontogeny. A preliminary investigation of the structure of the wall of *Elphidium* and *Nonion* has confirmed Wood's findings (1949) of the sharp difference in the character of their walls. A more detailed study of this problem is now under way and will be the subject of a future publication.

Cushman's *Reophax* sp. (1944, p. 10, pl. 1, fig. 20) is placed in the synonymy of *R. nana*. *Trochammina propria* Cushman (1944, p. 19, pl. 2, fig. 11) is suppressed and placed in the synonymy of *T. squamata*.

Narragansett Bay's *Reophax dentaliniformis* is without the characteristic neck. *Miliolinella* sp. of the above list resembles *Quinqueloculina vulgaris* in every detail except for the typical triangular large and flat tooth which closes the aperture.

THE DISTRIBUTION OF FORAMINIFERA

Method of study: Fifty grams of the dried grab samples and ten grams of the dried core samples were wet-sieved and fractions finer than 0.07 mm (200 mesh) were discarded. Coarser fractions were then treated by carbon tetrachloride for the separation of Foraminifera from the sediment. Foraminifera of each sample were then counted using the method described previously by the author (1950). Table II presents the results of this quantitative work in terms of numbers of specimens per gram of sediment. This method of presentation is believed to have the advantage of eliminating the discrepancies of the percentage method of presentation. For a complete discussion of the problems of the quantitative study of Foraminifera reference is given to a previous publication by the author (1950). Of the fifty-five species recorded in the area, only twenty-five occur abundantly enough to be counted separately and are therefore the only species to appear in table II. The remainder of the species occur in small numbers and in no case did they exceed 6% of the total number of Foraminifera.

Total numbers of Foraminifera: All Foraminifera observed in Narragansett Bay are benthonic. Coastal bays and protected lagoons are apparently unfavorable for the flourishing of pelagic species. The foraminiferal numbers of the Bay are small when compared with

TABLE II

	Proteonina atlantica	Armorella sphaerica	Reophax nana	Eggerella advena	Quinqueloculina seminula	Pyrgo subsphaerica	Trochammina lobata	Lagena gracillima mollis	Pseudopolymorphia novangliae	Nonion pauciloculum	N. tisburyensis	Nonionella atlantica	Elphidium advenum	E. frigidum	E. incertum	E. incertum clavatum	Bulimina elegans	Bolivina pseudoplicata	Hopkinsina pacifica atlantica	Discorbis bertheloti	Eponides frigidus calidus	Poroeponides lateralis	Rotalia beccarii	Cibicides lobatulus	Foraminiferal Number
1	☒			☒									▨	▨	⧓	▨				▨	▨		☒		21
2	☒			☒		▨	▨						▨		☒	▨	▨				▨		☒		12
3	☒			▨			▨					▨			▨	▨	▨						▨		4
4	▨			▨	▨	▨	▨	▨					▨	▨									▨		1
5				▨	☒	▨	▨		▨				▨	▨	▨	▨		▨		▨	▨	▨	☒		7
6											▨				☒	⧓					☒				18
7							▨			▨	▨		▨	▨	☒	▨					▨		▨		5
8							▨			▨	☒		▨	▨	⧗	☒					☒		▨		40
9		☒	▨							◢	☒		▨	☒	⧗	☒					◢		☒		80
10		▨	▨		▨				▨	☒			☒	◢	☒	⧗					◢				52
11		▨												☒	⧓	■					▨		☒		100
12															◢	⧓					▨		☒		25
13					▨										▨	▨									2
14														☒	⧓	⧗					☒				50
15										◢			☒	⧓	⧓	■					⧓		☒		150
16										☒			☒	☒	☒	⧗					◢		▨		38
17														☒	■	⧓					☒				100
18					▨				▨					☒	⧓	⧗					☒				60
19				▨										☒	◢	☒					☒		▨		15
20														▨	◢	▨					☒				10
21	▨	☒					▨		▨					▨	◢	☒					▨		▨		13
22				▨				▨						☒	◢								☒		14
23				☒	▨					☒	▨		☒	☒	☒	◢					☒	▨	☒		25
24					▨					☒	☒		☒	◢	☒	⧓					☒	▨	☒		36
25			▨		▨					☒	◢		▨	◢	☒	⧓					⧓		☒		58
26			▨		◢	☒	☒			◢	■	☒	⧓	☒	☒	⧓				⧓	⧓		⧓	◢	160
27				☒	▨					▨	⧓			◢	⧓	⧗				☒	☒		⧓		90
28		▨												▨	☒						☒		▨		2
29		☒	▨	▨	▨	▨	▨			☒	☒		☒	☒	▨	☒	▨	▨	☒	◢		☒	☒	☒	36
30	☒	☒	▨	☒			▨			☒				▨	◢	☒		▨	☒			▨	☒	▨	26
31	▨	▨		◢											☒	☒							☒		4
32	▨														☒	☒							▨		7
33											☒			☒	■	⧓					☒		☒		90
34														☒	■	☒					☒		☒		60

specimens in one gram of sediment

☐ none ▨ less than one ☒ 1 5 ◢ 5-10 ⧓ 10-20 ⧗ 20-40 ■ more than 40 the West Atlantic Shelf (Parker 1948) or the Red Sea (Said 1950). The average foraminiferal number of all samples studied is 41 specimens per gram of sediment, a figure which is much lower than the average of 200-300 specimens per gram found in the open-ocean areas. It must be emphasized that the count per gram is affected by the terrigenous material received in the basin of deposition. Detrital material tends to decrease foraminiferal numbers per unit weight of sediment and it is probable that lower foraminiferal numbers in Narragansett Bay are partly due to more rapid deposition of sediment than for example in the Red Sea, which is situated in an arid region. For this reason, it may prove of more correlative value to record the number of Foraminifera per unit area. The calculation of such numbers was possible in the case of Narragansett Bay by counting the number of Foraminifera in the top layer of a core (surface area of the core used is 57 cm^2). The average number of Foraminifera in the core area is about 400, which would give roughly about 7 specimens per cm^2. It might be of interest to mention that the number of Foraminifera recorded in Narragansett Bay could be roughly estimated as 2.5×10^{13}, an impressive number for such a small area which is also less densely populated than many of the normal marine areas.

The small foraminiferal numbers could be attributed to lower salinities of the Bay, since the "overwhelming majority of Foraminifera are adapted to normal salinity" (Glaessner 1945). However, some species seem to flourish under conditions of lower salinity and one would expect these species to fill in the niche left by the elimination of other stenohaline species. In other words salinity should be expected to affect the kind of species living in the area rather than the total numbers. However, as will be seen in the following discussion, there is a distribution pattern of the species which can only be regarded as indicative of salinity control. It is probable that diurnal and seasonal temperature fluctuations coupled with salinity could bring an explanation of the small number of Foraminifera recorded in the Bay.

Figure 2 shows the concentration of Foraminifera in the different areas of the Bay. It is interesting to note that in general, foraminiferal numbers increase progressively away from the open ocean. This is contrary to the findings of Morishima (1948) in the Ago Bay, Kii Peninsula, Japan. It is possible that Morishima's results would be substantially altered if *Globigerina* and other pelagic species abundant at the entrance of the Ago Bay were not counted. Larger numbers of Foraminifera per gram of sediment are noticed near the approaches of the Providence River, around Prudence Island and along the Western Passage particularly near Wickford. This area is characterized by lower salinities and sandy bottoms and flat topography. Greenwich Bay, a small bay in the north west corner of the area, is characterized by very low numbers of Foraminifera, particularly in the near shore sample No. 13. This sample is procured from the tidal flat and is subject to drought during at least part of the low tide.

The foraminiferal numbers of the Eastern and Western Passages around Conanicut Island are sharply contrasted, the former having low numbers (average foraminiferal number is 12) and the latter having higher numbers (average foraminiferal number is 65). It seems that flat shallow sandy bottoms of the Western Passage are more favorable for the Foraminifera, than the gravelly, irregular and deep bottom of the Eastern Passage. Sakonnet River area is shallow and silty and the foraminiferal numbers are very low, in fact the lowest recorded in the area (average foraminiferal number is 6).

Optimum depth conditions for the development of Foraminifera in Narragansett Bay is between 15 and 30 feet (average foraminiferal number of samples collected between these depths is 71). Samples procured from deeper water are impoverished in Foraminifera (average foraminiferal numbers of samples collected from areas deeper than thirty feet is 18).

An interesting feature in Narragansett Bay is the presence in some impoverished samples of a large number of faecal pellets. The pellets are rod-like structures, circular in section and homogeneous in consistency, built of very fine sand bound by mucous material and are apparently of the simple "rod-type" described by Moore (1939, p. 517). It is likely that the small number of Foraminifera in these samples is due to a sand-eating invertebrate of probable molluscan affinities. Foraminifera in Narragansett Bay are therefore subject to drastic reduction in numbers because of the predatory habits of some molluscs which tend to clear the area of Foraminifera. Samples No. 7 and 8 are composed of the same species of Foraminifera present in the same percentages, although sample No. 7 has a low foraminiferal number and a great quantity of these faecal pellets.

It is interesting to note that Arrhenius (1950) has recently emphasized the effect of mud-eating organisms on the breakage of accumulated dead pelagic Foraminifera in the deep sea. In spite of the fact that Narragansett Bay is infested by predators as can be attested by the abundance of faecal pellets, no broken foraminiferal shells have been observed. Myers (1942, p. 34) has noted that foraminiferal shells attacked by mud eaters "could pass through the digestive tract of most invertebrates many times before they could show . . . . resolution." It seems therefore that predators influence benthonic foraminiferal populations by attacking and completely eliminating a large number of the young and early naked stages of benthonic Forami-

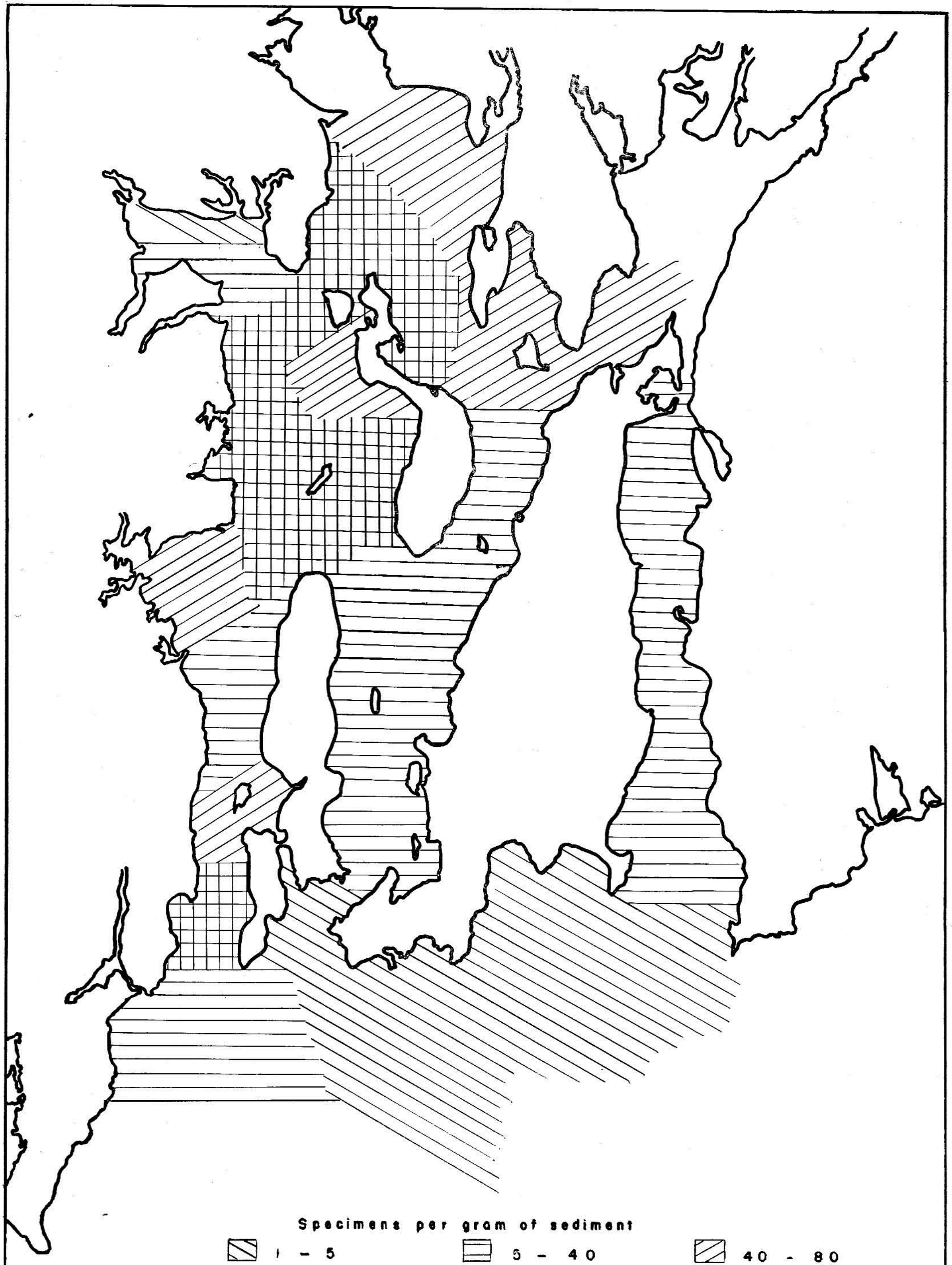


Figure 2 : The Distribution of Foraminifera in Narragansett Bay

nifera hindering the full development of the population. In the case of deep sea basins receiving largely dead shells of adult pelagic species, however, it is likely that the effect of predators would be the breakage of shells. Pelagic forms are more spherical and fragile than benthonic Foraminifera making them susceptible to crushing. It is therefore concluded that predators reduce total benthonic foraminiferal numbers without breaking the shells, while in a thanatocoenose of pelagic Foraminifera, the effect will be the destruction of shells without influencing directly total pelagic foraminiferal numbers.

Distribution of species: The number of foraminiferal species recorded in Narragansett Bay is limited, only fifty-five species having been observed. *Elphidium incertum* and *E. incertum clavatum* are by far the most abundant species in the area except in a few of the deeper water samples in the approaches of the Western Passage. These two species seem to have their maximum development in the less saline areas around Prudence Island. In fact, the number of specimens of these two species increases progressively away from the open ocean. Figure 3 shows the distribution of *E. incertum* in the Bay. Large numbers of this species are found in the Wickford area and along the eastern edge of Prudence Island, the approaches of Providence River and Taunton River. Greenwich Bay also has high numbers. The greatest concentration of *E. incertum clavatum* (as shown in figure 4) is along the western side of Prudence Island, although areas around Bristol also seem to favor the development of this species. The Western Passage has greater numbers of *E. incertum clavatum* than the Eastern Passage. An interesting observation is that the number of specimens of these two species increases away from the point of their origin, obviously the continental shelf of the Atlantic. This inference is of significance in view of the fact that some authors tend to consider the point of maximum number of a given species as the point of origin of that species. Biotic pressure is always in operation, but the success of the species is dependent not on its distance from the point of its origin, but on the suitability of the new environment. Although *E. incertum* and *E. incertum clavatum* occur together in most samples, one or the other is dominant in numbers: *E. incertum* is more common in silt samples, while *E. incertum clavatum* flourishes in sand samples.

The number of species in the northern samples is much less than those found in the southern approaches of the Bay. This is in harmony with Morishima's findings (1948). *Discorbis bertheloti, Proteonina atlantica, Eggerella advena, Bulimina elegans* and *Nonionella atlantica* are typical for the more saline southern waters. They either disappear completely in the northern areas or are represented only by a few specimens. It must be emphasized that although the southern part of the Bay contains a more diversified foraminiferal fauna, the foraminiferal numbers are lower.

Rotalia beccarii seems to flourish in the southern parts of the Bay. The number of specimens of this species is small and the species seems to occur uniformly along the southern approaches of the Bay in the Eastern and Western Passages as well as Sakonnet River, although there is evidence that it increases in numbers in sand samples. This is in harmony with Pratje's findings in the North Sea (1930). The restriction of this species to the southern parts of the Bay is in contrast with its widespread distribution in the Jade Bay (Bartenstein 1938).

Attached and arenaceous forms are few, but they seem to occur abundantly in the gravelly and deeper waters of the Eastern Passage.

Between the northern and southern foraminiferal assemblages, there is a zone of intermediate composition, particularly in the southern approaches of the Eastern Passage.

The distribution of *Nonion tisburyensis* is unique. This species occurs in large numbers in the approaches of the Western Passage, and less abundantly in Sakonnet River. It is not recorded in the normally saline waters off the Bay. *Elphidium* and *Nonion* assemblages found in the brackish upper Miocene deposits of the North Caucasus were interpreted as the result of grain size control (Glaessner 1945, p. 192). This is not apparent in Narragansett Bay, where *Nonion* specimens seem to be abundant in few samples irrespective of the mechanical composition of the sample.

Quinqueloculina seminula is the commonest representative of the family Miliolidae. This euryhaline species seems to develop abundantly in the more saline waters of the southern parts of the Bay. The distribution pattern of this species in Narragansett Bay coincides with its distribution in the Jade Bay (Bartenstein 1938, table 1b, p. 399).

SUMMARY AND CONCLUSIONS

The quantitative study of the Foraminifera occurring in thiry-four samples from Narragansett Bay is presented. The Bay is a coastal area characterized by an irregular bottom and shallow depth. The salinity is lower than normal and bottom temperatures vary greatly diurnally and seasonally. The sediments are either gravelly, sandy or silty. High nitrogen percentages are characteristic.

The total number of Foraminifera in the Bay is low, probably due to adverse conditions, particularly with regard to salinity. Zonation of the Bay into two facies is possible. There is a northern inner Bay facies characterized by an abundance of *Elphidium incertum* and *E. incertum clavatum* together with such euryhaline species as *E. frigidum* and *Eponides frigidus calidus*, and a southern outer bay facies characterized by the presence of *Proteonina atlantica, Discorbis bertheloti,*

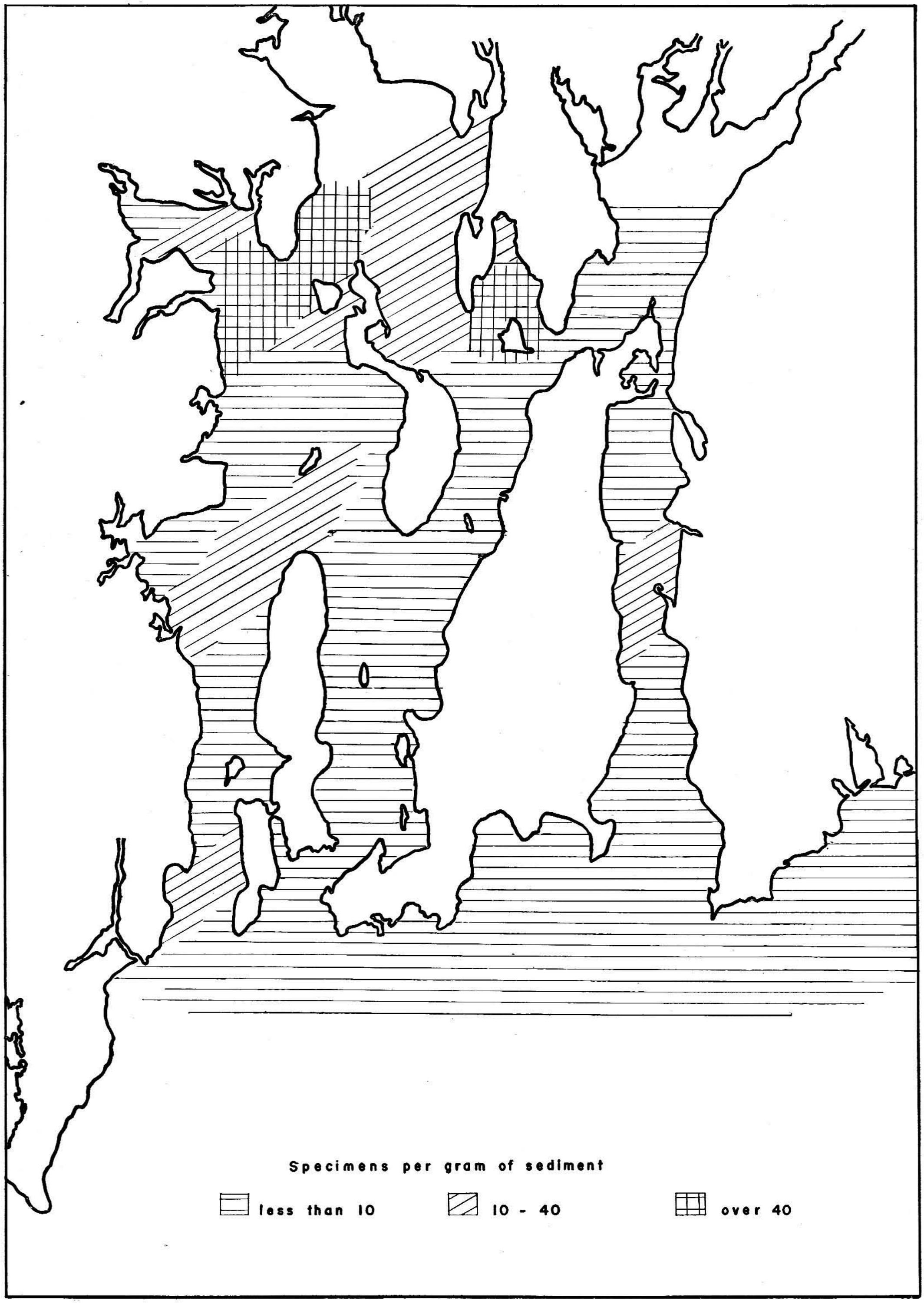


Figure 3 : The Distribution of *Elphidium incertum* in Narragansett Bay

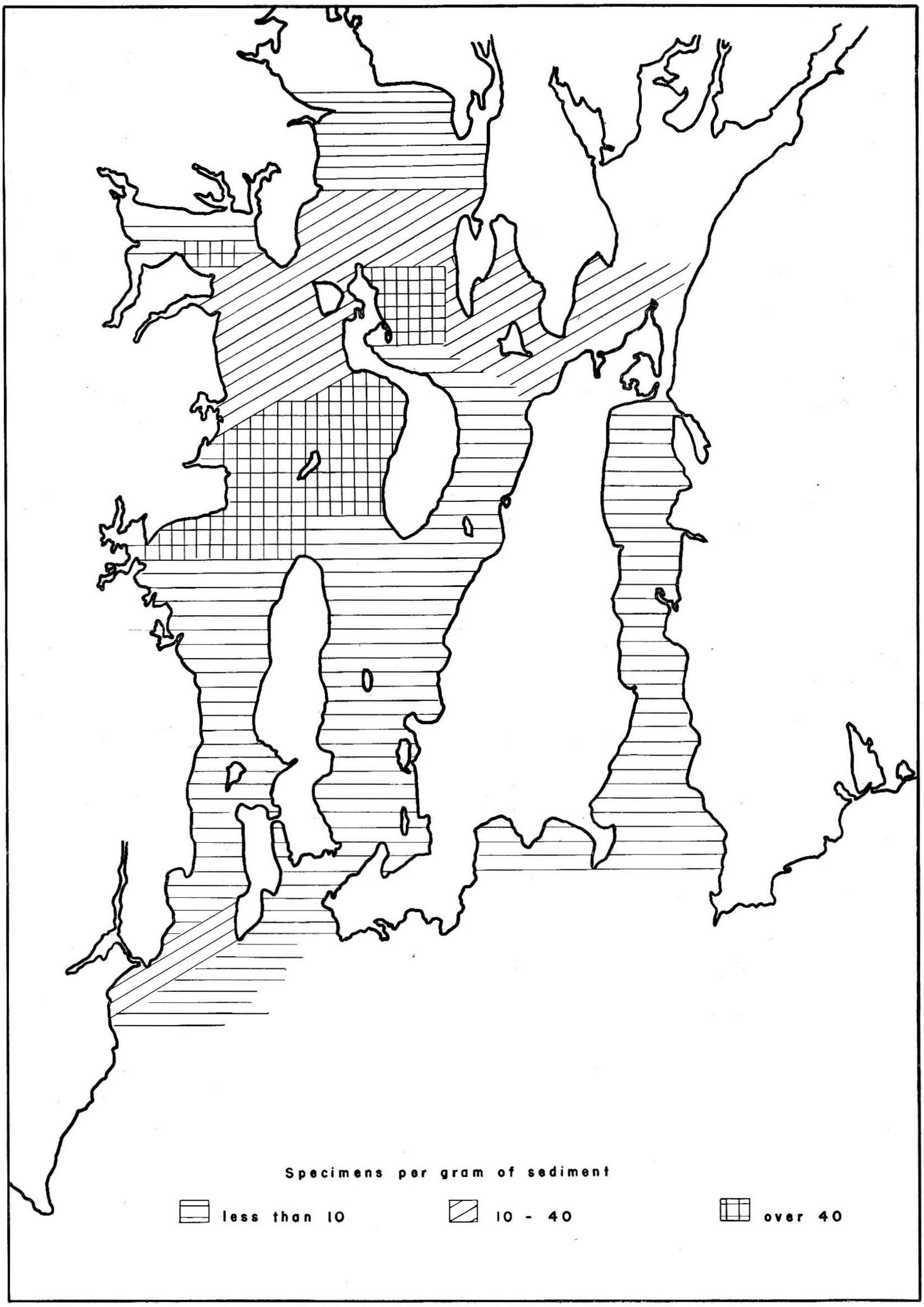


Figure 4 : The Distribution of Elphidium incertum clavatum in Narragansett Bay

Eggerella advena, Nonionella atlantica, Cibicides lobatulus and *C. concentricus.* An intermediate zone between these two facies is noticed with *Nonion tisburyensis, N. pauciloculum, Rotalia beccarii* and *Quinqueloculina seminula.* This zonation is probably due to salinity control.

Hiltermann (1949) has recently summarized and supplemented Remane's work on the North Sea postulating the presence of five brackish water biotopes defined by the salinity of the water. It is possible that the two facies recognized in Narragansett Bay correspond to Hiltermann's brachyhaline (16½-30 o/oo salinity) and pliohaline (9-16 o/oo) brackish-marine water facies. The general characteristics of analogous areas in Narragansett Bay coincides well with Hiltermann's observations.

The bottom topography and type of sediment exert some influence on the appearance of species: gravelly bottoms are more favorable for the development of attached arenaceous Foraminifera, sandy bottoms seem to influence the numbers of *E. incertum clavatum* favorably, while finer silty bottoms are essential for the development of *E. incertum.* The fact that the Eastern and Western Passages differ in their bottom topography and type of sediment is reflected in the different foraminiferal populations of the two areas.

Predators play an important role in determining the number of Foraminifera present in the sediment. Evidence of the drastic effect of a sand-eating mollusc on the numbers of Foraminifera is particularly noticeable in Sakonnet River and the northern reaches of the Eastern Passage.

Foraminiferal numbers increase northward away from the open ocean although the number of species recorded decreases in the same direction. This may be attributed to flourishing under less competitive environment. Temperature does not seem to be of importance in Narragansett Bay in the local distribution of Foraminifera, inasmuch as the entire Bay is subject to more or less the same temperature conditions. However, the bottom of Narragansett Bay is exposed to drastic diurnal and seasonal temperature fluctuations and this might render the area unfavorable for the development of larger populations.

With few exceptions all foraminiferal species recorded in the area belong to the typical fauna characteristic of the areas south of Cape Cod. Cushman (1944) has already extended to the Foraminifera the well-known observation of the effect of the Cape Cod area as a barrier separating the northern and southern faunas of the Atlantic Coast. Six foraminiferal species previously recorded only from north of Cape Cod are now seen in very small numbers south of the Cape for the first time: *Tholosina bulla, Saccorhiza ramosa, Haplophragmoides columbiense, Triloculina tricarinata, Lagena gracillima mollis* and *Fissurina globosa.*

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31. WALL STRUCTURES OF FUSULINID FORAMINIFERA

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INTRODUCTION AND ACKNOWLEDGMENTS

The wall above the chambers in the shells of members of the Late Paleozoic foraminiferal family Fusulinidae is generally referred to as the spirotheca, because of its spiral development from the beginning chamber or proloculus. Markedly different theories to explain its structure and origin have been proposed by different workers. Its method of formation and detailed structure seem of special importance to a better understanding of the family, since its finer features and their interpretation have played a major part in the establishment of the present classification of the fusulinids. This discussion concerns principally the spirothecal structure. The shell is largely calcite in composition. Some have considered that it is agglutinated and was formed of cemented particles or fragments of calcite. Most others consider that it was formed of secreted calcite.

Most proposals regarding the spirothecal structure may be grouped under three general theories. (1) The spirotheca originally contained a thin rind-like upper layer and a thicker lower layer, penetrated from its lower surface by tube-like structures which ended against the upper layer. (2) The spirotheca had a primary structure as outlined above in (1), except that the tube-like structures passed completely through the upper layer and that the spirotheca was truly perforate. (3) The spirotheca is considered by Gubler (1934) and some others as having been formed of organically secreted pillar-like crystals of clear calcite oriented normal to its surfaces and cemented together by darker fine-grained calcite including organic material.

Almost without exception, the fusulinid shells have been filled since death of the animal by solid mineral deposits. Most commonly these deposits are of calcite, but in some cases they are fillings or replacements by some form of silica, sphalerite, or one of many other types of minerals. Because all parts of the fusulinid shell have become entirely filled during or after fossilization, most considerations of its primary wall structure must be based on the determination of the relative ages of the mineral constituents of the fossilized shell.

All three of the above mentioned basic ideas of the fusulinid spirothecal structure seem about equally applicable to most specimens as observed under the microscope, for most structures that can be observed

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EXPLANATION OF PLATE 9

All illustrations on this plate are unretouched photographs.

In reproduction the lettering of the figures has been shifted upwards one mm. Read lettering on figures 1, 2, 3 and 4 one mm. downwards to correspond to structures indicated.

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3.	*Triticites* cf. *T. ventricosus* (Meek and Hayden), 1858. Sagittal section showing *Triticites*-type spirothecal structure, C-chomata deposit, T-tectum, and K-keriotheca, × 100. Americus limestone, Kansas.	87
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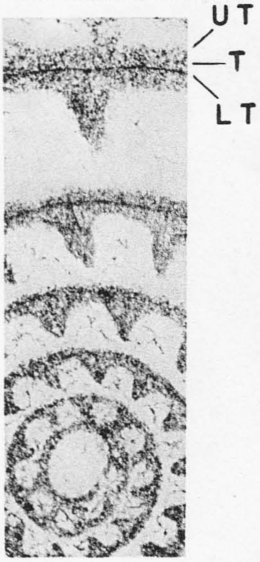

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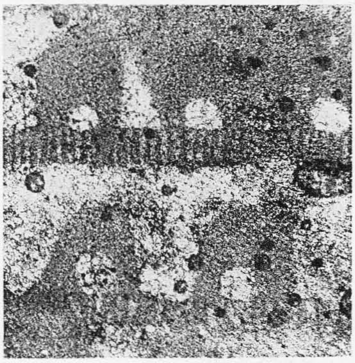

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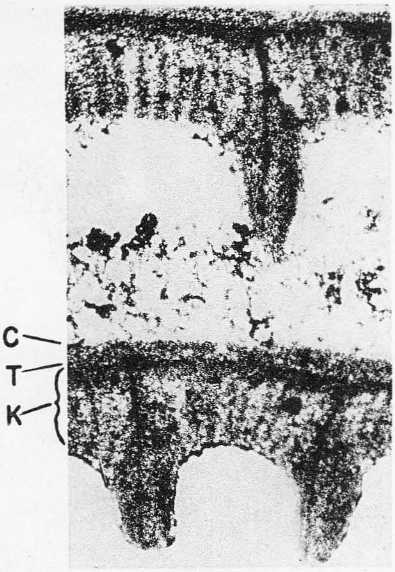

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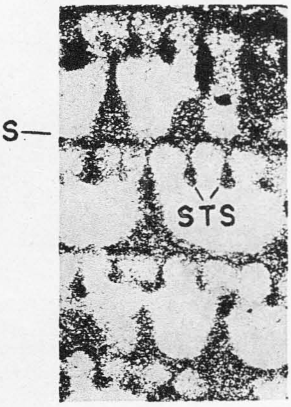

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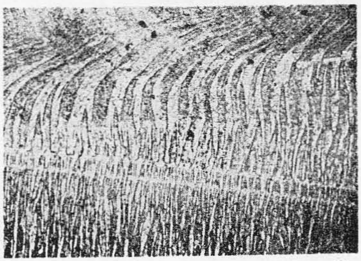

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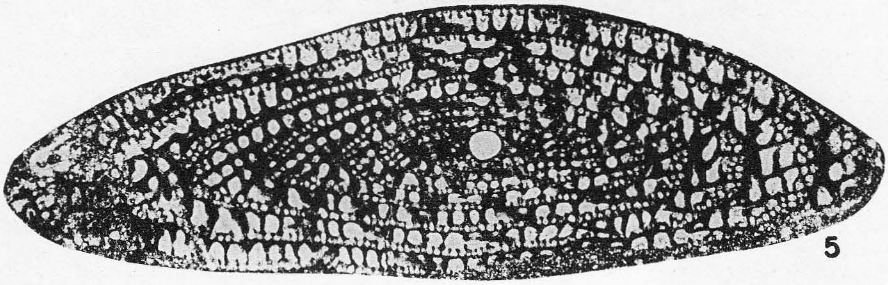

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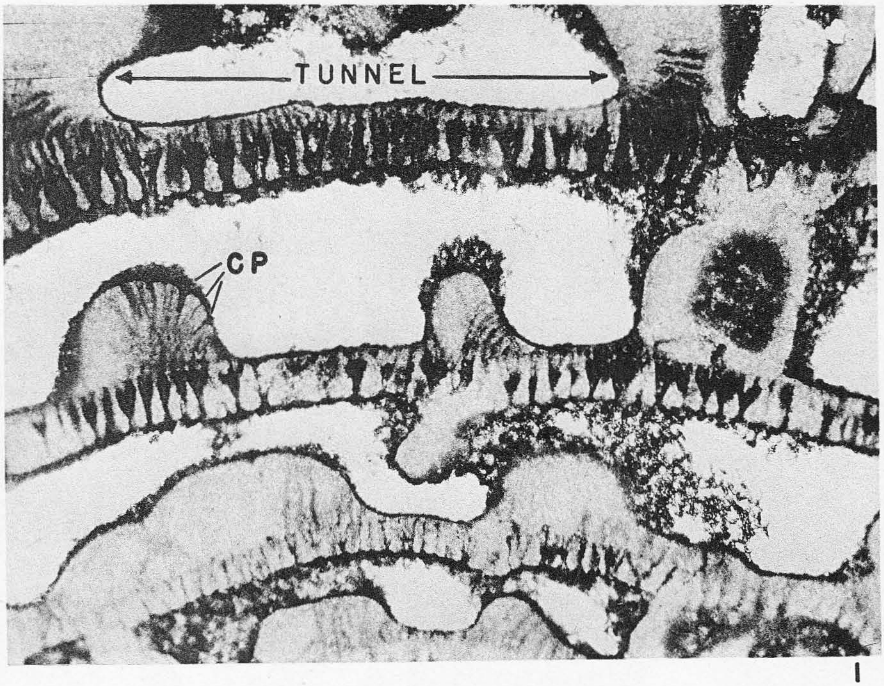
Thompson, Fusulinid wall structures



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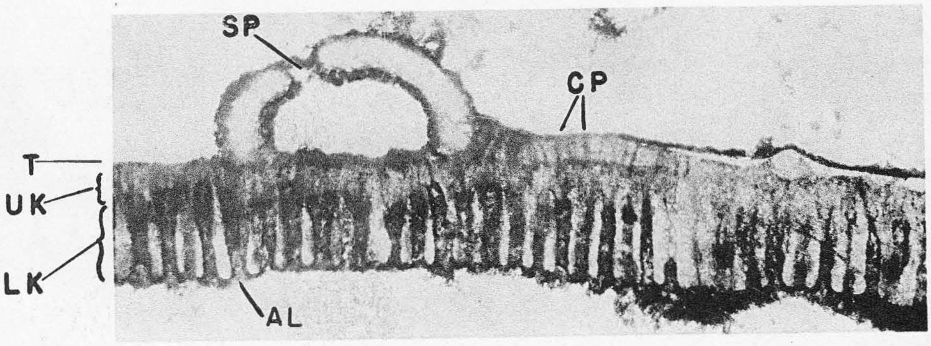

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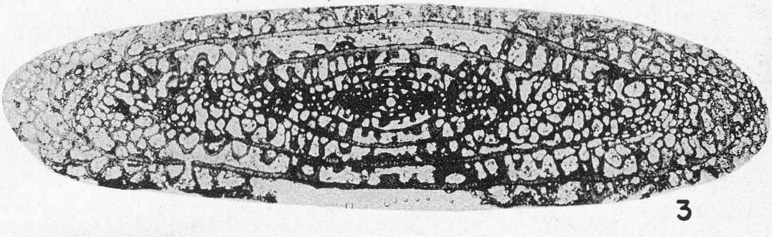

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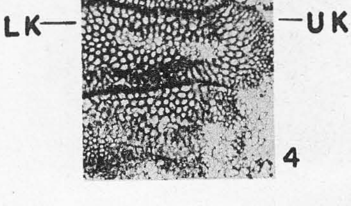

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Thompson, Fusulinid wall structures

seem explanable by any one of them. Thin sections showing fibrous-like structures passing completely through the spirotheca have been illustrated by many workers (Hayden, 1909; White, 1932; Thompson, 1936, 1946; Henbest, 1937; Dunbar and Skinner, 1937; Dunbar and Henbest, 1942; and others). Many of these illustrations show that the fibrous structures of the spirotheca continue through the overlying chomata or through other secondarily formed deposits on the top of the spirotheca. If the fibrous features were the bounding walls of open spaces or perforations, these sections would seem to demonstrate porosity for the spirotheca. However, the tops of the walls of many shells showing such penetrations completely through the spirotheca probably were partly excavated by the animal during its life, or possibly were later partly dissolved during fossilization, and the Gubler theory would be equally applicable. As for the specimens in which the fibrous structures of the spirotheca continue into overlying later formed deposits, such as the chomata, the proposal of Gubler could be here applied equally as well. It does not seem that any one of the theories has yet been completely established.

Several individuals to whom I wish to express my sincere thanks have assisted me with this study in various ways. S. A. Tyler and R. C. Emmons have given suggestions and information concerning secondary replacements and the development of organically formed minerals, and G. J. Verville and E. J. Zeller made some of the laboratory tests of the fusulinid shells. Financial support was supplied by the University of Wisconsin Research Committee, from funds furnished by the Wisconsin Alumni Research Foundation.

SPIROTHECAL TYPES

The members of the family possess several types of spirothecae, and some of the major divisions of the family have been distinguished principally or in part by them. Five major types of spirothecae have been recognized within the family, and there are many variations of these major types.

(1) The geologically earliest of these types, the *Profusulinella*-type, possesses in its original formation a thin layer, the tectum, in which finer structures have not been observed. As additional chambers were added to the shell, the chambers were lined with a deposit of fine-grained and dense calcareous material so that the spirotheca of internal volutions has a thick layer at the top and a thick layer at the bottom of the tectum. The first formed thin layer is distinguishable from those above and below and results in a spirotheca of three layers (Pl. 9, fig. 1).

(2) The second type of spirothecal structure is termed the *Fusulinella*-type. The fusulinids that have this type of spirothecal structure were descendant from those that possess a *Profusulinella*-type of wall structure, and the progressive change of the spirotheca is observed in transitional forms. The spirotheca of the last chamber possesses an upper thin layer, the tectum, and a thicker and much less dense lower layer, the diaphanotheca, in which finer structures are not observable in most thin sections. The internal spirotheca is composed of four layers, the upper tectorium, the tectum, the diaphanotheca, and the lower tectorium (Pl. 9, fig. 2). Artificial staining and, in some cases, natural variable weathering and oxidation have displayed a fibrous-appearing structure in the diaphanotheca. These fibrous structures penetrate the remainder of the spirotheca and the chomata of at least some specimens (White, 1932; Henbest, 1937).

(3) The third type of spirothecal structure is commonly referred to as the *Triticites*-type of spirothecal structure. It is found in all members of the subfamily Schwagerininae and in most of the verbeekinids and neoschwagerinids. It has a thin dark upper layer and a lower much thicker layer that shows in thin section fibrous-like structures oriented normal to its surfaces (Pl. 9, figs. 2, 3). The spirotheca of this type does not possess deposits above or below these two, except for the chomata or parachomata deposits. Artificial and natural staining show that the fibrous-like structure normal to the spirothecal surfaces continues through the tectum and through the overlying chomata in many specimens.

(4) The fourth type may be referred to as the *Schubertella*-type of spirothecal structure. It is similar to the *Triticites*-type, except that the lower layer is thinner and does not show fibrous-like structures.

EXPLANATION OF PLATE 10

All illustrations on this plate are unretouched photographs.

FIGS.		PAGE
1-3.	*Schwagerina* cf. *S. longissimoidea* (Beede), 1916. 1, Enlargement of an axial section of a heated and oxidized specimen showing structure of spirotheca, with dark areas of oxidized coatings on surfaces of shell material and insides of perforations, CP-chomata pores, × 200. 2, part of the same axial section showing T-tectum, UK-upper keriotheca, LK-lower keriotheca, SP-septal pore, AL-alveolus, and CP-chomata pores, × 200. 3, axial section, × 10. Camp Creek shale, Texas.	89
4, 5.	*Schwagerina rutschi* Thompson, 1936. 4, Section cut tangent to spirotheca of fifth or sixth volution showing cross section of alveoli in lower keriotheca (LK) and in upper keriotheca (UK); and 5, part of a sagittal section of sixth volution showing spirotheca, T-tectum, UK-upper keriotheca, and LK-lower keriotheca; both × 40. Lower Permian, Sumatra.	88

Many genera of widely different ages and presumably of widely different ancestry show this type of spirothecal structure.

(5) Many senile or aberrant fusulinids have a spirotheca that seemingly is composed of a single layer and can be referred to as a fifth type, the *Sumatrina*-type (Pl. 9, figs. 4, 5). No structural features other than one thin layer have been observed. Genera with this type of spirotheca seem to be the end products of long lines of evolutionary development of markedly different groups of fusulinids.

Although the fusulinids have spirothecae that may be divided into five major types and into many minor but distinct variations of these types, it is agreed by most specialists of the family that all of the spirothecae of the fusulinids were basically the same in their original formation, although giving different structural patterns under high magnification in thin section and showing marked differences in magnitude of detailed features and overall thickness. If the structure of the spirotheca of any fusulinid can be demonstrated, we probably will have the answer to the basic structure of all the fusulinid spiral walls.

The spirotheca of many of the fusulinids is thin, and, as would be expected, its detailed features are difficult to observe. However, the spirotheca of most members of the subfamily Schwagerininae is abnormally thick as compared to that of most of the other fusulinids, and it can be observed under the microscope more easily than that of most others. The fibrous-like lower layer contains small prismatic to rod-like transparent areas surrounded and separated by thin dark areas. These transparent areas extend from the basal surface of the spirotheca up toward its top with decreasing sharpness of boundaries, but in most specimens they seem to end against the thin darker upper surface of the spirotheca. The name keriotheca was proposed by Dunbar and Condra (1928) for the lower fibrous layer, and as the name implies, they considered that the spirotheca has a honey-comb like structure with a solid layer, the tectum, on top and with tubes opening downward. The term alveolus (a cavity or pit) was applied (Douvillé, 1906) to the clear areas of the spirotheca for they were considered to be the cells of the honey-comb like lower layer. The thin dark fibres normal to the surfaces of the spirotheca in thin section have been interpreted by most workers before and since 1928 to have been the bounding walls of the cells or perforations.

Many experiments and examinations of the fusulinid wall have been made to determine its original structure. Different types of fusulinids have been treated with various stains, and with approximately the same results as those described by Henbest (1937). It can not be demonstrated in most cases if the differential staining effects which accentuate the fibrous structure of the spirotheca obtained from these experiments were due to differential staining of the same minerals of different grain size in the clear areas and their surrounding thin layers or to different materials in these parts of the spirotheca. In other words, the same results probably would be obtained if the material of the clear areas were formed at the same time or at a later time than the darker layers around them. Furthermore, it could not be demonstrated clearly if the fibrous continuations into the tectum and the overlying chomata were due merely to mineralogical continuity from the lower part of the wall. If the more transparent areas were pillars of calcite as postulated by Gubler, they may have continued by mineral growth into the overlying chomata due to organic secretion by the animal, even though they curve and diverge as they approach the tops of the chomata. Similar curving mineral crystals can be observed (Bøggild, 1930) in the prismatic crystals in parts of mollusk shells (Pl. 9, figs. 7, 8).

In thin section many of the schwagerinids show widely spaced fibres in the lower part of the spirotheca and closely spaced fibres in its upper part. Furthermore, the fibres are much thicker in the lower part of the spirotheca of many specimens than in the upper parts and have been diagrammed and described by many students of the family as pendant-shaped in cross-section. Tangential sections demonstrate that in some fusulinids the fibres are darker layers surrounding more transparent prismatic areas, which are more numerous and considerably smaller in cross-section in the upper part of the spirotheca than in its lower part. This is shown in the illustration of a tangential slice at the top of the spirotheca of *Schwagerina rutschi* Thompson and from the lower part of the spirotheca of the same chamber (Pl. 10, figs. 4, 5). It seems evident in this form that three of the smaller prismatic areas of the upper part combine to form one larger area of the lower part. In some other fusulinids as many as nine areas at the tops of the spirotheca are replaced below by only one area. This attitude of the spacing of the fibres in the upper and lower parts of the spirotheca can be observed in many forms of the schwagerinids. In some fusulinids with a *Triticites*-type of spirothecal structure, the coarse alveoli at the base of the keriotheca continue without much change to the base of the tectum. In most specimens, however, the fibres of the upper part of the spirotheca are too fine and faint for clear observation under the microscope, and, as a result, the fibrous nature of the spirotheca fades as its top is approached.

It has often been observed that a few specimens of a given collection will show clearly defined wall structures, but that most others show poorly defined or no structures whatever. Experimentation with staining, mentioned above, and high temperatures has made it possible in many cases to bring out spirothecal structures not observed in the unaltered specimens. Since high temperature and artificial staining affect different parts of the spirotheca in different manners, it is suggested that the different parts of the spirotheca contain different types of material, either due to primary differences at the time of secretion by the animal or to additions, alterations, or replacements during or since fossilization. In any case, it at least suggests that the fibres and the intervening lighter areas were formed in a somewhat different manner.

SOLUTION STUDIES

Shells of *Triticites* collected from shales within Topeka limestone just west of Moline, Kansas are grayish in color and have wall structures so nearly perfectly preserved that the alveoli can be observed through the outer surface of the shell, the alveoli appearing as clear pillar-like crystalline calcite and the surrounding alveolar walls appearing more fine-grained and darker gray in color. Sectioning demonstrates that the walls are solid and that the chambers are filled with crystalline calcite. Some of the Topeka specimens were dissolved in our laboratory in various dilute acids, at very slow rates, and in a totally non-agitated environment. After several weeks time, it was observed that the fusulinid specimens maintain their original shape but that all of the calcite was dissolved, leaving a framework of the original specimen in the form of a hydrous jell. Edward J. Zeller carried this experiment still further and impregnated the residual specimens with parafine and sectioned them serially with a microtome. The microtome sections show the shapes of the shell, the top and bottom surfaces of the spirotheca, both sides of the septa, and most of the details of the fibrous structures of the wall. However, only the margins of the walls of the alveoli, surfaces of the septa, and the upper surface of the spirotheca or chomata seemed to remain in the residue. Most of the alveoli and all of their surrounding walls were dissolved by the acid. Also, the septa were dissolved, but thin residues were left on their former surfaces. Although this method of examination of the fusulinid shell is not entirely satisfactory because most of the shell is removed, it does permit the examination by serial sections of all parts of a given fusulinid specimen, so that the major internal structural features through all parts of the shell may be determined. Perhaps most important of all for this discussion is that it demonstrates that the internal surfaces of the alveoli contain material like that which covers the internal surfaces of the chambers. E. J. Zeller and C. W. Pitrat will describe this process for the examination of internal structures of fossils in more detail at a later time.

OXIDATION EFFECTS

Numerous specimens of *Schwagerina* cf. *S. longisssimoidea* (Beede) obtained from the Camp Creek shale of Texas were gray in color when collected. Of the many specimens sectioned, all were found to be filled with calcite. On heating to temperatures just short of calcining, the specimens became red to brown. The structural features of the shell became greatly accentuated, and the septa, septal pores, keriotheca, and the surfaces of the spirotheca are well defined (Pl. 10, figs. 1, 2). In most of them, the fibrous-like structures of the spirotheca penetrate the tectum and pass on through the chomata deposits. Both surfaces of the septa and the walls of the septal pores are covered by thin layers of reddish oxides. It seems evident that these surfaces were coated by iron-bearing deposits before the chambers were filled with crystalline calcite. Similarly, it can be observed that thin layers of oxidized deposits completely cover the surfaces of the thin fibres of the spirotheca and therefore completely line the inside of the clear pillar-like structures, the alveoli, and continue around the lower surfaces of their bordering walls. Although these films of iron oxide completely line the alveoli, they do not occur over their lower ends, indicating that the alveoli were open spaces at the time the films were deposited. Furthermore, thin films of oxide line the inside or completely fill the continuations of the alveoli as they pass through the overlying chomata. It might be argued that these films formed part of the outer area of secreted calcite crystals. However, if the clear areas were calcite pillars, the oxide films lining the alveoli should also be found over the lower ends of the prisms. Other convincing evidence that the spirotheca was perforate is observed in the continuity of the oxide films in the alveoli with those that occur as coatings on the septa, linings of the septal pores, coatings on top of the chomata, etc., all of which almost certainly were open spaces shortly after death of the animal.

Similar oxidized coatings within the wall of the fusulinid shell were observed and photographed by Henbest (1937). However, he did not state if these specimens were highly dissolved by weathering and replacement or if they contained solid calcite fillings. Dunbar (1947) observed that specimens of *Parafusulina alaskensis* have fillings of iron oxides in the alveoli of the spirotheca. The degree of replacement by oxides of associated fossils was not discussed.

The tectum has been interpreted by some to be a rind-like layer above the keriotheca, and the alveoli have been considered by them to end at the tectum. Since the alveoli and their bordering walls are so nearly perfectly displayed in these specimens of *Schwagerina* cf. *S. longissimoidea,* it is possible to demonstrate the cause for the seemingly solid nature of the dense tectum. I have been unable to show by photographs the structures of the tectum because its pores are very small and are partly filled with red oxides. However, the following diagrammatic sketch is taken from a high magnification of the tectum (Fig. 1). It is evident that although the tectum is not a solid layer, its den-

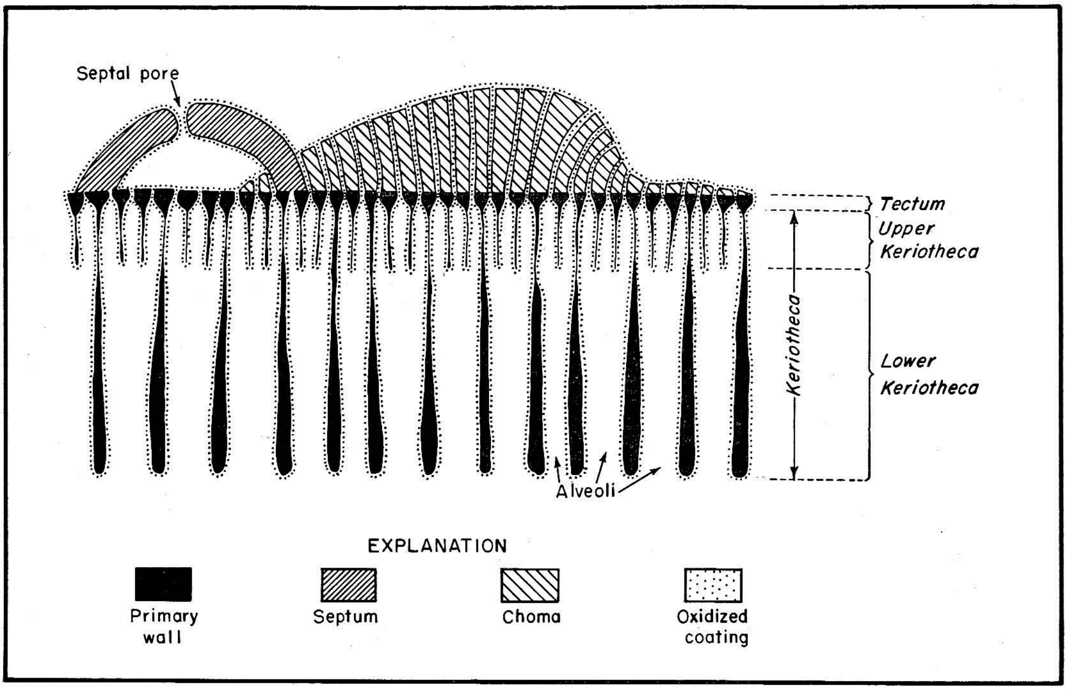

FIG. 1. Diagrammatic sketch of spirotheca and associated features of *Schwagerina* cf. *S. longissimoidea* (Beede), taken from specimens illustrated by figures 1-3 on Plate 10.

sity is due to a sharp reduction of the size of the pores of the keriotheca and a simultaneous and comparable sharp increase in the thickness of the pore walls. Perhaps most important for most thin sections, the pores of the tectum are considerably smaller in diameter than the thickness of the sections, and observation is nearly always through several of the pore walls.

It has been observed by a number of students of the fusulinids that the structure of the keriotheca is more evident in the lower area of the spirotheca than in its upper part. In the lower area, the alveoli walls are thick and widely spaced, but in the upper part they are thin and closely spaced. Many specimens show a faint line of demarcation between the lower coarser part of the keriotheca and its upper finer part. These oxidized specimens demonstrate that the line of demarcation parallel to the tectum and a short distance below the keriothecal top is a line that marks the lower ends of the tube-like fine alveoli at the point where they open into the larger alveoli below.

The terminology here employed for the different parts of the fusulinid spirotheca is the same, in general, as that commonly used in recent years by most students of the family. Although the tectum (a roof or covering) is not a complete covering as thought when proposed, the keriotheca (honey-comb wall) is not truly of a honey-comb nature, and the alveoli are tubes instead of pits or cavities as considered when proposed, these terms have become well established in the literature and most of them are more or less descriptive of these spirothecal structures.

The pendant shape of the walls of the alveoli as displayed in some thin sections is due to their downward thickening as they approach the lower surface of the spirotheca. Correspondingly, the alveoli become constricted downward as their walls increase in thickness. Some of the abnormal downward thickening of the alveoli walls as observed in thin sections is due partly to their oblique intersection with the thin sections. The growth of the fusulinid wall after its original formation does not seem difficult to understand under the general concept that the wall was porous (Thompson, 1948, pp. 13, 14).

As the accompanying photographs and diagrams indicate, the spirotheca of *Schwagerina* cf. *S. longissimoidea* (Beede) is divisible into three parts which are distinguishable largely because of the variation in size of the alveoli and in thickness of their surrounding walls. The terms applied to them are, from top to bottom, the tectum, the *upper keriotheca* composed of small alveoli with thin walls, and the *lower keriotheca* composed of large alveoli with thick walls. It seems probable that the walls of all fusulinids have the same three layers. The alveoli of many fusulinids are too small for observation, and in others it seems possible that the upper and lower keriotheca appear in thin section as a single layer because the upper one is too thin to be separated from the lower.

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Manuscript received May 14, 1951

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32. A MONOTHALAMOUS FORAMINIFER, *MARENDA NEMATOIDES* N. GEN. N. SP.

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During my work with some epsilonematoid nematodes from sandy habitats off the Catalan coast of the Mediterranean in the neighbourhood of Banyuls sur Mer (Pyr.-Orient.), numerous free-living nematodes, not so aberrant as the epsilonematoida crossed the field of my microscope. The characteristic movements of different forms, when irritated by light, were always a remarkable help in picking out and sorting material from living specimens. On some occasions I was astonished by the slow-motion movements of certain forms resembling nematodes as compared to the normal wriggling of the nematodes. The slow bending of the terminal portions occasioned a varying anchorage on different grains of quartz (fig. 4). In spite of the nematoid appearance of the organism the movement did not seem to have much in common with that of a nematode's usual swiftly-acting longitudinal muscle layer.

A closer investigation of these organisms made it apparent that they are certainly not nematodes, however aberrant may be the types which this large group can display. With reflected light and greater magnification this organism with the conspicuously nematoid appearance resembles a bent cord of close opaque protoplasm enclosed in a fragile colorless membrane-thin test of a chitinous character. A detailed study of living material, mainly after the plasm had been stained, showed round or somewhat oblong nuclei in the plasmatic cord (fig. 4 and 8). This observation alone could not, however, identify this type of organism more closely, even if it showed it to be very probably a protozoan. Only after culturing it did a fundamental characteristic appear, namely the occurrence of pseudopods (fig. 8). These pseudopods, which are of the "filoreticulous" type, belong to the plasm cord surrounded by the thin membrane. This discovery not only made it clear that the plasmatic cord was the matrix for the membranous envelope but also ruled out any possibility that the pseudopodia belonged to some parasite inside the membrane. However improbable it may seem at first sight the organism is certainly a rhizopod. It unfortunately proved impossible to place this type among those already described. For this reason a short description of the organism follows before further discussion.

Genus **Marenda** Nyholm, n. gen.

Genotype: *Marenda nematoides* Nyholm, n. gen., n. sp.

Test elongate, tubular, nonseptate, gradually pointed at the ends; no permanent, marked apertures; wall thin, membrane-like, chitinous without foreign bodies, colorless. The pliant tubular chamber is filled with opaque white plasm. The plasm is often constricted into sections with a nucleus in every section. Pseudopodia only from the ends of the tube.

Marenda nematoides Nyholm, n. sp.

Plate 11, figures 1-3; Text figures 1-14

Description. The organism nematoid, flexible, especially the ends, by plasmic movements within the tube. In the plasm several nuclei and sometimes non contractile vacuoles. No trace of a contractile vesicle. Filoreticulous pseudopodia only from narrow, generally temporary apertures at either end of the test. Length up to 9 mm.

Occurrence. Sandy localities at 8-20 m. Gulf of Lion, Mediterranean Sea, Banyls-sur-Mer.

Remarks. Encystment, possibly of a protective character, has been observed under direct light (fig. 10-14). The plasm flows out toward one of the apertures, which can thereby be considerably dilated. The nuclei flow out with it and a membrane is formed around the ball of plasm with its nuclei. The tube then becomes emptied of its contents and is seen lying shrivelled-up. It has not been possible to discover what then happens to the globular cysts, although they have been kept alive for two weeks.

The above-mentioned movements, particularly of the pointed ends, seem to be characteristic. Pseudopods have not been observed during these movements. If pseudopods have been formed and have penetrated in between the grains of quartz of the bottom substratum, an anchoring and a certain fixation of the terminal part follows as a consequence. The part between the two ends, which may both be fixed at the same time, can push up like an arch over the substratum (fig. 3) but usually lies close to its surface (figs. 1-2). The bending of the points through plasmic movements, without the pseudopods taking part, implies narrow apertures or the possibility of regulating the apertures, which are never clearly demarcated in this form. It has not been possible to observe any morphological differentiation between the pseudopodiaplasm and the rest of the plasm (*Rhyncosaccus* Rhumbler, 1904).

The division of the plasm cord into successive lobes have typical of the larger examples. As it has not been possible to distinguish any septa between the lobes, this organism may be considered unicellular and polynuclear. The detached test has throughout proved to be nonseptate and monothalamous. For these reasons and also because of the type of pseudopodia present, it may be justifiable to look for relations within the Monothalamia, which, represented by several families, has been included by an increasing number of experts in the Foraminifera (Rhumbler 1904, Cushman 1940, 1950, Höglund 1947). The Allogromid family is the first to be considered. There has however been much discussion about the position of this family in the classification of the Monothalamia, and the question will not be discussed here. In the main, Cushman's (1950) classification is followed here. Within the *Allogromidae* there are two subfamilies *Myxothecinae* and *Allogrominae,* the latter containing the greater number of forms with varying habits. *Shepheardella taeniformis,* described in England by Siddall (1880), (see also Rhumbler 1904, p. 210), has been included in this group. It is described as ". . . . unicellular, elongated, abruptly pointed at both ends. It is furnished with a flexible, transparent colorless integument of considerable firmness; and the whole tubular cavity is densely filled with yellowish, coarsely granular protoplasm, having a very distinct oval nucleus, and occasionally also a few scattered non-contractile hyaline vesicles" (Siddall 1880, p. 131).

Owing to their fragile construction and to the usual methods of sorting and concentration some of the Monothalamia are now less well known than the Polythalamia types. In spite of the fact that they are not known as fossils, several monothalams with thin hyaline tests may be assumed to be extremely primitive, and provide good opportunities for studying plasmatic conditions, about which very little is known in the foraminifera. It seems best however not to place the genus *Marenda* definitely in a family until the necessary revision of the Monothalamia, both those previously described and the many as yet undescribed, has been accomplished.

One must obviously always be on the look-out for the possibility that "new types" may prove to be stages of development of other species described with a different habit. It is relatively easy to ascertain that the organism discussed here is not identical with either *Shepheardella* or *Lieberkühnia* (Rhumbler 1904 and Krumbiegel 1928). Can it then be a stage of development of, for example, the genera *Bathysiphon* or *Reophax,* before definite tests have been formed? The occurrence of *Bathysiphon* as a fossil from Silurian to Recent times, is better known than the structure of its protoplasm, especially of the small species. Le Calvez (1938) has studied the plasm of the giant *Bathysiphon filiformis.* Even young specimens, however, in ad-

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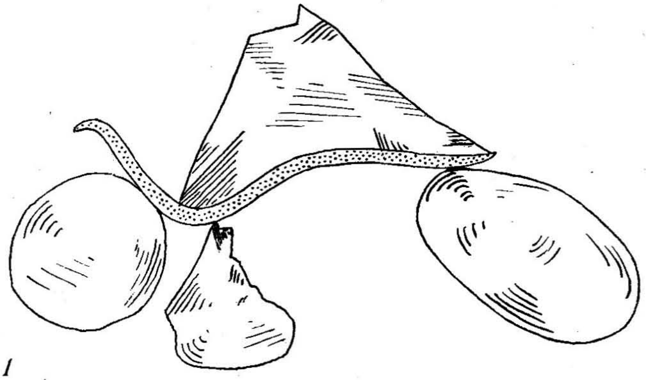
EXPLANATION OF TEXT FIGURES 1 - 6

FIGS.

1-6. *Marenda nemotoides* Nyholm, n. gen., n. sp. 1-3, *Marenda nematoides* in relation to the substratum, × 10. 4, showing the flexibility of the ends and nuclei in the plasm, × 20. 5, 6, parts of specimen with vitalstained plasm. (Spandau and Nyholm, del.)



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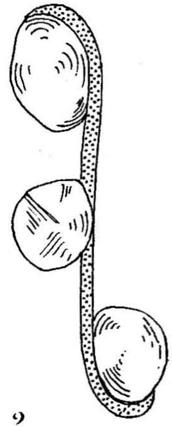

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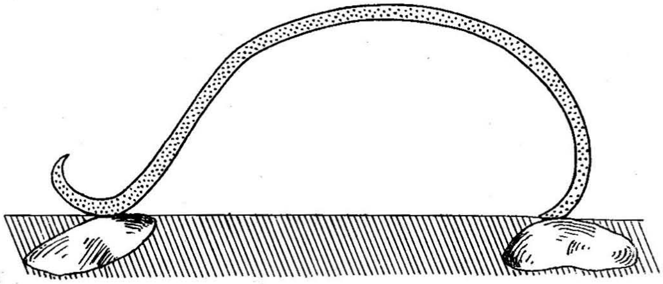

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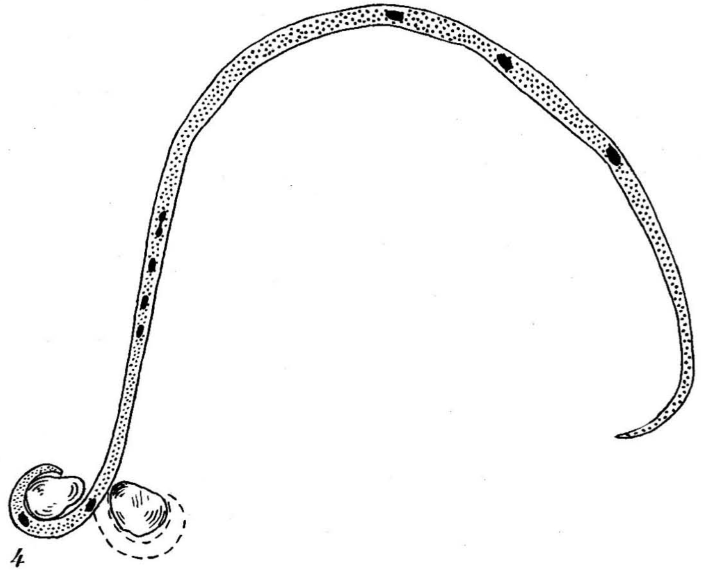

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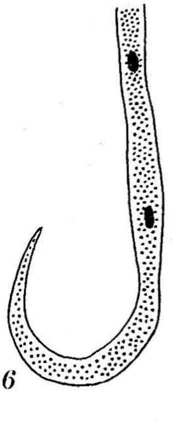

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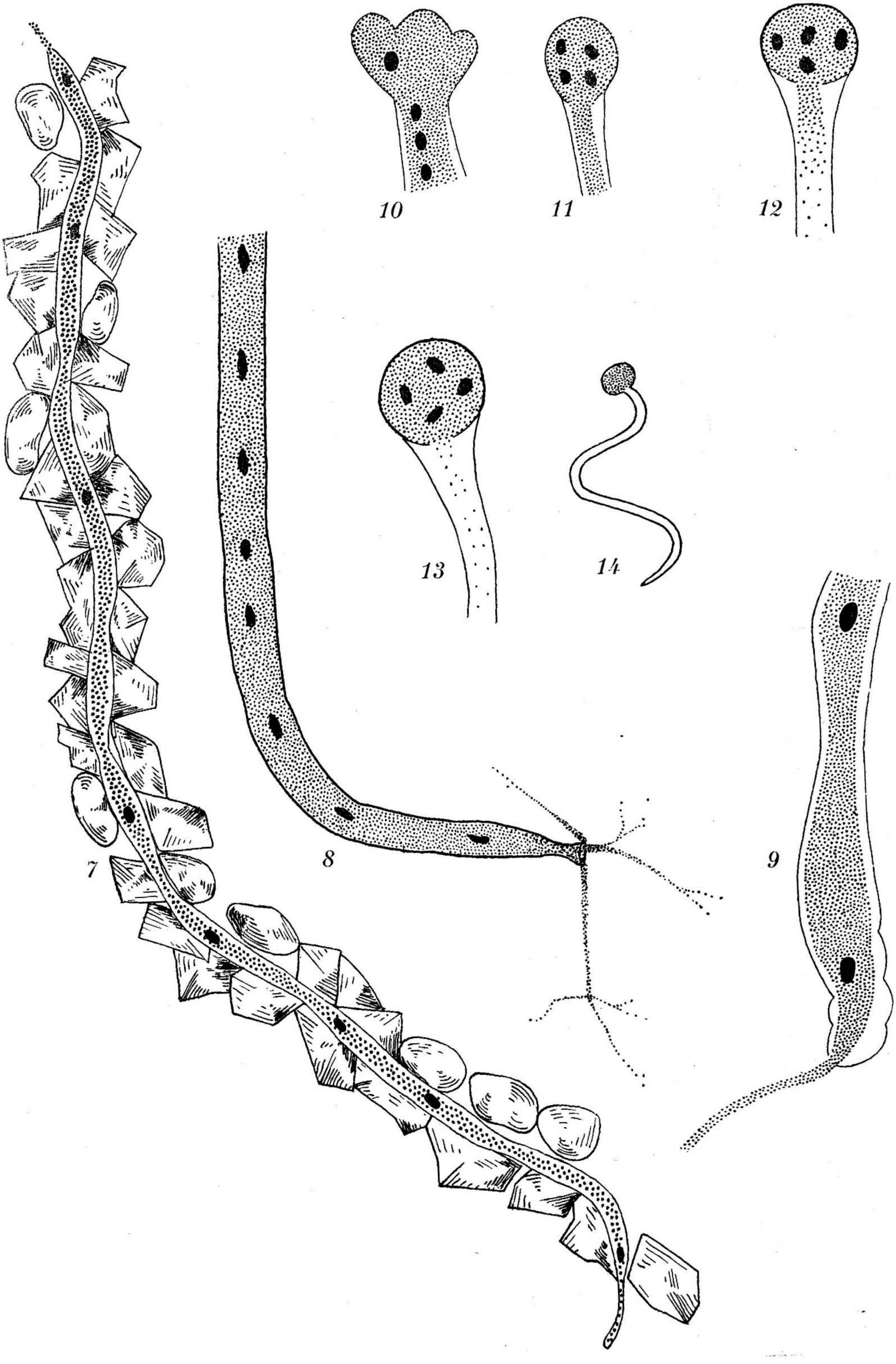
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dition to the typical test-formation, have the characteristic difference in thickness between the basal and apical part, with the orientation of living specimens typically in a greater or less degree perpendicular to the substratum. The organism *Marenda* discussed above can have just as little relation to the life-history of the Reophacidae. Attention should be directed, however, to the parallel shown by the constriction of the single plasm cord in *Marenda nematoides* to certain Reophacidae, although in the latter the division can be interpreted as having gone further, and is associated with chamber-building.

There is no reason to assume any connection between the *Marenda* and young *Schizammina* species, even if these forms do start as simple straight tubes before their bifurcation (Heron-Allen and Earland, 1929). Nor can the genus *Protobothelina* (Heron-Allen and Earland, 1929) be considered as particularly closely related.

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EXPLANATION OF TEXT FIGURES 7 - 14

FIGS.

7-14. *Marenda nematoides* Nyholm, n. gen., n. sp. 7, a specimen flat on the sand bottom, × 25. 8, pseudopodia from one end of the tube, × 40. 9, the thin wall and constricted plasm, × 50. 10-14, encystment (see text for explanation of process). (Spandau and Nyholm, del.)

33. AN ADDENDA TO ARENOPARRELLA AND ARENOPARRELLA MEXICANA (KORNFELD)

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INTRODUCTION

Recent brackish-water foraminiferal assemblages from the Louisiana Gulf Coast containing the species *Arenoparrella mexicana* (Kornfeld), have dictated the need for a redescription of the genus *Arenoparrella* Andersen, and the genotype *Arenoparrella mexicana* (Kornfeld).

The specimens used in the original description of *Arenoparrella* were recovered from beach samples. Material from inland environments, particularly tidal streams where the foraminiferal assemblages have not been subjected to wave action along the strand line, has revealed that an important characteristic of the genus and genotype was overlooked. The morphological feature of the test not originally reported is the relatively persistent occurrence of one or more cribrate openings in the apex of the final chamber. Only in specimens from a static environment where an abundance of perfectly preserved specimens of this fragile species can be observed, is the presence of these multiple openings (apertures) a predominant feature.

The specimen figured herein was recovered from a sample of the organic muck which had accumulated in the bottom of Lighthouse Bayou (L. S. U. Museum sample M-158). Lighthouse Bayou, located in Stake Island, is a tidal channel which opens into the Gulf of Mexico. Stake Island, now a part of the landmass which flanks the right bank of the western most major distributary of the Mississippi River (Southwest Pass), lies directly west of Burrwood, Louisiana.

The writer is indebted to Helen Tappan (Mrs. Alfred R. Loeblich, Jr.) for preparing the illustrations accompanying this report.

Family TROCHAMMINIDAE

Genus **Arenoparrella** Andersen, 1951

Genotype *Trochammina inflata* (Montagu) var. *mexicana* Kornfeld

Test free, trochoid, umbilical area closed and depressed, dorsal side convex; wall arenaceous. Primary aperture a slit-like opening with long axis oriented approximately parallel to the plane of coiling, either open at the base or separated from the preceeding volution by a thin everted lip; supplementary cribrate openings (apertures) at the apex of the final chamber.

Remarks. The major difference between this genus and the closely related *Trochammina* lies in the shape and position of the apertures. *Trochammina* encompasses those trochiform tests in which the aperture is a slit or arched opening at the ventral, inner margin of the last formed chamber; *Arenoparrella* those trochiform tests in which the primary aperture is an elongate slit roughly parallel to the periphery, and the supplementary apertures are cribrate openings at the apex of the final chamber.

Occurrence. Recent brackish-water deposits.

Arenoparrella mexicana (Kornfeld)

Plate 11, figures 4a-c

Trochammina inflata (MONTAGU) var. *mexicana* KORNFELD, 1931, Contr. Stanford Geol. Dept., vol. 1, p. 86, pl. 13, figs. 5a-c.

Arenoparrella mexicana (KORNFELD), ANDERSEN, 1951, Jour. Paleon., vol. 25, no. 1, p. 31, figs. 1a-c.

Test trochoid, dorsal side moderately convex, ventral side with a depressed, closed umbilicus; periphery bluntly acute, lobulate in adult specimens. Chambers typically five to each whorl, slightly inflated on dorsal side, ventral side with pronounced inflation of chambers near the umbilicus; sutures distinct, slightly curved on dorsal side, radial and straight on ventral side. The primary aperture is a curved, almost angular slit in the apertural face of the last chamber, the inner portion of the curve extending from the periphery ventrally at an angle of 30 to 40 degrees with the plane of coiling, the outer portion of the curve oriented almost parallel to the plane of coiling. This primary aperture is surrounded by a thin, delicate everted lip which in some specimens continues across the base of the aperture thus separating the aperture from the preceeding volution. Supplementary apertures typically present, consisting of one to four large, circular, cribrate openings, and are located at the apex (anterior peripheral margin) of the final chamber. Supplementary apertures on preceeding chambers have either been closed or concealed when subsequent chambers were added. The adult portion of the test is composed of approximately equal amounts of yellowish-brown cement and fine grained arenaceous material.

Maximum diameter of figured specimen 0.46 mm.; maximum thickness 0.18 mm.

Remarks. The holotype of this species, recovered from a littoral sample collected at Timbalier Island off the coast of Louisiana, has not been examined by the writer. However, specimens recovered from a sample collected by Kornfeld on the south side of Calumet Island in Timbalier Bay[1] provided for study specimens

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[1] M. M. Kornfeld Sample No. 33 collected April 8, 1929.

which for all practical purposes can be considered topotypes of *A. mexicana.* A re-examination of this suite of specimens from Calumet Island has revealed that the few complete tests present do bear cribrate apertures, a morphological feature of the test overlooked by both the writer and Kornfeld.

Distribution. The distribution of *A. mexicana* along the Louisiana and Texas coasts as reported by Kornfeld in 1931 was from Calcasieu Pass, south of Lake Charles, Louisiana, to the Chandeleur Island, south and east of New Orleans, Louisiana. The samples collected by the writer which bear this species lie within the geographical limits defined above. It should be noted, however, that the species is present in mangrove swamp samples from the Gulf of Paria, Trinidad.[2]

Repository. Hypotype U. S. National Museum No. P. 31.

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Manuscript received April 14, 1951

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[2] Personal communication with Miss Ruth Todd.

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34. GUPPYELLA, ALVEOVALVULINA, AND DISCAMMINOIDES, NEW GENERA OF ARENACEOUS FORAMINIFERA FROM THE MIOCENE OF TRINIDAD, B. W. I.

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INTRODUCTION

The new arenaceous genera *Guppyella* and *Alveovalvulina* (Valvulinidae) and *Discamminoides* (Lituolidae), are characterized by the presence of alveoles arranged normal to the inner walls of the chambers, which are not visible on the surface of well preserved specimens. The existence of alveolar structures, which obviously are a re-enforcement of the tests, is indicated by the slight degree of deformation in these forms, as compared with similar and contemporaneous arenaceous foraminifera that are without alveoles or interior subdivisions. The term "alveolar" has been used in order to avoid the ill-applied designation "labyrinthic," a term that should be reserved exclusively for the description of wall structures or for subdivisions of the interior of chambers where no regular arrangement of structural elements can be seen. A study of the interior of *Cyclammina cancellata* H. B. Brady, a foremost example of a prototype of the "labyrinthic" interior (Cushman, 1948) shows that although the structure of the chamber walls is complex, at least in the last ontogenetic stages, it is regular and follows a certain definite pattern, hence is *not* labyrinthic. Sections through the last ontogenetic stages of *Guppyella* exhibit a remarkable complexity of the interior of the chambers and it is rather difficult to establish the arrangement of the alveoles from axial sections only. The pseudo-labyrinthic but nevertheless regular arrangement of alveoles in *Guppyella* can easily be discerned on broken or worn specimens, especially when iron stained, or when the lumina are filled with pyrite. In the author's opinion, there are morphologic differences between the alveoles of *Guppyella-Alveovalvulina* on one hand and of *Discamminoides* on the other, but no nomenclatural distinction is proposed at present. In a future monographic study of the Valvulinids, Lituolids and related groups of foraminifera, it will be necessary to revise the wall structures and study the internal subdivisions of the chambers very carefully.

The three new genera are monotypic and geographically and stratigraphically are apparently restricted to the Miocene deltaic deposits of South Trinidad, although morphologically related forms are also known from the clays of the Oligocene Nariva and Cipero formations and from the Oligo-Miocene Karamat formation. These related forms have not yet been investigated in detail and therefore are not included in the present descriptions. The new genera, especially *Guppyella* and *Alveovalvulina,* often occur abundantly in the non-calcareous clays of the Cruse and Forest formations. The texture of the walls depends largely on the type of environment, i. e. the surface is usually smooth and velvet-like in clays, and more or less arenaceous in silts and silty clays.

ACKNOWLEDGMENTS

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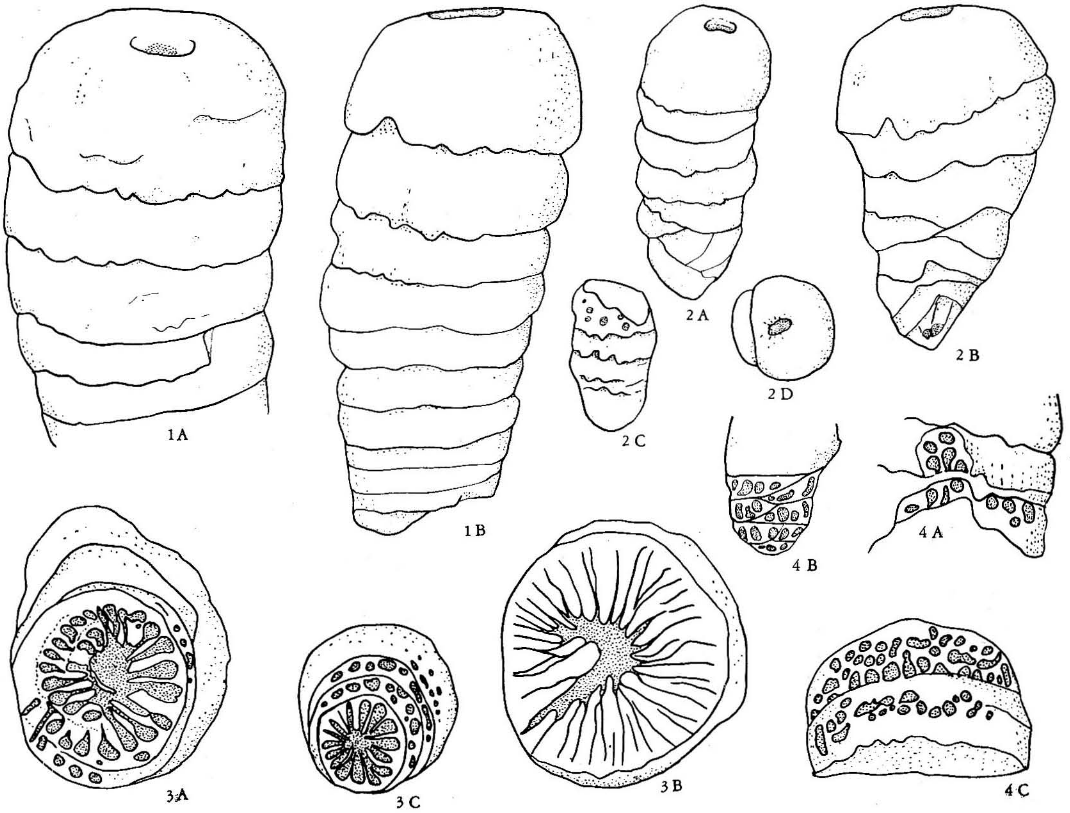
seum, Washington, D. C. for suggestions and criticism.

The holotypes are deposited in the Cushman collection of the U. S. National Museum in Washington, D. C., U. S. A. The original samples from wells (F. R.: Forest Reserve field, T. L. L.; B. P.: Barrackpore field, T. L. L.; T. P. D.: Trinidad Petroleum Development Company; A. T. O.: Apex Trinidad Oil Company) and from the surface, collected by Trinidad Leaseholds geologists (H. G. K.: H. G. Kugler; R. M.: R. Muhlemann; Sh.: M. Shepherd; B. A.: K. W. Barr; B. B.: B. Bessin; S. L.: S. Lee) remain in the collection of Trinidad Leaseholds Ltd., at Pointe-a-Pierre, Trinidad, B. W. I.

Family VALVULINIDAE

Genus **Guppyella** Bronnimann, n. gen.

Test elongate, tapering, rounded in transverse section. In the early stage a trochoidal spiral with more than 3 chambers in a whorl (probably 4 to 6), rapidly reducing to 3 chambers, then to 2 and finally to one. The major portion of the adult test is uniserial, at least in the microspheric generation. The chambers are



EXPLANATION OF TEXT FIGURES 1 - 4

Guppyella miocenica (Cushman). Miocene, South Trinidad, B. W. I.

Figs.

1a, b. Exterior views of microspheric specimens, × 35. 1a, Sh. 1421, T. L. L. Cat. No. 159323; 1b, T. P. D., Palo Seco well 205, at 3318 feet, T. L. L. Cat. No. 5629.

2a-d. Exterior views. 2a, Megalospheric specimen. 2b, microspheric specimen, both × 35. Sh. 1421, T. L. L. Cat. No. 159323. 2c, megalospheric specimen with broken end chamber and slightly eroded outer wall showing alveoles and indentations along sutures. × 23. A. T. O. well 447, at 590 feet, T. L. L. Cat. No. 118889. 2d, aperture of biserial stage × 35. Sh. 1421, T. L. L. Cat. No. 159323.

3a-c. Microspheric specimens, T. P. D., Palo Seco well 205, at 3318 feet, T. L. L. Cat. No. 5629, all × 23. 3a, Transverse section through uniserial chamber with 4 rows of alveoles. 3b, transverse section through chamber of early portion (bi- or triserial) showing the basal alveoles. 3c, slightly eroded surface of end chamber with irregularly shaped aperture and alveolar structure filling the chamber lumen almost completely.

4a-c. Views showing alveoles. All × 23. 4a, portion of eroded outer wall, F. R. well 773, at 6278-6308 feet, T. L. L. Cat. No. 121469. 4b, early portion of megalospheric specimen. F. R. well 761, at 3190 feet, T. L. L. Cat. No. 112768. 4c, end chambers of microspheric specimen with eroded outer wall. Quinam well 18, at 2818 feet, T. L. L. Cat. No. 162859.

peripherally subdivided into alveolar cavities, arranged normal to the outer wall. In late ontogenetic stages, particularly in microspheric specimens, the alveolar structures extend from the periphery into the axial cavity, thus nearly completely filling the chamber lumina. In tangential sections parallel to the axis, this structure gives a labyrinthic appearance. Wall arenaceous; amount of cement variable. Surface generally smooth. Aperture basal and slit-like at first, becoming terminal, subcircular-elongate in the later biserial and uniserial stages, occasionally sunken; no lip or neck developed.

Genotype.—Goësella miocenica Cushman, 1936, Special Publication No. 6, Cushman Lab. for Foram. Research, pl. 5, fig. 9, Miocene, Trinidad, B. W. I.

Remarks.—Goësella miocenica was described by Cushman in 1936 from the "upper middle Miocene '*Cyclammina* clay,' Forest clay series," of Trinidad. Although this species externally resembles typical representatives of *Goësella* very closely, sectioning revealed a complex internal structure which distinguishes it from this genus. *Goësella* has simple undivided chambers, without alveolar subdivision and pseudo-labyrinthic structures. Because of these morphologic differences the new genus *Guppyella* is proposed.

The following Valvulinid genera with uniserial adult stages, *Cubanina* Palmer 1936, *Liebusella* Cushman 1933, and *Pseudogoësella* Keijzer 1945, are likewise not related to *Guppyella*. They all possess interior pillars connecting the roof and floor of each chamber, but do not develop peripheral alveolar subdivisions. *Tritaxilina* Cushman 1911, with a uniserial adult and "labyrinthic interior" differs from *Guppyella* in the well developed 4-5 chambered early ontogenetic stage, the predominant biserial stage, the rounded aperture with a slight lip and in the raised sutures. Furthermore, it appears that the "labyrinthic interior" of *Tritaxilina* differs from the non-labyrinthic system of alveoles in *Guppyella*. On the other hand, the internal structure of *Guppyella* shows definite affinities with that of the textularoid genus *Textulariella* Cushman 1927, which is biserial in the adult. Sections and eroded faces normal to the axis (pl. 11, fig. 6 and text fig. 3) show nearly the same internal structure in both genera (Cushman, 1937, pl. 7, figs. 7, 8).

Guppyella is monotypic and occurs, often abundantly, in the clays of the Miocene Cruse and Forest formations of South Trinidad ("*Haplostiche assemblages*"). The genus is named after R. J. L. Guppy for his contributions to the knowledge of Trinidad's natural history.

Morphologically related forms which may belong to this genus occur also in the Oligocene Nariva and Oligo-Miocene Karamat formations.

Guppyella miocenica (Cushman), 1936

Plate 11, figure 6; Text figures 1-4

Goësella miocenica Cushman, 1936, Special Pub. No. 6, Cushman Lab. Foram. Research, p. 33, pl. 5, figs. 9a, b; Cushman, 1937, Special Pub. No. 8, Cushman Lab. Foram. Research, p. 115, pl. 13, figs. 10-12.

Cushman's original description states, "Test elongate, microspheric form tapering throughout, megalospheric form with adult portion generally cylindrical, first whorl with more than three chambers, later three, then two, and adult uniserial; chambers numerous, indistinct except in the adult, there slightly inflated; sutures mostly indistinct except in adult, there slightly depressed; wall finely arenaceous, with a few coarse, angular grains, particularly about the aperture, smoothly finished, vacuolar, with a large amount of cement; aperture large, terminal rounded. Length up to 2.65 mm.; diameter 1.15 mm. This species differs from *G. flintiana* (Cushman) in the somewhat chitinous, flexible wall which is vacuolar."

This description may be amplified by the following remarks, pertaining essentially to the internal organization of the test:

Slight indentations along the sutures, discernible in well preserved specimens with smooth surface, correspond to the system of alveoles at the base of the chambers (text figs. 1, 2). Small indistinct, rounded depressions (vacuolar wall of Cushman) indicate the presence of the interior, peripheral alveoles arranged normal to the outer walls. The latter are frequently exposed in worn specimens (text figs. 3, 4). Axial sections show 2 to 4 alveoles per chamber in the initial portion. The alveoles do not pierce the outer wall and open widely into the general chamber cavity. The end portions of the main septum and of the alveolar partitions are slightly thickened in the early ontogenetic trochoidal stages. About 6 alveoles have been counted from the base of the chamber to the aperture in axial sections of the adult (pl. 11, fig. 6, text fig. 3). The alveoles of the later stages are distinctly narrowing in axial direction into tubular canals, running almost parallel to the chamber floor and opening into the axial cavity. From sections and eroded surfaces normal to the axis (text fig. 3), one can see that the narrowing of the alveolar lumina toward the chamber axis is accompanied by a distinct thickening of the alveolar walls. The original chamber cavity which already has been reduced by the development of alveoles in the earlier ontogenetic stages is almost completely filled with the alveolar structures in the adult, leaving only a small axial cavity just below the aperture. It appears that the alveolar lumina do not interconnect, although this could be definitely determined by means of the available sections.

The number of chambers per whorl of the initial portion could not be established due to the indistinct sutures. The aperture is basal, slit-like at first, later terminal, rounded and somewhat sunken (text figs. 1, 2, 3). The inner walls of chambers and alveoles are usually lined with a thin, brown ?chitinous layer.

Dimensions.—Specimen 1, microspheric individual with 4 uniserial chambers in the adult. Chambers filled with brown substance. Axial section. Length of test 1150μ, maximum diameter of test 750μ, thickness of outer wall of end chamber ± 25μ, and of initial chamber ± 10μ, alveoles of end chambers are from ± 50 - ± 100μ in length and ± 30 - ± 50μ in diameter. End chamber with 6 alveoles from base of chamber to aperture.

Specimen 2, megalospheric individual, chambers filled with brown substance. Axial section. Length of test 1150μ, maximum diameter of test 690μ, diameter of initial chamber ± 140μ, height of early chambers ± 80μ, height of end chamber ± 170μ, diameter of alveoles in initial portion ± 50μ. End chamber with 6 alveoles, young chambers with 3 alveoles from chamber base to aperture. Number of chambers in initial coil not established.

Specimen 3, microspheric individual, with 11-12 uniserial chambers, filled with brown substance. Axial section. Length of test 2080μ, maximum diameter of test 1150μ, height of end chamber ± 110μ, greater diameter of aperture in uniserial stage 230-460μ, diameter of initial chamber ± 60μ, thickness of outer wall of end chamber ± 20μ. Alveoles of end chambers are 220-350μ in length, 50-110μ in diameter, openings toward aperture 10-60μ, thickness of wall 10-20μ.

Specimen 4, megalospheric individual, chambers filled with brown substance. Axial section. Length of test 1200μ, maximum diameter of test 800μ, diameter of initial portion 460μ, diameter of initial chamber 130-175μ, maximum height of young ontogenetic chamber near aperture ± 80μ, thickness of outer wall of initial portion ± 35μ, thickness of chamber wall ± 15μ. Alveoles of initial portion 30-120μ in diameter, and 20-50μ in length.

Specimen 5, microspheric individual, laterally slightly compressed, chambers filled with brown substance. Transverse section. Greater diameter of test 1250μ, smaller diameter of test 865μ, greater diameter of aperture 278μ, smaller diameter of aperture 70μ. Alveoles of adult stage 40-80μ in diameter at base, 10-50μ in diameter toward axial cavity. Thickness of outer wall plus 20μ, thickness of alveolar walls 10-25μ at base, 30-60μ at end.

Holotype.—Goësella miocenica Cushman. Well of Apex Co. at 1720 feet, Fyzabad, Trinidad. Deposited in Cushman Collection, No. 21191.

Genus **Alveovalvulina** Bronnimann, n. gen.

Test a trochoid spiral with more than 3 chambers, possibly 5-6, in the initial whorl and with 3 chambers, rarely with 4, in the adult. Chambers increase rapidly in size and the adult whorl represents the larger portion of the test. The chambers of the later whorls are peripherally subdivided into small alveolar cavities, arranged normal to the outer wall. Wall arenaceous, amount of cement variable. Surface generally smooth, occasionally with small rounded superficial depressions indicating the interior alveolar structure. Aperture a low arched slit with distinct lip, situated in an umbilical depression at the base of the apertural face of the end chamber.

Genotype.—Alveovalvulina suteri Bronnimann, n. sp., Miocene, Trinidad, B. W. I.

Remarks.—Alveovalvulina differs from all other known Valvulinid genera in the mode of coiling and in the interior alveoles (Cushman 1937, 1947, 1948). However, the new genus appears to be related to the adult uniserial genus *Guppyella.* The earlier stages of the latter genus, prior to the biserial-uniserial development, exhibit principally the same features as *Alveovalvulina* (text figs. 7, 8). The alveoles in *Alveovalvulina* do not become narrow toward the chamber lumina and apparently no alveoles are developed in the initial whorl (text figs. 7c, d).

Similar alveolar structures to those in *Alveovalvulina* have also been described by Stschedrina (1936) in the Lituolid genus *Alveolophragmium* (Genotype: *A.*

EXPLANATION OF TEXT FIGURES 5 - 8

Alveovalvulina suteri Bronnimann, n. gen., n. sp. Miocene, South Trinidad, B. W. I.

FIGS.

5a-i. Exterior views. 5a, d, i, specimens from B. A. 3213, T. L. L. Cat. Nos. 17320-21, × 35. 5b, c, opposite views of specimen from F. R. well 846, at 5887 feet, T. L. L. Cat. No. 158586, × 35. 5e, Specimen from T. P. D., Moruga well 1, at 1484-1503 feet, × 35. 5f, specimen from B. B. 5438, T. L. L. Cat. No. 2437, × 35. 5g, h, specimens from Sh. 1431, T. L. L. Cat. No. 159333, × 23.

6a-g. Internal structure. 6a, specimen from H. G. K. 3871, T. L. L. Cat. No. 14713. 6b, T. P. D., Moruga well 1, at 1484-1503 feet. 6c, F. R. well 846, at 5887 feet, T. L. L. Cat. No. 158586. 6d, transverse section through initial portion, R. M. 8008, T. L. L. Cat. No. 5753. 6e, transverse section through end chamber, R. M. 8008, T. L. L. Cat. No. 5753. 6f, end chamber eroded, showing the alveolar interior. Sh. 1431, T. L. L. Cat. No. 159333. 6g, Sh. 1431, T. L. L. Cat. No. 159333. Figs. 6a-c, × 35, figs. 6d-g, × 23.

7a-8. Axial sections. all approximately × 88. 7a, b, specimens from F. R. well 471, at 4630-40 feet, T. L. L. Cat. Nos. 20786-88. 7c, T. P. D., Palo Seco well 205, at 5497 feet, T. L. L. Cat. No. 5477. 7d, B. B. 5438, T. L. L. Cat. No. 2437. 8, microspheric specimen, T. P. D., Palo Seco well 205, at 5497 feet, T. L. L. Cat. No. 5477.


5A
5B
5C
5D
5E
5F
5G
5H
5I
6A
6B
6C
6D
6E
6F
6G
7A
7D
7B
8
7C

orbiculatum Stschedrina, Recent). Stschedrina traced this genus from the simple walled *Haplophragmoides,* to which it is related on account of the general structure.

Alveovalvulina is monotypic and is often abundantly represented in clays and silty clays of the Miocene Cruse and Forest formations, associated with *Guppyella miocenica* (Cushman), *Discamminoides tobleri* Bronnimann, and additional as yet undescribed arenaceous species.

Alveovalvulina suteri Bronnimann, n. sp.

Plate 11, figure 5; Text figures 5-8

The chambers of the trochoidal test increase rapidly in size and the 3 to 4 chambers of the adult whorl represent the larger portion of the test (pl. 11, figure 5, text fig. 5). The initial portion is rather pointed, at least in microspheric forms and therefore often damaged. The sutures are well developed in the adult, but very indistinct in the young ontogenetic stages. This renders it difficult to determine the number of chambers in the initial whorl, although it is definitely greater than 3, probably 5-6 (text fig. 6d). The aperture is a low arched slit with distinct lip, situated in an umbilical depression at the base of the apertural face of the end chamber (text fig. 5f). As a rule the umbilical depression is filled with matrix, thus concealing the aperture (pl. 11, figure 5, text fig. 5). The walls are arenaceous with a variable amount of cement. The finish of the surface varies with the type of environment (smoothly finished in clays, coarsely arenaceous in the silts), but it is predominantly smooth, with occasional angular grains in the walls of the last chambers, and sometimes with sub-circular-elongate superficial depressions indicating the interior alveolar structure (pl. 11, figure 6). The alveoles are excellently exposed in worn specimens (text figs. 6a, b, c, g). The tests, especially their last chambers (text fig. 5f), are frequently deformed, but deformations are never so extreme as in the arenaceous tests without interior structures.

The interior is characterized by small alveoles, rounded in transverse section, and arranged normal to the outer walls (text figs. 6-8). They open widely into the chamber lumina which are not much reduced by the alveolar wall structures. The early ontogenetic chambers apparently do not possess alveoles (text fig. 7). In sections through end chambers, normal to the axis of coiling, 9 to 15 plus alveoles were counted along the periphery. The end chamber of the specimen figured in text figure 7a has 15-16 alveoles. Specimens with eroded surface (text figs. 6a, b, c) show the sub-circular-elongate transverse sections of the alveoles. In some cases alveoles appear to interconnect. This however could not be established beyond doubt.

In well preserved specimens the inner walls of alveoles and chambers are coated with a thin brown ?chitinous film.

The species is named for Dr. H. H. Suter, for his contribution to the geology of Trinidad.

Dimensions.—Length of holotype 0.7 mm, maximum diameter 0.57 mm. Other specimens range from 0.7 to 1.2 mm (average ± 0.9 mm) in length and from 0.54 to 0.7 mm (average ± 0.6 mm) in maximum diameter.

Sectioned specimens: Specimen 1, maximum height of end chamber 230μ, height of aperture of 2nd last chamber 69μ, thickness of outer wall 10-25μ, diameter of alveoles in end chamber 20-60μ, length of alveoles in end chamber 50-80μ.

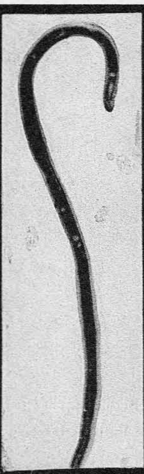
Specimen 2, height of aperture of end chamber 115μ, thickness of outer wall 10-25μ, diameter of alveoles in end chamber 20-60μ, length of alveoles in end chamber 50-80μ.

Specimen 3, diameter of alveoles in end chamber ± 57μ, length of alveoles in end chamber 50-100μ, diameter of alveoles in early chambers 10-35μ, length of alveoles in early chamber ± 25μ, thickness of outer wall of early portion 10-25μ.

Holotype.—*Alveovalvulina suteri* Bronnimann, pl. 11, fig. 5, Miocene, S. Trinidad, B. W. I., B. A. 3213; T. L. L. Cat. Nos. 17320-21. Deposited in Cushman Collection, U. S. National Museum, Washington, D. C., U. S. A.

EXPLANATION OF PLATE 11

FIGS.		PAGE
1-3.	*Marenda nematoides* Nyholm, n. gen., n. sp. 1, 2, photographs of living specimens. Actual size 6.5 mm. 3, photograph showing encystment.	92
4a-c.	*Arenoparrella mexicana* (Kornfeld). 4a, dorsal view showing spire and one peripheral aperture; 4b, ventral view showing the primary slit-like aperture near the base of the apertural face, and a supplementary peripheral aperture at the dorsal angle; 4c, edge view showing the primary slit-like aperture and two supplementary peripheral apertures. All × 95.	96
5.	*Alveovalvulina suteri* Bronnimann, n. gen., n. sp. Umbilical view of holotype, with aperture. × 72. B. A. 3213; T. L. L. Cat. Nos. 17320-21. Miocene, South Trinidad, B. W. I.	102
6.	*Guppyella miocenica* (Cushman), microspheric individual, showing general organization of the test, alveoles. and pseudo-labyrinthic structure. × 33. F. R. well 773, at 6278-6308 feet, T. L. L. Cat. No. 121469. Miocene, South Trinidad, B. W. I.	99
7.	*Discamminoides tobleri* Bronnimann, n. gen., n. sp. Side view of holotype, × 33. F. R. well 729, at 5330-35 feet, T. L. L. Cat. No. 98829. Lower Miocene, Cruse formation, Naparima area, Trinidad, B. W. I.	103



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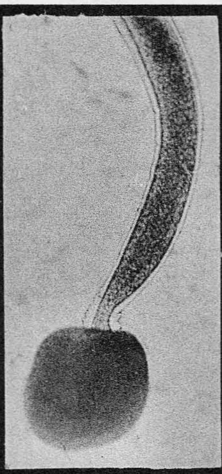

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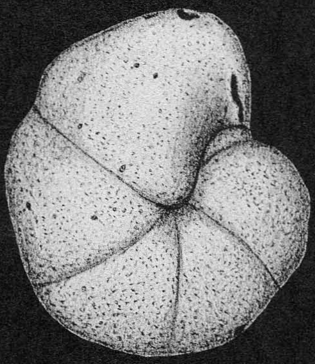

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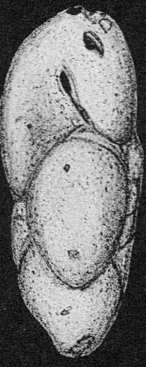

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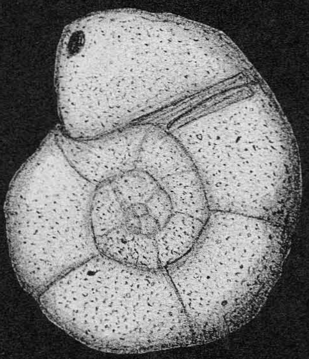

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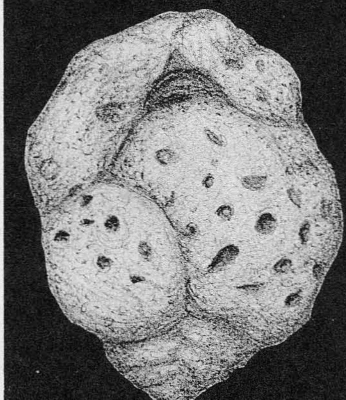

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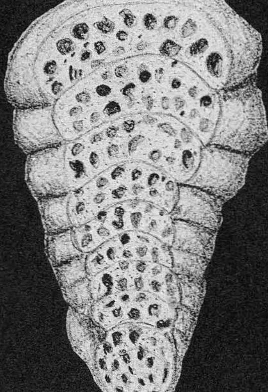

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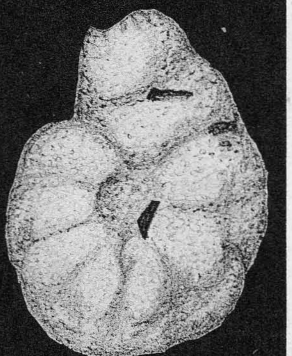
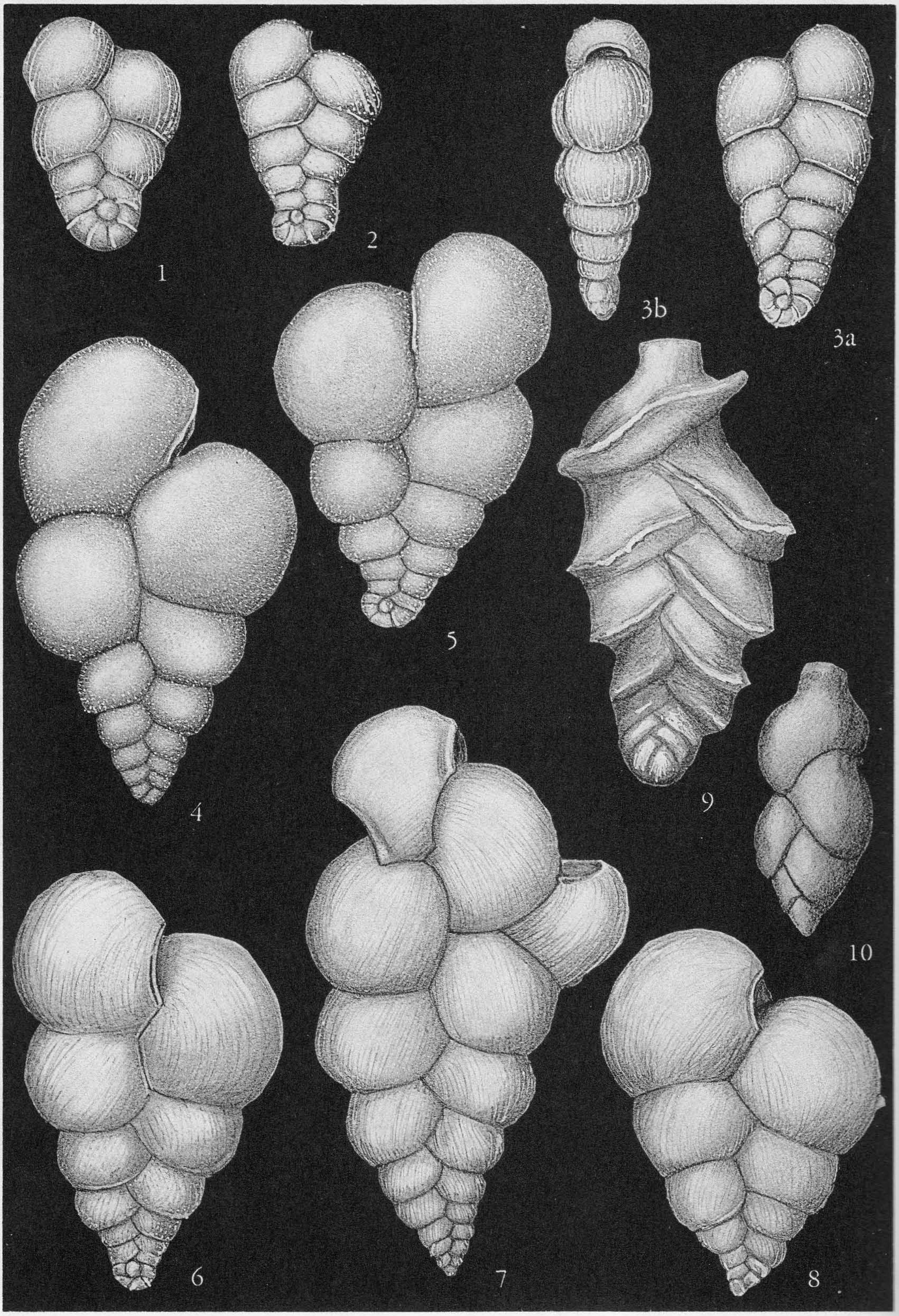


7

Nyholm, *Marenda nematoides*, n. gen., n. sp.
Andersen, *Arenoparrella*
Bronnimann, New arenaceous genera

PLATE 12



Loeblich, Heterohelicidae

Family LITUOLIDAE

Subfamily LITUOLINAE

Genus **Discamminoides** Bronnimann, n. gen.

Test planispiral, axially much compressed, uniserial in the adult. Spiral semi-evolute to evolute, departing from the equatorial plane of symmetry in its last phase; subdivided by thin, slightly curved, non-alveolar septa into chambers. Subdivision faintly marked by slight undulations of test. Chamber lumina reduced by a peripheral filling of fine-grained arenaceous material, differing in its spongy texture from that of the walls. This filling is pierced by narrow tubular alveoles which do not break through the outer walls. Alveoles arranged normal to the outer wall, either regularly spaced in a single row or in two alterntaing rows. No labyrinthic layer developed. Walls arenaceous, thin. Surface generally very smooth, velvet-like, chamber septa not discernible. Aperture of spirally arranged chambers basal to subbasal, irregularly shaped, of uniserial chambers not known (?cribrate).

Genotype.—Discamminoides tobleri Bronnimann, n. sp., Miocene, Trinidad, B. W. I.

Remarks.—The new genus belongs in the family Lituolidae and in general appearance the axially compressed test shows affinities to *Cyclammina, Pseudocyclammina, Lituola* and *Choffatella.* The arrangement of the alveolar cavities in the peripheral zone of the chambers filled with spongy arenaceous material, distinguishes *Discamminoides* from these Lituolids however. The recent Lituolid genus *Alveolophragmium* Stschedrina, 1936, differs from *Discamminoides* by the presence of alveolar cavities over the entire interior of the chamber walls. The new genus resembles morphologically the similarly recent genus *Discammina* LaCroix 1932, which is placed with the Ammodiscidae because of the planispiral arenaceous test, composed of a globular initial chamber and an undivided second chamber. According to LaCroix, the second chamber has a "labyrinthic" marginal portion which in equatorial section shows affinities to the system of peripheral alveoles of the new genus (1932, text fig. c of *D. fallax*). In the generic definition LaCroix states that the whole interior of the second chamber possesses the "labyrinthic" structure which, however, is predominant in the peripheral portion. Further, *Discammina* appears to be subdivided into chambers. The exterior shows certain chamber-like markings (1932, text fig. a) and longer septa seem to be present in the equatorial section (text fig. c). Based on these observations Lacroix did not exclude the possibility that *Discammina* could belong to the Lituolidae. Even if *Discammina* had to be assigned to the Lituolidae, the two genera should be differentiated because of the development and arrangement of the alveolar cavities in the peripheral fillings of the chambers, the uncoiling adult, and the asymmetry of the adult chambers.

The initial stage of *Discamminoides* is planispiral, at least in the A-generation (all the sectioned specimens were megalospheric). The tendency of the adult to become asymmetrical and finally to become uniserial is also known in *Lituola* and in *Pseudocyclammina* (*P. sequana* (Merian) var. *minor* Mohler, 1938, pl. 2, fig. 5). The new genus is monotypic, like many of the highly differentiated arenaceous genera, and is stratigraphically confined to the basal Miocene Cruse formation. It presumably also occurs in the upper Oligocene of Trinidad.

Discamminoides tobleri Bronnimann, n. sp.

Plate 11, figure 7; Text figures 9-12

In general appearance this species is similar to *Pseudocyclammina* Yabe and Hanzawa (compare figures of *P. personata* Tobler, in Mohler, W., 1938, pl. 1, figs. 1, 2). Test discoidal, axially very much compressed, central portion somewhat depressed; periphery rounded to subacute (pl. 11, fig. 7, text fig. 9). Spiral semi-

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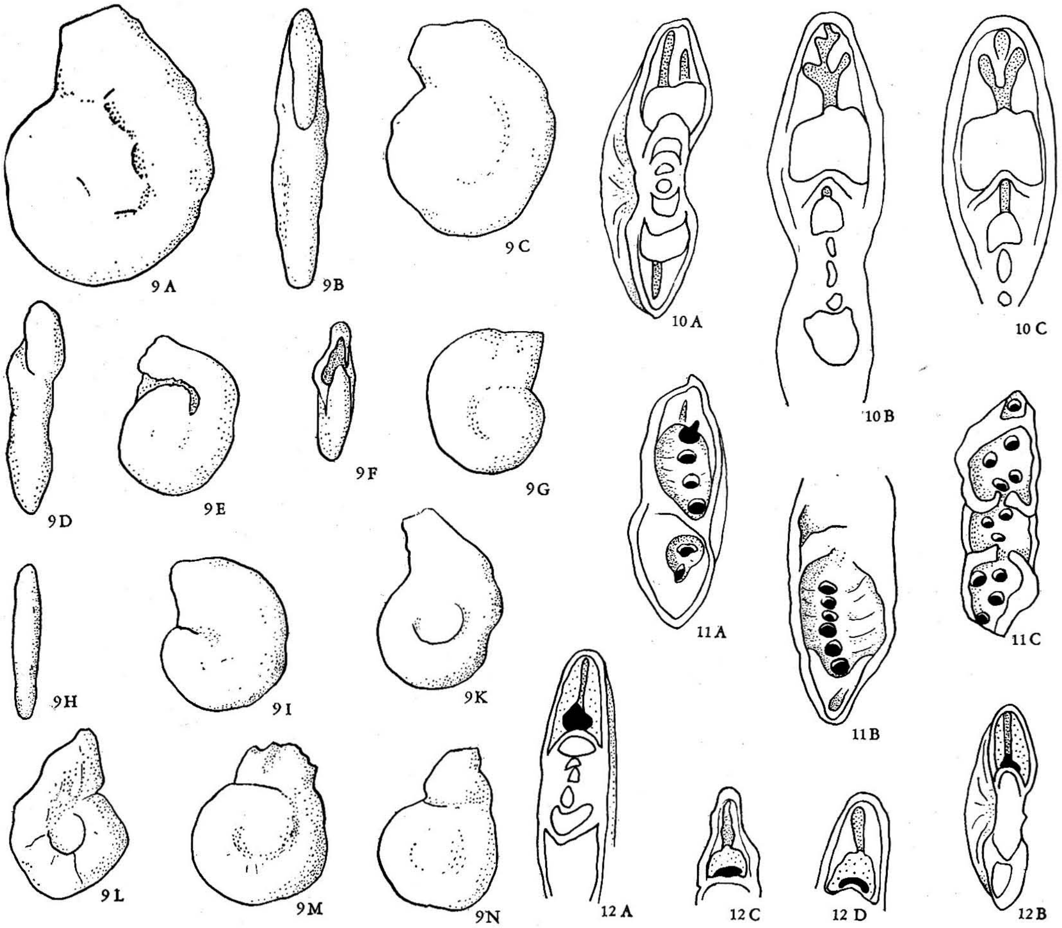
EXPLANATION OF PLATE 12

Figs.		Page
1-3b.	*Heterohelix navarroensis* Loeblich, n. sp. 1, side view of paratype (USNM P. 32a) showing minute size, prominent early coil with low chambers and later flaring test ornamented by faint striae and fine pores; 2, side view of paratype (USNM P. 32b); 3a, side view of holotype (USNM P. 33) showing somewhat smaller coil than the paratype specimens, and a gradually expanding test; 3b, edge view of holotype, showing low aperture. All × 218.	107
4, 5.	*Gümbelina globulosa* (Ehrenberg). 4, side view of megalospheric hypotype (USNM P. 34a) showing completely biserial test; 5, side view of microspheric hypotype (USNM P. 34b) showing early coil and later biserial chambers. × 158.	108
6-8.	*Ventilabrella carseyi* Plummer. 6, Side view of microspheric hypotype (USNM P. 35a) showing the much larger test than the associated *Heterohelix navarroensis,* early coil and later biserial chambers ornamented by fine striae; 7, side view of megalospheric hypotype (USNM P. 35b) showing early biserial stage followed by a series of three chambers arranged in the plane of biseriality; 8, side view of megalospheric hypotype (USNM P. 35c) showing completely biserial test. × 158.	109
9.	*Eouvigerina americana* Cushman. Side view of holotype (Cushman Coll. 4986), showing completely biserial test, strongly angular chambers with transverse ridge, and the final chamber which is becoming central in position. × 218.	110
10.	*Eouvigerina laxistoma* Loeblich and Tappan. Side view of holotype (USNM P. 36), showing biserial test, central final chamber and terminal aperture. × 234.	109

evolute to evolute with 2 to 3 whorls in megalospheric individuals. Sutures of chambers not visible or faintly indicated in the adult by slight undulations and occasional radial depressions. Last whorl with 5 to 7 chambers. Adult becomes uniserial and asymmetrical (text fig. 9). Uniserial portion somewhat tapering, laterally much compressed. Wall arenaceous, thin, amount of cement variable, depending on the type of



EXPLANATION OF TEXT FIGURES 9 - 12

Discamminoides tobleri Bronnimann. Cruse formation, lower Miocene, South Trinidad, B. W. I.

Figs.

9a-n. Exterior views. 9a, side view showing distinctly uncoiling adult and slightly asymmetric end chamber. 9b, edge view of same specimen, F. R. well 729, at 5282-84 feet, T. L. L. Cat. No. 98825, × 23. 9c, d, side and edge views of specimen with distinctly asymmetric end chamber, F. R. well 747, at 5910-40 feet, T. L. L. Cat. No. 105837, × 15. 9e, f, side and edge views of distinctly asymmetric specimen with end chamber opening laterally, F. R. well 729, at 5282-84 feet, T. L. L. Cat. No. 98825, × 15. 9g, h, i, opposite sides and edge view of specimen from F. R. well 747 at 5200 feet, T. L. L. Cat. No. 105616, × 15. 9k-m, side views of specimens from F. R. well 729, at 5282-84 feet, T. L. L. Cat. No. 98825, × 15.

10a-c. Sections of megalospheric individuals, all × 35. 10a, nearly axial section, end chamber with two straight alveoles, F. R. well 846, at 5887 feet, T. L. L. Cat. No. 158586. 10b, section parallel to axis, with branching alveoles in end chamber, from private collection. 10c, section parallel to axis, with dichotomous alveole in end chamber from private collection.

11a-c. Broken specimens showing alveoles, all × 35. 11a, specimen showing one row of alveoles in the peripheral filling, F. R. well 747, at 5910-40 feet, T. L. L. Cat. No. 105837. 11b, specimen in private collection. 11c, broken specimen showing two rows of alternating alveoles, S. L. 1003, T. L. L. Cat. No. 3631.

12a-d. 12a, b, Axial sections through septum, aperture and alveole adjoining septum, F. R. well 729, at 5282-84 feet, T. L. L. Cat. No. 98825, 12a, × 35. 12b, × 23. 12c, specimen from F. R. well 586, × 35. 12d, specimen from F. R. well 747, at 5910-40 feet, T. L. L. Cat. No. 105837, × 35.

environment, but surface usually smoothly finished. The peripheral portion of the test is filled with fine-grained arenaceous material, reducing the chamber lumina considerably. Tubular alveoles penetrate this spongy filling either in a single row or in two alternating rows in the larger chambers (text fig. 11). The alveoles are normal to the outer walls, regularly spaced and do not penetrate the chamber walls. In equatorial sections, the alveolar system appears like a series of small, thin septa which in the last whorl are in groups of 3-5 between somewhat longer septa. This alone might suggest that the chambers defined by the long septa are subdivided by smaller septa, but this assumption cannot be maintained if axial sections are examined. Axial sections show single straight alveoles in the younger stages (text fig. 10a) and frequently branching alveoles or two alveoles in the adult chambers (tex fig. 10). An average of 4 to 5 alveoles have been noted in the adult chambers and 1 to 2 in the early chambers. The first spiral chambers possibly have none or only very indistinctly developed alveoles. Chamber lumina are simple, undivided and slightly reduced in the marginal direction by the peripheral filling. The septa are thin, only slightly curved and sometimes thickened near the aperture. The apertures are either irregularly shaped, subcircular or slit-like openings at or near the base of the septa (text fig. 12). The aperture of the uniserial stage is not known (cribrate?).

The alveoles in the roofs of the chambers can only be studied in sections or in fragments of the marginal portion of the test. In well preserved specimens, the inner walls of alveoles and chambers are lined with a brown ?chitinous layer. The peripheral filling has a spongy texture and differs from that of the walls.

The species is named after Dr. August Tobler for his contribution to the geology of Trinidad and to the paleontology of the Lituolidae.

Holotype.—Discamminoides tobleri Bronnimann. Lower Miocene, Cruse formation, Naparima area, Trinidad, B. W. I. F. R. well 729 at 5330-35 feet, T. L. L. Cat. No. 98829. Deposited in Cushman Collection, U. S. National Museum, Washington, D. C., U. S. A.

Stratigraphic occurrence.—D. tobleri is a characteristic arenaceous foraminifer of the basal Miocene Cruse clays. Similar forms which may also belong to *Discamminoides,* but are different from the present species, are found in the upper Oligocene Cipero formation. These specimens possess a much coarser arenaceous test and are yet to be investigated in detail. It is possible that the Paleocene *Alveolophragmium planum* Bykova 1939 also belongs to *Discamminoides,* but the original material must be studied for confirmation.

Dimensions.—The equatorial sections are slightly oblique and the measurements therefore are only approximate. Diameter of holotype 1.13 mm; diameter, including the uniserial portion 1.6 mm; thickness of test 0.28 mm. Diameter of other specimens range from 0.8-1.2 mm (excluding the uncoiled portion, which is about 0.6 mm wide at its base and which varies considerably in length), thickness of test ± 0.15 - ± 0.3 mm.

In the last whorl of sectioned specimens: thickness of outer wall 10-25μ, thickness of septa 10-25μ, length of septa plus 300μ, diameter of alveoles (measured at periphery) 20-60μ, height of alveolar layer ± 100μ, height of chambers ± 150μ - ± 600μ, length of chambers (measured at periphery) ± 150 - ± 450μ, maximum width of chamber ± 120 - ± 180μ, height of aperture 30-60μ, diameter of initial chamber 50-100μ.

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35. COILING IN THE HETEROHELICIDAE

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INTRODUCTION

Few families among the Foraminifera contain genera as poorly known as are several of the genera belonging to the family Heterohelicidae, particularly the type genus of the family, *Heterohelix*. A restudy of the more primitive genera of the Heterohelicidae has shown some errors in previous interpretations of their morphology and suggests that there may be a different phylogenetic relationship than that hitherto proposed.

The type genus *Heterohelix,* described by Ehrenberg (1843, p. 429) was first illustrated (1854, pl. 32, I, figs. 13-14, 11, fig. 25) by drawings of specimens mounted in balsam. While showing the internal structure, this method obscures surficial features and renders difficult comparison with free material. Thus for more than a century the type genus of the family has been based on inadequately illustrated material, and all later references to this genus have merely refigured Ehrenberg's original drawings. A new species of *Heterohelix* is here described, from the Texas Upper Cretaceous.

Although early planispiral stages have been mentioned in several genera, they have seldom been figured. The genus *Gümbelina* has often been described as having a coiled early portion in the microspheric generation, but this feature is here illustrated for the first time in the genotype species.

Coiling is also demonstrated in the microspheric generation of *Ventilabrella,* for comparison with the early coils found in the associated species of *Heterohelix* and *Gümbelina.*

The genus *Eouvigerina* was defined as having a basal coil, but a restudy of the genotype species *Eouvigerina americana* Cushman (1926, p. 4) as well as numerous other species has proved this assumption erroneous, and the generic description is emended. *Eouvigerina* is found to be biserial throughout with the final one or two chambers tending to become central and uniserially arranged. This emended description removes the distinctions upon which the genus *Zeauvigerina* Finlay was based, and the latter name becomes a junior synonym.

RELATIONSHIPS IN THE HETEROHELICIDAE

It must be clearly evident that the construction of any phylogenetic series must take into consideration the geological occurrence of genera and species and in addition, the morphology of the latter, if such "phylogeny" is to be anything more than superficial. Also, much more attention must be paid to a study of the very fine material in samples if we are to eventually increase our knowledge of the distribution in time of many of the genera of the Foraminifera. Many early species of the various genera are quite small and easily overlooked and the young or immature specimens of other species, which may shed light on their morphology, are also to be found in the smaller fractions.

The phylogenetic development of the Heterohelicidae, as often expressed in publications, is at variance with the geologic occurrence of many genera and needs revision.

The family Heterohelicidae as described by Cushman (1948, p. 252) was derived from a planispiral ancestry. He stated that this planispiral feature is retained in the early stages of all of the most primitive genera, at least in the microspheric generation. Cushman's diagram (op. cit., pl. 21) showing relationships of the genera of the Heterohelicidae, regards *Heterohelix* as the origin of the family and evidently the most primitive member as it appears at the base of the "phylogenetic" tree. From *Heterohelix* Cushman derived a host of genera, including *Gümbelina, Eouvigerina, Bolivinopsis, Plectofrondicularia* etc., with *Gümbelitria* being derived from *Gümbelina.* However, *Gümbelina, Gümbelitria, Gümbelitriella* and *Eouvigerina* all occur abundantly in American Lower Cretaceous strata much earlier than does their "ancestor" *Heterohelix,* which first appears in late Cretaceous time. Thus, the "most primitive" member of the family seems restricted to the late Cretaceous, although some of its "descendents" *(Gümbelina)* occurred as early as the Jurassic.

Gümbelina has been described by Cushman (1948, p. 254) as having the early chambers planispirally coiled, at least in the microspheric generation. Although a very few species have been figured showing this early coiled stage, this feature has never been demonstrated in the genotype species. Loetterle (1937, p. 33) described both *Gümbelina globulosa* (Ehrenberg) and *G. plummerae* Loetterle as being coiled in the earliest stages, but he figured no coiled specimens. Material collected recently by the writer contained *G. globulosa* showing a coil in the microspheric generation and specimens of both forms are figured on plate 12, figures 4 and 5.

A coiled stage was also shown in *Gümbelina paucistriata* Albritton, from the Lower Cretaceous of the Malone Mountains, Texas (Neocomian) and this is apparently the earliest species of the genus in which it has been noted. Many of the other early species do not show this coil in either the megalospheric or microspheric generations. Thus the genus cannot be decribed, without qualification, as "planispiral, at least in the microspheric form," because many of the species do not have a planispiral stage in either generation.

Furthermore, *Gümbelitria, Gümbelitriella, Eouvigerina,* and *Gümbelina* (with the exception of *G. paucistriata* Albritton, noted above) all occurring in the Lower Cretaceous, have no coil in their early stages in the microspheric generation although they are certainly primitive forms. *Eouvigerina* not only lacks an early coil, but very probably is not even very closely related to *Heterohelix, Gümbelina* etc., and perhaps should even be placed in a different family, as it has neither the early coil, the inflated and globular chambers, nor the large prominent aperture characteristic of the family.

In general, the early coiling is quite rare among the Heterohelicidae, being found only in the less abundant microspheric forms of only a small percentage of the species of a very few of the genera.

SYSTEMATIC DESCRIPTIONS

Genus **Heterohelix** Ehrenberg, 1843

Genotype: *Spiroplecta americana* Ehrenberg = *Heterohelix americana* (Ehrenberg): Monotypic, lectotype (Mikrogeologie, pl. 32, II, fig. 25) designated by Cushman, Contr. Cushman Lab. Foram. Res. Vol. 3, p. 190.

Heterohelix Ehrenberg, 1843, Abh. k. Akad. Wiss. Berlin Phys.-Math. Cl., 1841, pp. 366, 398, 429; Cushman, 1927, Contr. Cushman Lab. Foram. Res. Vol. 3, p. 59; 1927, Contr. Cushman Lab. Foram. Res. Vol. 3, p. 190; 1927, Jour. Paleon. Vol. 1, p. 214, pl. 34, figs. 13-14, pl. 36, fig. 25; 1928, Cushman Lab. Foram. Res. Spec. Pub. 1, p. 229, pl. 33, fig. 1; 1933, Cushman Lab. Foram. Res. Spec. Pub. 5, pl. 26, fig. 1; 1940, Foraminifera, their classification and economic use, 3d ed. p. 231, pl. 21, fig. 1, key pl. 26, fig. 1; 1946, U. S. Geol. Surv. Prof. Paper 206, p. 101, pl. 44, fig. 3; 1948, Foraminifera, their classification and economic use, 4 ed., p. 253, pl. 21, fig. 1, key pl. 26, fig. 1; Galloway, 1933, A manual of Foraminifera, p. 345, pl. 31, fig. 10.

Spiroplecta Ehrenberg, 1844, Bericht K. preuss. Akad. Wiss. Berlin, p. 75; 1854, Mikrogeologie, pl. 32, I, figs. 13-14, pl. 32, II, fig. 25; Schubert, 1902, Verh. k. k. geol. Reichs., Wien, p. 81.

Original description by Ehrenberg (1843, p. 429): "302 T. [*Textilaria*] *americana,* parva, saepius micros., celerius dilatata laevis, cellulis primis globosis (1/300 lineae 1.), dein ovatis, summis in papillam superiorem externam productis subaculeatis.

Cellulae primae nonnullis spirales. Tales formae forsan proprio generi addicendae sunt: Heterohelix."

Remarks—Ehrenberg evidently considered two different generic forms in the above description, *Textilaria americana* (= *Gümbelina americana*) and *Heterohelix,* which was defined without naming a species. A year later (1844, p. 75) Ehrenberg abandoned the name *Heterohelix* and proposed *Spiroplecta* naming the first species *S. americana,* a form with a spiral early portion and later biserial stage, stating that it was related to *Textilaria americana. Spiroplecta* is thus a junior synonym of *Heterohelix.* These forms were later figured by Ehrenberg (1854, pl. 32, I figs. 13-14, II, fig. 25) and designated as *Spiroplecta americana* with the added note in parenthesis (Heterohelix 1843 S. 429). In addition *Textilaria americana* (1843, S. 398, 429) was also figured (Pl. 32, I, fig. 4a) thus showing definitely that in 1843 Ehrenberg was concerned with two genera in his original description and that the correct genotype designation should be *Spiroplecta americana,* the first and only species assigned to the genus, and not *Textilaria americana,* which is not conspecific and was not so considered by Ehrenberg.

Heterohelix americana (Ehrenberg) was listed by Wickenden (1945, p. 42) from the Boyne member of the Vermilion River formation of Canada. However in a recent personal communication to the writer, Wickenden stated that the Canadian form represents a new species and is not *H. americana.* Nevertheless, this occurrence is the only additional published record of the genus since Ehrenberg's original description.

In the upper Cretaceous rocks of Texas, especially in beds of Navarro age the writer has found *Heterohelix* to be an abundant foraminifer. Hundreds of specimens can be selected from many samples, although the genus has not been noted in sediments below the Navarro.

The genotype species was described from the Upper Missouri and Mississippi regions, U. S. A. No topotype material has been available to the writer as the locality is so vaguely described by Ehrenberg that it would be impossible to locate the exact type area.

Heterohelix navarroensis Loeblich, n. sp.

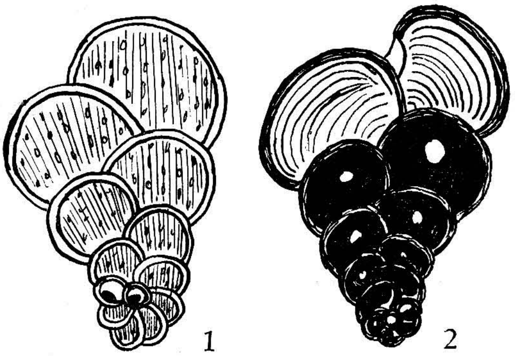
Plate 12, figures 1-3b; Text figure 1

Test minute and subtriangular in side view, the biserial portion flaring widely from the tiny planispiral coil, periphery broadly rounded; the five to six chambers of the coil are low and not much inflated, the later 6 to 11 biserially arranged chambers increasing rapidly in height so that later ones are inflated and subglobular; sutures distinct, straight, somewhat oblique, depressed; wall calcareous, hyaline, surface faintly striate, finely perforate; aperture a low arch at the inner margin of the final chamber, sometimes with a slight lip.

Length of holotype 0.23 mm, greatest breadth of coil 0.04 mm, greatest breadth of biserial portion 0.13 mm, greatest thickness 0.05 mm. Other specimens range between 0.13 and 0.29 mm in length.

Remarks—In an attempt to duplicate Ehrenberg's conditions of observation, specimens of the present species were mounted in balsam and drawn with a camera lucida. One is shown in text figure 2 and a copy of Ehrenberg's Plate 32, II, figure 25, is reproduced for comparison in text figure 1. This is the specimen designated as "genotype" by Cushman (1927 a, p. 190). A striking difference is apparent in the pattern of the ornamentation. Ehrenberg's illustration of *H. americana* shows faint vertical striae crossing the chambers, with occasional pores, but the Texas specimens show broadly curved striae, generally paralleling the upper surface of the chambers. In addition the early coil in *H. americana* is much more lobulate, the early biserial chambers are much more nearly globular and the aperture is much less prominent than in *H. navarroensis*.

The present species may possibly be conspecific with *H. americana,* if Ehrenberg's drawings should later be proved inaccurate, as the two are of approximately the same size and outline. However, it is difficult to compare abundant free specimens with diagramatic illustrations and with a meager description. Ehrenberg's types have not been available for study and because of the very generalized horizon and locality data no topotype material could be collected. For these reasons, the writer feels it reasonable to consider as new the present species, unless and until a study of Ehrenberg's original material proves otherwise.



EXPLANATION OF TEXT FIGURES 1 - 2

FIGS.

1. *Heterohelix americana* (Ehrenberg). Lectotype mounted in balsam and viewed with transmitted light. The parallel vertical striae and small pores can be seen. (After Ehrenberg, 1854 Pl. 32, II, fig. 25)
2. *Heterohelix navarroensis* Loeblich, n. sp. Paratype (USNM P. 32c) mounted in balsam and viewed with transmitted light for comparison with Ehrenberg's illustration. Early chambers are filled with mineral matter and are not transparent. The test tapers rapidly, the final pair of chambers shows curved striae paralleling the upper chamber surface and the large aperture is also visible. × 218.

Types and occurrence—Holotype (USNM P. 33), figured paratypes (USNM P. 32a-c) and unfigured paratypes (USNM P. 37) from the Navarro (Kemp clay) in a pit of the Seguin Tile and Brick Company at McQueeney, Guadalupe County, Texas. From the type sample, 6 to 8 feet above the base of the pit, 329 specimens were examined. *Heterohelix navarroensis* is also common in the basal Navarro strata exposed in a steep slope on the right bank of Onion Creek just east of the bridge (known as Jones Crossing) on the Austin-Bastrop highway, Travis County, Texas. All material collected by the writer.

Genus **Gümbelina** Egger, 1899

Genotype: *Textularia globulosa* Ehrenberg. Subsequent designation by Cushman, Contr. Cushman Lab. Foram. Research, vol. 3, p. 190.

Gümbelina globulosa (Ehrenberg)

Plate 12, figures 4, 5

Textilaria globulosa EHRENBERG, 1834, K. preuss. Akad. Wiss. Berlin Abh., p. 135, pl. 4, fig. 4 B.

Gümbelina globulosa (Ehrenberg) EGGER, 1899, K. bayer. Akad. Wiss. Mat.-naturh. Abt., Abh. Kl. 2, Vol. 21, pt. 1, p. 32, pl. 14, fig. 43.

Test small, flaring, periphery broadly rounded; up to 14 biserially arranged chambers in the megalospheric form, the microspheric form possessing an extremely tiny initial coil of about five chambers, followed by 11 to 12 biserially arranged chambers which increase rapidly in size and degree of inflation, final pair of chambers occupying 2/5 to 1/2 the length of the test; sutures distinct, depressed, straight, ranging from slightly oblique to nearly horizontal; wall calcareous, hyaline, finely perforate; aperture a high arch at the inner margin of the final chamber, bordered above by a distinct rim of clear shell material.

Length of figured megalospheric hypotype 0.47 mm, greatest breadth 0.26 mm, greatest thickness 0.23 mm. Length of figured microspheric hypotype 0.39 mm, greatest breadth of coil 0.05 mm, greatest breadth of biserial stage 0.23 mm. Other specimens vary between 0.36 and 0.47 mm in length.

Remarks—Although *Gümbelina* is mentioned frequently in the literature as being planispiral in its early stage, few figures have previously been published illustrating this character. Specimens of both the microspheric and megalospheric generations are here figured to demonstrate this feature and to serve for comparison with the associated and much smaller *Heterohelix navarroensis.*

Types and occurrence—Figured hypotypes (USNM P. 34a-b), and unfigured hypotypes (USNM P. 38) from the Navarro (Kemp clay), 6 to 8 feet above the base of the pit of the Seguin Tile and Brick Company at McQueeney, Guadalupe County, Texas.

Genus **Ventilabrella** Cushman, 1928

Ventilabrella carseyi Plummer

Plate 12, figures 6-8

Ventilabrella carseyi PLUMMER, 1931, Univ. Texas Bull. 3101, pp. 178-179, pl. 9, figs. 7-9; CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 112, pl. 48, figs. 1-5.

Test small, subtriangular in side view, periphery rounded; early portion of microspheric form consisting of about five planispirally arranged chambers, later biserial, megalospheric generation biserial throughout, a few of the megalospheric forms having the final chambers irregularly arranged in the plane of biseriality, the irregular portion usually having only three chambers across, chambers low in the coil and early biserial portion, rapidly increasing in height, later chambers inflated and globular; sutures distinct and incised; wall calcareous, hyaline, surface finely striate; aperture a broad opening at the inner margin of the final chamber of the biserial portion, sometimes with supplementary apertures on the opposite side of the later chambers.

Length of figured microspheric hypotype 0.42 mm, breadth of coil 0.04 mm, breadth of biserial stage 0.27 mm. Length of figured megalospheric biserial hypotype 0.36 mm, breadth 0.26 mm. Length of figured megalospheric hypotype showing three chambers across the top 0.55 mm, breadth 0.31 mm. Other specimens vary from 0.31 to 0.55 mm in length.

Remarks—This species was well described by Plummer, who described and figured the microspheric coil. Plummer noted that no microspheric form progressed beyond the biserial stage and this has been supported by the present investigation of the species. The microspheric form of this species is quite rare, in samples studied by the writer, as are also the megalospheric forms that progress beyond the biserial stage.

Types and occurrence—Figured hypotypes (USNM P. 35a-c) and unfigured hypotypes (USNM P. 39) from the Navarro (Kemp clay), 6 to 8 feet above the base of the pit of the Seguin Tile and Brick Company at McQueeney, Guadalupe County, Texas.

Genus **Eouvigerina** Cushman, 1926

Genotype: *Eouvigerina americana* Cushman, Contr. Cushman Lab. Foram. Res. Vol. 2, pp. 4-5, pl. 1, fig. 1a-c. Original designation.

Sagrina (part) of authors.

Zeauvigerina FINLAY, 1939, Trans. Roy. Soc. New Zealand Vol. 68, p. 541.

Test free, elongate, chambers biserial with later chambers becoming less closely appressed and tending toward a uniserial development; sutures constricted; wall calcareous, hyaline; aperture terminal, rounded, produced on a slight neck, occasionally with a phialine lip.

Remarks—A restudy of the holotype of the genotype species (here refigured on plate 12, figure 9) and all paratypes and hypotypes in the National Collections has shown the species to be biserial in the early stages and not coiled as stated in the original description. Under certain lighting the inner margin of the third chamber from the base of the holotype shows a distinct highlight which may have been mistaken for an additional chamber and the center of the "coil" of Cushman's type figure. When dampened with glycerine, the true character is shown, with the early development completely biserial.

The biserial character is also shown in an early unornamented species, *Eouvigerina laxistoma* Loeblich and Tappan, from the Texas Lower Cretaceous (Weno, Paw Paw, Main Street and Grayson formations). If the genus did have a coiled ancestry and if the theory of recapitulation can be followed then the early coiling should be most evident in the ontogeny of the earliest species. In *E. laxistoma*, a smooth, unornamented species, with no ridges or other concealing features, there is absolutely no suggestion of a coil in any of the many specimens found at four different stratigraphic levels. The terminal chamber also shows a tendency toward uniseriality.

The development of the early portion of *E. gracilis* Cushman, associated with the genotype species in the Taylor marl of Texas, was described as "obscure but the test for the most part made up of biserial chambers." The gradual increase in chamber size shown in the original figure suggests that this form is biserial throughout. Re-examination of the types supports this conclusion. This species also shows a tendency toward an irregular uniserial character and brings to mind the intermediate cuneate segments found in the gradation from biserial to uniserial arms in the Crinoidea. The later chambers of *E. gracilis* are cuneate in shape with the thicker part of the wedge alternating from one side to the other, but the last chambers do not touch the previous chamber on the same side as would be the case in truly biserial chambers. Although certain specimens of this and other species can be found in which the terminal chamber is somewhat out of the original plane of symmetry, this feature is quite variable and does not seem sufficiently regular as to indicate a triserial development.

In other species described by Cushman the early chambers are either described as biserial or as indistinct, but development "mostly biserial" (*E. aculeata* Cushman, *E. austinana* Cushman, *E. excavata* Cushman and *E. hispida* Cushman). No coil is shown in figures of *E. aspera* (Marsson) or its varieties, *E. major* Brotzen or *E. stormi* Brotzen.

Inasmuch as the genotype species, as well as E. *excavata* Cushman (from the Paleocene Midway formation, and thus the youngest species yet referred to *Eouvigerina*) also show only biserial or irregularly uniserial development and no definite triserial stage, it is considered advisable to redefine the genus and thus lessen the confusion as to the true generic characters.

This redefinition of *Eouvigerina* places the name *Zeauvigerina* Finlay in synonomy. Finlay's (1939, p. 541) type description states, "genus similar to *Eouvigerina* in size, biserial arrangement of most chambers and spout-like uvigerine aperture, but differing in first and last stages. The early chambers show not the slightest trace, even in the microspheric form, of spiroplectine coiling; the final chambers have no tendency to become irregularly triserial, the whole test being regularly bolivine throughout." The emended decription of *Eouvigerina* removes the distinctions mentioned by Finlay and the name *Zeauvigerina* Finlay thus becomes a junior synonym.

Eouvigerina americana Cushman

Plate 12, figure 9

Eouvigerina americana CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res. Vol. 2, p. 4, pl. 1, fig. 1a-c.

Test free, tiny, elongate, chambers biserially arranged, early chambers low, later chambers much higher and becoming very angular in outline with a pronounced ridge slightly below the mid portion of each of the later chambers, chambers becoming loosely biserial as added, final chambers tend to become nearly central in position; sutures constricted; wall calcareous, hyaline, surface smooth, ornamented only by the angular ridges that cross the chambers; aperture terminal, rounded, produced on a slight neck, with a phialine lip present in some specimens.

Remarks—Cushman (1926, p. 4) describes this species, the genotype species of *Eouvigerina,* as being coiled in the early stages, at least in the microspheric form. A close examination of all specimens referred to this species by Cushman has failed to produce a single form showing this "coiled stage," and all specimens examined are definitely biserial in the early portion. Cushman also described this form as having the final chambers irregularly triserial. However the chambers appear to be merely tending toward an irregular uniserial arrangement and in most specimens the final chamber becomes nearly central in position.

Types and occurrence—Holotype (Cushman Coll. 4986) and unfigured paratypes (Cushman Coll. 4987) from the Taylor marl in a clay pit of the Dallas Brick Company, 1/2 mile west of Mesquite, Texas.

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EHRENBERG, C. G., 1843, Verbreitung und einfluss des Mikroskopischen lebens in sud - und nord - amerika: Abh. K. Akad. Wiss. Berlin. Phys. - Math. Cl., 1841, pp. 291-445 pls. 1-3.

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RECENT LITERATURE ON THE FORAMINIFERA

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

WEBER, HANS. "Foraminiferen des Tertiärs" I. Bemerkungen zur Systematik und Biologie tertiärer Foraminiferen.—Badischen Geol. Abhandl., Jahrg. 10, Heft 1/2, 1938/39, pp. 9-24, text figs. 1-4.—Changes of generic placement of several species and varieties, and discussion of dextral and sinistral coiling.

"Foraminiferen des Tertiärs" II. Die Beziehungen der Foraminiferenfauna von Gross-Sachsen a. d. Bergst. zum Sediment.—Badischen Geol. Abhandl., Jahrg. 10, Heft 1/2, 1938/39, pp. 25-37, 2 tables.—Distribution of foraminifera as related to facies is shown in tables. Two main provinces are recognized, one characterized by **Peneroplis pertusus** and abundant miliolids, the other by the absence of **P. pertusus** and presence of arenaceous forms.

DE MAREZ OYENS, F. A. H. W. Over het voorkomen van **Fusulina**-kalken in het Basleogebied.—Geol. Instit. Mededeel. No. 110, Univ. Amsterdam, 1940?, pp. 1-3, text fig. 1 [map].

CIRY, R. and H. TINTANT. Sur la présence d'une microfaune dans le Pliocène marin de Millas (Pyrénées—Orientales).—C. R. S. Soc. Géol. France, séance du 5 novembre 1945, pp. 165-167.—Foraminifera are listed.

Sur la microfaune des sables pliocènes de Montpellier.—C. R. S. Soc. Géol. France, séance du 25 mars 1946, pp. 102, 103.—Foraminifera are listed.

CIRY, RAYMOND. Un nouveau fusilinidé permien, **Dunbarula mathieui**.—Bull. Sci. Bourgogne, vol. 11, 1946-1947, 1948, pp. 103-110, pl. 1, text fig. 1.—From southern Tunisia.

BARTENSTEIN, HELMUT. Taxonomische abgrenzung der Foraminiferen-gattungen **Palmula** Lea, **Flabellina** Orbigny und **Falsopalmula** n. g., gleichzeitig eine revision der Jura-arten von **"Flabellina."**—Senckenbergiana, vol. 28, No. 4/6, Dec. 1, 1948, pp. 119-137, pls. 1, 2, text figs. 1-3.—**Falsopalmula** n. gen. (genotype **Flabellina tenuistriata** Franke). Lists of species and varieties belonging to the following four genera are given: **Palmula** (23), **Flabellina** (38), **Falsopalmula** (5), and **Frondicularia** (8).

Entwicklung der gattung **Lenticulina (Lenticulina)** Lamarck 1804 mit ihren unter-gattungen (For.).—Senckenbergiana, vol. 29, No. 1/6, Dec. 15, 1948, pp. 41-65, pls. 1-6, text figs. 1a-l.—Seven subgenera of **Lenticulina** and four other related genera are studied as to description and stratigraphic range.

Ein neues leitfossil in der nordwestdeutschen Oberkreide.—Senckenbergiana, vol. 30, No. 4/6, Dec. 20, 1949, pp. 213-216, text figs. 1-5.—**Cyclocibicides triebeli** n. sp.

Die trennung von gattungen und arten innerhalb der Lagenidae, ein beitrag zur problematik der Foraminiferen-taxonomie.—Senckenbergiana, vol. 31, No. 5/6, Dec. 30, 1950, pp. 339-345, pls. 1-3.—Gradation between genera is illustrated by numerous photographs.

Neoflabellina, nomen novum pour **Flabellina** d'Orbigny 1839 (Foraminifères).—C. R. S. Soc. Géol. France, No. 9, séance du 9 mai 1949, pp. 164, 165.

Stratigraphische und ökologische Folgerungen aus dem Auftreten von Ostracoden und Foraminiferen im produktiven Ruhr-Oberkarbon.—Neuen Jahrb. f. Min. etc., Monats., Jahrg. 1949, Abt. B, Heft 1-3, pp. 60-64.

Micropalaeontological research in European Upper Carboniferous stratigraphy.—Geol. Mag., vol. 87, No. 4, July-Aug. 1950, pp. 253-262, pl. 12.—A few arenaceous genera of foraminifera are used in correlation.

HAGN, HERBERT. Zur Paläogeographie und Mikropaläontologie des oberbayrischen Paleozänflysches.—Zeitschr. Deutschen Geol. Gesell., Band 101/11, 1949, pp. 164-183, pls. 1, 2.—A few foraminifera are listed and figured in section.

Das alter der konglomerate des Tratenbachs bei Lenggries (Bayr. Alpen). Ein beitrag zur mikropaläontologie der Alpenrandzone.—Neuen Jahrb. f. Geol. Pal., Monats., Jahrg. 1951, Heft 4, pp. 103-118.—A few foraminifera are mentioned.

SOCIN, COSTANTINO. Nuova microfauna a foraminiferi in regione val Salice (Torino).—Mem. Istit. Geol. Univ. Padova, vol. 16, 1949, pp. 1-9, 1 pl.—Thirty-seven species are recorded and figured from Miocene beds.

REICHEL, MANFRED. Alvéolines de l'oligo-miocène de Cuba.—Actes Soc. Helvétique Sci. Nat., 1949, p. 148.—Note of the forthcoming description of **Fusarchaias bermudezi** n. gen., n. sp.

Remarques sur le genre **Boreloides** Cole et Bermudez.—Actes Soc. Helvétique Sci. Nat., 1949, p. 148.—**Boreloides** is related to **Helicostegina** and **Eoconuloides.**

WICHER, CARL A. On the age of the higher upper Cretaceous of the Tampico embayment area in Mexico, as an example of the worldwide existence of microfossils and the practical consequences arising from this.—Bull. Mus. Hist. Nat. Pays Serbe, ser. A, livre 2, 1949, pp. 49-105, pls. 2-8. (pp. 76-105 in English).—Ranges and abundance of 142 species and varieties are represented graphically.

WICHER, C. A. and S. OBRADOVIC. Zur deutung des alters der schichten auf der Avala vom standpunkte der mikropalaeontologie.—Bull. Mus. Hist. Nat. Pays Serbe, ser. A, livre 3, 1950, pp. 81-93, 1 map.—Foraminifera are listed.

ARRHENIUS, GUSTAF. Foraminifera and Deep Sea Stratigraphy.—Science, vol. 111, No. 2881, March 17, 1950, p. 288.—Mud-eating bottom organisms as cause for zones of crushed foraminifera in submarine cores.

PARR, WALTER J. Foraminifera.—B. A. N. Z. Antarctic Research Expedition 1929-1931, Reports—Ser. B (Zoology and Botany), vol. 5, pt. 6, May 24, 1950, pp. 233-392, pls. 3-15, text figs. 1-8.—Four hundred fifty-three species and varieties are recorded and many of them figured. One hundred twenty-seven species and seven varieties are new and three new names are assigned. Seven new genera are erected: **Pelosinella** (genotype **P. bicaudata** n. sp.), **Plectotrochammina** (genotype **P. subglobosa** n. sp.), **Planispirinoides** (genotype **Miliolina bucculenta** Brady), **Siphoglobulina** (genotype **S. siphonifera** n. sp.), **Siphouvigerina** (genotype **Uvigerina porrecta** Brady, var. **fimbriata** Sidebottom), **Ceratobuliminoides** (genotype **C. bassensis** n. sp.), and **Elphidioides** (genotype **Polystomella imperatrix** Brady).

CIRY, RAYMOND, HENRI TINTANT, and HÉLÈNE CHAREYRON. Sur la microfaune du Pliocène de Fréjus.—Bull. Sci. Bourgogne, vol. 12, 1948-49, July 27, 1950, pp. 65-75, text figs. 1-3.—Foraminifera are listed and their abundance represented graphically at two different horizons.

CIRY, RAYMOND, and PIERRE RAT. Sur le présence d'une microfaune maestrichtienne près de Vitoriano (Alava).—Travaux du Lab. Geol., Faculté Sci. Dijon, 1950, pp. 1-13, pl. 1, text figs. 1-4.—Two species, in the genera **Siderolites** and **Orbitoides**, are recorded and illustrated.

ROZOVSKAYA, S. E. On Systematics in the family Fusulinidae.—Akad. Nauk SSSR Doklady N. S., tom 73, No. 2, 1950, pp. 375-378.—New subfamily Fusulinellinae. In Russian only.

DOUGLAS, J. A. The Carboniferous and Permian Faunas of South Iran and Iranian Baluchistan.—Mem. Geol. Survey of India, Palaeontologia Indica, n. ser., vol. 22, Mem. No. 7, 1950, pp. 1-57, pls. 1-5.—Eighteen species of foraminifera, 13 fusulinids and a few others are described and most of them illustrated.

HOFFET, J. H. Notes sur la Géologie de la Province du Haut-Mékong.—Bull. Service Géol. Indochine, vol. 29, fasc. 2, 1950, pp. 1-21, 3 text figs. (map and sections). —Fusulinids are listed.

CITA, M. B. L'Eocene della sponda occidentale del Lago di Garda.—Riv. Ital. Pal. Stratig., vol. 56, No. 4, 1950, pp. 129-152, text fig. 17.—Numerous lists of species and a table showing distribution and abundance.

M. R. de GAONA and G. COLOM. Estudios sobre las Sinecias de los Foraminiferos Eocenicos de la Vertiente Meridional del Pirineo (Cataluña-Vizcaya).—Estudios Geologicos, Instit. Invest. Geol. ''Lucas Mallada,'' No. 12, 1950, pp. 293-434, pls. 53, 54, text figs. 1-19, charts 1-4.—A detailed study of Eocene foraminifera, including particularly alveolines and nummulites, of the southern Pyrenees. Also included are descriptions and figures of 198 species and varieties of other smaller foraminifera, of which five species and two varieties are new.

Mapa Geológico de España, escala 1:50,000, Explicación de la Hoja No. 249, Alquézar, 1950, pp. 1-58, 4 photographs, 2 maps, 1 section.—Foraminifera are mentioned pp. 24-26.

Explicación de la Hoja No. 314, Cilleruela de Abajo, 1950, pp. 1-78, pls. 1-38, 2 maps, text figs. 1-13.—A few Upper Cretaceous forms, particularly **Idalina**, are mentioned and illustrated.

BIRKET-SMITH, JORGEN. Serial sections of small fossils. A new method.—Danmarks Geol. Unders., IV. Raekke, Bd. 3, No. 7, 1950, pp. 1-32, text figs. 1-4.

OVEY, C. D. On the interpretation of climatic variations as revealed by a study of samples from an equatorial Atlantic deep-sea core.—Centenary Proc. Royal Meteorological Soc., 1950, pp. 211-215, text figs. 1, 2 (graphs).—Variations are studied, using percentage counts of planktonic formanifera and percentage of CO_2 by weight.

KHAN, M. H. On some new Foraminifera from the Lower Gault of southern England.—Journ. Royal Micr. Soc., ser. 3, vol. 70, Sept. 1950, pp. 268-279, pls. 1, 2.—Eleven new species and four new varieties are described and illustrated.

HOFKER, J. Wonderful animals of the sea: Foraminifera, I.—The Amsterdam Naturalist, vol. 1, No. 3, Oct. 23, 1950, pp. 1-20, text figs. 1-42.—Discussion of nature and significance of toothplates.

The Toothplate-Foraminifera.—Archives Néerlandaises Zool., vol. 8, 4e livr., 1951, pp. 353-373, text figs. 1-30. —Discussion of generic and family relationships as indicated by toothplates, fine and large pores (protopores and deuteropores), and peripheral and ventral apertures (protoforamina and deuteroforamina).

FUJIMOTO, H. et al. Geological Studies of the Oku-chichibu.—Bull. Chichibu Mus. Nat. Hist., No. 1, November 1950, pp. 1-27, pl. 1, sections, maps.—A few foraminifera, mostly fusulinids, are mentioned and illustrated.

FUKUTA, OSAMU. On the fossil foraminiferal fauna from Kimo, Haraya-mura, Chichibu-gun, Saitama-pref., Japan.—Bull. Chichibu Mus. Nat. Hist., No. 1, November 1950, pp. 147-156, pl. 1, map, columnar section. (English résumé).—Two new species and one new subspecies of **Nonion** are described and figured. A list, showing abundance, is given for the lower Miocene beds at Kimo.

CHIJI, MANZO, and KOJIRO NAKASEKO. New Species of Neogene Foraminifera from the Toyama Basin, Japan. (Microbiostratigraphic Study of Cainozoic Strata in Japan. Part III).—Journ. Geol. Soc. Japan, vol. 56, No. 663, December 1950, pp. 519-522, 1 pl.— Four new species are described.

UCHIO, TAKAYASU. Tertiary fossil fauna from Tochiji Prefecture (1).—Journ. Geol. Soc. Japan, vol. 56, No. 661, 1950, pp. 455-458, English abstract.—Foraminifera are listed and relative abundance indicated in two Miocene formations.

Foraminiferal Study of Tertiary Formations near Otaki Gas-Field, Chiba Prefecture.—Journ. Geol. Soc. Japan, vol. 57, No. 664, Jan. 1951, pp. 13-20, text figs. 1, 2. —The foraminiferal assemblage of a standard section is represented graphically. Two zones and 29 zonules are recognized. Frequencies of the main species as they change throughout the section are shown on a chart.

INOUE, HIROO and KOJIRO NAKASEKO. Foraminifera of the Miocene Sakuma Formation, Japan.—Journ. Geol. Soc. Japan, vol. 57, No. 664, Jan. 1951, pp. 7-11, text figs. 1-4.—Three new species are described and illustrated. The distribution of 52 species in the Sakuma formation is shown in a table, indicating shallow, warm conditions of deposition.

SUZUKI, KOITI, and UMEKA KITAZAKI. Applied Micropaleontological Studies of the Cenozoic Formations in the northern part of Miura Peninsula.—Journ. Geol. Soc. Japan, vol. 57, No. 665, Feb. 1951, pp. 65-78, maps, columnar sections, diagrams representing percentage composition of benthonic foraminifera (in Japanese with English abstract).—Formational members are recognized by their foraminiferal faunal groups.

KOIKE, KIYOSI. On some **Lepidocyclina** from Japan.— Journ. Geol. Soc. Japan, vol. 57, No. 666, March 1951, pp. 87-93, pl. 2, text figs. 1-7.—A study of range of specific variation in **L. (Nephrolepidina) japonica** (Yabe) and comparisons of various of its features with those of several related species.

ASANO, KIYOSHI. Illustrated Catalogue of Japanese Tertiary Smaller Foraminifera. (compiled and edited by Leo. W. Stach)—Tokyo, Japan, Part 2: Buliminidae, Oct. 2, 1950, pp. 1-19, text figs. 1-96, correlation table, map.—Continuing the series started by Part 1, 54 species and varieties, 5 new, are described and illustrated.

Part 3: Textulariidae, Part 4: Valvulinidae, Part 5: Verneuilinidae, Oct. 25, 1950, pp. 1-7, text figs. 1-36; pp. 1-4, text figs. 1-26; pp. 1-4, text figs. 1-24.—Forty-two species and varieties, 4 new, are described and illustrated.

Part 6: Miliolidae, Jan. 31, 1951, pp. 1-20, text figs. 74-77, 1-135.—Fifty-seven species and varieties, 1 new, are described and illustrated, plus one species and one variety of **Elphidium**, belonging with Part 1.

Part 7: Cassidulinidae, Part 8: Polymorphinidae, April 2, 1951, pp. 1-7, text figs. 1-45; pp. 1-14, text figs. 1-72.—Sixty-one species and varieties, 4 new, are decribed and illustrated.

BRAMLETTE, M. N. in W. P. WOODRING and M. N. BRAMLETTE. Geology and Paleontology of the Santa Maria District, California.—U. S. Geol. Survey Prof. Paper 222, 1950 (Jan. 24, 1951), Foraminifera, pp. 58-61, pls. 22, 23.—Seven new species and one new variety are described and figured and five other forms are figured. Numerous species are listed throughout the stratigraphic part of the paper.

ANDERSEN, HAROLD V. Two new genera of Foraminifera from Recent deposits in Louisiana.—Journ. Pal., vol. 25, No. 1, Jan. 1951, pp. 31-34, text figs. 1, 2.—**Arenoparrella** (genotype **Trochammina inflata** (Montagu), var. **mexicana** Kornfeld) in the family Trochamminidae and **Bisaccium** (genotype **B. imbricatum** n. sp.) in the family Nonionidae.

YOUNG, KEITH. Foraminifera and stratigraphy of the Frontier formation (Upper Cretaceous), southern Montana.—Journ. Pal., vol. 25, No. 1, Jan. 1951, pp. 35-68, pls. 11-14, text figs. 1-6.—Thirty-three species, six indeterminate and 24 new of which 12 are given names, are described and illustrated.

HILLY, J., and J. SIGAL. Sur la présence du Sénonien supérieur dans la région d'Herbillon,—Cap de Fer (Département de Constantine, Algérie).—C. R. S. Soc. Géol. France, No. 2, séance du 22 janvier 1951, pp. 26-28.—Numerous species are listed.

ABRARD, R. Individus tératologiques de Nummulites d'Aquitaine.—C. R. S. Soc. Géol. France, No. 6, séance du 12 mars 1951, pp. 95, 96, text figs. 1-7.

CUSHMAN, JOSEPH A., and R. M. STAINFORTH. Tertiary Foraminifera of coastal Ecuador: Part 1, Eocene.—Journ. Pal., vol. 25, No. 2, March 1951, pp. 129-164, pls. 25-28, text figs. 1-4.—One hundred sixty-one species and varieties, 10 new, are recorded and illustrated from 12 Eocene units.

BOLLI, HANS. The genus **Globotruncana** in Trinidad, B. W. I.—Journ. Pal., vol. 25, No. 2, March 1951, pp. 187-199, pls. 34, 35, tables 1, 2, text fig. 1.—Eighteen species and subspecies are studied, with four described as new. Stratigraphic ranges and probable evolutionary relationships are represented on charts.

Zur altersbestimmung von Tertiärshiefern aus dem Helvetikum der Schweizer Alpen mittels kleinforaminiferen.—Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 105-114.—Twenty-two species and varieties are recorded, confirming the Priabonian (Jacksonian) age as indicated by larger foraminifera.

BRONNIMANN, P. A model of the internal structure of **Discocyclina** s. s.—Journ. Pal., vol. 25, No. 2, March 1951, pp. 208-211, text fig. 1.—A new family Asterocyclinidae is proposed.

Weitere beobachtungen an Hantkeninen.—Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 245-251, text figs. 1-3.—A study of early stages of three upper Eocene species of **Hantkenina.**

Bemerkungen uber den Bau von **Amphistegina** d'Orbigny. —Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 251-254, text figs. 1-6.—A study of apertural characteristics.

Tremastegina, ein neues Genus der Familie Asterigerinidae d'Orbigny.—Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 255-265, text figs. 1-7.—**Tremastegina** (genotype **Amphistegina senni** Cushman).

LALICKER, CECIL G. **Pealerina,** new name, replacing **Ellisina** Lalicker.—Journ. Pal., vol. 25, No. 2, March 1951, p. 237.

OINOMIKADO, TSUNETERU. Bibliography of Japanese papers on Cenozoic and Recent Foraminifera published prior to 1950.—Hosokawa Printing Co., Tokyo, Japan, Feb. 2, 1951, pp. 1-19.

ALLEMANN, FRANZ, and RUDOLF BLASER. Vorläufige Mitteilungen über die Flyschbildungen im Fürstentum Liechtenstein.—Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 187-200, text figs. 1, 2 (diagrams).—Stratigraphic ranges of some species of **Globotruncana** and a few others are represented diagramatically.

THALMANN, HANS E. Mitteilungen über Foraminiferen IX.—Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 221-225.—Three new generic names: **Coscinophragma** for **Polyphragma** Reuss (not Quatrefages), **Bermudezella** for **Carpenterella** Bermudez (not Collenetti), **Parrellina** for **Elphidioides** Parr (not Cushman), and a note of homonymity of **Parrella** Finlay, 1939, with **Parrella** Ginsburg, 1938. Eight specific and varietal homonyms are listed. The new name, **dominicana,** previously assigned for **Globorotalia lobata** Bermudez (not Brotzen) was in error, thus **G. lobata** Bermudez is validated. Discussion of **Amphicoryne** vs. **Amphicoryna.** A note of occurrence of the genus **Hastigerinella** in the middle Eocene of Austria, together with a list of associated species.

SCHWEIGHAUSER, JAKOB. Spirillinen aus dem Lias von Arzo (Tessin).—Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 226-236, text figs. 1-9.—Two species are studied in thin section and as free specimens. One, **Spirillina ticenensis,** is new.

SCHAUB, HANS, and JAKOB SCHWEIGHAUSER. Nummuliten und Discocylinen aus dem tiefsten Untereocaen von Gan.—Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 236-242, text figs. 1-7.—A new subspecies of **Nummulites** is described and figured.

SCHAUB, HANS. Über die zugehörigkeit der paleocaenen und untereocaenen Nummuliten zu entwicklungsreihen. —Eclogae geol. Helvetiae, vol. 43, No. 2, 1950 (April 30, 1951), pp. 242-245, pl. 12 (diagram).—Stratigraphic ranges and evolutionary connections are represented for 56 species and varieties.

SNAVELY, PARKE D., JR., WELDON W. RAU, LINN HOOVER, JR., and ALBERT E. ROBERTS. McIntosh formation, Centralia-Chehalis coal district, Washington.—Bull. Amer. Assoc. Petr. Geol., vol. 35, No. 5, May 1951, pp. 1052-1061, text figs. 1-6.—Foraminifera are listed.

RUTH TODD