CONTRIBUTIONS
FROM THE
CUSHMAN FOUNDATION
FOR
FORAMINIFERAL RESEARCH

Volume II, Part 4
December, 1951

Contents

WASHINGTON, D. C., U. S. A.
1951

36. NEW GENERA OF FUSULINID FORAMINIFERA

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A critical evaluation of the classification of the fusulinids demonstrates that three groups of forms are so distinct from other fusulinids that new genera should be established for them. The new genus *Paramillerella* is therefore here proposed for part of the fusulinids formerly referred to *Millerella* Thompson, the new genus *Pseudofusulinella* is proposed for some forms formerly referred with question to the genus *Neofusulinella* Deprat, and the new genus *Oketaella* is proposed for distinctive forms, like the new species described below as *O. fryei.*

The genus *Millerella* Thompson was proposed in 1942 with *M. marblensis* Thompson, 1942 (Pl. 13, figs. 14, 17; Pl. 14, figs. 3-5), from the upper part of the Marble Falls limestone of Texas and from the lower part of Derryan rocks of New Mexico and Texas, lowermost Oklan Series, designated as genotype species.* Studies made of *M. marblensis* since that time show that not only is it almost completely evolute in the outer part of the shell, but that occasional specimens are uncoiled in the outer parts of the shell as in the genera *Codonofusiella* Dunbar and Skinner and *Nipponitella* Hanzawa (Pl. 14, fig. 4).

The latitude generally assigned to *Millerella* includes forms ranging from those slightly evolute like *M. pressa* Thompson, 1944, to those almost if not entirely involute like *M. pinguis* Thompson, 1944 (Pl. 13, fig. 18), *M?. advena* Thompson, 1944 (Pl. 13, fig. 16; Pl. 14, fig. 2), *M?. ampla* Thompson, 1944 (Pl. 13, fig. 13), and *M. circuli* Thompson, 1945 (Pl. 13, fig. 15; Pl. 14, fig. 1). Now that we know that *M. marblensis* is uncoiled in its gerontic stages, at least in some individuals, it becomes obvious that many of the numerous forms generally referred to *Millerella* are not congeneric with that form. Therefore, I am here establishing the new genus *Paramillerella* for many of the species formerly referred to *Millerella*, with *M?. advena* Thompson, from the type section of the Morrowan at Morrow, Arkansas, as genotype species.

Numerous fusulinids have been found in the Lower Permian of California, Nevada, Utah, Idaho, and British Columbia which resemble the genus *Neofusulinella* Deprat in some respects. Two of these were described by Thompson and Wheeler (1946) and referred with some question to *Neofusulinella* as *N. occidentalis* Thompson and Wheeler and *N. montis* Thompson and Wheeler. Later, Thompson and Verville (1950) studied specimens of the same type from the Permian rocks exposed east of Kamloops, British Columbia. D. A. Bostwick* has found several examples of this group in the Lower Permian part of the Wood River formation near Bellevue, Idaho, and Thompson and Bissell have found them in the Lower Permian part of the Oquirrh formation of the Wasatch Mountains of Utah.* The Lower Permian faunas of Nevada contain rather common undescribed forms of this same group. The new genus *Pseudofusulinella* is here established for these numerous Permian forms, with *Neofusulinella occidentalis* Thompson and Wheeler, 1946, as genotype species (Pl. 14, figs. 6-11).

Genus **Paramillerella** Thompson, new genus

Genotype (Type Species): Millerella? advena Thompson, 1944, Kansas Geol. Survey, Bull. 52, pp. 427-429, Pl. 1, figs. 10-14.

Diagnosis: Shell minute, planispiral in all volutions, subellipsoidal to subdiscoidal in shape; with rounded to subangular periphery, straight axis of coiling, flush, slightly extended, to slightly umbilicate axial ends. The first one to one and a half volutions of most forms are evolute, the following two to three volutions are completely involute, and the outer volutions are slightly evolute to involute. Mature shells contain less than eight volutions and are slightly more than or less than one millimeter in maximum diameter. In contrast to most fusulinids, the form ratios of most forms decrease slightly as maturity is approached. The proloculus is minute in size, and the chambers increase slowly and uniformly in height. The spirotheca is thin and is composed of a thin primary layer. In inner volutions, the primary layer is covered above and below by thick tectoria. The septa are plane throughout all parts of the shell and are closely spaced. They are distinctly curved anteriorly as the poles are approached, but are about normal to the spirotheca above the tunnel. The tunnel is narrow, and its path is straight. The chomata are massive, high, and distinctly asymmetrical; with steep tunnel sides and broad but low poleward slopes.

Remarks: Paramillerella resembles somewhat closely

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* Elias (1950, p. 141) inadvertently stated, "Almost as soon as **Millerella** was declared to be confined to the Morrow series (Thompson, 1942) [the original source of publication of the genus], diligent stratigraphic paleontologists, including the author of the genus himself, found **Millerella** in the Chester below the Morrow and in the Atoka above it." The genotype species of **Millerella, M. marblensis,** is from the upper part of the Marble Falls limestone of Texas and from lower Derryan rocks of New Mexico and extreme west Texas (associated with **Profusulinella**), all of lower Derryan (Atokan) age. Furthermore, when proposed, **Millerella** was stated (Thompson, 1942, p. 405) to have a stratigraphic range "in the Pennsylvanian at least from the Wapanucka limestone [Morrowan] to the Cisco [Virgilian]."

* Bostwick, D. A., Manuscript.

* Manuscript.

the general shell shape of *Staffella* Ozawa but is smaller in size and has a distinctly different early shell shape, more deeply umbilicate axial areas in most forms, seemingly has a distinctly different spirothecal structure, larger chomata, a relatively more loosely coiled shell, and has a smaller number of volutions in most forms. The primary shell composition of these two genera may have been quite different.

Paramillerella can be distinguished from *Millerella* Thompson by its more tightly coiled shell, more massive chomata, and more nearly spherical shell. The last volution of *Millerella* is only slightly impressed over earlier volutions or is uncoiled.

Occurrence: The genus *Paramillerella* seemingly has a long geologic range and is known from late Mississippian Chesteran rocks and throughout most if not all of the Pennsylvanian, but is most abundant and varied in the Morrowan and Derryan (Atokan) stages. Its value as indices for age determination is not fully understood.

Genus **Oketaella** Thompson, new genus

Genotype (Type Species): Oketaella fryei Thompson, new species.

Diagnosis: Shell minute and inflated, ellipsoidal to fusiform in shape; with convex surfaces, straight to slightly irregular axis of coiling, and sharply pointed to rounded polar ends. Mature specimens are composed generally of less than six volutions and are approximately a millimeter in maximum diameter, which is in the direction of the axis of coiling. The ratio of the axial length to the width of the shell normal to the axis of coiling is greater than unit value but is less than three in all forms known. The proloculus is large in comparison to the size of the shell, and all volutions are relatively loosely coiled. The septa are thick and are unfluted throughout their length. They are composed of the tectum, an extension of the keriotheca to the base of the septa on the posterior side of the tectum, and a short extension of the keriotheca of the following chamber down the anterior side of the tectum. The spirotheca is relatively thick in comparison to the size of the shell and is composed of the tectum and a thick keriotheca with coarse alveoli in its lower part. The upper keriotheca is very finely perforate. The tunnel is singular, and its path is straight to slightly irregular. Chomata occur throughout the shell except for the last part of the last volution. They are low and narrow in the first volution and are high, broad, and asymmetrical in outer volutions. They seem continuous with coatings on top of the spirotheca that merge with small fillings in the axial zone.

Remarks: Oketaella resembles the genera *Triticites* Girty and *Schubertella* Staff and Wedekind. It resembles *Triticites* especially in its spirothecal structure, symmetrical coiling, and lack of intense septal fluting. However, it differs from typical *Triticites* in that its shell is much smaller in size, is composed of a smaller number of volutions, is more loosely coiled, has a relatively larger proloculus, and, perhaps most important of all, has unfluted septa.

Oketaella differs from *Schubertella* by its thicker spirotheca, more loosely coiled shell, symmetrical shell for all volutions, and more inflated fusiform to ellipsoidal shell.

The genotype species of *Oketaella, O. fryei,* n. sp., resembles closely some Middle Pennsylvanian forms that have been assigned to *Eoschubertella* Thompson, such as *E. gallowayi* (Skinner) and *E. oliviformis* (Thompson). However, the shells of *E. gallowayi* are more nearly spherical and may have different spirothecal structures. *O. fryei* is almost identical to *E. oliviformis* in shell shape, mode of coiling, shell expansion and size, and size of proloculus, but its spirothecal structure seems different.

Occurrence: The genotype and only described species of *Oketaella, O. fryei,* n. sp., is from the middle Wolfcampian Oketa shale of Kansas. Undescribed forms of the genus are known from the lower part of the Waldrip beds, the Camp Colorado shale, and the Coleman Junction limestone of Texas, all seemingly of Wolfcampian age.

Oketaella fryei Thompson, new species

Plate 13, figures 1-12

The shell of *Oketaella fryei,* n. sp., is minute in size and subellipsoidal fusiform in shape; with distinctly convex lateral slopes, and rounded to bluntly pointed poles. Mature shells of three to four volutions are 0.64 to 1.1 mm. long and 0.37 to 0.64 mm. wide, giving form ratios of 1.8 to 2.2. The shell is subspherical to subellipsoidal in shape in the first volution, is slightly elongate ellipsoidal in the second volution, and is more elongate ellipsoidal in the third volution. All volutions are involute. Averages of the form ratios of the first to the fourth volution of five specimens, including the holotype, are 1.3, 1.7, 2.0, and 1.8, respectively. All parts of the shell have distinctly convex lateral slopes.

The proloculus is relatively very large. It is spherical in shape in most specimens, but in some it is slightly elongate parallel to the axis of coiling. The outside diameter of the proloculus measures 59 to 122 microns, averaging 95 microns for seven specimens. The shell is inflated throughout all volutions. In general, the chambers are lowest above the tunnel, but they increase in height only slowly as the poles are approached. Averages of the heights of the chambers in the first to the fourth volution of seven specimens are 40, 57, 73, and 95 microns, respectively.

The septa are thick and are straight throughout the length of the shell. In some specimens a slight irregularity is observed in the extreme polar ends, but the irregularity is not interpreted to represent fluting. It

Measurements of *Oketaella fryei*, new species, in millimeters

SPECIMEN	L.	W.	R.	No. Vol.	Diam. of Prol.	Height of volutions				Form ratio of volutions			
						1	2	3	4	1	2	3	4
1	-	0.52	-	3½	.103	.044	.053	.076	-	-	-	-	-
2	0.89	0.50	1.8	4	.059	.037	.042	.059	.095	1.1	1.6	1.9	1.8
3	0.86	0.45	1.9	3	.118	.035	.060	.084	-	1.8	1.9	1.9	-
4	-	0.64	-	3	.122	.052	.075	.066	-	-	-	-	-
5	1.10	0.42	2.2	3	.090	.043	.061	.085	-	1.1	1.5	2.2	-
6	0.69	0.37	1.9	3	.085	.028	.059	.071	-	1.4	1.8	1.9	-
7	0.64	0.39	1.9	3	.085	.038	.049	.071	-	1.3	1.5	1.9	-

SPECIMEN	Thickness of spirotheca					Septal count			Tunnel angle (degrees)			
	0	1	2	3	4	1	2	3	1	2	3	4
1	-	-	-	.024	-	10	13	14	-	-	-	-
2	-	-	-	.024	.027	-	-	-	-	25	32	28
3	.008	.010	.020	.038	-	-	-	-	35	39	-	-
4	-	.017	.023	.036	-	10	13	16	-	-	-	-
5	-	.011	.021	.020	-	-	-	-	-	32	43	-
6	-	-	.015	.024	-	-	-	-	-	24	25	-
7	-	-	.024	.038	-	-	-	-	-	-	-	-

is composed of thick extensions of the keriotheca to the base of the septa on the posterior side of the tectum and a short downward extension of the keriotheca on the anterior side of the tectum. The septa are relatively widely spaced. The septal counts of the first to the third volution of two specimens are 10, 13, and 15, respectively.

The keriotheca is thick and is composed of the tectum and a relatively coarsely perforate keriotheca. Evidently, an upper and a lower keriotheca are present, but their bordering zones cannot be defined. The keriothecal perforations continue through the chomata. Average thicknesses of the spirotheca in the first to the fourth volution of seven specimens are 13, 21, 29, and 27 microns, respectively. The above measurement of the spirotheca for the first volution is only a close approximation. The proloculus wall is too thin to measure accurately in most specimens, but in one specimen it is about 8 microns thick.

The tunnel is singular, rather narrow, and has a slightly irregular path. Averages of the tunnel angles of the second to the fourth volution of six specimens are 30, 33, and 27 degrees, respectively. The holotype specimen has tunnel angles of 25, 32, and 28 degrees in the second to fourth volution, respectively. Chomata occur throughout the shell except for the outer part of the last volution. They are very narrow and low in the first one and one half volutions but become high and very asymmetrical in outer volutions. They spread toward the poles with gradual thinning in the second and third volutions. The end zones of the third volution and, in some specimens, those of the second volution contain secondary deposits that may be comparable to axial fillings of some other fusulinids.

Remarks: *Oketaella fryei*, n. sp., is the only described species of the new genus *Oketaella*, and specific comparisons are given under the generic diagnosis.

The species is named in honor of Dr. John C. Frye.

Occurrence: *Oketaella fryei*, n. sp., is abundant in the Oketa shale in the old railroad quarry in the northwest edge of the village of Florence, Kansas.

Genus **Pseudofusulinella** Thompson, new genus

Genotype (Type Species): *Neofusulinella occidentalis* Thompson and Wheeler, 1946, Geol. Soc. America, Mem. 17, pp. 25, 26, Pl. 2, figs. 1-4.

Diagnosis: Shell inflated to elongate fusiform; with narrowly rounded to pointed poles, straight axis of coiling, and concave lateral slopes. Mature shells have as many as twelve volutions, and most of them are less than 6 mm. in maximum length. The general shape of the shell is closely similar throughout all volutions; in some it decreased, and in others it increased as the shell grew. The proloculus is minute, and the early volutions are very tightly coiled. The increase in height of the chambers is uniform but rather rapid. The spirotheca is thin and is composed of a tectum and diaphanotheca with very minute but distinct pores. The perforations pass through the tectum and through the chomata. The massive chomata and axial fillings form thick layers on the top of the spirotheca, and the chomata cover the lower surfaces of the spirotheca in the center of the shell to give it the appearance of a spirotheca of four layers as found in *Fusulinella* Möller and *Fusulina* Fischer de Waldheim. The chomata are very massive and highly asymmetrical. Their tunnel sides are steep to overhanging, and their poleward slopes are lower. The chomata spread to join with the axial fillings and spread as thick layers up the septa and onto the base of the spirotheca in inner volutions. Only a small circular lateral opening remains at the top and center of the chamber above the highest part of the chomata. The tunnel is narrow, and its path is about straight. The septa are closely spaced. In the center of the shell they are plane, but in the axial areas they are fluted rather narrowly at their base and are plane in their upper surfaces.

Remarks: The similarity between the new genus *Pseudofusulinella* and *Fusulinella* Möller is striking on first examination. However, more critical comparison reveals two distinct differences, other than the fact that *Fusulinella* is confined to rocks of lower Oklan age and *Pseudofusulinella* is confined to rocks considerably higher in section. *Pseudofusulinella* has axial fillings not present in *Fusulinella,* and it possesses a different spirothecal structure.

Forms from the McCloud limestone of California, including the genotype species, here referred to *Pseudofusulinella* were formerly referred with question to *Neofusulinella* Deprat by Thompson and Wheeler (*In* Thompson, Wheeler, and Hazzard, 1946) as *N. occidentalis* and *N. montis.* They did not describe the axial fillings that are present in those forms. Thompson and Verville (1950) later referred a form with question to *Neofusulinella* as *N.* sp. from the Cache Creek series near Kamloops, B. C. D. A. Bostwick has found common forms of *Pseudofusulinella* in the Wolfcampian part of the Wood River formation of Idaho.[*] Rather abundant forms of *Pseudofusulinella* have been found in the Wolfcampian of the Great Basin area of Utah and Nevada.

Pseudofusulinella can be distinguished from *Neofusulinella* by its axial fillings, fluted septa, more massive chomata, and shell shape.

Pseudofusulinella can be distinguished from *Yangchienia* Lee[†] by its less massive chomata, fluted septa, and symmetrical shell in all volutions.

Pseudofusulinella resembles *Waeringella* Thompson in many respects and probably is a descendant from it. The former genus has a different spirothecal structure, including a distinct diaphanotheca, a more inflated shell, more loosely coiled shell, more widely spaced septa, much lighter axial fillings, and in general a different mode of coiling.

Occurrence: Pseudofusulinella is very widespread in Lower and Middle Permian rocks of Utah, Nevada, Idaho, California, and British Columbia. Probably congeneric forms are present in Virgilian rocks of the Great Basin. The distribution of the genus outside North America is not well known.

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[*] Bostwick, D. A., Fusulinids of the Wood River formation of Idaho: manuscript, Univ. Wis. Thesis, 1951.

[†] The form described by Ozawa (1925a, 1925b) as **Fusulinella itoi** Ozawa and reported as being associated with Upper Permian Tethyan fusulinids was referred with question to **Yangchienia** by Thompson (1935) and later was referred with question by Thompson, Wheeler, and Hazzard (1946) to **Neofusulinella.** Professor R. Toriyama is now restudying this form at Wisconsin and finds that it is referable to **Fusulinella** Möller and is associated with a typical Middle Pennsylvanian (Moscovian) fauna.

EXPLANATION OF PLATE 13

All illustrations on this plate are unretouched photographs.

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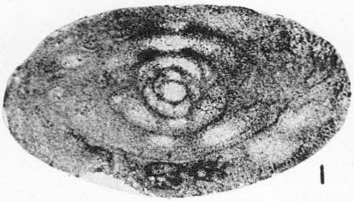
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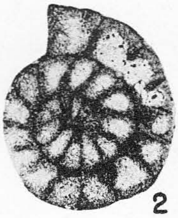
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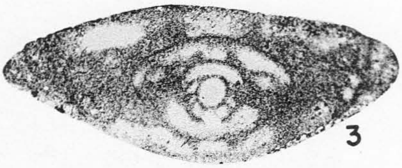
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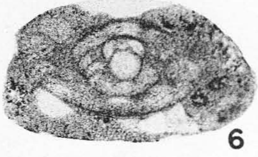
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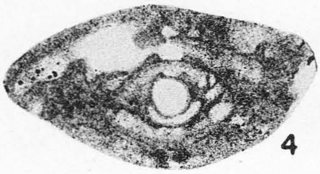
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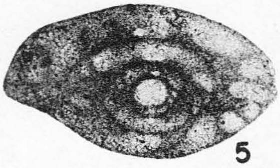
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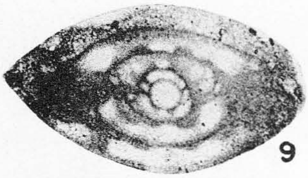
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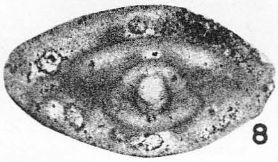
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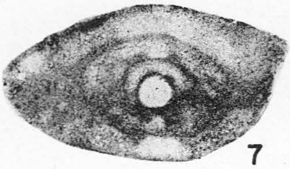
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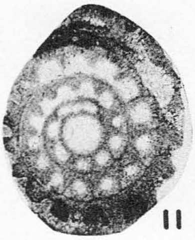
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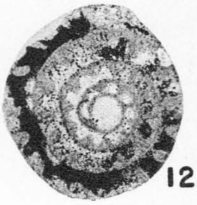
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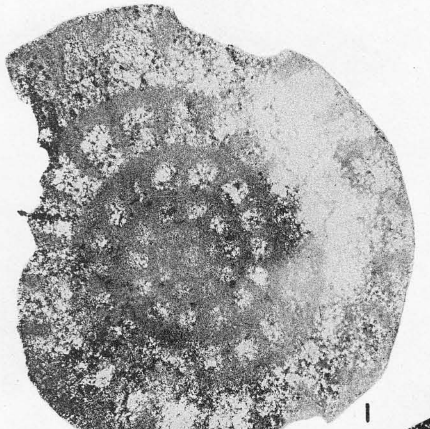
Thompson, New Fusulinid genera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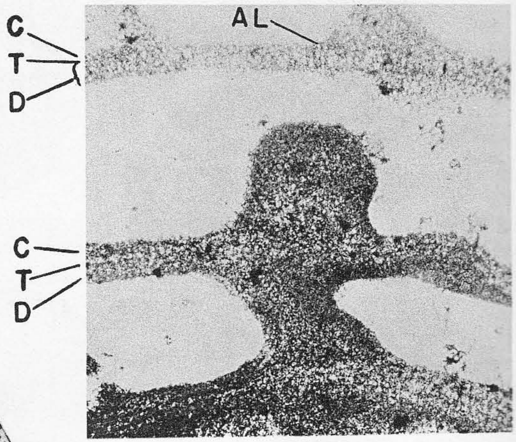

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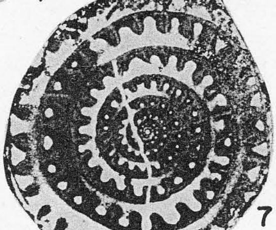
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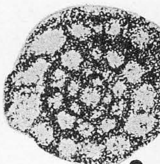
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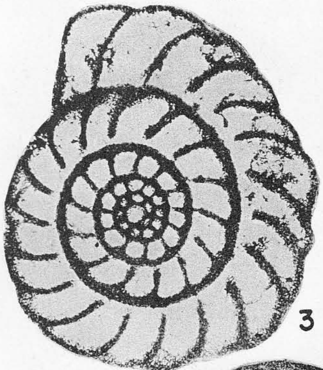
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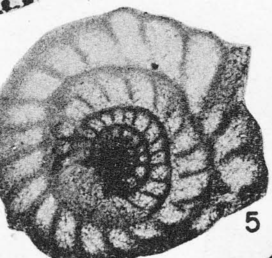
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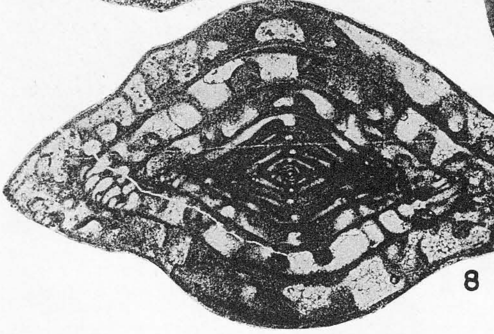
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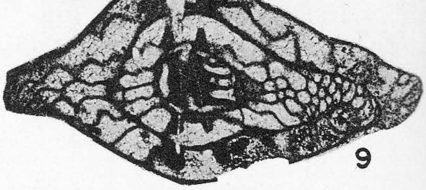
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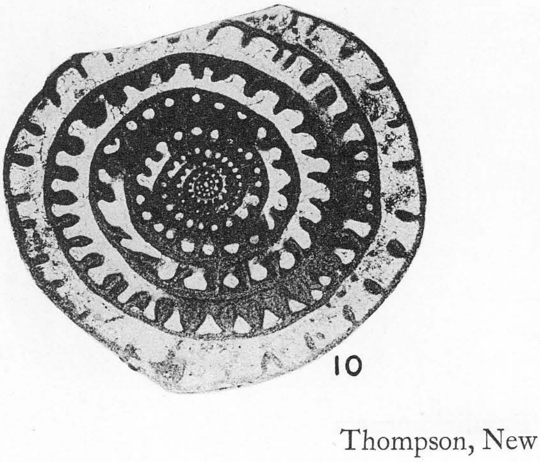
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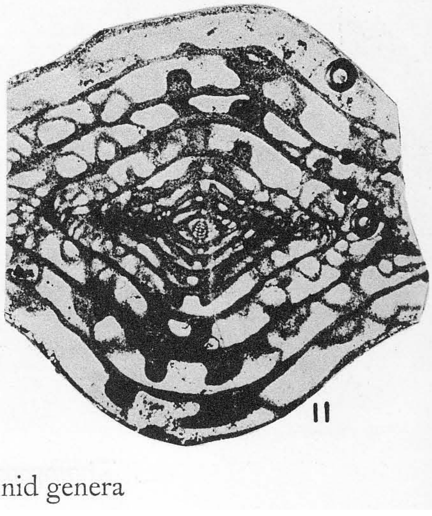
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Manuscript received May 14, 1951

37. RESTUDY OF THE "RACES" OF *NUMMULITES GIZEHENSIS*

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ABSTRACT—Results are given of a quantitative study of **Nummulites gizehensis**, hitherto considered as a variable species comprising eight "races." The study shows these eight "races" to be distinct and valid species which, although related, must have developed along two lines of evolution. The median and geometric quartile deviation are introduced in quantitative paleontology. The eight species are excellent index fossils for the upper Lutetian. They appear suddenly at the beginning of this stage and undergo little change in either time or space. This mode of evolution is discussed.

Because of its large size and abundance, in one of the most ancient lands, *Nummulites gizehensis* (Forskal) has long attracted the attention of naturalists and been the subject of their speculation. Strabo and various other early writers considered it the petrified remains of the lentil which was the food of the builders of the Gizeh pyramids, for this Nummulite is found frequently at their base and in the hills around them.

Our present knowledge of *Nummulites gizehensis* is due almost exclusively to de la Harpe, the great student of Nummulites (1881, 1883). De la Harpe's conception of the species was quite different from that now prevailing in the classification of Foraminifera. This author was inclined to gather forms related to each other and connected with each other by transitional stages into one species, and to separate the different forms as "races." In his works de la Harpe believed that the well-known *Nummulites gizehensis* comprised a single species formed of eight "races": *N. gizehensis ehrenbergi, lyelli, champollioni, cailliaudi, viquesneli, zitteli, pachoi* and *mariettei.* Subsequent workers have accepted this classification and augmented the number of "races." The present study deals only with the original eight "races" described from Egypt, and embodies the results of a quantitative study of these eight "races" "races" in an attempt to settle their taxonomic position. It seems quite surprising that sixty-five years after de la Harpe's work, the position of the different "races" of *N. gizehensis,* one of the often mentioned species and a classical index fossil still remains ambiguous and unsettled. Cuvillier (1931), the most recent worker on the Egyptian Eocene, lists this fossil and admits that its "races" are rather difficult to separate but does not go further into their study. Rozlozsnik (1927) in his excellent treatise on the *Nummulites* leaves the systematic position of this species intact. Silvestri (1942) in his recent work on the *Nummulites* of Somaliland, accepts de la Harpe's eight "races," stating that the species is very variable. Meffert (1931) agrees

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EXPLANATION OF PLATE 14

All illustrations on this plate are unretouched photographs.

FIGS.		PAGE
1.	*Paramillerella circuli* (Thompson), 1945. A sagittal section of a paratype, × 100. Belden formation, Utah.	115
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3-5.	*Millerella marblensis* Thompson, 1942. 3, 4, Sagittal sections, the latter of which shows the uncoiled part of the shell; and 5, sagittal section of a paratype specimen, all × 100. 3, 4 are from the base of the Big Saline limestone at Onion Creek Crossing, Richard's Ranch, Texas, and 5 is from the Marble Falls limestone, Marble Falls, Texas, × 100.	116
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with de la Harpe's ideas and erects a variety of one of the "races," *N. gizehensis ehrenbergi armeniensis,* thus introducing into the taxonomy a peculiar quadrinomial nomenclature[1].

The position of *N. gizehensis* in the general line of evolution of the genus *Nummulites* is unknown. Davies (1935) flatly admits that the species does not show any relation to any of his three lineages of evolution. *N. gizehensis* is not considered in Abrard's work (1928), and has not been incorporated in Glaessner's modified table (1945). More knowledge of this species is therefore needed to help to piece together the picture of Nummulite evolution, which is thus far highly controversial and purely speculative.

Acknowledgments: The Standard Oil Company of Egypt generously extended travel facilities to Dr. N. M. Shukri, Faculty of Science, Cairo, Egypt thus facilitating the collection of the Fayum material which forms part of that upon which this work is based. Professor W. Leupold, Federal Polytechnic Institute, Zurich, Switzerland introduced the author to this field of study, guided him during the first steps of this research, and contributed many useful suggestions particularly as to the methods of storing fossils. Mr. Naguib F. Said, Cairo has graciously consented to draft the figures.

Synonymy: The quantitative study embodied in this work shows that de la Harpe's eight "races" are valid distinct species. These "races" are therefore elevated to specific rank in the following discussion. The work also reveals that only quantitative methods can throw light on the classification and evolution of Nummulites, because the genus is extremely diversified, and superficial qualitative examination may be misleading as to its true characteristics.

Owing to the great confusion of nomenclature the following list of synonymy is prepared. *N. gizehensis* has been observed since ancient times and the synonymy is therefore extensive. Most of the early workers' descriptions and figures, however, are poor, inadequate and incomplete. The matter is further complicated because many of the early naturalists were "lumpers," and it is impossible to recognize from their work the fine distinctions upon which the species erected in this paper are based. Furthermore, in many instances magnifications were not given, and the plesiotypes are lost.

At the beginning of the present study an exhaustive synonymy was prepared. A painstaking search through the literature has shown quite clearly that many of the older works prove useless as references for the identification of the species and must be dropped from the synonymy. To cite only two examples: *N. nummiformis* (Cailliaud, 1827, vol. 4, p. 267, atlas, pl. LXV, figs. 3-5) is frequently placed in the synonymy of *N. gizehensis* and *N. lyelli.* This is not justified, as the drawings are extremely poor, and the equatorial section given in fig. 5 of this work cannot belong to any Nummulite of the *N. gizehensis* group.

N. arbiensis (Lynch, 1852, p. 227, pl. 22, fig. 127) should also not be assigned to the synonymy of *N. gizehensis* as has been done previously. The figure consists of a poor drawing of an equatorial section of a Nummulite (?). The number of whorls, the direction of septa and the size do not conform with any known *N. gizehensis.*

The following list of synonymy has been prepared from authentic and valid descriptions of the *N. gizehensis* group.

Genus **Nummulites** Lamarck, 1801

Nummulites gizehensis (Forskal)

Nautilus gizehensis FORSKAL, Descriptiones animalium, 1775, p. 140.

Nummulites gyzehensis D'ARCHIAC and HAIME, 1853, Déscription Anim. foss. groupe nummulitique Inde, vol. 1, p. 94, pl. II, figs. 6a, b, c, d, e, f, 7a, 8; HERON-ALLEN and EARLAND, 1913, Journ. Queckett Micr. Club, ser. 2, vol. 12, pp. 9 and 16, pl. 3, fig. 1.

Nummulites gizehensis CUVILLIER, 1930, Mém. Inst. Égypte, vol. 16, p. 141, pl. 14, figs. 1, 2, 7, 8; pl. 16, figs. 1, 2, 7; CIZANCOURT, 1934, Bull. Soc. géol. France, ser. 5, vol. 4, p. 752, pl. 45, figs. 1-3; SILVESTRI, 1942, Palaeontogr. Italica, vol. 32, supplt. 5, p. 41, pl. 25, figs. 9, 10; pl. 28, figs. 9, 10.

Nummulites gizehensis ehrenbergi DE LA HARPE, 1881, Mém. Soc. pal. Suisse, vol. 8, p. 91, pl. 1, figs. 1a, 2, 3a, 5a, 6, 7 (non figs. 4a, 8, 11; 1883; Palaeontographica, vol. 30, p. 190, pl. 32, figs. 16-25; pl. 33, fig. 12; CHAPMAN, 1900, Geol. Mag., London, p. 370, pl. 14, fig. 15.

Nummulites lyelli d'Archiac and Haime

Nummulites lyelli D'ARCHIAC and HAIME, 1853 (part), Déscription Anim. foss. groupe nummulitique Inde, p. 95, pl. 3, figs. 1a, b, 2 (non pl. 2, figs. 9a, b, c, 10a, b).

Nummulites gizehensis lyelli DE LA HARPE, 1881, (part), Mém. soc. pal. Suisse, vol. 8, p. 115, pl. 2, figs. 5a, 6a, 7a, 10, 11 (non figs. 8a, 9); 1883, Palaeontographica, vol. 30, p. 192, pl. 33, figs. 3-10.

Nummulites champollioni de la Harpe

Nummulites lyelli var. b D'ARCHIAC and HAIME, 1883, Déscription Anim. foss. groupe nummulitique Inde, p. 96, pl. 2, figs. 10a, b.

Nummulites gizehensis champollioni DE LA HARPE, 1883, Palaeontographica, vol. 30, p. 193, pl. 33, figs. 11-13.

Nummulites pachoi de la Harpe

Nummulites gizehensis lyelli DE LA HARPE, 1881 (part), Mém. Soc. pal. Suisse, vol. 8, p. 114, pl. 2, fig. 8a.

Nummulites gizehensis pachoi DE LA HARPE, 1883, Pal-

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[1] This is quite different from the quadrinomial nomenclature suggested by Strausz before the International Geological Congress held in London in 1948 (1950).

aeontographica, vol. 30, p. 193, pl. 33, figs. 14-18, pl. 34, figs. 1-5.

Nummulites cailliaudi d'Archiac and Haime

Nummulites cailliaudi D'ARCHIAC and HAIME, 1853, Déscription Anim. foss. groupe nummulitique Inde, p. 97, pl. 1, figs. 82, b, c; ZITTEL, 1880, Denkschr. d. k. Acad. Wiss., München, p. 40.

Nummulites gizehensis cailliaudi DE LA HARPE, 1881, Mém. Soc. pal. Suisse, vol. 8, p. 113, pl. 2, figs. 16a, 17a, 18, 19a; 1883, Palaeontographica, vol. 30, p. 197, pl. 34, figs. 34-41.

Nummulites delaharpei Said, n. name

Nummulites gizehensis ehrenbergi DE LA HARPE, 1881 (part), Mém. soc. pal. Suisse, vol. 8, pl. 1, fig. 11.

Nummulites gizehensis viquesneli DE LA HARPE, 1883, Palaeontographica, vol. 30, p. 195, pl. 34, figs. 15-24.

The new name is suggested because *N. viquesneli* d'Archiac and Haime (1853) has been put in synonymy of *N. contorta* by Silvestri (1942).

Nummulites zitteli de la Harpe

Nummulites lyelli var. a D'ARCHIAC and HAIME, 1853, Déscription Anim. foss. nummulitique Inde, p. 96, pl. 2, figs. 9a, b, c.

Nummulites gizehensis zitteli DE LA HARPE, 1881, Mém. soc. pal. Suisse, vol. 8, p. 113, pl. 2, figs. 12a, 13a, 14a, 15; 1883, Palaeontographica, vol. 30, p. 194, pl. 34, figs. 6-14.

Nummulites mariettei de la Harpe

Nummulites gizehensis ehrenbergi DE LA HARPE, 1881 (part), Mém. soc. pal. Suisse, vol. 8, pl. 1, fig. 4a.

Nummulites gizehensis mariettei DE LA HARPE, 1883, Palaeontographica, vol. 30, p. 196, pl. 34, figs. 25-33.

The material forming the basis of this study was collected from the *N. gizehensis* zone of the Egyptian Lutetian from the following localities: Cairo environs (el-Mokattam, Old Cairo, Gizeh, Tura and Helwan), Beni Suef, el-Minieh, Beni Hassan and Mikrieh. In addition to these, a large number of specimens of *N. lyelli,* collected by Dr. N. M. Shukri along the Lutetian scarp of the Fayum area, Egypt, were also at my disposal. In this variation study the following specimens were considered: 1000 specimens of *N. gizehensis,* 500 of *N. lyelli,* 100 of *N. champollioni,* 200 of *N. pachoi,* 250 of *N. cailliaudi,* 200 of *N. zitteli,* 200 of *N. delaharpei* and 125 of *N. mariettei.* These specimens came from different localities as noted in table I.

The characteristics of the different species are fairly uniform, irrespective of the locality or horizon from which they came. The specimens of *N. lyelli* collected from every zone in the Fayum area showed but little variation in either internal or external structure throughout the entire stratigraphic range. This observation was made clear by the quantitative study undertaken and seems to be most significant in view of the fact that many authors, perhaps influenced by early students of Foramininifera, regard all species as showing great variations. This study showed that, although Foraminifera on the whole show the greatest variability of form, many of these forms keep their identity in the assemblage both in space and in time, thus exhibiting no evolutionary tendency or saltation (Swinnerton 1947). This mode of evolution will be the subject of interpretation in the following discussion.

TABLE I

	Cairo environs	Beni Suef	el-Minieh	Beni Hassan	Fayum	Mikrieh
N. gizehensis	500	100	135	165		100
N. lyelli	200		50		250	
N. champollioni	100					
N. pachoi	50		50	50	50	
N. cailliaudi			50	200		
N. delaharpei			100	100		
N. zitteli			100	100		
N. mariettei	50	40		15		20

This observation has also made it unnecessary to tabulate the results according to the geographic position of the specimen, except in few instances where attention is drawn to the nature of the population or to the uniformity of the species. Results are therefore tabulated according to the species.

Method of study: In any quantitative study the problem of sampling becomes immediately evident. Much has been written on sampling of sedimentary rocks for quantitative study (Krumbein and Pettijohn 1938), but very little if any work has been devoted to the subject of collecting fossils for this purpose. The reason for this is the difficulty by which a large number of fossils of one species is obtained. Much paleontologic work is concerned with a single or even part of a specimen of the species. In cases where large numbers of individuals of one species are found, work on the population as a whole has been largely neglected. This neglect of variation studies of fossil populations is largely due to the legacy of nineteenth century philosophical thought still prevailing in paleontology. Spencer's ideas of rugged individualism has influenced systematics to a considerable extent. Even the rules of zoological nomenclature show this tendency. The *holotype* is, according to the definition given by Schenck and McMasters (1948, p. 7) "a *single* (italics inserted) specimen taken as the type by the original author of the species." Kuhn (1948, p. 391) in his recent paper on the species problem presented clearly the philosophical background of most paleontologists when they examine a fossil "Jeder Fossilrest stellt uns zwei Hauptfragen: Wohin gehört er? Wie alt ist er? Zwei Richtungen machten sich von Anfang an geltend: eine biologische und eine stratigraphische." Each fossil is a specimen to be given a name and assigned an age. This idea in which the individual is emphasized and regarded as an entity in itself, apart from being in disharmony with recent zoological thought (Mayr 1942; Schmalhausen 1949) is unnatural. It conceals the principle of variation, the corner stone of evolution which determines the future possibilities of the species. The emphasis on population studies has recently gained weight by the publication of Simpson's paper (1940) and Newell's comments on it (1949).

To undertake a quantitative study on a species population is a laborious process abhorred by many paleontologists. Analyses are nevertheless important even if they are lengthy and time-consuming. When possible a quantitative treatment of large populations should be carried out as it should prove of immense value for tracing evolutionary lineages.

Any fossil-bearing sample collected in the field represents the burial place of a population accumulated over some time and under certain physical conditions. It is therefore essential that every individual present be collected from the site chosen to insure whether the assemblage lived at this locality, or whether it was sorted at that place (Menard and Boucot 1951). Samples in this study were therefore collected as block units of the sediments, from which all specimens of the different *Nummulites* were then separated. Storing was facilitated by the use of simple wooden plates described in a succeeding article of this *Journal.* Identification was greatly facilitated by comparison with de la Harpe's collection, now housed in the Geology Museum, Palais de Rumine, Lausanne, Switzerland to which the writer had complete access. When a large number was encountered in one sample, quartering methods were used to reduce large quantities to reasonable numbers for handling.

Shape: The external shape of the different specimens examined was found to be best expressed by computing two measurements: the diameter and thickness, measured by a caliper, and an index: thickness/diameter.

If we assume that the diameter is a morphological manifestation of age, it follows that if the specimens of each sample were arranged according to diameter, the percentage of different age groups can then be determined. It was found that the diameter of 165 specimens of *N. gizehensis* extracted from samples collected within a half kilometer in Beni Hassan, ranged from 9 to 25 mm. Fig. 1 is a histogram of diameter variations of the specimens studied from this area. About 48% lie in the range between 15 and 20 mm, 34% between 20 and 25 mm and 18% between 9 and 15 mm. The population therefore is composed of a large number of adults in varying phases. Young individuals (less than 9 mm in diameter) are entirely absent. The distribution of the different age groups in other samples coincides remarkably with this example. A natural biocoenose of a given species consists of a large number of young and few "successful" members who reached the adult stage (Allee 1949). However, this well-known principle cannot be applied to a thanatocoenose of Foraminifera, where adults of numerous generations are continuously added to the assemblages through normal processes of reproduction. This brings an increment of adults and changes the composition of the thanatocoenose in favor of older members. The life history of a foraminifer starts with a large number of naked young which soon commence building a shell. The most critical period of survival is, therefore the early naked stage where the process of elimination through predators and other adverse conditions is at a maximum. Elimination decreases progressively with age, establishment of a shell, and increase in size. The number of progeny therefore, that reach maturity is small and if living forms only are considered, the population would be composed largely of young individuals. However, in any paleontological study, we are dealing with thanatocoenoses that represent death accumulations of many generations. In such an assemblage the number of adults is greatly increased in proportion to the young.

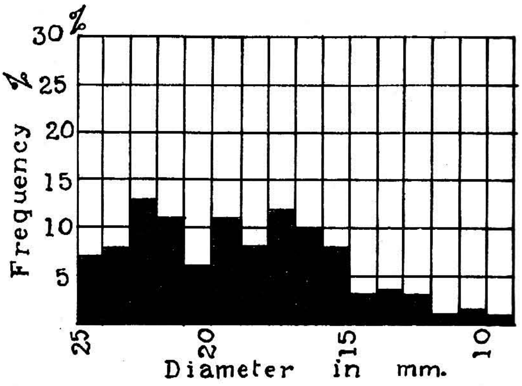

Fig. 1: Histogram of diameter variations of *N. gizehensis* based on 165 specimens from Beni Hassan.

In the case of *N. gizehensis* cited above, the distribution of different age groups seems to suggest that the assemblage does not represent a community preserved in place, but probably constitutes a diverse assortment of shells brought together by physical agencies. The absence of young forms might be attributed to the fragility of their shells causing them to be comminuted under strong current action, thereby contributing to the fine-grained groundmass of limestone (Said 1951).

Method of presentation: For the statistical presentation of data, the median and geometric quartile deviation were chosen (Krumbein and Pettijohn 1938). This method is believed to be less laborious and to have the advantage of presenting the minimum and maximum values together with the whole spread of data in a very concise form.

The shape indices of the different specimens vary between 0.050 and 0.500. This spread of indices was divided into conventional classes of 0.050 difference each. The number of specimens of each of these classes was then recorded and percentages of the different classes were calculated. Table II gives the results of this procedure, as used on 250 specimens of *N. gizehensis* from Cairo environs (el-Mokattam):

TABLE II

Classes of shape indices	No. of Specimens	Percentage	Cumulative Percentage
Between .100-.150	12	5	5
.150-.200	131	52	57
.200-.250	58	23	80
.250-.300	24	9	89
.300-.350	12	5	94
.350-.400	8	3	97
.400-.450	5	2	99
.450-.500			

Curves based on the cumulative percentages thus obtained were prepared by plotting the indices on a logarithmic scale along the horizontal axis and the frequency along the vertical scale. A cumulative curve offers an easy way of obtaining an average around which other indices cluster by calculating the median index (Md) representing the middlemost member of distribution. The median corresponds to the point where the 50% line crosses the curve. It has the advantage of not being affected by the extreme and erratic indices of either end of the distribution.

The measure of average spread of data around this central tendency, is obtained by using the geometric quartile deviation. The standard deviation hitherto used in similar studies, involves considerable time for its computation. The quartiles (Q_1 and Q_3) lie on either side of the median and are the indices which correspond to the points where the 25% and 75% frequencies cross the curve respectively. The geometric quartile deviation (QDg) equals $\sqrt{Q_3/Q_1}$. Obviously the smallest possible value for QDg is one, which would represent a perfectly uniform condition where no deviation from the median is present. The values of this deviation become progressively greater with increase in the spread of the distribution.

Fig. 2 gives the cumulative curves of index variations of *N. gizehensis* collected from three localities: Beni Hassan (165 specimens), Cairo, Gizeh (125 specimens) and Cairo, el-Mokattam (250 specimens). As can be seen from the shape of the curves and the values of the median and the geometric quartile deviation of shape indices listed in table III, the shape of the different specimens studied is almost uniform irrespective of the locality. In all other species, the geographic position of the sample did not affect the characteristics of the specimens.

TABLE III

Locality	Index Md	Index QDg
el-Mokattam	.190	1.16
Gizeh	.214	1.15
Beni Hassan	.220	1.15

The spread of the shape indices of the eight species studied are diagramatically represented by cumulative curves in figure 3. Figure 4 shows the diameter variations of the eight species, while table IV gives the median index, indices geometric quartile deviation, the median diameter, the diameter geometric quartile deviation and the median thickness.

The shape of these eight species and their external features provide a basis for their differentiation. *N. lyelli* is distinguished by its large size, sharp irregular edge and its relative thinness. *N. champollioni* has a thick and large shell, while *N. pachoi* is characterized by a thin shell. *N. delaharpei* and *N. zitteli* may be separated by the former being thin, with an irregular and undulating edge, while the latter has a regular and rounded edge. *N. mariettei* can only be distinguished by its internal structure, since it could otherwise be mistaken for a young *N. gizehensis*.

The eight species could be subdivided on the basis of the median diameter into two broad groups; the first comprised of the large species: *N. gizehensis, N. lyelli, N. champollioni* and *N. pachoi;* and the second including the small species: *N. cailliaudi, N. delaharpei, N. zitteli* and *N. mariettei*. This arbitrary division seems to be more natural when the various other characteris-

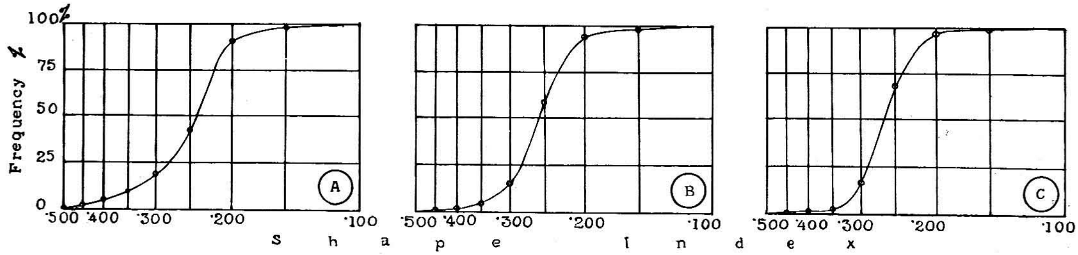

Fig. 2: Cumulative curves of shape index variations of *N. gizehensis* based on (A) 250 specimens from el-Mokattam, (B) 125 specimens from Gizeh, and (C) 165 specimens from Beni Hassan.

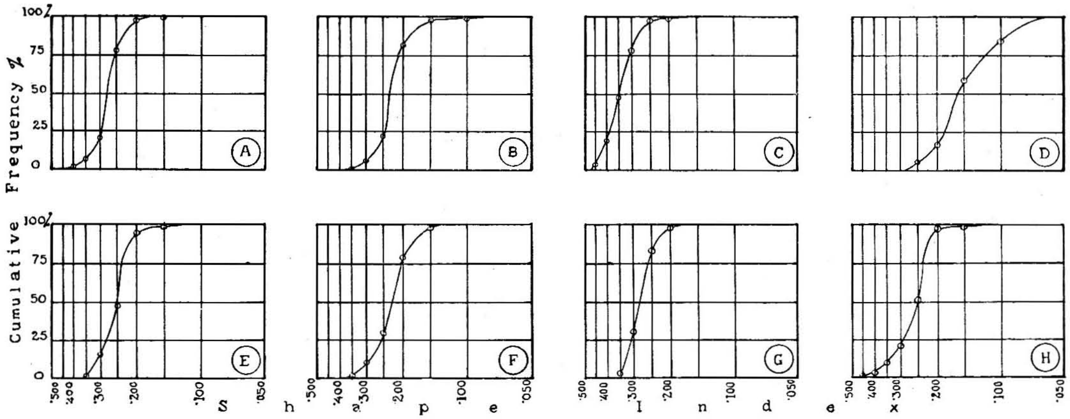

Fig. 3: Cumulative curves of shape index variations of (A) *N. gizehensis*, (B) *N. lyelli*, (C) *N. champollioni*, (D) *N. pachoi*, (E) *N. cailliaudi*, (F) *N. delaharpei*, (G) *N. zitteli*, and (H) *N. mariettei*.

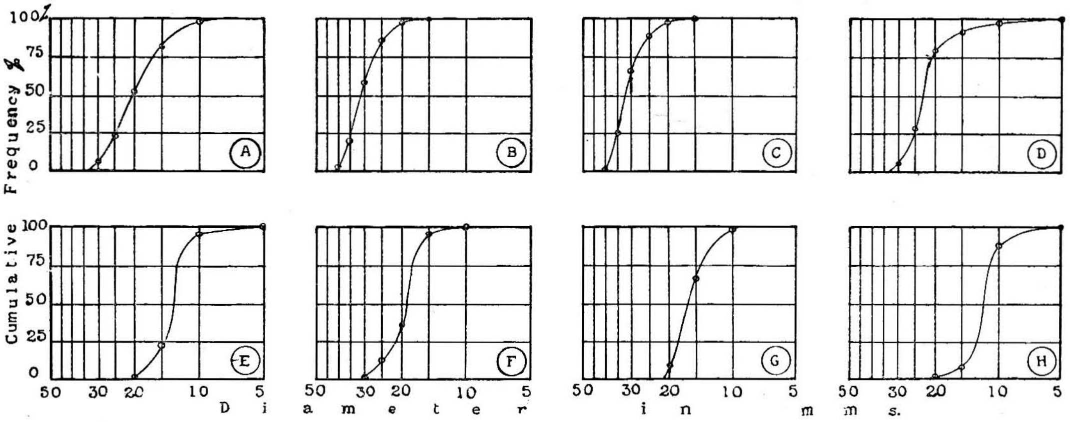

Fig. 4: Cumulative curves showing diameter variations in (A) *N. gizehensis* (B) *N. lyelli* (C) *N. champollioni*, (D) *N. pachoi*, (E) *N. cailliaudi*, (F) *N. delaharpei*, (G) *N. zitteli*, and (H) *N. mariettei*.

TABLE IV

	Shape Index		Diameter		Thickness
	Md	QDg	Md (mm)	QDg	Md (mm)
N. gizehensis	.215	1.18	21	1.12	4.5
N. lyelli	.162	1.18	31	1.12	5.0
N. champollioni	.305	1.15	31	1.13	9.4
N. pachoi	.112	1.35	23	1.06	2.4
N. cailliaudi	.202	1.18	14	1.04	2.9
N. delaharpei	.182	1.20	17	1.11	3.2
N. zitteli	.233	1.11	16	1.14	3.8
N. mariettei	.204	1.04	13	1.03	2.6

tics of the shell are studied. It is seen that the two groups are different with regard to the pace of the spire, the number of whorls, the inclination of the septa and the shape of the chambers. It is of interest to note that this subdivision coincides broadly with the geographical distribution of the eight species. The four larger species occur abundantly in the area bound by Siwa, Baharieh, Cairo and Beni Suef and extend westward through the entire North African continent and northward into southern Europe. The smaller Nummulites are extensively found in the Arabian desert between Farafra and Beni Hassan extending eastward into Syria and Turkey.

The spire: The spire exhibits many characteristics which merit attention. It is best studied in equatorial sections which are easily prepared by heating the specimens in sand and then plunging them in cold water. The split specimens are then mounted in glycerine and studied under the binocular microscope. Measurements were made of the distances between successive spiral laminae from the proloculum outwards. The measurements were tabulated and the cumulative distances then plotted along the vertical axis against the number of whorls plotted along the horizontal axis. The arithmetical means of the different measurements of all specimens of one species were then calculated, and a hypothetical curve based on these averages was then plotted. Figure 5 shows the curves of the eight species in question.

The subdivision already made on the basis of the diameter is further stressed by a study of the spire. The larger species are seen to have tight spires, while the smaller ones have a laxer spire. Interesting changes occur in the spire of the larger species. They begin with a series of tight whorls, followed by laxer and regular ones, and later the spire becomes tighter again. These changes are very constant and have been consistently observed in the hundreds of measurements made, with few exceptions. This feature has been the subject of a previous publication by the author (1950a). It is believed that the change in the pace of the spire is due to a change in the external conditions particularly with regard to the organic production of the sea.

The height of the spire has been considered as one of the features which suffered great phylogenetic changes. Abrard (1928) regarded progressive evolution in Nummulites to be from lax and irregular to tight and regular. Davies (1935) adopted the idea and worked out Abrard's table of evolution on this basis. As can be seen from the above discussion, both types of spires are known in the *N. gizehensis* group which were developed independently from a single ancestor. It is therefore concluded that both types of spires are not successive in the sense that one gives way to the other, but are independent variations which are not significant in the phylogeny of the group.

The spire pace is calculated by dividing the diameter of the specimen by the number of the whorls. The following table gives the median height of the spiral cavity of the eight species and the pace geometric quartile deviation, while figure 6 is a diagrammatic presentation of the cumulative curves of the spire pace variations in the different species.

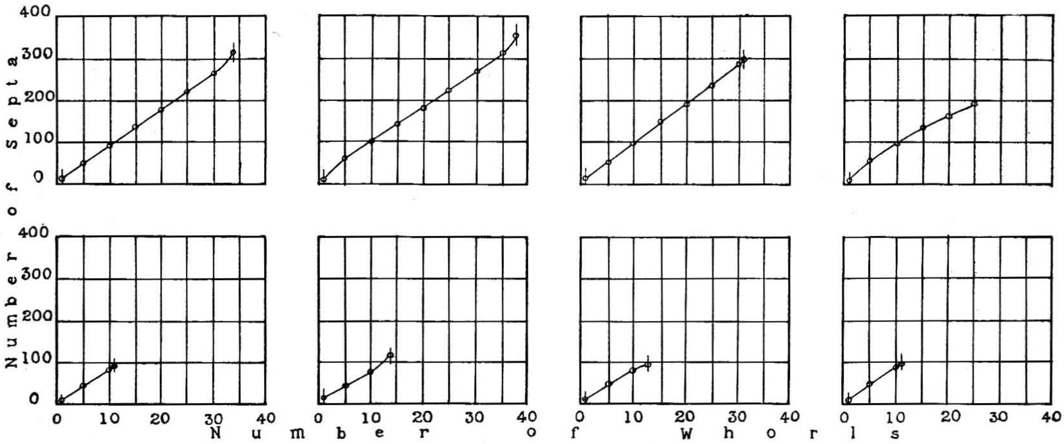

Fig. 5: Spiral diagrams of average hypothetical specimens of: (top row, left to right); *N. gizehensis*, *N. lyelli*, *N. champollioni*, *N. pachoi;* (lower row, left to right); *N. cailliaudi*, *N. delaharpei*, *N. zitteli*, and *N. mariettei.*

TABLE V

	Spire Md	Pace QDg
N. gizehensis	.37	1.50
N. lyelli	.39	1.37
N. champollioni	.51	1.22
N. pachoi	.46	1.23
N. cailliaudi	.56	1.15
N. delaharpei	.61	1.16
N. zitteli	.63	1.15
N. mariettei	.64	1.17

The pace of the spire is seen to be smaller in the group of larger Nummulites (between .37 and .51 mm) than in the group of smaller Nummulites (between .56 and .64 mm).

Septal diagram: The septal diagram is obtained by plotting the number of septa in each whorl along the vertical axis, against the number of whorls which is plotted along the horizontal axis. Figure 7 gives the average hypothetical curves of the eight species. The group of smaller Nummulites are seen to possess less septa per whorl than the group of larger Nummulites, although the difference is not great. It is seen that the addition of septa is a uniform process throughout the spire. The rate of addition of new septa in successive whorls is about nine for the group of larger *Nummulites* and eight for the group of smaller *Nummulites*.

The curvature of the septa is one of the most important features in the classification and evolution of *Nummulites*. The importance of the curvature of the septa was first noticed by Boussac (1911). In this respect *N. cailliaudi* stands in a category by itself. The septa tend to lose their uprightness and become curved

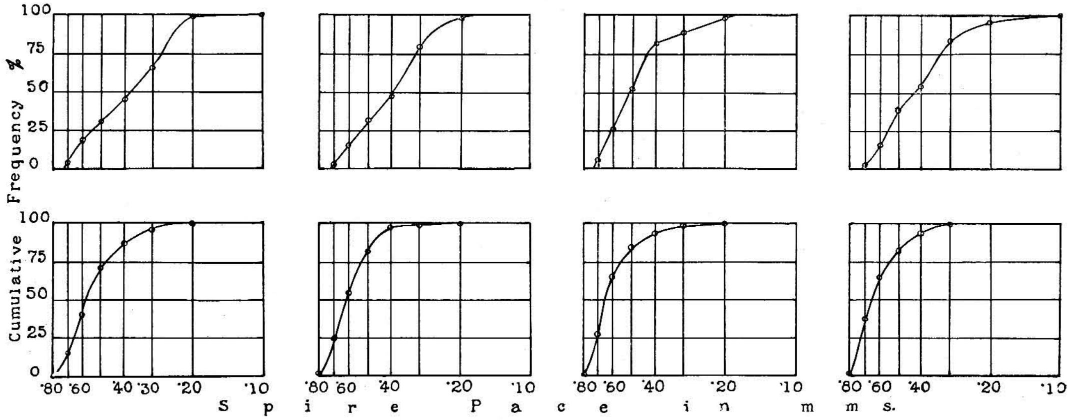

Fig. 6: Cumulative curves showing spire pace variations in (top row, left to right); *N. gizehensis*, *N. lyelli*, *N. champollioni*, *N. pachoi;* (lower row, left to right); *N. cailliaudi*, *N. delaharpei*, *N. zitteli*, and *N. mariettei.*

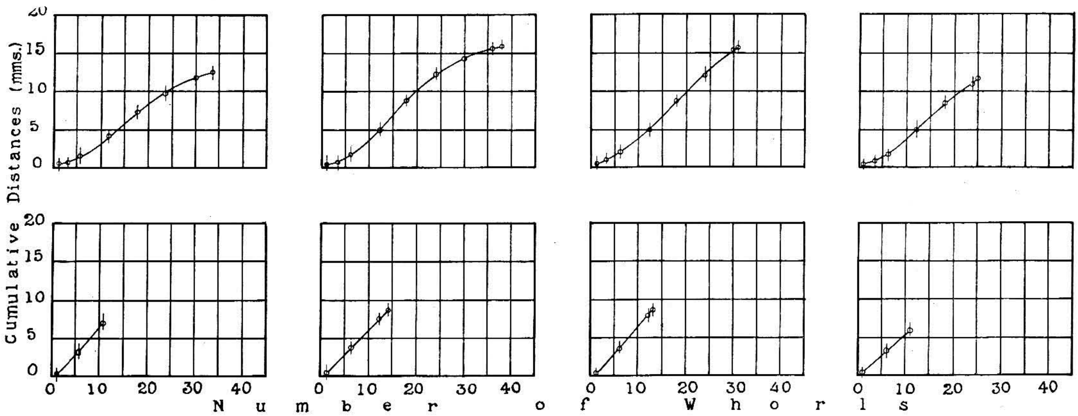

Fig. 7: Septal diagrams of average hypothetical specimens of: (top row, left to right); *N. gizehensis*, *N. lyelli*, *N. champollioni*, *N. pachoi;* (lower row, left to right); *N. cailliaudi*, *N. delaharpei*, *N. zitteli*, and *N. mariettei.*

before they reach the chamber roof. *N. gizehensis* and the other three larger species are characterized by having upright septa. *N. zitteli*, *N. delaharpei* and *N. mariettei* bridge the gap between these two extremes, their septa possessing slight curvature. Nothing, however, is seen in the ontogeny of the individual to indicate any change from one kind of septum to another.

The chamber index: The chamber index is calculated by dividing the length by the height of the chamber. Measurement of the length and height of all chambers was found practically impossible. Only the chambers of one whorl in every six whorls were chosen and their indices calculated. From the data thus tabulated, cumulative curves were prepared (figure 8), and the median index and the index geometric quartile deviation was calculated. Table VI summarizes the results of these calculations:

TABLE VI

	Chamber index	
	Md	QDg
N. gizehensis	.51	1.45
N. lyelli	.64	1.26
N. champollioni	.61	1.20
N. pachoi	.71	1.16
N. cailliaudi	.70	1.11
N. delaharpei	.69	1.11
N. zitteli	.71	1.14
N. mariettei	.73	1.09

The data shows clearly that the group of smaller *Nummulites* have higher indices in comparison with the group of larger *Nummulites*. It seems also that the chamber index deviates but little from the median in the case of the smaller *Nummulites* than in the case of larger *Nummulites*.

Spiral lamina: A further distinction between the larger and smaller species can be seen immediately

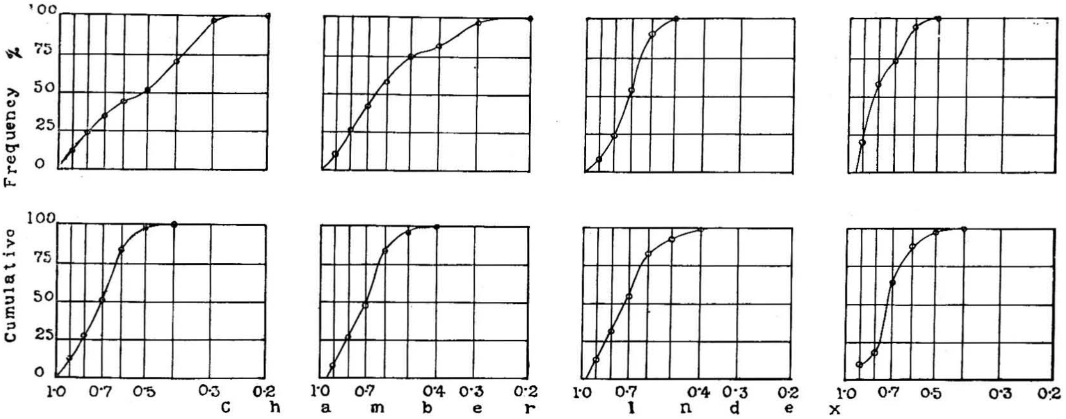

Fig. 8: Cumulative curves showing chamber index variations in: (top row, left to right); *N. gizehensis, N. lyelli, N. champollioni, N. pachoi;* (lower row, left to right): *N. cailliaudi, N. delaharpei, N. zitteli,* and *N. mariettei.*

when a study of the spiral lamina is undertaken. The large *Nummulites* are characterized by having rather thick and high spiral laminae. In fact the spiral laminae are higher than the spiral cavity itself. The group of smaller *Nummulites,* on the other hand, possess thin and low spiral laminae.

This quantitative work has shown that the eight "races" of de la Harpe do not represent a homogenous group of *Nummulites.*

Table VII summarizes the results of this quantitative work.

Summary and conclusions: The results of a quantitative study carried on the different "races" of *N. gizehensis* have shown that these "races" are valid distinct species, which constitute two different groups of related *Nummulites. N. cailliaudi, N. delaharpei, N. zitteli* and *N. mariettei* are small Nummulites with lax spires, longer chambers, thin spiral laminae, smaller number of curved thin septa and less complicated meanderine septal filaments. *N. gizehensis, N. lyelli, N. champollioni* and *N. pachoi* constitute another group of related species, being large *Nummulites* with tight spires, high chambers, thick spiral laminae, large number of thick upright septa and complicated meanderine septal filaments.

The work has also shown that these two groups seemed to have developed along two evolutionary lines after their differentiation from a common ancestor. The geographic distribution of the species supports the theory of the independent development of the two groups. The small *Nummulites* are seen in large numbers in the area between Farafra and Beni Hassan and extend eastward into the Arabian desert. The center of concentration of the group of larger *Nummulites* is the area between Siwa and Baharieh extending to Cairo and Beni Suef. Figure 9 shows the distribution of the different species in the Mediterranean area. It is of interest to point out that the eastern and western Mediterranean so characteristically different in their faunas and stratigraphic succession during the mid Tertiary period (Haug 1907) is vaguely foreshadowed in the Eocene period by the presence of two different groups of *Nummulites* although a certain amount of overlapping is noticed.

The remarkable flourishing and sudden appearance of the eight species in prodigious numbers at the base of the upper Lutetian indicates that their evolution must have been eruptive. It seems that the onset of a new and large ecologic niche, excessive mutability and relaxation of selective pressure in large populations of two not unrelated species of Nummulites (probably descending from *N. deserti*) concentrated in two different areas early in the upper Lutetian time, have produced a large number of varieties, which through local adaptation and random segregation have developed into the eight species in question. The appearance of the species of the two groups is so sudden that the time factor involved in speciation must have been a negligible one. Such an eruptive type of evolution in which time plays but a secondary role can be hardly represented by a normal genealogical tree in which time is emphasized. The evolutionary lines in such a type of evolution would be best diagrammed on a geographical map in which centers of radiation and areas of probable origin and routes of migration are indicated. Figure 9 is an attempt to show the genealogy of the eight species along this line. Many of the lines on the map are purely speculative. This is due to the fact that paleontological observations are incomplete as information regarding fossil associations is scanty and because the differentiation of genuine communities from sorted ones has not been attempted and also due to the confusion of taxonomy particularly in the case of *N. gizehensi.* Although largely speculative, this attempt is nevertheless worth emphasizing to indicate the extreme importance of study of fossils in space and in associations. Figure 9 has been compiled from available literature. *N. gizehensis* is known to occur as far east as India and Java (Doornink 1932). However, the record is

TABLE VII

	Diameter			Shape Index						Spire Pace		Chamber Index			
	Md (in mm)	QDg	Thickness Md (in mm)	Md	QDg	Edge	Septal Filaments	Spiral Lamina	Spire	Md (in mm)	QDg	Md	QDg	No. of Septa in last whorl	Other
N. gizehensis	21	1.12	4.5	.21	1.18	rounded	meanderine typical	high	tight	.37	1.50	.51	1.45	310	Pillars in early whorls
N. lyelli	31	1.12	5.0	.16	1.18	sharp & undulating	meanderine less undulations	high	tight	.39	1.37	.64	1.26	356	Pillars in early whorls
N. champollioni	31	1.13	9.4	.30	1.15	rounded & straight	meanderine less undulations	high	tight	.51	1.22	.61	1.20	290	Pillars in early whorls
N. pachoi	23	1.06	2.4	.11	1.35	sharp & straight	meanderine less undulations	high	tight	.46	1.23	.71	1.16	192	Pillars in early whorls
N. cailliaudi	14	1.04	2.9	.20	1.18	rounded & straight	simple meanderine to sigmoidal	low	lax	.56	1.15	.70	1.11	95	Pillars suppressed
N. delaharpei	17	1.11	3.2	.18	1.20	sharp & undulating	resembles *lyelli*	low	lax	.61	1.16	.69	1.11	115	Pillars poorly developed
N. zitteli	16	1.14	3.8	.23	1.11	rounded & straight	resembles *lyelli*	low	lax	.63	1.15	.71	1.14	102	Pillars poorly developed
N. mariettei	13	1.03	2.6	.20	1.04	sharp & straight	resembles *lyelli*	low	lax	.64	1.17	.73	1.09	90	Pillars poorly developed

not very satisfactory. Davies and Pinfold (1937) who described the Punjab Eocene Nummulites, did not list *N. gizehensis*. Hanzawa (1947) records a closely allied species *N. bonensis* from Haha-Jima (Hillsborough Island) and notes that it is slightly different from *N. gizehensis* particularly with regard to the spire and granulations. Few workers differentiate the "races" of *N. gizehensis* in their works, and when consulting references, it was difficult in many instances to determine which "race" the author had in mind when he listed the occurrence.

Local adaptation and isolation are prerequisites in this mode of evolution. The different varieties of the ancestral stock were sorted in different space points and the species were rapidly established before any contamination with other varieties could take place. The fact that there were no micro-geographic races (Dobzhansky 1937, p. 146) in the species studied strongly suggests that the sorting, establishment and stabilization of the different early varieties into species took place in a rather short period followed by a lapse of comparatively little change. Although the eight species appeared in one seemingly connected sea, the possibility of isolation of one area within it should not be ruled out. The present writer (1950) has shown that in the Recent Red Sea there exist areas within the sea which are virtually isolated from adjacent parts because of the nature of the dominant currents.

From an ancestor probably close to *N. deserti*, two species are assumed to have been differentiated, an eastern species giving rise to the smaller *Nummulites* and a western species giving rise to the larger *Nummulites*. From these two ancestors originated a host of varieties with recurring mutations emphasizing certain genetical traits. Isolation of some varieties for a relatively short time have given rise to the species in ques-

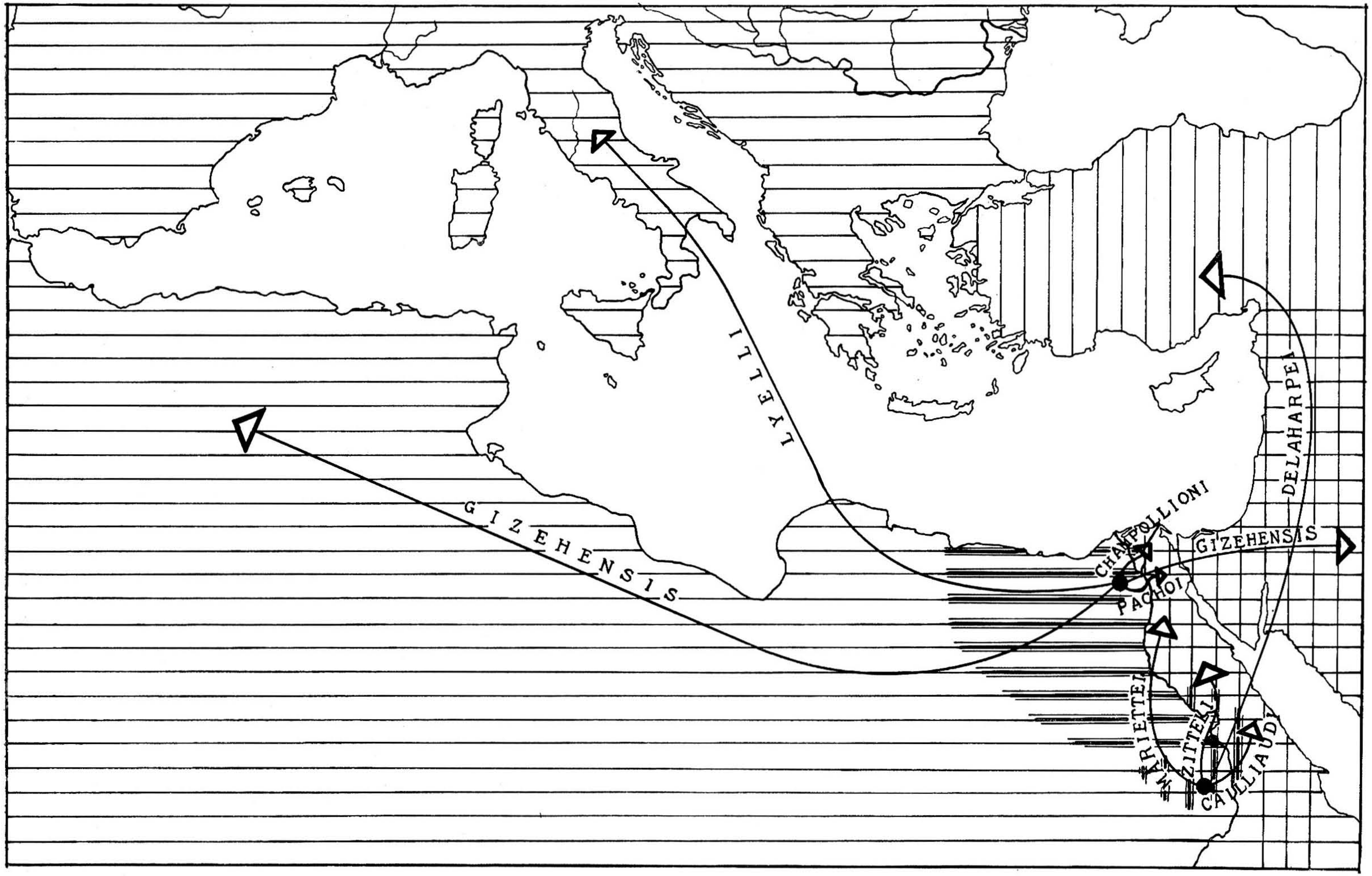

Fig. 9: Distribution, probable centers of origin and probable routes of migration of *N. gizehensis* and related species. Horizontal lines indicate extent of distribution of larger species; vertical lines that of smaller species.

tion. When the species were definitely established, their specialization to a particular niche, their loss of plasticity in structural and functional reorganisation rendered them conservative. It is of interest to note that *N. lyelli* when studied all along the Lutetian scarp of the Fayum area, does not show any variation in any character throughout its phylogenetic history. Uniform organisms that show little change for long periods of time are liable to degradation and extinction.

The distribution of the species can only be explained if we assume that migration took place after the stabilization of the species. The fact that the eight species studied possess a peculiar geographic distribution indicates that complete mixing of the original ancestors, and subsequent migration of the species was limited. Huxley (1942, p. 264) was aware of the problem of isolation of two related species occupying the same ecologic niche from breeding together. We have to assume that in the case of the species studied, speciation was so rapid that a relatively short time of isolation of the community resulted in the establishment of definite species that could not interbreed when mixing took place.

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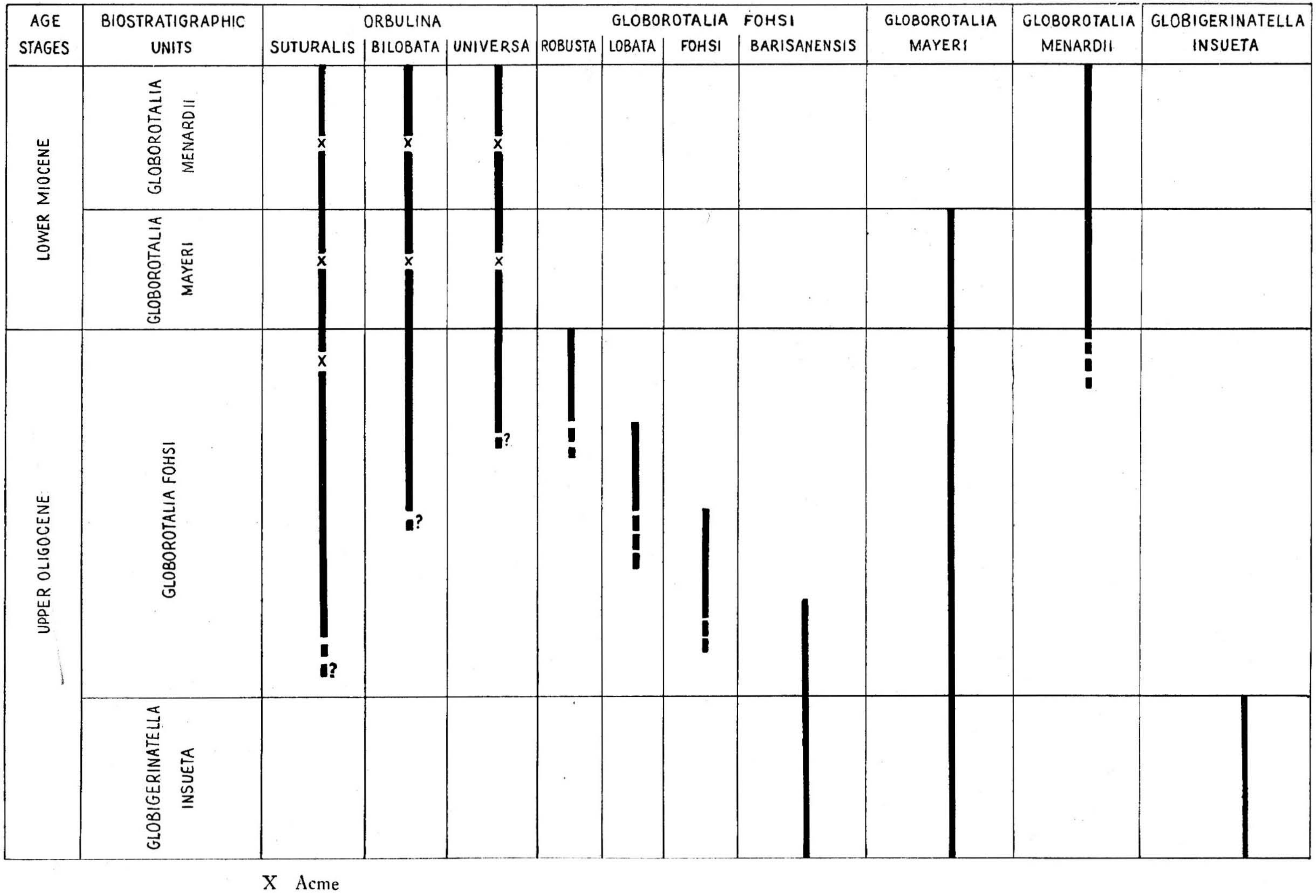
Manuscript received November 29, 1950

Text fig. I: Stratigraphic Distribution of Orbulina and other Pelagic Foraminifera in Trinidad, B. W. I.



38. THE GENUS ORBULINA D'ORBIGNY IN THE OLIGO-MIOCENE OF TRINIDAD, B. W. I.

P. Bronnimann
Pointe-a-Pierre, Trinidad, B. W. I.

INTRODUCTION

The originally monotypic foraminiferal genus *Orbulina* (Oligocene-Recent) was described by d'Orbigny (1839, p. 34) from recent sands of Cuba (genotype: *O. universa* d'Orbigny 1839, p. 2, pl. 1, fig. 1). He also recorded it from Jamaica, St. Thomas, Guadeloupe, Martinique, the Mediterranean region, and the East Indies. Brady (1884, pp. 608-611) discussed in great detail the morphologic features of recent specimens of *O. universa* but failed to recognize in the adult a definite aperture in the sense of d'Orbigny (Cushman 1948, p. 326). His investigation on the other hand corroborated the phylogenetically important observation of Pourtales, Owen and others regarding the occurrence of small delicate shells of *Globigerina* in the interior of *Orbulina*. The more or less spherical test with its numerous perforations of various size and fine elongate spines, which are not preserved in the fossil state, makes *O. universa* remarkably well adapted to planktonic life (Kemna 1903), although it is possible that thick shelled individuals become benthonic during late ontogenetic stages. Rhumbler's (1911, p. 218) *O. imperfecta,* found only in bottom samples, has a wall ranging in thickness from 24-34 μ. Brady (1884, pp. 609-610) recorded small bottom living specimens of *O. universa* with walls from 28-63 μ in thickness. The walls of thick shelled specimens appear to be composed of two or more thin layers. "Bottom specimens differ," according to Brady (1884, p. 609), "from those taken at the surface much more in the thickness of the walls than in the external dimensions of the test."

Numerous globular forms have been incorrectly assigned to *Orbulina* as representing new species and varieties. From the descriptions and figures in the "Catalogue of Foraminifera" (1940 and supplements up to 1950) it becomes evident that the species introduced by Zalessky, Terquem, Matthew, Häusler, Kübler and Zwingli, and others, do not belong to *Orbulina* d'Orbigny.

In addition to adult specimens with a single more or less globular end chamber, individuals with two or

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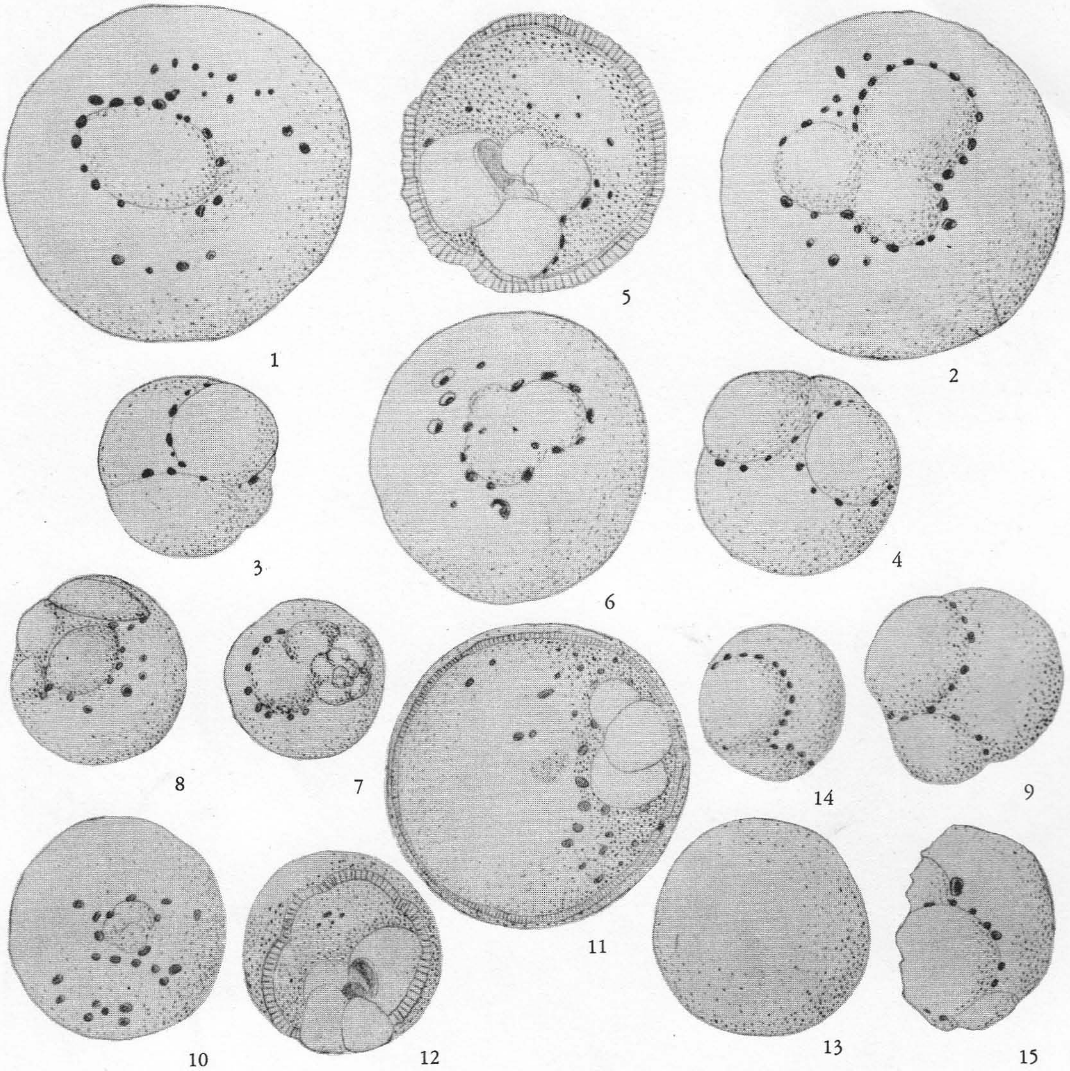
EXPLANATION OF TEXT FIGURE II
(All figures approximately × 80)

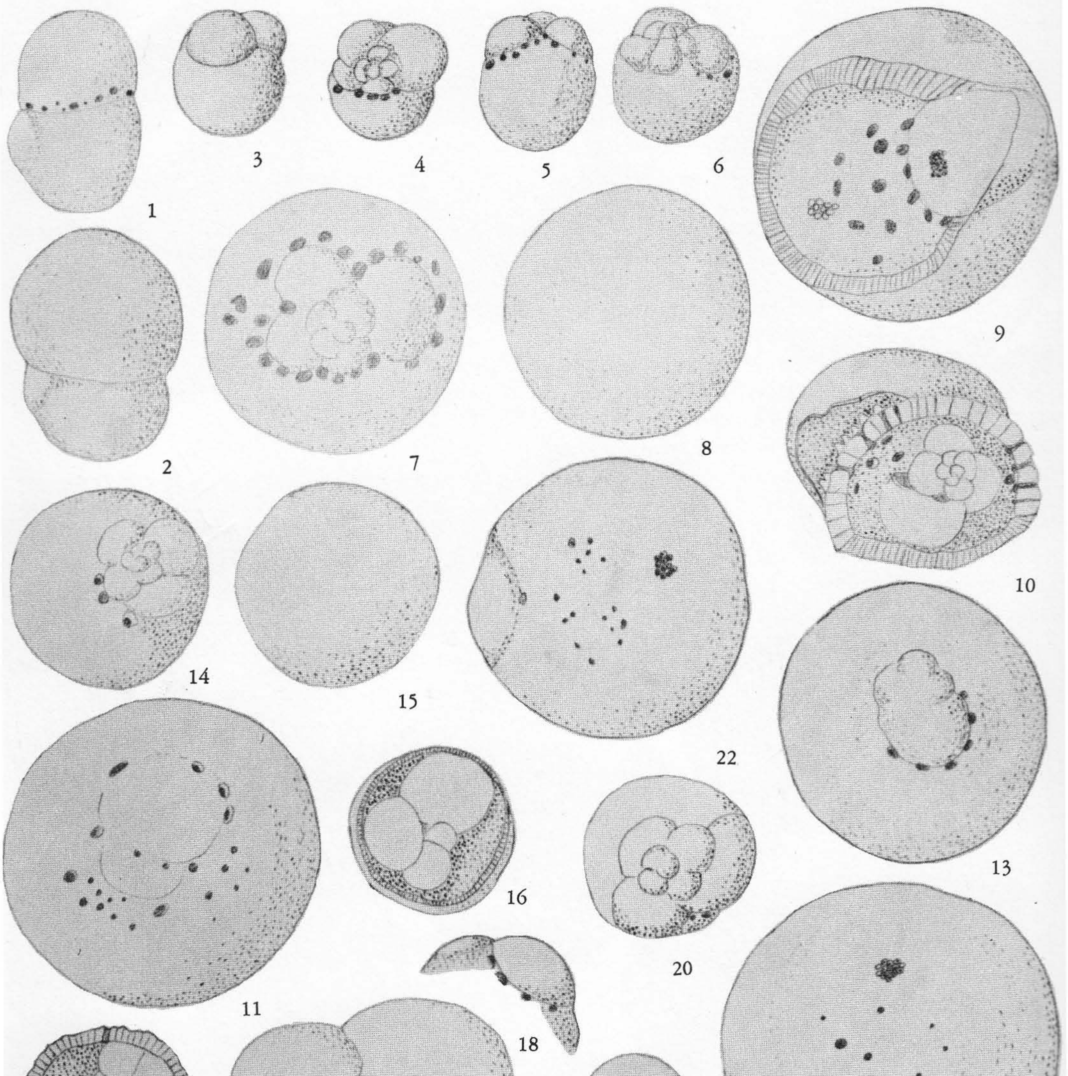
Figs.
1-6. *Orbulina suturalis* Bronnimann, n. sp.
Orbulina association occurring with *Globorotalia fohsi barisanensis,* Upper Oligocene, Naparima area, Trinidad, B. W. I.
1, K. R. 18055, T. L. L. Cat. No. 61366.
2, K. R. 18060, T. L. L. Cat. No. 61372.
3, 4. Kern Oil Company, auger sample 284.
5, 6. K. R. 18057, T. L. L. Cat. No. 61368.
7-15. *Orbulina suturalis* Bronnimann, n. sp.
Orbulina association occurring with *Globorotalia fohsi fohsi,* Upper Oligocene, Naparima area, Trinidad, B. W. I.
7-9, K. R. 19518, T. L. L. Cat. No. 94112.
10-15, K. R. 18056, T. L. L. Cat. No. 61367.
(Figures 10, 12-13, 15 are all of the same specimen)

EXPLANATION OF TEXT FIGURE III
(All figures approximately × 80)

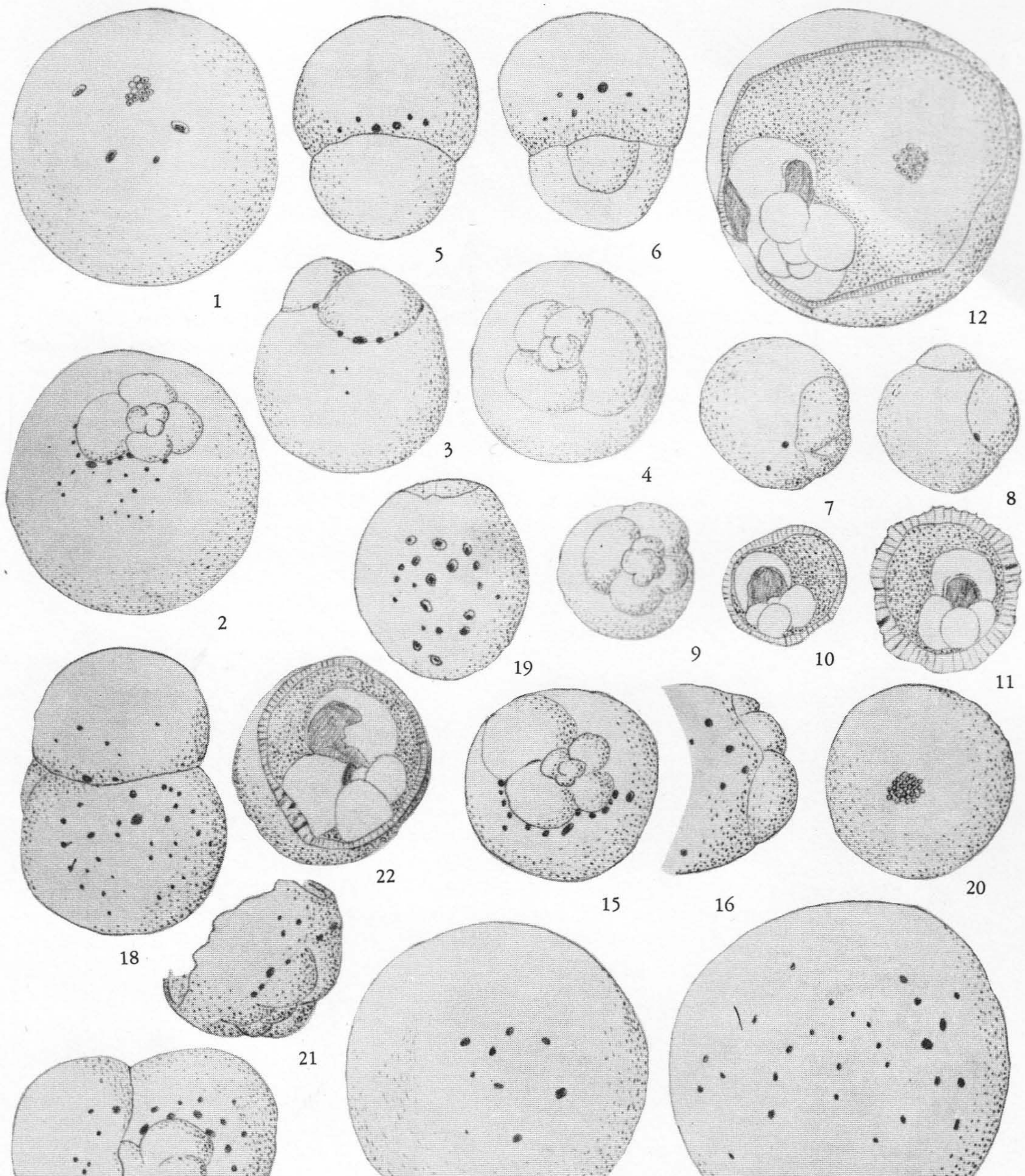
Figs.
1-10. *Orbulina* association occurring with *Globorotalia fohsi lobata,* Upper Oligocene, Naparima area, Trinidad, B. W. I. K. R. 19056.
1, 2, 9, 10, *Orbulina bilobata* (d'Orbigny), specimen of fig. 10 shows an additional dorsal (?) aperture of *Globigerinoides type.*
3-8, *Orbulina suturalis* Bronnimann, n. sp.
3, 4, opposite views of same specimen; 5, 6, opposite views of same specimen.
11-22. *Orbulina* association occurring with *Globorotalia fohsi robusta,* Upper Oligocene, Naparima area, Trinidad, B. W. I.
11, 13-16, 18, 20-22, *Orbulina suturalis* Bronnimann, n. sp.
11, K. R. 18793, T. L. L. Cat. No. 88935; 13, 22, same specimen, Hg. 4472b, T. L. L. Cat. No. 108011; 14. 15, same specimen, Hg. 4472b, T. L. L. Cat. No. 108960; 16, 20, same specimen, and 18, 21, all Hg. 4551c, T. L. L. Cat. No. 108177.
12, *Orbulina universa* d'Orbigny. K. R. 18793. T. L. L. Cat. No. 88936.
17, 19, *Orbulina bilobata* (d'Orbigny). 17, Hg. 4551b, T. L. L. Cat. No. 108176; 19, K. R. 18793, T. L. L. Cat. No. 88937.



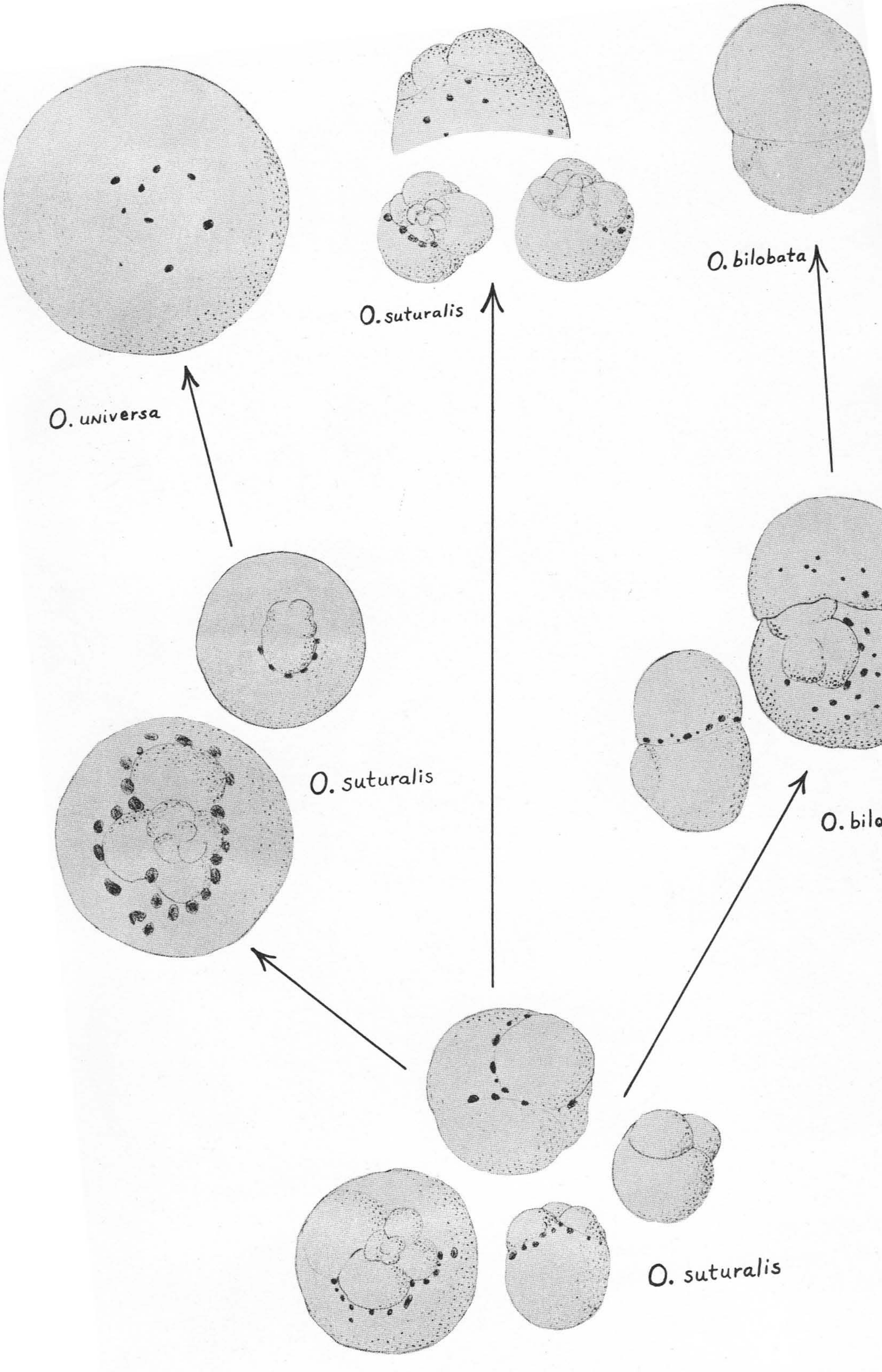
TEXT FIGURE II. *Orbulina* association occurring with *Globorotalia fohsi barisanensis* (figs. 1-6) and *Globorotalia fohsi fohsi* (figs. 7-15), upper Oligocene, Trinidad, B. W. I.



TEXT FIGURE III. *Orbulina* association occurring with *Globorotalia fohsi lobata* (figs. 1-10) and *Globorotalia fohsi robusta* (figs. 11-22), upper Oligocene, Trinidad, B. W. I.



TEXT FIGURE IV. *Orbulina* association of the *Globorotalia mayeri* zone (figs. 1-12) and the *Globorotalia menardii* zone (figs. 13-22), lower Miocene, Trinidad, B. W. I.



TEXT FIGURE V. Bioseries of *Orbulina* d'Orbigny.

three (?) such chambers are also known and have been described under various generic names [see synonomy under *O. bilobata* (d'Orbigny)]. Brady (1884) observed that these multichambered adults preserve all the true *Orbulina* characters and therefore considered them to be abnormal forms of the typical *Orbulina* with a single globular end chamber. Jedlitschka (1934) allocated the multichambered specimens from the Miocene of Ostrau, Olmützer, Bucht and Brünn, Czechoslovakia, to the genus *Candeina* d'Orbigny, 1839, because of the circular pores along the sutures between the last two or three chambers. He restricted the species *C. bilobata* to two-chambered, and *C. trilobata* for three-chambered adults. The multichambered individuals, however, differ completely in the structure of the test and the texture of the walls from the typical representatives of *Candeina.* As Brady suggested, there is no doubt that these specimens of possibly aberrant character belong to *Orbulina.* Cushman and Dorsey (1940, p. 42, pl. 8, figs. 8, 9) regarded the two-and three-chambered adults as variations of *Candorbulina universa.* Le Roy (1941) described that bilobed form as a new subspecies of *O. universa,* but later (1948, p. 501, fig. 1) included it in *Candorbulina universa* as a bilobed variety. Palmer (1941, p. 286) and Bermudez (1949, p. 282; 1950, p. 351) correctly assigned it to *Orbulina* as a separate species.

Jedlitschka (1934, vol. 65, p. 20) introduced the monotypic genus *Candorbulina* for globular adult tests, structurally and texturally very similar to *Orbulina,* but differing in the presence of small circular openings along the sutures between the earlier *Globigerina* chambers and the globular end chamber. He proposed as genotype *C. universa* (1934, p. 21, p. 24, textfigs. 1-7, 19, 21-23) from the Miocene of Czechoslovakia.

Brady (1884, pl. 81, figs. 15, 16) obviously assigned forms of the *Candorbulina* type to *Orbulina,* and Jedlitschka linked the typical Candorbulines and the typical Orbulines by transitional series, as shown in his textfigures 21-23 (1934, p. 24). The globular *Candorbulina* form with circular pores along the sutures separating the early *Globigerina* portion from the almost spherical end chamber (Cushman and Dorsey, 1940, p. 41), grades into the distinctly spherical test without the projecting *Globigerina* chambers of the true *Orbulina.*

Candorbulina, however, was not generally accepted (Cushman and Dorsey, 1940; Glaessner, 1945). Based on Jedlitschka's and Cushman and Dorsey's descriptions and supplemented by a detailed study of the upper Oligocene - lower Miocene Orbulinas from Trinidad, we arrive at the conclusion that *Candorbulina* Jedlitschka is very closely related to *Orbulina* d'Orbigny. By a slight amplification of the generic definition the genus *Candorbulina* can be included in *Orbulina,* thus avoiding the splitting into two genera of a natural group of forms. This seems to be preferable also from the biostratigraphic point of view since the two genera can only be clearly distinguished if the fossil material is well preserved.

Orbulinas are among the commonest of the planktonic Foraminifera throughout tropic and subtropic regions. Easily recognizable, they are found in sediments of various facies, being transported by currents into the different marine environments. All these qualities make *Orbulina* an excellent guide fossil for regional and even world wide correlation. Tromp (1941, 1949) and Le Roy (1948) proposed to use the first occurrence, or the acme of *Orbulina,* as a world wide middle Tertiary time datum (*Orbulina* surface).

O. universa ranges from the middle Tertiary to Recent (Tromp, 1941, 1949; Le Roy, 1948, p. 501). Glaessner (1945, p. 14) states that most pre-Miocene records of *Orbulina* d'Orbigny are erroneous. Tromp (1949, p. 14) indicated in 1941 on Chart No. 2 (Microfauna of the Mesozoic and Tertiary sections of Southern Turkey, Anatolian facies) the appearance of *O. universa* in marl sections below the basal Miocene.

EXPLANATION OF TEXT FIGURE IV

(All figures approximately × 80)

FIGS.

1-12. *Orbulina* association of the *Globorotalia mayeri* zone, Lower Miocene, Naparima area, Trinidad, B. W. I.
1, *Orbulina universa* d'Orbigny K. R. 23422, T. L. L. Cat. No. 160021.
2-4, 7-12, *Orbulina suturalis* Bronnimann, n. sp
2-4, K. R. 23422, T. L. L. Cat. No. 160021 (3, 4 are the same specimen); 7, 8, K. R. 18198, T. L. L. Cat. No. 62413; 9, K. R. 18192, T. L. L. Cat. No. 62407; 10, 11, K. R. 23422, T. L. L. Cat. No. 160021; 12, Br. 33, T. L. L. Cat. No. 119287.
5-6, *Orbulina bilobata* (d'Orbigny) K. R. 23422, T. L. L. Cat. No. 160021.

13-22. *Orbulina* association of the *Globorotalia menardii* zone, Lower Miocene, Naparima area, Trinidad, B. W. I. All K. R. 23425, T. L. L. Cat. No. 160637.
13, 14, *Orbulina universa* d'Orbigny.
15-16, 19-22, *Orbulina suturalis* Bronnimann, n. sp. 15-16, 20, same specimen, 21, 22, same specimen.
17-18, *Orbulina bilobata* (d'Orbigny), same specimen.

EXPLANATION OF TEXT FIGURE V

Bioseries of *Orbulina* d'Orbigny, from Upper Oligocene to Lower Miocene, all figures approximately × 90. See text p. 16.

As far as the Caribbean region is concerned, the stratigraphic conclusions of Cushman and Stainforth (1945, p. 69, pl. 13, fig. 10) are of special interest. They recorded the first appearance of *Candorbulina universa* in the *Globorotalia fohsi* Zone of the upper Oligocene Cipero marl formation of Trinidad. Bermudez (1949, p. 282, pl. 22, figs. 3, 4; 1950, stratigraphical chart, p. 351-52) observed *O. universa* and *O. bilobata* in the middle Oligocene deep water deposits of the Trinchera and Sombrerito formations of Santo Domingo, and *O. universa* in the middle Oligocene marls of the Jaruco formation of Cuba, in association with *Globigerina dissimilis* Cushman and Bermudez. In Cuba, *O. bilobata* is known from the upper Oligocene Cojimar formation upwards. According to Bermudez, *O. universa* and *O. bilobata* usually occur together and the spherical forms are more abundant than the bilobed ones. Both species are known in the Recent of Cuba and Santo Domingo. Palmer (1941, p. 286-287, pl. 28, fig. 3) reported *O. bilobata* and *O. universa* from the upper Oligocene Cojimar formation of Cuba and *O. universa* from the lower Miocene Bowden formation of Jamaica (1945, p. 69).

The records of the first appearance of *Orbulina* in Cuba - Santo Domingo differ considerably from those in Trinidad, where this genus is never found associated either with *G. dissimilis* or the stratigraphically younger *Globigerinatella insueta* Cushman and Stainforth (see Textfigure I). In Trinidad the arrival of *Orbulina* apparently occurred some time after *Globigerinatella insueta* became extinct. It would however not be suitable to use *Orbulina* for a middle Tertiary world wide datum line as proposed by Tromp and Le Roy, if it should be established that the first appearance of *Orbulina* occurred at different times in different localities within the same region.

SYSTEMATIC DESCRIPTIONS

As already pointed out, transitional series link those *Orbulinas* without a completely enveloping end chamber with the truly spherical ones described by d'Orbigny. Stratigraphically arranged material from Trinidad (Textfigure I) further indicates that the older, morphologically primitive, non-enveloping forms and the younger more progressive, completely spherical forms represent a bioseries. This bioseries is characterized by the tendency of the end chamber to become completely enveloping in the course of time. It has been observed that the primitive types appear prior to the progressive ones and that both co-exist in the uppermost Oligocene and basal Miocene of Trinidad.

Diagnosis of Orbulina d'Orbigny 1839.—In order to include in the genus *Orbulina* the forms described by Jedlitschka under *Candorbulina* and *Candeina* it is proposed to emend d'Orbigny's original diagnosis as follows:-

Family GLOBIGERINIDAE

Subfamily ORBULININAE

Genus **Orbulina** d'Orbigny, 1839

Candorbulina Jedlitschka, 1934
Candeina Jedlitschka (not d'Orbigny), 1934.

Emended Diagnosis.—Test in early stages like *Globigerina,* later with a globular end chamber partially or completely enveloping the earlier ones. No definite aperture present, but subcircular to irregularly shaped openings of various sizes occur along the sutures separating the *Globigerina* chambers from the globular end chamber, with occasional irregularly distributed subcircular openings in the wall of the end chamber. Spherical tests with only the irregularly distributed subcircular openings. Wall calcareous, usually very thin, sometimes composed of two or more layers, with numerous regularly arranged minute perforations. Exterior with fine elongate spines (not preserved in fossil specimens), surface cancellate, rather rough in thick shelled individuals.

Genotype.—*O. universa* d'Orbigny 1839, Foraminifères. In Ramon de la Sagra: Histoire physique et naturelle de l'Ile de Cuba. Paris, p. 2, pl. 1, fig. 1 - Recent, Cuba.

Diagnosis of species.—Three closely related species are distinguished.

Orbulina universa d'Orbigny, 1839

Text figure III, figure 12;
Text figure IV, figures 1, 13-14

Orbulina universa d'Orbigny, 1839 and of various authors.

End chamber spherical; early *Globigerina* chambers not projecting above general surface of test. No definite aperture developed, but subcircular, sometimes irregularly shaped and scattered openings of various sizes present. Wall cancellate, with regularly arranged minute perforations, thin or fairly thick, composed of one or more thin layers.

Holotype.—*O. universa* d'Orbigny 1839, p. 2, pl. 1, fig. 1. Recent, Cuba.

Remarks.—As a rule, large specimens are thin walled and small specimens are thick walled. The latter possess a rough cancellate surface due to the secondary growth of the wall. The scattered larger openings are frequently filled and masked by matrix and although the openings are not always clearly discernible they often appear to be concentrated on one side of the sphere. Occasionally, a large irregularly shaped opening occurs, possibly of accidental origin (Brady 1884, Cushman 1948).

Orbulina suturalis Bronnimann, n. sp.

Text figure II, figures 1-5;
Text figure III, figures 3-8, 11, 13-16, 18, 20-22;
Text figure IV, figures 2-4, 7-12, 15-16, 19-22

Orbulina universa D'ORBIGNY of various authors (not d'Orbigny, 1939).

Candorbulina universa JEDLITSCHKA 1934, Naturforsch. Vereinigung Brünn, Verh., Vol. 65, p. 21.

Candeina trilobata JEDLITSCHKA 1934, ibid., p. 24, text-fig. 13.

Diagnosis.—End chamber globular, not entirely enveloping the preceding *Globigerina* chambers. Tests showing all transitional stages from a partly enveloped *Globigerina* to an almost completely enveloped one. In the final stage, the *Globigerina*-chambers visible only as a small rounded area, projecting slightly above the general surface. Tests small. No definite aperture present, but subcircular to irregularly shaped openings occur along sutures, separating the *Globigerina* chambers from the globular end chamber and occasionally outside the sutural grooves as well. Wall cancellate, with regularly arranged minute perforations, thin or fairly thick, composed of one or more layers.

Diameter of holotype 0.312 mm.

Holotype.—*O. suturalis* Bronnimann, Text figure IV, figs. 15, 16, 20, Trinidad, B. W. I., Miocene, *Globorotalia menardii* Zone. Deposited in U. S. National Museum (Cushman Coll. No. 64181), Washington, D. C., U. S. A.

Remarks.—The openings along the sutures are not always discernible due to the masking effect of adhering matrix. Additional larger openings pierce the wall of the globular chamber, and although scattered they appear to be limited within a certain area. The dimensions of the tests and the sizes of the openings vary considerably and it may be possible that the perforations in general can be used as a morphologic criterion (Hofker, 1950, pp. 16-17).

The *Globigerina* stage is somewhat concealed in thick shelled individuals because the additional thin layers also cover the initial portion of the test. The initial chamber is very rarely visible, and the number of *Globigerina* chambers cannot be exactly established.

Orbulina bilobata (d'Orbigny) 1846

Text figure III, figures 1-2, 9-10, 17, 19;
Text figure IV, figures 5-6, 17-18

Globigerina bilobata D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 164, pl. 9, figs. 11-14.

Globigerina bipartita REUSS, 1863, Acad. R. Sci., Bull. Bruxelles, Ser. 2, Vol. 15, p. 156, pl. 3, fig. 46.

Globigerina ovoidea SEGUENZA, 1880, R. Accad. Lincei, Roma, Mem., Vol. 6, p. 334, pl. 17, fig. 39.

Orbulina universa (d'Orbigny), H. B. BRADY, 1884, Report Voyage Challenger, Vol. 9, p. 608, pl. 81, fig. 2 (double specimen).

Orbulina gemina TERRIGI, 1891, Mem. Descr. Carta Geol. Ital., Vol. 4, pt. 1, p. 103.

Orbulina universa var. *bisphaerica* LE ROY, 1941, Colorado School of Mines, Quart., Vol. 36, no. 1, p. 44, pl. 1, fig. 3.

Candeina bilobata JEDLITSCHKA, 1934, Naturforsch. Vereinigung Brünn, Verh., Vol. 65, p. 22, p. 24, text-figs. 8-12.

Candeina trilobata JEDLITSCHKA, 1934, ibid., pp. 22, 24, textfigs. 14-18, 20.

Orbulina bilobata (d'Orbigny), PALMER, 1941, Mem. Soc. Cubana Hist. Nat., Vol. 15, p. 286, pl. 28, fig. 3.

Orbulina bilobata (d'Orbigny), BERMUDEZ, 1949, Cushman Lab. Foram. Research, Special Publ. No. 25, p. 282, pl. 22, fig. 4.

Diagnosis.—Test bilobate, composed of an *O. suturalis* stage with an additional globular chamber of variable size, not enveloping the *suturalis* portion. No definite aperture, but subcircular to irregularly shaped openings occur as in *O. suturalis,* along the suture between the first and the second globular chambers. Additional larger openings sometimes present on the second globular chamber, irregularly distributed as in *O. universa.* The second chamber is attached in such a way that the *Globigerina* chambers of the *suturalis* portion are visible or only partially hidden. Features otherwise identical with those described in *O. universa* and *O. suturalis.*

Holotype.—*Globigerina bilobata* d'Orbigny 1846, Foraminifères fossiles du Bassin tertiaire de Vienne (Autriche), Paris, pl. 9, figs. 11-14. Tertiary, near Nussdorf, north of Vienna, Austria.

Remarks.—The bilobate and ? trilobate *Orbulina* tests considered by Brady (1884), Cushman and Dorsey (1940), and Le Roy (1948) to represent abnormal variants of the typical *Orbulina* or *Candorbulina* are here given specific rank (Palmer, 1941, Bermudez, 1949). They appear stratigraphically above *O. suturalis* and below *O. universa.* The trilobate individuals figured by Jedlitschka (1934, p. 24, textfigs. 14-20) are distinct bilobate forms showing the *Globigerina* stage of *O. suturalis.* The other specimen he figured (1934, p. 24, textfig. 13) is apparently a slightly enveloped *O. suturalis,* with the last two subglobular chambers of the *Globigerina* spiral clearly visible. Cushman and Dorsey's "trilobate adult" (1940, pl. 8, fig. 9) could be a true tripartite individual, but from the rather indistinct photograph it could be taken as a bilobate form with a fairly large *Globigerina* stage protruding on the right hand side. This should be checked in the original material. No true trilobate individuals have been encountered in the Trinidad material although a great many samples were investigated. The bilobate forms are associated at first with *O. suturalis* and later with *O. suturalis* and *O. universa.*

It has been noted that the *suturalis* portion invariably develops a much thicker wall than the adjoining subglobular end chamber. The surface of the early portion is also much rougher and the perforations more widely spaced than in the relatively thin-walled final chamber. The latter, as a rule, is formed over a concentration of larger openings of the *suturalis* portion near the projecting *Globigerina* stage.

The dimensions of the bilobate specimens show considerable variation as compared to the dimensions of *O. suturalis*. The end chamber can be smaller or larger than the *suturalis* test. Deformations are fairly frequent.

FACIES DISTRIBUTION AND BIOSTRATIGRAPHIC SIGNIFICANCE OF ORBULINA IN TRINIDAD

In Trinidad, *Orbulinas* are found abundantly in the upper Oligocene marl facies (Cipero marl formation), and commonly in shallow, clear-water, near-shore and reef environments. However, the genus is virtually absent from the non-calcareous, muddy water clays of the upper Oligocene—lower Miocene Karamat formation and in the sandy-silty, turpid water, deltaic deposits of the Miocene Moruga group. In contrast *Globigerinas, Globorotalias* and *Orbulinas* are common in the interbedded calcareous clays, thus permitting the zonal age correlation of the deposits which are virtually barren of planktonic foraminifera. *Orbulinas* are very scarce in the upper Miocene - Subrecent neritic clear water deposits of the Northern Depression, although various species of *Globigerina* and related genera are recorded. The genus is also known from recent beach sands of the Atlantic Coast and even occasionally encountered in the recent mud of the landlocked, brackish water, Gulf of Paria (Bronnimann, 1949).

The subdivision of the Trinidad upper Oligocene into zones and subzones based on *Globigerina* and *Globorotalia* (Cushman and Stainforth, 1945 and Bolli, 1950) made possible the zonal age determination of 65 closely analyzed *Orbulina* assemblages from surface marl samples of the Naparima area of South Trinidad. The biostratigraphic results obtained in this way were checked by age determinations of a great many *Orbulina* bearing samples from the surface and subsurface in the course of routine work. The results are tabulated in textfigure 1 which shows that the genus is not known in the lower zone of the upper Oligocene characterized by the life range of *Globigerinatella insueta* Cushman and Stainforth (Cushman and Stainforth, 1945, p. 12; Stainforth, 1948, Bronnimann, 1950). The first representatives of *O. suturalis* appear abruptly in the lower part of the *Globorotalia fohsi* Zone. This latter zone of our present terminology is equivalent to Zone III of Cushman and Stainforth of the Trinidad upper Oligocene. There is no indication that *O. suturalis* evolved gradually from a morphologically primitive type of *Globigerina* occurring in the *Globigerinatella insueta* Zone, or from *Globigerinoides conglobata* (H. B. Brady) as suggested by Cushman and Stainforth (1945, p. 69). It was noted that even in the earliest assemblages the species *suturalis* is represented by a series of specimens exhibiting various degrees of envelopment, the most progressive type being an almost spherical *Orbulina* with the *Globigerina* stage projecting slightly above the general surface as a small subcircular area (Textfigure II, figs. 1-6). The first specimens of *O. bilobata* (Textfigure III, figs. 1-2, 9-10) are at present recorded in the *Globorotalia fohsi* Zone, associated with *Globorotalia fohsi lobata* and the first *O. universa* (Textfigure III, fig. 12) appears near the top of this zone with *Globorotalia fohsi robusta*. The lower Miocene *Globorotalia mayeri* and *Globorotalia menardii* Zones in their typical development are characterized by extremely rich pelagic faunas with *O. suturalis, O. bilobata* and *O. universa*.

In Trinidad, the genus *Orbulina* reaches a maximum development in the topmost Oligocene - basal Miocene.

It appears that assemblages of the younger Miocene (calcareous clays of the Forest formation) do not yield any autochitinous specimens of *O. suturalis*.

REMARKS ON ONTOGENY AND PHYLOGENY OF ORBULINA

Ontogeny.—The globular end chamber of typical *Orbulina* or the two globular chambers of the species *bilobata* represent the final ontogenetic stages in a development beginning with a small trochoidal *Globigerina,* showing four thin-walled subglobular chambers with large apertures, in the last whorl prior to the *Orbulina* stage. The ontogeny of *Orbulina* therefore can be divided into two main stages: a) *Globigerina* stage and b) *Orbulina* stage.

Globigerina stage.—In fossil material the *Globigerina* stage can only be studied by breaking, or by destroying with acid, the adult globular chamber and without exception the *Globigerina* stage was encountered in the interior of well preserved specimens (Textfigure II, fig. 12; Textfigure III, figs. 10, 16, 21; Textfigure IV, figs. 10-11, 22). It was not possible, however to establish the exact number of chambers of the *Globigerina* stage. In some individuals approximately 10 *Globigerina* chambers were counted, which increased in size as added, and formed a rather loosely coiled, open umbilical, trochoidal spiral of about two whorls. As a rule the subglobular *Globigerina* chambers are very thin-walled in comparison to the wall of the adult chamber, and often are even transparent, and the relatively large arched apertures are surrounded by minute lip-like projections. The walls are penetrated by very fine and not too closely spaced perforations, which can only be seen under suitable illumination. Each chamber possesses a single, large aperture, and the only specimen of the Trinidad collection with an apparently accessory aperture in the last chamber of the *Globigerina* stage (Textfigure III, fig. 10) was probably damaged in the course of preparation. In any case, no additional apertures were observed in the early chambers of the *Globigerina* stage. Cushman and Dorsey (1940, p. 41) stated that the early *Globigerina* stage suggests the presence of dorsal secondary apertures which would indicate that *Orbulina* sprang from *Globigerinoides* instead of from *Globigerina*. These authors refer in particular to the drawing of a young specimen published by Jedlitschka. The figures of broken specimens (1934, p. 24, figs. 1c, 21a, 22a, 23a) show however only the loosely coiled four end chambers of the *Globigerina* spiral with no indication of additional *Globigerinoides*-like apertures. Cushman (1948, pl. 34, fig. 18) reproduced after Rhumbler the figure of a specimen of *O. universa* with distinct openings of the *Globigerinoides* type. The nature of these apertures should be checked on the original material as it is possible that in reality they coincide with the normal apertures of the primitive *Globigerina*. Brady (1884) and later Rhumbler (1901, 1911) do not mention additional openings of the *Globigerinoides* type.

The writer cannot at present definitely settle the generic allocation of the *Globigerina*-stage, but from the observations made on the Trinidad material, it appears improbable that such a specialized type as *Globigerinoides* represents the initial stage of *Orbulina*.

Based on the available information and on general considerations, it is believed that the ancestor of *Orbulina* is a small loosely coiled trochoidal *Globigerina* with large apertures opening into a wide umbilicus. This ancestral form morphologically approaches very closely *Globigerina bulloides* d'Orbigny (Brady, 1884, pl. 79, figs. 6, 7) which is four-chambered in the adult, although the apertures are much smaller and the coiling of the spiral is more compact.

Orbulina stage.—The *Orbulina* stage has been discussed in some detail in the description of *O. universa*. No additional remarks are necessary.

Phylogeny.—In the time interval from upper Oligocene to lower Miocene, *Orbulina* (Textfigure V) developed three bioseries, originating from *O. suturalis*, the morphologically most primitive and stratigraphically oldest species.

a) Bioseries *O. suturalis* - *O. universa*, characterized by the tendency of the globular chamber to become enveloping in the course of time.

b) Bioseries *O. suturalis* - *O. bilobata*, characterized by the adding of a second subglobular chamber on the *suturalis* portion.

c) Bioseries *O. suturalis* - *O. suturalis*. No evolutionary trends recognizable.

The stratigraphical occurrence of the species *bilobata* and *universa* support the derivation of the bioseries, which was based on morphological features alone. It is striking that the bilobate form did not evolve into a completely spherical one by enveloping the *suturalis* test.

The dimensions of the tests of the three species are widely variable and no appreciable difference is evident in comparing the dimensions of the *Orbulina* species of the *Globorotalia fohsi* and the *Globorotalia menardii* Zones. In order to establish the possible existence of an evolutionary trend, a statistical analysis of this feature was made. This is true also of the investigation of other measurable features of potential phylogenetic significance, such as the variation in the number of minute perforations per surface unit (Hofker, 1950, p. 16-17), and the relation between the sizes of the *Globigerina* stage and the adult test, a feature used by Rhumbler (1901) for the definition of varieties of *Orbulina*.

ACKNOWLEDGMENTS

The writer wishes to express his sincere thanks to Drs. H. G. Kugler, Trinidad, and H. E. Thalmann, Pasadena, California, for many suggestions and for taxonomic comments.

The paper is published by permission of the Management of Trinidad Leaseholds Ltd.

The holotype of *Orbulina suturalis* is deposited in the Cushman Collection of the U. S. National Museum, Washington, D. C. The original samples remain in the collections of the Geological Laboratory of Trinidad Leaseholds Ltd. at Pointe-a-Pierre, Trinidad, B. W. I.

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Manuscript received January 2, 1951

39. A METHOD FOR STORING LARGER FORAMINIFERA FOR VARIATION STUDY

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ABSTRACT—A simple method for storing great numbers of larger Foraminifera is described.

During the course of a variation study of the *Nummulites* of Egypt based on statistical methods, the author worked with large numbers of individuals of the same species and from the same stratigraphic horizon. As these methods involved the study of each fossil as a separate distinct individual in a community of others, it was important to store the thousands of fossils studied in a manner in which the individuality of each is kept and in which the selection of any particular individual is always possible whenever reference to it is needed. The following simple method was found convenient in this respect. Square wooden plates of 28 centimeters on each side and one to two centimeters in thickness (according to the thickness of the fossil) were prepared. Circular recesses of six to sixteen millimeters in depth, and arranged in rows were then grooved along the plates as can be seen from the accompanying diagram. The diameter of the recesses varied according to the size of the fossil studied. For the majority of *N. gizehensis* specimens, as an example, a diameter of 2½ centimeters was found convenient.

For packing and storing, a few plates can be arranged in bundles by placing one above another and covering the top with a simple ungrooved plate. The bundle may be held together by four bolts and nuts fixed in holes along the edges of the plates (designated A in the diagram).

Manuscript received November 29, 1950

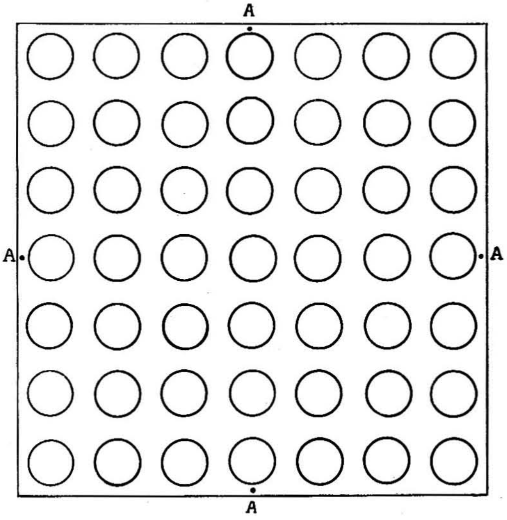

Fig. 1: Diagram of plate used in storing larger Foraminifera.

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40. *LAGENA SAMANICA* BERRY, A SYNONYM

By Benton Stone

Subsequent to my brief note in The Micropaleontologist (vol. 4, no. 2, 1950, p. 17) expressing the opinion that *Lagena samanica* Willard Berry is really a termite pellet and not a foraminifer, Mr. L. G. Henbest of the U. S. National Museum has kindly provided additional information on this point. Mr. Henbest has found in the U. S. National Museum collections the single specimen which Berry labeled as the "type" of *Lagena samanica.* He reports that though this specimen is covered with a thin veneer of gum adhesive, it seems to be composed of woody material and is not a fossil. As the specimen in the National Museum collection is the holotype it was not sectioned.

Dr. Thomas E. Snyder, termite authority of the Department of Forest Insects of the Department of Agriculture, has provided me with termite pellets of *Cryptotermes brevis* (Walker), 1853. These forms are identical with specimens from Peru which I have examined. Dr. Snyder also examined Berry's "type" specimen in the U. S. National Museum collections and has kindly submitted the following comment:

> "I have carefully compared the holotype of *Lagena samanica* Berry with pellets of excrement of the Recent termite *Cryptotermes brevis* (Walker), now living in Peru. Except that these pellets are slightly larger, I can see no differences."

This additional information seems to definitely establish that *Lagena samanica* Berry is a synonym of fecal pellets of the termite *Cryptotermes brevis* (Walker) and consequently should be removed from the Order Foraminifera.

Manuscript received May 9, 1951

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41. NOTES ON THE DIRECTION OF COILING OF ROTALID FORAMINIFERA

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1. THE DIRECTION OF COILING IN THE EVOLUTION OF SOME OLIGOCENE-MIOCENE GLOBIGERINIDAE FROM TRINIDAD, B. W. I.

Certain rules governing the direction of coiling in Globorotaliidae and other foraminiferal families during their life ranges have been discussed in a recent paper by the author (Bolli, 1950). Investigations were extended to a number of species of Globigerinidae from the Oligocene-Miocene of Trinidad, B. W. I.

The stratigraphic section, in which the direction of coiling of these species was investigated includes the major part of the Oligocene Cipero formation and the Lower Miocene Lengua formation. Figure 1 shows the biostratigraphic subdivision of these formations (Cushman and Stainforth 1945, Cushman and Renz 1947, Bolli 1950, Bronnimann 1951).

In this connection the writer wishes to thank Dr. A. M. Oosterbaan of the United British Oilfields of Trinidad Ltd., for his co-operation in establishing the stratigraphic subdivision of the Oligocene *Globorotalia fohsi* Zone.

Observations were restricted to those Globigerinidae species which proved to be abundant and thus allowed a rapid count of a great number of specimens. As a rule the direction of coiling was determined in 100 specimens of each species picked from representative samples of each of the 9 zones or subzones. Where a species was scarce, and the picking of 100 specimens would have been too time-consuming, countings were made on 50 specimens only.

The percentages of sinistral coiling of the investigated species are plotted in figure 1. It can clearly be seen, that certain rules govern the coiling of these species during their stratigraphic range, although the preferences for one direction are not as strong as those observed in some Globorotaliidae (Bolli, 1950). Six out of the seven investigated species prefer sinistral coiling and this to such a degree, that not one series of countings of these species showed a majority for dextral coiling. Only one, *Globigerina dissimilis,* favours the dextral direction.

It should be pointed out that the curves of figure 1 indicate only the approximate percentage of sinistral coiling of the species in the various stratigraphic levels, this, despite the considerable number of counted specimens. Additional countings from intermediate samples would presumably alter the shape of the curves to a small extent. It is believed however, that the scale on which the present investigations were carried out, suffices to give a reliable picture of the general trend of the direction of coiling.

The following 7 species have been investigated:

Globigerinoides sacculiferus (Brady) var. **immatura** Le Roy

Globigerinoides sacculiferus (Brady) var. *immatura* Le Roy, 1939, Natuurk. Tijdschr. Nederl.-Indie, Vol. 99, p. 263, pl. 3, figs. 19-21.

Globigerinoides sacculiferus (Brady) Cushman and Stainforth, 1945, Cushman Lab. Foram. Research, Special Publ. No. 14, p. 68, pl. 13, fig. 3.

Globigerina triloba Reuss, 1850, K. Akad. Wiss. Wien. Math.-Nat. Kl., Denkschr., Vol. 1, p. 374, pl. 47, figs. 11a-e.

Globigerina venezuelana Hedberg

Globigerina venezuelana Hedberg, 1937, Jour. Paleontology, vol. 11, No. 8, p. 681, pl. 92, figs. 7a-b; Cushman and Stainforth, 1945, Cushman Lab. Foram. Research, Special Publ. No. 14, p. 67, pl. 12, figs. 13a-b.

Globigerina altispira Cushman and Jarvis

Globigerina altispira Cushman and Jarvis, 1936, Contr. Cushman Lab. Foram. Research, Vol. 12, pt. 1, p. 5, pl. 1, figs. 13-14.

Globoquadrina quadraria (Cushman and Ellisor) var. **advena** Bermudez

Globoquadrina quadraria (Cushman and Ellisor) var. *advena* Bermudez, 1949, Cushman Lab. Foram. Research, Special Publ. No. 25, p. 287, pl. 22, figs. 36-38.

Globigerina cf. *inflata* d'Orbigny, Cushman and Stainforth, 1945, Cushman Lab. Foram. Research, Special Publ. No. 14, p. 67, pl. 12, figs. 12a-b.

Globigerinoides sacculiferus (Brady) var. **irregularis** Le Roy

Globigerinoides sacculiferus (Brady) var. *irregularis* Le Roy, 1944, Colorado School of Mines, Quart., Vol. 39, No. 3, p. 40, pl. 3, figs. 42-46.

?*Globigerina apertura* Cushman 1918, U. S. Geol. Survey, Bull. No. 676, p. 57, pl. 12, figs. 8a-c.

?*Globigerina trilocularis* d'Orbigny, Deshayes, 1832, Encyclopédie Méthodique; Histoire naturelle des vers. Paris, Vol. 2, pt. 2, p. 170; Fornasini, 1897, R. Acad. Sci. Inst. Bologna, Vol. 2, fasc. 1, pl. 1, figs. 6, 7-7a.

Globigerina grimsdalei Keijzer

Globigerina grimsdalei Keijzer, 1945, Utrecht, Univ. Geogr. Geol. Medel. Physiogr.-geol. Reeks, ser. 2, No. 6, p. 205, tf. 33a-c.

Globigerina cf. *digitata* H. B. Brady, Cushman and Stainforth, 1945, Cushman Lab. Foram. Research, Special Publ. No. 14, p. 68, pl. 13, figs. 5a-b.

Globigerina dissimilis Cushman and Bermudez

Globigerina dissimilis Cushman and Bermudez, 1937, Contr. Cushman Lab. Foram. Research, Vol. 13, pt. 1, p. 25, pl. 3, figs. 4-6; Cushman and Stainforth, 1945, Cushman Lab. Foram. Research, Special Publ. No. 14.

The following 3 groups of species, each typified by similar percentage curves, can be distinguished in figure 1:

Group 1: *Globigerinoides sacculiferus* var. *immatura, Globigerina altispira, Globigerina grimsdalei, Globoquadrina quadraria* var. *advena.*

Group 2: *Globigerina venezuelana, Globigerinoides sacculiferus* var. *irregularis.*

Group 3: *Globigerina dissimilis.*

Group 1.—Notable are the almost identical curves of *Globigerinoides sacculiferus* var. *immatura* and *Globigerina altispira,* two species with apparently no close morphologic relationship. Countings in the *Globigerina*

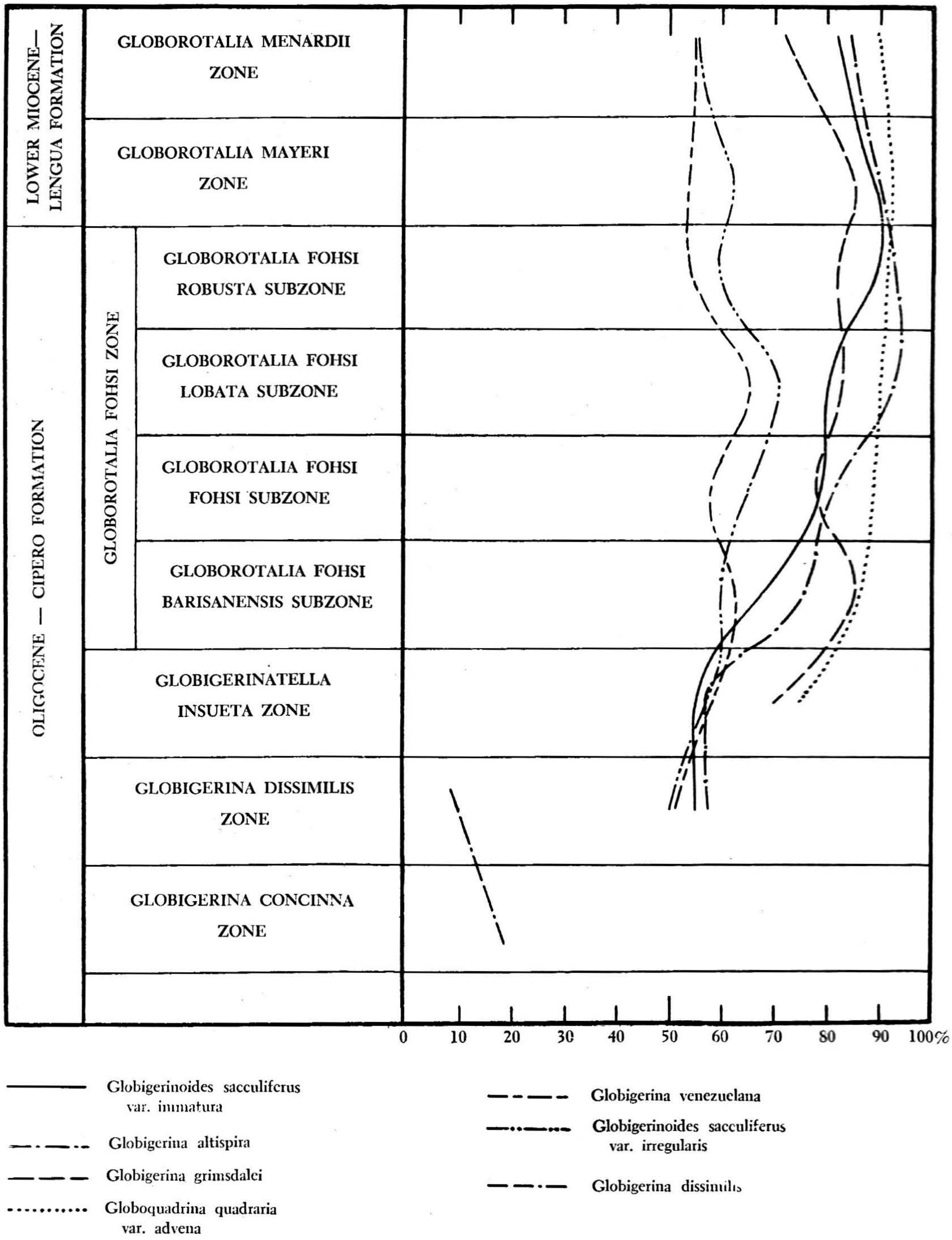

Fig. 1: Percentage of sinistral coiling of some Oligocene-Miocene Globigerinidae

dissimilis Zone and *Globigerinatella insueta* Zone, where these species seem to appear for the first time, resulted in nearly random coiling, with only a slight preference for the sinistral direction. But a continuous increase of this tendency throughout the higher *Globorotalia fohsi barisanensis* - *G. fohsi fohsi* - *G. fohsi lobata* and *G. fohsi robusta* Subzones was noted, with a maximum of 90-95% in the latter. Countings in the two zones of the Lengua formation showed a slight reduction again but sinistral specimens still account for 80-90%.

The other two species of group 1, *Globigerina grimsdalei* and *Globoquadrina quadraria* var. *advena* also show similar curves. Samples from the *Globigerinatella insueta* Zone already yield 70-75% sinistral specimens. It appears probable that samples from earlier stages at the base of the *Globigerinatella insueta* or top of *Globigerina dissimilis* Zones would show a smaller percentage of sinistrally coiling specimens. The countings in the overlying *Globorotalia fohsi barisanensis* to *Globorotalia fohsi robusta* Subzones and *Globorotalia mayeri* Zone resulted in fairly constant sinistral percentages, 85-95% for *Globoquadrina quadraria* var. *advena*, 75-85% for *Globigerina grimsdalei*. A slight decline in the number of sinistral specimens especially in *Globigerina grimsdalei* was found again in the youngest sample. This could be due to random counting results, but more probably has some evolutionary significance.

Group 2.—The curves of *Globigerina venezuelana* and *Globigerinoides sacculiferus* var. *irregularis* of this group are very similar. Both species coil practically at random in the *Globigerina dissimilis* Zone, but the number of sinistral specimens increases throughout the *Globigerinatella insueta* Zone - *Globorotalia fohsi barisanensis* - *Globorotalia fohsi fohsi* - *Globorotalia fohsi lobata* Subzones. The maximum of sinistral coiling specimens with 65-70% is present in the *Globorotalia fohsi lobata* Subzone. It is followed again by a reduction to about 55% in the *Globorotalia menardii* Zone.

Group 3.—A distinct preference for dextral coiling was found in *Globigerina dissimilis*, which amounts to approximately 90% towards the end of its life range in the *Globigerina dissimilis* Zone. A slight reduction in the number of dextral coiling specimens is found in the next older *Globigerina concinna* Zone, thus indicating that this species probably follows similar rules as established for specimens of the *Globigerinoides sacculiferus* var. *immatura*, *Globigerina altispira*, *Globoquadrina quadraria* var. *advena*, *Globigerina grimsdali* group.

Group 1 of these species (*Globigerina grimsdalei*, *Globigerinoides sacculiferus* var. *immatura*, *Globigerina altispira*, *Globoquadrina quadraria* var. *advena*) shows during evolution a similar curve as that obtained for some *Globorotalia* species (e. g. *Globorotalia fohsi* group). The maximum values of sinistral coiling of this group (85% and 95%) are not quite as high however as those for the *Globorotaliae* (95-100%). Group 2 with *Globigerina venezuelana* Hedberg and *Globigerinoides sacculiferus* (Brady) var. *irregularis* Le Roy show the preference for sinistral coiling to a lesser degree, hardly exceeding 70%.

These investigations show clearly that not only the Globorotaliidae but also some Globigerinidae follow certain rules in coiling during their vertical ranges.

2. PHYLOGENETIC SIGNIFICANCE OF THE DIRECTION OF COILING

It is of interest to compare the direction of coiling of the Oligocene-Miocene Globorotaliidae and Globigerinidae with that of the same families of the Upper Cretaceous. All the *Globotruncanae* and at least some of the Upper Cretaceous *Globigerinae*, e. g. *Globigerina rugosa* Plummer (which in a single sample was found to coil dextrally at the rate of 98:2), prefer dextral coiling to a very marked degree in their later stages (95% or over). Most Oligocene-Miocene species of *Globorotalia* and *Globigerina* on the other hand favour sinistral coiling, although to a lesser degree than the dextral coiling found for the Upper Cretaceous species. There are exceptions however in the Oligocene-Miocene, e. g. *Globigerina dissimilis*, *Globorotalia menardii* in parts and others, which prefer dextral coiling.

The results of the two studies of coiling would seem to point to some conclusions indicative of genetic relationships between species or generas of the families investigated. These conclusions can be formulated as follows:

1. *Random coiling.*—Random coiling appears to be the early stage in the evolution of the direction of coiling.

2. *Preferred coiling.*—Once a species has chosen preference for either sinistral or dextral coiling in its later stage, it does not revert to random coiling in its further evolution.

Based on this *it appears unlikely that a species with random coiling in its early phylogenetic stage can be genetically related to a stratigraphically older species which shows a distinct preferential direction of coiling in its later stages.*

Thus, the coiling rules of these and probably other rotaliid families can be taken as important phylogenetic factors.

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Manuscript received April 23, 1951

42. ON THE SPECIES *HOMOTREMA RUBRUM* (LAMARCK)

Cesare Emiliani
Walker Museum, University of Chicago

During a recent trip to Bermuda, Dr. Heinz Lowenstam of the University of Chicago collected a large number of specimens of *Homotrema rubrum* (Lamarck), some attached to the original substratum and others loose in sands. The attached specimens are particularly important for a study of the animal because they are fresh and well preserved. They usually adhere to the lateral or lower surfaces of shells, corals or blocks of reef material.

Specimens were obtained from the following localities:

No.	Long. West	Lat. North	Geogr. name	*
L1	64° 46′ 5″	32° 28′ 27″	North Rock	1
L2	64° 44′ 10″	32° 26′ 36″	North Reef	14
L3	64° 44′ 55″	32° 26′ 39″	-	10
L4	64° 40′ 31″	32° 23′ 36″	St. Catherine's Pt.	15
L5	64° 39′ 53″	32° 20′ 40″	Cock Rock	1
L6	64° 39′ 8″	32° 20′ 37″	-	0.0
L7	64° 41′ 20″	32° 19′ 32″	-	0.0
L8	64° 42′ 48″	32° 19′ 2″	Gravely Bay	1.5

* Depth below low tide level (feet)

ACKNOWLEDGMENTS

The writer is indebted to Dr. Heinz Lowenstam, who kindly supplied the material for the present study; to Dr. Alfred R. Loeblich, Jr., who loaned material for comparison; and to Dr. J. Marvin Weller for the revision of the manuscript.

HISTORICAL REVIEW

The earliest reference to *Homotrema rubrum* (Lamarck) was made by Pallas in 1776 under the name *Millepora miniacea*. Lamarck (1816) gave this species the name *M. rubra* and described it as "Millepora minima, sublobata, poris crebris minutis punctata." Dujardin (1841) recognized this animal as a rhizopod and assigned it to the genus *Polytrema*. The first full description was given by Carpenter, Parker and Jones (1862). These authors recognized its external polymorphism and described the areolate character of the external surface, with its cribrate plates separated by imperforate ribs. The planispiral arrangement of the initial chambers was correctly inferred from the appearance of young specimens.

Later, Hickson (1911) erected the genus *Homotrema* on this species.

Hofker (1927) distinguished different arborescent and encrusting types without, however, mentioning any globose or subglobose types. As far as the arrangement of the initial chambers is concerned, this author mentioned a "raspberry" and a spiral type, the first being formed by a protoconch 6 Dμ[1] in diameter surrounded irregularly by other chambers, the second formed by a protoconch 3.6 Dμ in diameter followed by planispirally arranged chambers. Both types, according to Hofker, should be megalospheric. It seems more probable, however, that the smaller protoconch indicates a microspheric form.

The complete synonymy of this species is as follows:

Millepora miniacea Pallas, 1776, p. 251; Chapman, 1902, pp. 66, 226-27, pl. 12, fig. Q.

Millepora rubra Lamarck, 1816, p. 202.

Polytrema rubra Dujardin, 1841, pp. 258-59; Carpenter, Parker and Jones, 1862, pp. 235-37.

Polytrema miniaceum Carter, 1876, pp. 185-98, pl. XIII, figs. 1-6; Verrill, 1907, pp. 139, 188.

Homotrema rubrum Hickson, 1911, pp. 445-47, pls. 30-32; Pearcey, 1914, p. 1041; Heron-Allen and Earland, 1915, p. 279; Cushman, 1921, p. 364; ———, 1922, pp. 53-54, text-figs. 4-6, pl. 14, figs. 6-8; ———, 1925, p. 47; ———, 1927, p. 97, pl. 21, fig. 3; Hofker, 1927, pp. 31-33, pl. 13, figs. 8-9, pl. 14, figs. 12-30, pl. 15; Yabe and Hanzawa, 1930, pp. 19, 36; Norton, 1930, pp. 358-385; Chapman and Parr, 1931, pp. 238-240; Cushman, 1931, pp. 142-143; ———, 1933a, p. 282; ———, 1933b, pl. 37, figs. 27-29; Galloway, 1933, p. 305, pl. 28, fig. 7; Cushman, 1940, p. 310, pl. 37, figs. 27-29; Marie, 1940, p. 348; Glaessner, 1947, p. 153; Cushman, 1948, p. 346, pl. 37, figs. 27-29; Bermudez, 1950, p. 345.

DEVELOPMENT AND MORPHOLOGY

The initial part of the test is a protoconch followed by a series of 5 or 6 spirally arranged chambers (pl. 15, figs. 1-3) after which the arrangement becomes irregular. The diameter of the protoconch is 3.2 Dμ in the microspheric forms (pl. 15, figs. 1-2) and 6.4 Dμ in the megalospheric forms (pl. 15, fig. 3) (cfr. Hofker, 1927,

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[1] Dμ: a new unit of length proposed for foraminiferal measurements. 1 Dμ = 0.01 mm. (see: Emiliani, 1950, Journ. Pal., vol. 24, p. 486).

Fig. 1. Geographical distribution of the species *Homotrema rubrum* (Lamarck).

p. 32). The initial part of the test is dark brown, insoluble in HCl, and seems to be chitinous.

The calcareous part of the test consists of roughly concentric layers of cells, which usually do not extend all the way to the lateral margins. In this area the roofs and floors of the layers are directly in contact. The whole construction is quite irregular and the cells communicate with each other through irregular openings. This is particularly evident in the inner parts of the test where resorption seems to have been common (pl. 15, figs. 4, 18; pl. 16, figs. 1-2). This fact, together with the chitinous character of the initial part, accounts for the loose fastening of the test to the substratum and the abundant occurrence of specimens in sands.

The outer wall is formed, as is well known, by cribrate areolae surrounded by imperforate rims (see Hofker, 1927, pl. XIII, figs. 8-9).

Different growth stages in the material from Bermuda reveal the details of the process by which new layers are added.

First, films of transparent material are deposited 2-3 Dμ above the cribrate areolae and these are shortly transformed into new cribrate plates. One or more plates are added in this way, with their margins fastened to the imperforate rims, until the last one bulges outwards (pl. 15, fig. 6). Either these expand laterally as the result of resorption and renewed deposition or new layers are added to form a continuous thin cribrate wall with numerous scattered invaginations (pl. 15, fig. 7). The surface of a specimen at this stage resembles *Miniacina* as described by various authors. There is little doubt that the so called "composite specimen" (Hickson, 1911, p. 446) figured by Carter (1876, pl. 13, fig. 6) and the "anomalous specimen" described and figured by Chapman and Parr (1931, pp. 238-40) are in reality individuals of this type. It is possible to see the cribrate areolae of the underlying older outer wall through the invaginations of the new wall (pl. 15, fig. 7).

Later, the borders of the invaginations become thicker both distally and laterally, and the pores are closed by added material. Also thin, transparent films, similar to those previously described, are formed across the invaginations (pl. 15, fig. 8) and they are soon transformed into a cribrate wall. At this stage, the outer wall consists of a porous surface with slightly raised rings of non-porous material (pl. 15, fig. 9). This stage is shown in the lower left part of Carter's figure (1876, pl. 13, fig. 6). Gradually, these rings become thicker and expand laterally until they come in contact, separating the cribrate wall into distinct areolae (pl. 15, fig. 10). During or after this process, the older cribrate plates are covered on the outside with an imperforate layer of calcareous material about 2 Dμ thick. Therefore, no porosity remains inside the outer wall, and communication between the cells is established through numerous large irregular openings.

The outer wall is not continuous, as some of the original invaginations are not covered by cribrate plates. Large openings remain where cribrate areolae of underlying layers have not been covered. Projecting from these are sponge spicules, fastened together and to the wall by protoplasmic material.

Most of the spicules are siliceous, uniaxial, with globose heads and longitudinal internal canals (pl. 16, figs. 4, 9-12). They are formed of opaline material, with an index of refraction varying between 1.42 and 1.46, and are similar to those in the sponge genus *Cliona*. Some calcareous triaxial spicules may occur (pl. 16, figs. 3, 7).

A profusion of spicules may be present over certain continuous external areas of the animal, particularly where the surface is well protected. The spicules are connected to the calcareous skeleton by a layer of protoplasmic material (pl. 16, fig. 6).

Usually, two or more spicules are connected to each other to form single units, in the way described by Cushman (1922, p. 54, text-fig. 6). The cement is an elastic, hyaline, protoplasmic material, considerably resistant to concentrated HNO_3. Particularly thick tufts are formed by the spicules projecting from wall openings. Two-siliceous spicules cemented together and their protoplasmic base are shown in plate 16, fig. 5.

Most of the spicules are eliminated during later growth; a few are incorporated into the wall.

The external shape of the test is quite variable. In the material from Bermuda, the following types may be distinguished:

1. *Globose type* (pl. 15, figs. 11-13). A globose, hemispherical, verruca-like mass more or less inflated or flattened. The greatest diameter is about 4.5-6 mm.
2. *Globose-composite type* (pl. 15, fig. 15). A form consisting of globose bodies more or less irregularly united together. This is transitional between the globose and the encrusting types.
3. *Pseudo-ramose type* (pl. 15, fig. 14). An encrusting mass from which rise truncated conical projections. Some of them, in the more protected areas, are continued by white, hyaline, siliceous spicules. These specimens are considerably smaller than the globose ones, usually being about 2-3 mm. in greatest diameter. This type grades into the encrusting type by reduction of the projections.
4. *Branching type* (pl. 15, fig. 17). It consists of several branches on a common stem. Its length is about 2.5 mm.
5. *Encrusting type* (pl. 15, fig. 16). An encrustation with irregular swellings, on top of which occur larger openings. The greatest diameter is from 4 to 8 mm.

The relative frequency distribution of these types varies at different localities and seems to be related to environmental or micro-environmental factors. The material available, however, is too scanty for a statistical investigation.

Radiolaria and diatoms are important food sources of the animal. If specimens are dissolved in HCl, a residuum of protoplasmic material, sponge spicules, and skeletons of radiolaria and diatoms remain (pl. 16, fig. 8).

After the death of the animal, the test is slowly bleached and the colour changes from red to light pink. In Recent sand the more or less rounded specimens of *Homotrema* show varying degrees of bleaching but very few, if any, have been reduced to a pure white colour.

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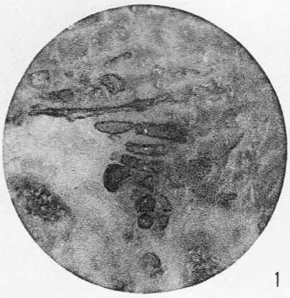
EXPLANATION OF PLATE 15

Homotrema rubrum (Lamarck)

FIGS.		PAGE
1.	Microspheric form, initial chambers, Locality L3, × 56.	145
2.	Microspheric form, initial chambers, Locality L3, × 54.	145
3.	Megalospheric form, initial chambers, Locality L7, × 81.	145
4.	Section of an entire specimen, Locality L5, × 13.	145
5.	Detached portion of new wall, Locality L7, × 54.	145
6.	Swelling and fusion of the areolae wall, Locality L6, × 180.	145
7.	The new wall covers more or less continuously the older wall. Through the invaginations, whose borders start becoming thicker, the older surface is visible, Locality L6, × 160.	145
8.	Thin layers of transparent material are deposited across the invaginations, Locality L6, × 100.	145
9.	The transparent material has been transformed into cribrate areolae. The borders of the former invaginations have been transformed into imperforate rings, Locality L8, × 170.	145
10.	The inter-areolar wall becomes thicker and imperforate, Locality L5, × 100.	145
11-13.	Globose type, × 3.	145
14.	Pseudoramose type, × 3.	145
15.	Globose-composite type, × 3.	145
16.	Encrusting type, × 3.	145
17.	Branching type, × 3.	145
18.	Section of an entire specimen, Locality L1, × 10.	145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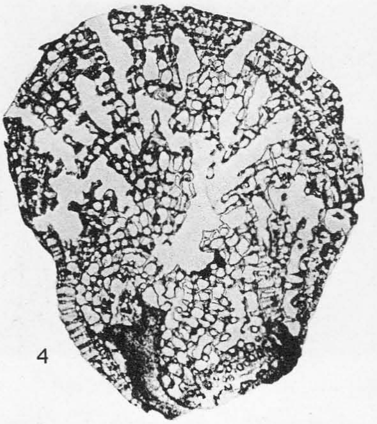
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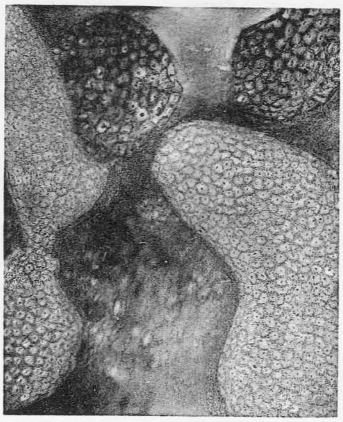
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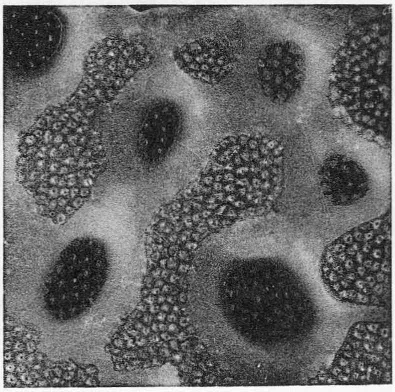
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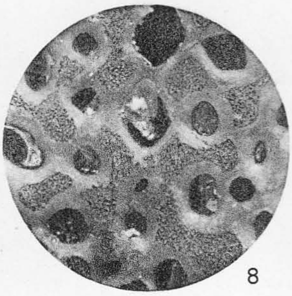
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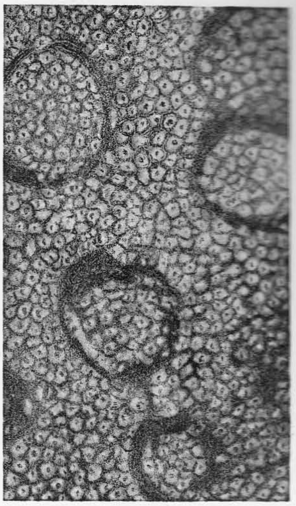
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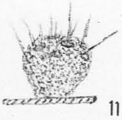
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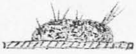
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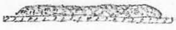
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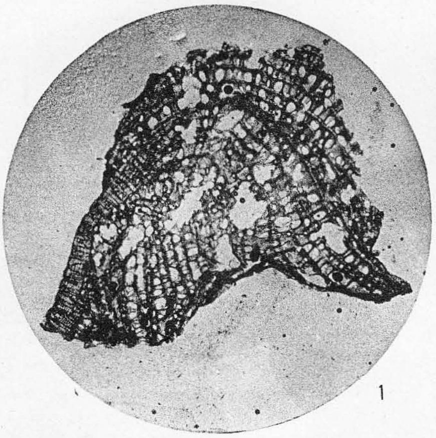
Emiliani, *Homotrema rubrum*



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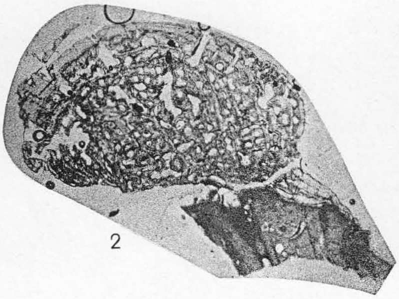

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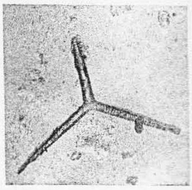

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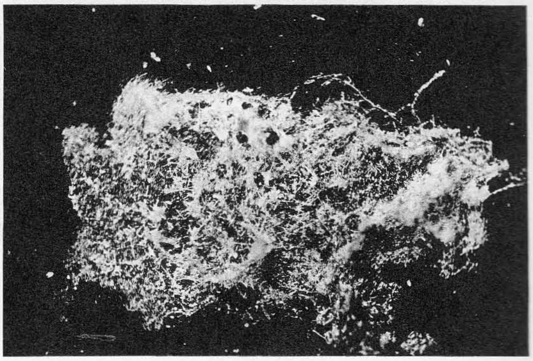

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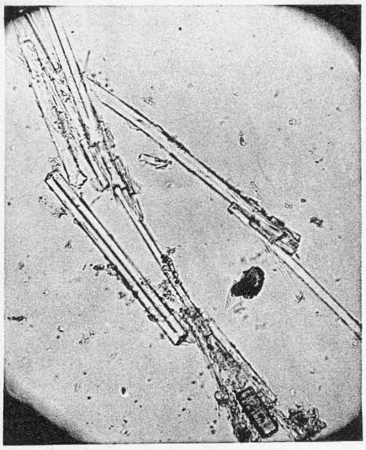

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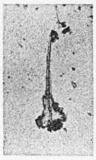

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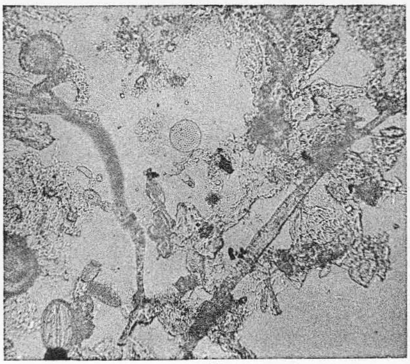

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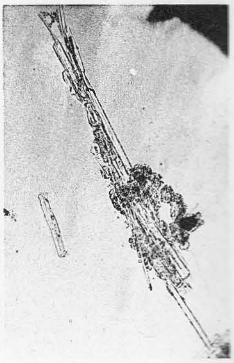

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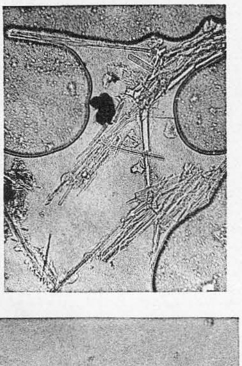

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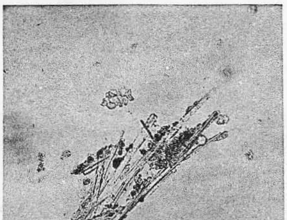

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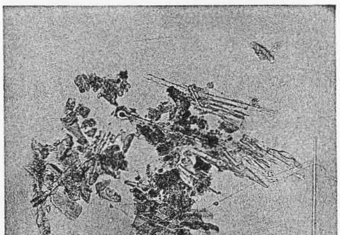

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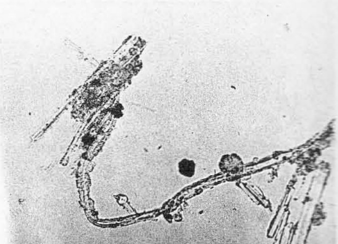

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Manuscript received March 10, 1951

RECENT LITERATURE ON THE FORAMINIFERA

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

COGGI, LEONIDA, and ENRICO di NAPOLI ALLIATA. Pliocene e Pleistocene nel Colle di S. Colombano al Lambro (Lombardia).—International Geol. Congress. Rept. 18th Session, pt. 9, Proc. Sec. H, 1950, pp. 19-25.—Foraminifera are listed.

PANNEKOEK, A. J., and J. H. van VOORTHUYSEN. Some Remarks on the marine lower Pleistocene of the Netherlands.—International Geol. Congress, Rept. 18th Session, pt. 9, Proc. Sec. H, 1950, pp. 74-77, figs. 1, 2.—Cold-water and lagoonal species of foraminifera indicate that the Pliocene-Pleistocene boundary should tentatively be placed at the base of the Amstelian. A graph shows percentage distribution of foraminifera in a boring.

RUGGIERI, G., and R. SELLI. Il Pliocene e il Postpliocene dell' Emilia.—International Geol. Congress, Rept. 18th Session, pt. 9, Proc. Sec. H, 1950, pp. 85-93.—Foraminifera are mentioned.

THALMANN, HANS E. Foraminiferal Evidence for Pliocene-Pleistocene Boundary (abstract).—International Geol. Congress, Rept. 18th Session, pt. 9, Proc. Sec. H, 1950, p. 100.—A number of index genera are mentioned.

van der VLERK, I. M. Correlation between the Plio-Pleistocene deposits in East Anglia and in the Netherlands. —International Geol. Congress, Rept. 18th Session, pt. 9, Proc. Sec. H, 1950, pp. 101-106, figs. 1, 2.—Foraminifera are mentioned.

de GAONA, M. RUIZ. Sobre algunas monstruosidades en los "Nummulites" Españoles.—Instit. Geol. Min. España, Libro Jubilar, vol. 1, 1950, pp. 69-98, pls. 1-3, text figs. 1-3.—Abnormalities in embryonic chambers are explained as due to the simultaneous development of two individual spores.

COLOM, G. Sobre la extensión e importancia de los calizas con "Nannoconus" en el Apenino Central (Italia). —Instit. Geol. Min. España, Libro Jubilar, vol. 1, 1950, pp. 99-120, pls. 1-4, text fig. 1.

EXPLANATION OF PLATE 16

Homotrema rubrum (Lamarck)

FIGS.		PAGE
1.	Section of an entire specimen, Locality L3, × 14.	145
2.	Section of an entire specimen, Locality L1, × 14.	145
3.	Calcareous triaxial spicule, Locality L2, × 100.	145
4, 9.	Siliceous sponge spicules showing inner canals and occasionally round heads, Locality L2, × 125.	
5.	Two cemented sponge spicules with their protoplasmic base. They were attached to the outer surface of a well protected specimen, Locality L2. × 57.	145
6.	Residue after dissolving in HCL part of a specimen carrying profuse spicules on its outer wall. The protoplasmic base and a great number of spicules are visible, Locality L2, × 33.	145
7, 10-12.	Same as figs. 4 and 9. Figure 7 shows a broken calcareous triaxial spicule. This is particularly evident because of its higher index of refraction, Locality L2, × 125.	145
8.	Residue after dissolving a specimen in HCL, radiolaria and diatoms are visible, × 142.	146

GRIMSDALE, T. F. **Hantkeninella** Bronnimann, a synonym of **Hantkenina** Cushman (Foraminifera, Eocene). —Ann. Mag. Nat. Hist., ser. 12, vol. 4, March 1951, pp. 292-294, pl. 8.

RAU, WELDON W. Tertiary Foraminifera from the Willapa River Valley of southwest Washington.— Journ. Pal., vol. 25, No. 4, July 1951, pp. 417-453, pls. 63-67, text figs. 1-3.—Eighty-one species, 7 new, are discussed and illustrated from strata ranging in age from upper Eocene to lower Miocene.

BANDY, ORVILLE L. Upper Cretaceous Foraminifera from the Carlsbad area, San Diego County, California.—Journ. Pal., vol. 25, No. 4, July 1951, pp. 488-513, pls. 72-75, text figs. 1, 2, table 1.—Fifty-six species and varieties, 9 species and 5 varieties new, are described and figured.

McLAUGHLIN, KENNETH P., and MERTON E. SIMONS. Upper Paleozoic microfossils from Stevens County, Washington.—Journ. Pal., vol. 25, No. 4, July 1951, pp. 514-519, pl. 76, tables 1, 2.—One fusulinid species is discussed and illustrated.

EMILIANI, CESARE. Notes on thin sectioning of smaller Foraminifera.—Journ. Pal., vol. 25, No. 4, July 1951, pp. 531, 532.

McLEAN, JAMES D. Jr. **Cibicides** or **Eponides cocoaensis** Cushman.—Journ. Pal., vol. 25, No. 4, July 1951, pp. 534, 535.

HANZAWA, SHOSHIRO. Recent and fossil **Cycloclypeus** from the Ryukyu Islands and their adjacent sea. —Short Papers from the Institute of Geology and Paleontology, Tôhoku Univ., Sendai, No. 3, July 20, 1951, pp. 1-12, pls. 1, 2, text figs. 1-10.—Detailed description and illustration of **Cycloclypeus guembelianus**, including abnormalties.

Fossil Foraminifera from Angaur Island.—Short Papers from the Institute of Geology and Paleontology, Tôhoku Univ., Sendai, No. 3, July 20, 1951, pp. 109-126. —Species are listed from numerous thin-section samples and interpretations made as to origin of the formations.

ASANO, KIYOSHI. Recent and Tertiary **Cyclammina** from Japan and the adjacent regions.—Short Papers from the Institute of Geology and Paleontology, Tôhoku Univ., Sendai, No. 3, July 20, 1951, pp. 13-24, pls. 3, 4.—Six Recent and nine fossil species, none new, are recorded and illustrated.

UCHIO, TAKAYASU. New species and genus of the Foraminifera of the Cenozoic formations in the middle part of the Boso Peninsula, Chiba-ken, Japan.—Trans. Proc. Palaeont. Soc. Japan, n. ser., No. 2, June 1951, pp. 33-42, pl. 3, 2 text figs.—Fourteen species and varieties, 6 species and 4 varieties new, are described and illustrated. An English description is given for the recently proposed genus **Pseudoeponides.**

New species of Foraminifera of the Miocene age in Tochigi Prefecture, Japan.—Journ. Geol. Soc. Japan, vol. 57, No. 671, August 1951, pp. 369-377, pl. 5, text figs. a-c.—Nine species and two varieties, all new, are described and figured, and a new name is proposed.

PHLEGER, FRED B. Ecology of Foraminifera, Northwest Gulf of Mexico.—Mem. 46, Geol. Soc. America, Sept. 14, 1951, Part I. Foraminifera distribution, 88 pp., 2 pls., 33 text figs., 37 tables.—An important study of foraminiferal populations as represented by living specimens and empty tests and as taken from the water as well as the bottom sediments and submarine cores. Benthonic depth facies are recognized and late glacial conditions are interpreted in the cores.

PHLEGER, FRED B, and FRANCES L. PARKER. Ecology of Foraminifera, Northwest Gulf of Mexico.— Mem. 46, Geol. Soc. America, Sept. 14, 1951, Part II. Foraminifera Species, 64 pp., 20 pls.—One hundred ninety-one species and varieties, 37 new, are systematically recorded and illustrated.

ALLEMANN, FRANZ, RUDOLF BLASER, and PAUL NÄNNY. Neuere Untersuchungen in der Vorarlberger Flyschzone.—Eclogae Geol. Helvetiae, vol. 44, No. 1, Sept. 15, 1951, pp. 159-168, text figs. 1-7, table 1.— Foraminifera are mentioned and figured in section.

RUTH TODD