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301. LOWER PERMIAN (WOLFCAMPIAN) FUSULINIDS FROM THE BIG HATCHET MOUNTAINS, SOUTHWESTERN NEW MEXICO

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ABSTRACT

New fusulinids from the Lower Permian (Wolfcampian) portion of the Horquilla Limestone in the Big Hatchet Mountains of southwestern New Mexico include **Triticites (Leptotriticites) hatchetensis**, n. subgen., n. sp.; **L. gracilitatus**, n. sp.; **Rugosochusenella zelleri**, n. gen., n. sp.; and **Biwaella americana**, n. sp. In addition, topotypes from Japan of **Biwaella omiensis** Morikawa and Isomi, the type species, are described and illustrated for purposes of comparison.

Leptotriticites occurs widely over the midcontinent region and ranges stratigraphically throughout the Wolfcampian; **Biwaella** and **Rugosochusenella** are known only from the **Pseudoschwagerina** zone. These fusulinids are considered to be important for worldwide correlations and phylogenetic interpretations.

INTRODUCTION AND ACKNOWLEDGEMENTS

During the course of a relatively comprehensive investigation of fusulinids from the Pennsylvanian and Permian rocks of the Big Hatchet Mountains of New Mexico, several distinctive types occurring in Lower Permian (Wolfcampian) beds have been noted that merit consideration at this time. The forms here discussed belong to *Biwaella* Morikawa and Isomi (1960), *Triticites* (*Leptotriticites*), n. subgen., and *Rugosochusenella*, n. gen. All are considered Lower Permian in age.

The genus *Biwaella* Morikawa and Isomi has, until now, been known only from the Lower Permian of Japan and Yugoslavia. Its discovery, therefore, in Lower Permian (Wolfcampian) rocks of the Big Hatchet Mountains is considered of importance in gaining a better understanding of correlations within the Permian on a worldwide basis.

A hitherto unknown genus, described as *Rugosochusenella*, n. gen., occurs generally in about the same part of the section as *Biwaella*, and is considered to be important for a better appreciation of phylogenetic trends among the fusulinids.

Numerous species of *Triticites* (*Leptotriticites*), n. subgen., occur throughout the Wolfcampian in the Big Hatchet Mountains. Two species have been chosen for inclusion here to show the range of variation within *Leptotriticites*. This subgenus includes those Permian species which Thompson (1954) referred to *Dunbarinella*.

The Big Hatchet Mountains (text-fig. 1) are part of the Basin and Range province and are the result of a series of orogenies beginning in the Cretaceous, followed by block-faulting in Tertiary to Recent time. In the Big Hatchet Peak Quadrangle nearly 20,000 feet of Paleozoic and Cretaceous rocks rest on Precambrian granite and are overlain by Tertiary volcanics (Zeller, 1958).

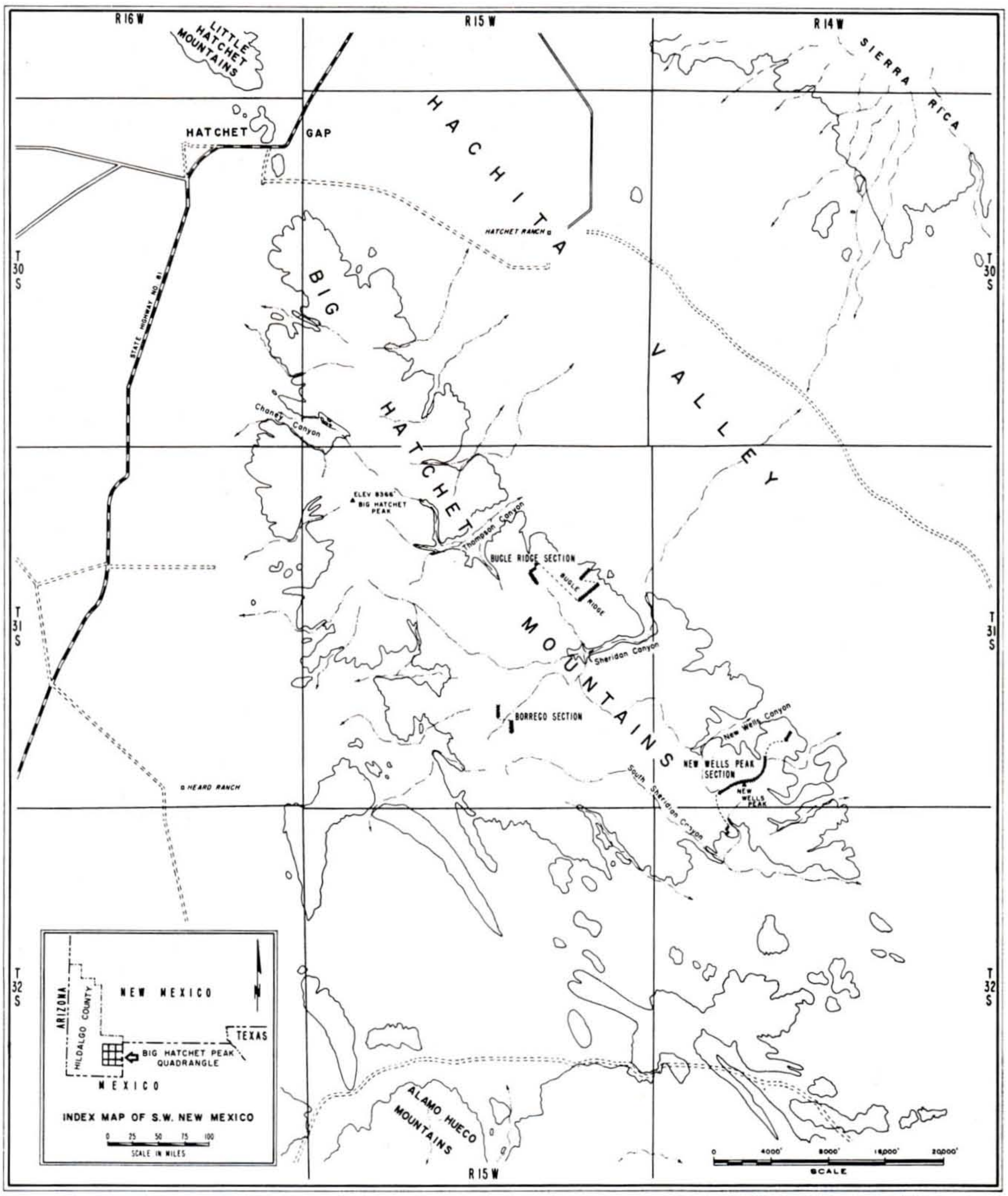
Pennsylvanian rocks are approximately 2,400 feet thick and Permian beds are about 5,400 feet thick in the Big Hatchet range. The Horquilla Limestone, which includes the entire Pennsylvanian and the Wolfcampian part of the Lower Permian section in this area, is approximately 3,200 feet thick and is nearly all carbonate. This thick unit contains abundant fusulinids throughout, a circumstance which facilitates a detailed analysis of these foraminifers.

The Horquilla Limestone rests on the Paradise Formation of Mississippian (Chesteran) age throughout the range and is overlain by the Earp Formation of Permian age. Earp facies, composed of shale and siltstone, and some limestone, apparently replaces upper Horquilla beds in a westerly direction. The top of the Horquilla is Pennsylvanian (Virgilian) in age in the Chiricahua Mountains of southeastern Arizona (Sabins, 1957; Sabins and Ross, 1963). This change is probably more abrupt than it would first appear, inasmuch as in the Peloncillo Mountains, near the Arizona-New Mexico state line, Gillerman (1958) found Earp-Horquilla age relationships more nearly like those of the Big Hatchet Mountains than of the Chiricahua Mountains.

We express our thanks to Dr. Robert A. Zeller, Jr. for providing us with many collections of Big Hatchet fusulinids and for his continuing help in our studies. Dr. Zeller's material has been supplemented by extensive collections of our own; consequently, we have at our disposal a truly notable amount of material. Thanks are given to Dr. Haruyoshi Fujimoto and Dr. Hisayoshi Igō of the Tokyo University of Education for sending us Japanese material for comparative purposes, and to Dr. Russell M. Jeffords, who critically read the manuscript. In addition, we are indebted to Humble Oil and Refining Company for permission to publish this study. All figured specimens are deposited in the files of Humble Oil and Refining Company, Midland, Texas.

STRATIGRAPHIC AND PALEONTOLOGIC CONSIDERATIONS

Biwaella omiensis was described as the type species of the genus by Morikawa and Isomi (1960).



TEXT FIGURE 1

Index Map of the Big Hatchet Peak Quadrangle.

Their material came from the Lower Permian (Wolfcampian) Samegai Formation of Japan. A comparison of topotype material of *B. omiensis* with *B. americana,* n. sp., indicates that the two species are congeneric. The genus is similar to *Schubertella* in coiling and size, but the wall structure is clearly of the schwagerinid type. *B. americana,* n. sp. is the first species of the genus to be described from the western hemisphere. A third species, *B. europaea* Kochansky-Devidé and Milanović (1962) was described from Lower Permian rocks in central Crna Gora (Montenegro), Yugoslavia.

In Japan, *Biwaella omiensis* Morikawa and Isomi was found with *Pseudoschwagerina, Paraschwagerina* and *Misellina.* In Yugoslavia, *B. europaea* Kochansky-Devidé and Milanović occurs with species of *Pseudofusulina* (*Rugosofusulina* of authors), *Schwagerina,* and *Schubertella. B. americana,* n. sp., is also found with species of *Pseudofusulina, Schwagerina* and *Schubertella* in the zone of *Pseu-*

doschwagerina of the Big Hatchet Mountains. Thus, the stratigraphic position of *Biwaella* is reasonably well established as Lower Permian (Wolfcampian).

Among the collections available for this study are fusulinids that represent an undescribed genus, which is described here as *Rugosochusenella zelleri*, n. gen., n. sp. This genus is similar to *Chusenella* Hsu in the tight coiling of the inner volutions and nearly plane septa in the early stages accompanied by chomata deposits. *Rugosochusenella* also resembles *Pseudofusulina* Dunbar and Skinner in that its shell wall displays "rugosity," or a "cobblestone-like surface," irregularly fluted septa, and coarsely alveolar walls.

In the Big Hatchet Mountains, *Rugosochusenella* occurs with species of *Pseudoschwagerina, Paraschwagerina, Schwagerina, Pseudofusulina, Triticites* (*Leptotriticites*), n. subgen., and *Schubertella*. It, too, then is clearly Lower Permian (Wolfcampian) in age. *Rugosochusenella* has not been identified definitely elsewhere, but may well include species which have been described in the literature under the genera *Schwagerina* and *Chusenella*.

Many workers have questioned the generic importance of "rugosity" in the various forms which display this character (e.g., *Pseudofusulina* Dunbar and Skinner [*Rugosofusulina* of authors] and *Hidaella* Fujimoto and Igō). The important point, however, is whether such characters are present wherever a given species is encountered. Certainly enough is known about the geographic and stratigraphic distribution of the numerous species of *Pseudofusulina* that little question remains as to the validity of this genus.

Hidaella has only recently become known (Fujimoto and Igō, 1955), and is not so well documented; but topotype specimens of the type species, *H. kameii*, show consistent furrowing of the walls. In the same manner, all specimens of *Rugosochusenella* seen in the Big Hatchet Mountains, regardless of location in the range, display the furrowing, or "rugosity." As this new genus is recognized and documented elsewhere, it is expected that such features will hold true.

Thompson (1954) referred a large number of species of *Triticites* to the genus *Dunbarinella*, which he had described earlier (Thompson, 1942) from Virgilian rocks. Species of this genus are widespread in Upper Pennsylvanian (Virgilian) rocks over much of the midcontinent.

The large group of Lower Permian species of *Triticites* which Thompson (1954) assigned to *Dunbarinella* is here regarded more properly assignable to *Triticites* (*Leptotriticites*), n. subgen., with *L. hatchetensis*, n. sp., as the type species. Reasons for such assignment are: (1) *Dunbarinella* is a well-recognized Pennsylvanian (Virgilian) genus of fusulinids whose species are widespread and constitute a distinctive group because of a combination of features including extremely tight coiling of the inner ovoid-shaped volutions, minute proloculus, lack of well-developed chomata deposits, *Schwagerina*-like fluting of the septa, and heavy axial filling. *Dunbarinella*, therefore, is related closely to the *Schwagerina* stock. (2)*Leptotriticites* is characterized by the presence of massive chomata deposits, slender fusiform to sub-globular shape, and thin walls which are very finely alveolar; thus, *Leptotriticites* belongs clearly to the *Triticites* stock and species of *Leptotriticites* have, in fact, been classified with *Triticites* for many years. (3) *Leptotriticites* is restricted apparently to rocks of Lower Permian (Wolfcampian) age, ranging throughout that unit; therefore, like *Dunbarinella* (s. s.), *Leptotriticites* can be very useful stratigraphically.

Because of close affinities between *Triticites* and *Leptotriticites,* the latter seems best considered a subgenus, at least for the present. *Leptotriticites* is equally distributed throughout the Wolfcampian, whereas the typical form of the genus, i.e., *Triticites* (*Triticites*), occurs most commonly in the lower part of the Wolfcampian.

In the Big Hatchet Mountains *Leptotriticites* is found near the base of the Wolfcampian associated with species of *Triticites* (*Triticites*), *Schwagerina, Pseudofusulina,* and *Schubertella.* Higher in the section it occurs with species of *Pseudoschwagerina* and *Paraschwagerina.*

The new species described below come from three measured sections of the Wolfcampian portion of the Horquilla Limestone (text-fig. 2). The stratigraphic position of each species is shown by name and sample number. Geographic location of each of the measured sections is indicated with each section, and diagrammatically (text-fig. 1).

SYSTEMATIC PALEONTOLOGY

Genus **Biwaella** Morikawa and Isomi, 1960

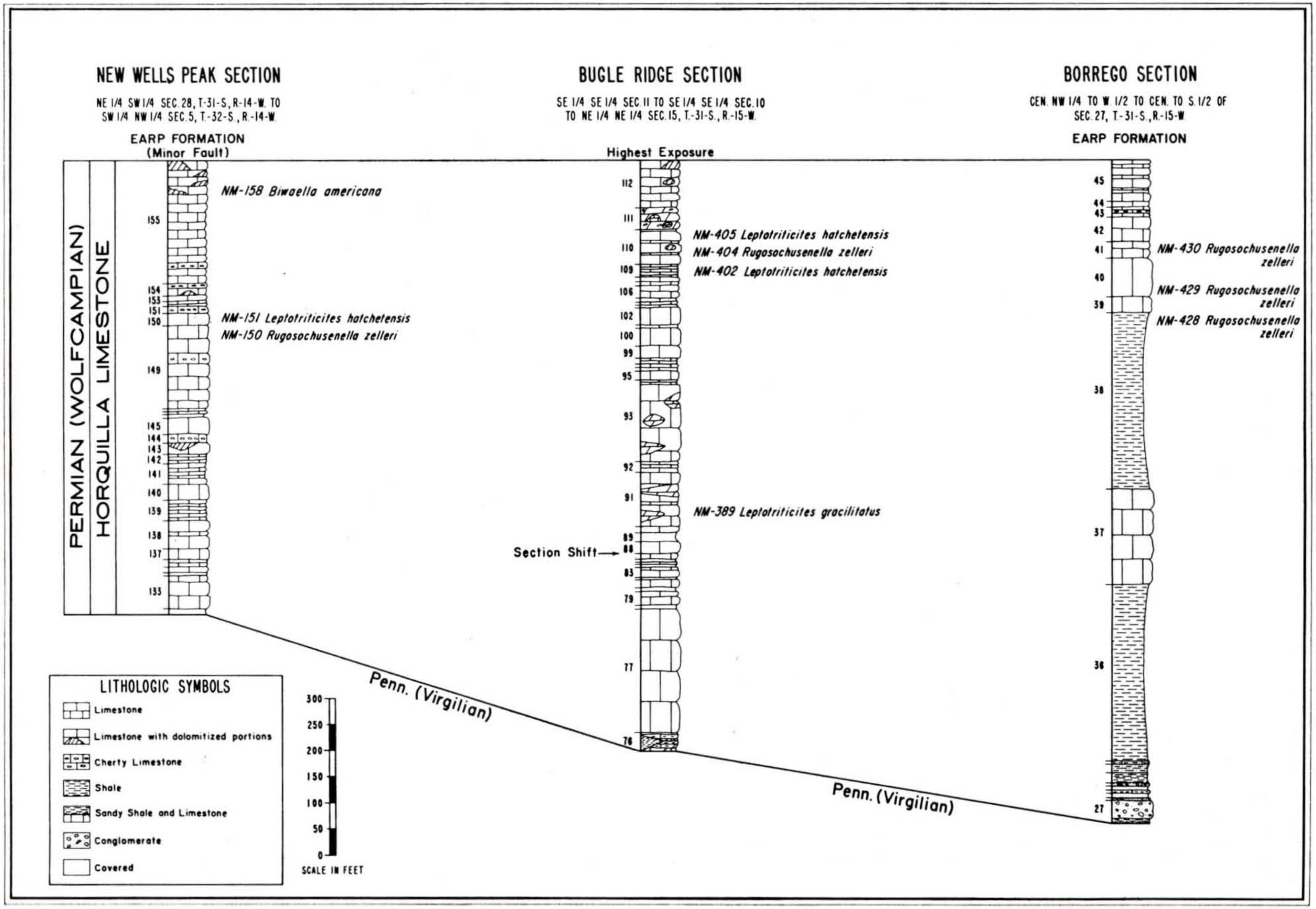
Biwaella omiensis Morikawa and Isomi

Plate 13, figures 1-6

Biwaella omiensis MORIKAWA and ISOMI, 1960, p. 301-305, pl. 54, figs. 1-5.

The following description is based on that given by Morikawa and Isomi (1960) and on topotype specimens which were available for this study:

Shell very small, fusiform to elongate fusiform, with bluntly pointed poles. Axis of coiling straight to slightly irregular, with first whorl commonly askew to the outer volutions. Equatorial region slightly inflated, lateral slopes convex to slightly concave. Mature specimens of 4 to 5½ volutions measure 1.60 to 3.20 mm. in length and 0.50 to 0.90 mm. in diameter. The best four specimens available for this study, however, are generally smaller than the figures given by Morikawa and Isomi. Such speci-



TEXT FIGURE 2

Measured sections of the upper Horquilla Limestone, Permian (Wolfcamp), Big Hatchet Mountains, New Mexico, showing stratigraphic position of fusulinids described in this paper. (After Robert A. Zeller, Jr., 1958).

mens measure 1.60 to 1.84 mm. in length, and 0.62 to 0.73 mm. in diameter, and the form ratio varies from 2.4 to 2.9. The form ratios given in the original diagnosis varied from 2.1 to 4.2. The authors stated, however, that "considerable variation in shell shape appears at maturity, being represented by short inflated shells associated with elongate, very slender shells" (p. 304).

The thin spirotheca is composed of a tectum and poorly differentiated keriotheca. Alveoli, however, may be observed in the outer volutions of most specimens. Thickness of the spirotheca in the outer volutions is about 30 to 40 microns. The septa are relatively thin and plane, tending to arch forward, and the septal furrows are deep, giving the chambers a vaulted appearance. Septa average 7, 10, 10, 11, and 10, in the first to fifth volutions, respectively.

Proloculus is minute, its outside diameter varying from 45 to 63 microns. Tunnel is moderately wide and is about one-half to two-thirds as high as the chambers. The tunnel angle varies from 44 to 78 degrees in the fourth whorl. Chomata are poorly defined in the innermost whorls, but are very prominent and strongly asymmetrical in the outer volutions. On the tunnel side the chomata are steep to overhanging, and are steep to broadly sloping on the polar sides.

Discussion.—As understood presently, *Biwaella omiensis* seems to vary considerably in size and general shape. Whether more than one species is represented is difficult to determine; accordingly, a relatively wide latitude is preferred until more is known about these unusual fusulinids.

Biwaella omiensis is not likely to be confused with any previously described species. The genus differs from *Schubertella* Staff and Wedekind and *Mesoschubertella* Kanuma and Sakigama in having a schwagerinid wall structure, and from *Oketaella* Thompson in the *Schubertella*-like coiling and proloculus size relative to size of shell. *Toriyamaia* Kanmera differs from *Biwaella* in wall structure and general development of the shell. *Toriyamaia* is clearly related more closely to *Rauserella* Dunbar and *Leëlla* Dunbar and Skinner.

Occurrence.—The holotype and three of the figured paratypes are stated by Morikawa and Isomi to have come from Minamitoba. One of the figured paratypes came from Yadani. Specimens available for the present study (Coll. J-124) were collected from the Samegai Formation, Minamitoba, Shiga Prefecture, Japan, and represent topotypes.

Biwaella americana Skinner and Wilde, n. sp.

Plate 13, figures 7-16

Shell minute, subcylindrical to cylindrical, with bluntly rounded poles. Axis of coiling straight to only slightly irregular, with the first volution often coiled askew to the outer whorls. Mature specimens of 4 to 5 volutions measure 1.57 to 2.25 mm. in length, and 0.50 to 0.75 mm. in diameter, giving a form ratio of 2.85 to 4.34.

Spirotheca, which is composed of a tectum and a keriotheca, measures 19 to 27 microns and 32 to 43 microns in thickness in the third and fourth whorls, respectively. The septa are plane and thin, averaging 7 in the first whorl, 10 in the second, 11 in the third, and 10 in the fourth. One large specimen possibly has 13 septa in the fifth volution.

Proloculus is minute, measuring 47 to 67 microns in outside diameter, and it is spherical. The tunnel is extremely wide in the outer whorls, measuring 81 to 102 degrees in the two best specimens available. Most specimens, however, are difficult to measure for tunnel angle because of a great amount of crushing and distortion. The tunnel is high in most volutions, being about two-thirds as high as the chambers. The chomata are not prominent, but where present are commonly steep to overhanging on the tunnel side with steep slopes on the poleward sides.

Discussion.—Measurements of the overall size for *Biwaella americana* and *B. omiensis* Morikawa and Isomi differ but little. The essential differences, however, are their shape and tunnel angles. *B. omiensis* is fusiform or subfusiform with bluntly pointed poles, whereas *B. americana* is subcylindrical to cylindrical with rounded polar extremities. This difference in shape holds true for all stages of growth. The tunnel angle of *B. omiensis* averages about 55 degrees, whereas that of *B. americana* averages about 90 degrees.

Biwaella europaea Kochansky-Devidé and Milanović has a greater average length and width than *Biwaella americana,* and also is thicker for its length; consequently it has a smaller form ratio. The proloculus of *B. europaea* is smaller, too, than that of *B. americana.* Averages of the measurements of the three specimens given by Kochansky-Devidé and Milanović (1962, p. 207) are as follows: length, 2.6 mm.; width, 1.2 mm.; form ratio, 2.4; proloculus size, 39 microns; wall thickness, 30 microns in the third whorl, and 41 microns in the fourth whorl.

Occurrence.—All the material on which the description of *B. americana* is based came from collection NM-158 of the New Wells Peak section, from the upper part of Zeller's bed 155, where it occurs with *Schwagerina, Pseudofusulina,* and *Schubertella.*

Genus **Triticites** Girty, 1904

Subgenus **Leptotriticites** Skinner and Wilde, n. subgen.

Type Species: *Leptotriticites hatchetensis* Skinner and Wilde, n. sp.

Diagnosis.—Shells of small to large size, varying from elongate subcylindrical to subglobose shape. Axis of coiling generally straight and polar extremities sharply pointed, but not uncommonly bluntly pointed, with concave to convex lateral slopes. Most species seemingly are inflated fusiform with sharply pointed poles. Mature shells vary from 6 to 13 volutions, measuring 3.8 to 11.1 mm. in length and 1.4 to 4.2 mm. in width. Form ratios vary from 1.30 to 3.4.

A distinctive feature of *Leptotriticites* is the thinness of the spirotheca, which gives most species a delicate appearance. For 12 known species, the thickness in the outer volutions does not exceed 80 microns, and is normally 65 to 70 microns. The spirotheca, which is composed of tectum and keriotheca, is often exceedingly thin and poorly differentiated. The keriotheca is finely alveolar in all known species, and alveoli are commonly not discernible at all in the early whorls of most species.

Septa are numerous and rather closely spaced. They are strongly fluted from pole to pole, although fluting is more intense in the polar region where the folds extend nearly to the tops of the chambers.

Proloculus is normally quite small, varying from 65 to 220 microns, but usually not exceeding 150 microns. The proloculus is spherical and its small size relative to the size of shell is typical for the subgenus. The tunnel is normally about half as high as a given whorl.

The tunnel angle is nearly always very narrow, with a maximum of 40 degrees in the last volution of a number of species. Chomata deposits are massive and typically blocky in outline as seen in axial sections. The chomata extend commonly to the tops of whorls.

Discussion—*Triticites* (*Leptotriticites*) is distinguished by the following combination of characters: thin, poorly developed schwagerinid walls, small proloculus, massive chomata, intensity of septal fluting, and narrow tunnel. Reasons for not including species of *Leptotriticites* in *Dunbarinella* Thompson have already been discussed and hardly need repeating here. *Leptotriticites* differs from the typical subgenus, *Triticites* (*Triticites*) Girty in its thin and poorly developed wall, the intensity of its septal fluting, massive chomata, and narrower tunnel.

Elongate species of *Leptotriticites,* which are not common, resemble *Kansanella* Thompson superficially. A look at the following comparisons of characteristics serves to show the many differences.

	Leptotriticites	*Kansanella*
SHELL SHAPE:	Typically inflated fusiform with pointed poles and regular lateral slopes.	Elongate, subcylindrical with irregular slopes.
SEPTA:	Strongly, but regularly fluted.	Strongly, but very irregularly fluted.
CHOMATA:	Massive.	Poorly to moderately developed.
TUNNEL:	Typically narrow.	Typically rather wide.

Leptotriticites is closer to *Iowanella* in shape, chomata deposits, and tunnel angle, but *Iowanella* has intense but highly irregular septal fluting. The walls of *Iowanella* are much more primitive and poorly developed than in *Leptotriticites. Kansanella* and *Iowanella* occupy stratigraphic positions well below that of *Leptotriticites. Kansanella* occurs in Pennsylvanian (Missourian-Virgilian) rocks and *Iowanella* apparently is confined to a position low in the Missourian Series. Both *Kansanella* and *Iowanella* are perhaps better understood as subgenera of *Triticites* than as separate genera. It is quite possible also that *Leptotriticites* emerged near the beginning of the Permian from a *Kansanella-Iowanella* stock.

Wilde (1955) suggested tentatively that *Pseudofusulinella* Thompson (1951) might have developed from the group described here as belonging to *Leptotriticites* because of superficial resemblances and supposed replacement of *Leptotriticites* by *Pseudofusulinella* during late Wolfcampian time. It is now known that *Pseudofusulinella* is related more closely to the Pennsylvanian *Waeringella* stock; and it is known also that *Pseudofusulinella* developed before *Leptotriticites* first appeared. Another difficulty in accepting the thesis would be the necessity to reverse an evolutionary pattern of development of wall structure. For these reasons, the idea is abandoned here in favor of homeomorphy as a better explanation for similarities between *Pseudofusulinella* and *Leptotriticites.*

The following species are considered here as belonging definitely to *Leptotriticites:*

L. fivensis (Thompson), 1954
L. americanus (Thompson), 1954
L. eoextentus (Thompson), 1954
L. extentus (Thompson), 1954
L. hughesensis (Thompson), 1954
L. glenensis (Thompson), 1954
L. wetherensis (Thompson), 1954
L. obesus (Beede), 1916
L. tumidus (Skinner), 1931
L. koschmanni (Skinner), 1931
L. victorioensis (Dunbar and Skinner), 1937
L. brownvillensis (Douglass), 1962

Geologic age and distribution.—Lower Permian (Wolfcampian) of south central and southwestern United States.

Leptotriticites hatchetensis Skinner and Wilde, n. sp.

Plate 14, figures 6-15

Shell of medium to large size, highly inflated fusiform with pointed poles. Lateral slopes convex to concave and the axis of coiling is straight, except in the case of possibly microspheric individuals whose innermost whorls are askew to the outer volutions. Mature shells of 10½ to 12½ volutions are 4.80 to 7.05 mm. in length and 3.80 to 4.05 mm. in diameter. Form ratio varies from 1.30 to 1.74. One possible microspheric specimen (pl. 14, figs. 10, 14) is somewhat smaller, but it has fewer whorls than most of its megalospheric counterparts. It has 10½ whorls, is 3.50 mm. long and measures 2.70 mm. in diameter, giving a form ratio of 1.30.

The spirotheca is thin and composed of a tectum and finely alveolar keriotheca. In the tenth volution its thickness varies from 46 to 62 microns. The septa are quite numerous, closely spaced, and rather strongly folded throughout most of the shell. Septal folds, however, increase in intensity poleward where they extend to the tops of chambers and form rounded chamberlets. The septa number about 7 in the first whorl, 10 in the second, 15 in the third, 18 in the fourth, 20 in the fifth, 21 in the sixth, 25 to 33 in the seventh, 31 to 38 in the eighth, 37 to 44 in the ninth, 38 in the tenth, and approximately 44 in the eleventh volution.

The proloculus is small, and ranges from 75 to 124 microns in outside diameter. The tunnel is narrow and is one-half to two-thirds as high as the chambers. Tunnel angle varies from 18 to 23 degrees in the tenth volution and is rather constant at 19 degrees in the eleventh. Chomata are very massive and blocky in appearance. Their lateral slopes are usually steeply concave poleward, but commonly are straight to overhanging in that direction. They are normally straight to overhanging on the tunnel side.

Discussion.—In shape, *Leptotriticites hatchetensis* belongs among the most obese species of the subgenus. It does, however, display all the characteristics attributable to the group, hence its choice as type species.

Leptotriticites hatchetensis superficially resembles *L. tumidus* (Skinner) and might easily be confused with that form. *L. tumidus,* however, is larger at all stages of growth than *L. hatchetensis.* Mature shells of *L. tumidus* have fewer whorls, 7 to 10½, yet average 2 to 3 mm. greater length than mature shells of *L. hatchetensis.* The tunnel is narrower and the chomata are distinctly more massive in *L. hatchetensis* than in *L. tumidus.*

Possibly the specimens described recently as *Triticites tumidus* by Sabins and Ross (1963) actually belong with *Leptotriticites hatchetensis.* They give measurements of only 5.5 mm. length and 3.5 mm. diameter for specimens of 9 to 11 volutions. The wider tunnel angle and large proloculus of their only illustrated axial section prevents definite assignment, however, to *L. hatchetensis.*

Occurrence.—*Leptotriticites hatchetensis* occurs in collections NM-151 of the New Wells Peak section, and in NM-402 and NM-405 of the Bugle Ridge section. The holotype and all figured paratypes are from NM-151. Here *L. hatchetensis* occurs in association with species of *Pseudoschwagerina, Paraschwagerina,* and *Pseudofusulina.* NM-151 comes from Zeller's bed 150 of the New Wells Peak section; NM-402 comes from bed 109 and NM-405 comes from the uppermost massive limestone of bed 110 in Zeller's Bugle Ridge section.

Leptotriticites gracilitatus Skinner and Wilde, n. sp.

Plate 14, figures 1-5

Shell of medium to large size, elongate fusiform with sharply to bluntly pointed poles, and relatively straight axis of coiling. Specimens of 7½ to 8 volutions measure 8.00 to 9.75 mm. in length and 2.05 to 2.25 mm. in diameter. The form ratio varies from 3.63 to 4.56.

The spirotheca is composed of a tectum and a thin and finely alveolar keriotheca. In the sixth whorl, the thickness of the spirotheca varies from 47 to 62 microns. The septa are rather strongly and regularly fluted throughout the length of the shell. Commonly, the septal folding runs both vertically and horizontally so that closed chamberlets as seen in axial section rest one on top of another. Septal counts from the first through the ninth whorls number 9 to 12, 14 to 17, 16 to 20, 19 to 23, 19 to 25, 23 to 30, 25 to 33, 28, and 34, respectively.

Proloculi are spherical and small, varying in outside diameter from 91 to 136 microns. The tunnel is wide for the subgenus, but wider tunnels seemingly are characteristic of the more elongate species of most genera. The tunnel angle varies from 24 to 48 degrees in the seventh volution. Chomata are prominent, but not massive, and they are about one-half to two-thirds the chamber height in most whorls. The chomata vary a great deal in general shape, some being blocky and some triangular in outline as seen in axial sections.

Discussion.—*Leptotriticites gracilitatus* is not closely similar to any previously described species. *L. koschmanni* (Skinner) is larger and more inflated, and *L. victorioensis* (Dunbar and Skinner) is shorter at maturity and has a narrower tunnel than *L. gracilitatus.*

Occurrence.—This species is common in collection NM-389 of the Bugle Ridge section, where it occurs in the lower part of Zeller's bed 91. It has not been found in association with other fusulinids.

Genus **Rugosochusenella** Skinner and Wilde, n. gen.
Type species: *Rugosochusenella zelleri* Skinner and Wilde, n. sp.

Diagnosis.—Shell of medium to large size, elongate fusiform with straight axis of coiling. Mature shells of 6 to 8 volutions vary from 4.18 to 7.24 mm. in length and 0.93 to 2.43 mm. in diameter, giving form ratios which vary from 2.80 to 3.83. The first few volutions have very thin walls and are tightly coiled, so that a distinct juvenarium is suggested. There is no abrupt expansion of the shell following the tightly coiled portion, however.

Spirotheca is composed of a tectum and coarsely alveolar keriotheca. Not only are the septal furrows deeply indented, but the wall between septa is rather strongly furrowed both axially and transversely so that the spirotheca presents a rough pebblestone surface. Among fusulinid workers, such a wall structure has been referred to as *rugose*. Thickness of the spirotheca in the sixth whorl varies from 46 to 73 microns in the type species.

The septa are strongly and irregularly fluted throughout the length of the shell, except in the innermost whorls, where they are plane. The irregularly fluted septa, combined with the deeply furrowed spirotheca, give the shell an irregularly ragged appearance. Septal count in the type species averages 9, 14, 15, 17, 19, 22, 27, and 32 from the first to the eighth whorl, respectively.

Proloculus is small, measuring 97 to 161 microns in outside diameter. The tunnel is moderately wide, varying from 44 to 60 degrees in the sixth whorl, and its path is rather straight. Chomata are present in the early, tightly coiled volutions, but are generally lacking in the outer whorls. Where present in the outer whorls, they are poorly developed and are more properly considered pseudochomata.

Heavy deposits of secondary filling are present along the axis throughout the shell. In the outer whorls there is an extension of the secondary material away from the axial area. Along with this extension, the axial filling was deposited farther and farther away from the center of the shell as the latter increased in size. Consequently, the equatorial region of the shell has a rather open appearance except in the innermost whorls.

Comparisons.—Dunbar and Skinner (1931) erected the genus *Pseudofusulina,* with *P. huecoensis* Dunbar and Skinner as the generotype, for Permian fusulinids possessing a keriothecal spirotheca and strong septal fluting, but lacking cuniculi and having only weakly developed chomata or none at all. In 1936 these authors were enabled to study the type specimens of *Borelis princeps* Ehrenberg, which Möller (1877) had designated as the typical species of his genus *Schwagerina,* and concluded that *Pseudofusulina* is congeneric with Ehrenberg's species. Accordingly, they suppressed *Pseudofusulina* as a junior synonym of *Schwagerina* Möller. The following year Rauser-Chernoussova (1937) erected the genus *Rugosofusulina,* with *Alveolina prisca* Ehrenberg as the generotype, to embrace species which differ from *Schwagerina* principally in possessing a "rugose" spirotheca. Rauser recognized two general types of "rugosity." The first, which she regarded as more primitive, consists of "sharply expressed undulations of the whole wall," while the second consists of "rugosity of its surface due to the rugose structure of the tectum—the outside layer of the theca." Dunbar (1948) pointed out that the wall is not actually rugose, saying, "Since the wall appears to undulate, regardless of the orientation of the section, it is evident that the inequalities are of the nature of dimples and mounds rather than rugae." An examination of the exterior of specimens free of matrix shows that the "rugosity" is the result of narrow grooves or furrows which indent the spirotheca in both the axial and sagittal directions, producing a pebbled appearance much like that of a cobblestone pavement.

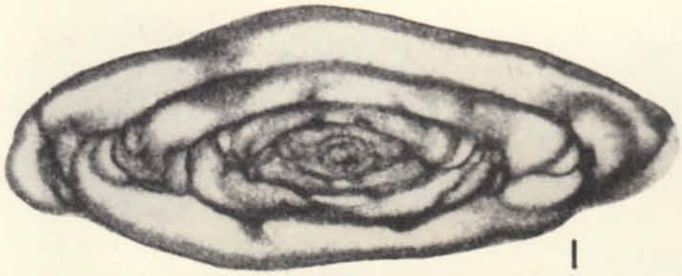
A recent re-examination of the type specimens of *Pseudofusulina huecoensis* has shown that it, too, possesses a "rugose" spirotheca of the sort in which the entire wall is involved. Consequently, since *Pseudofusulina* has a priority of some six years over *Rugosofusulina* the latter must be regarded as a junior synonym of the former, and the species which have been assigned to *Rugosofusulina* should be regarded as belonging in *Pseudofusulina.* Also, since *Pseudofusulina* differs from the generotype of *Schwagerina* in the character of its spirotheca it can no longer be regarded as a synonym of the latter.

EXPLANATION OF PLATE 13

Biwaella

(All × 40 except Fig. 16)

FIGS.		PAGE
1-6.	*Biwaella omiensis* Morikawa and Isomi. 1-4, axial sections of topotypes; 5, 6, sagittal sections of topotypes, Samegai Formation, Minamitoba, near Lake Biwa, Shiga Prefecture, Honshu, Japan (loc. J-124).	97
7-16.	*Biwaella americana* Skinner and Wilde, n. sp. 7, axial section of the holotype; 8-11, axial sections of paratypes; 12, tangential section of a paratype; 13-15, sagittal sections of paratypes; 16, same specimen as in fig. 7, enlarged, × 100. Horquilla Limestone, Big Hatchet Mountains, Hidalgo County, New Mexico (loc. NM-158).	99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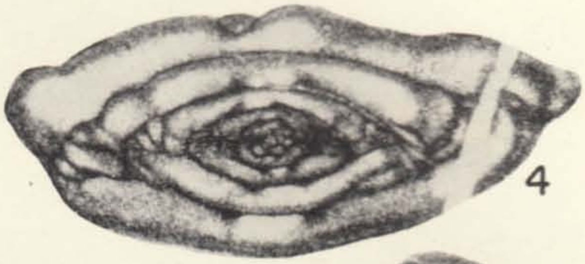
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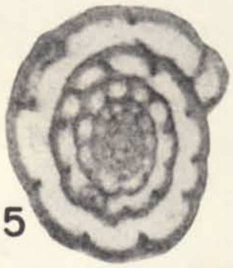
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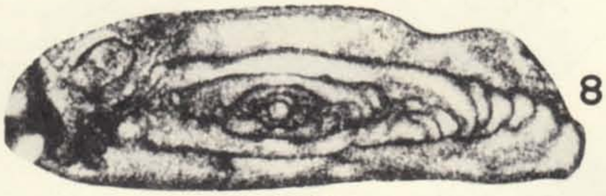
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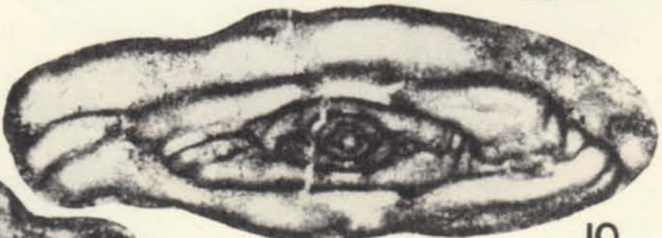
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Skinner and Wilde: Wolfcampian Fusulinids from New Mexico


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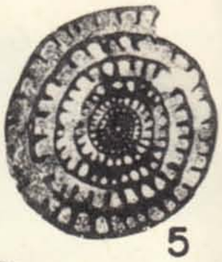
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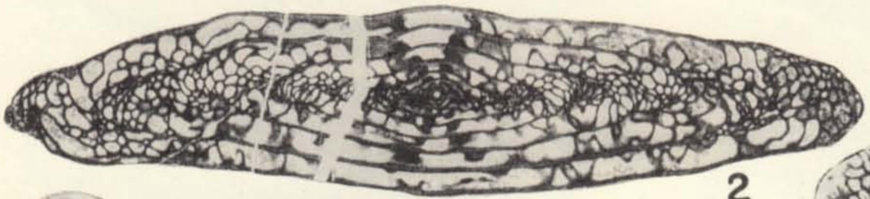
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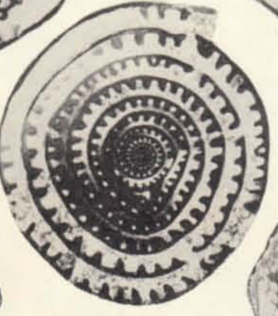
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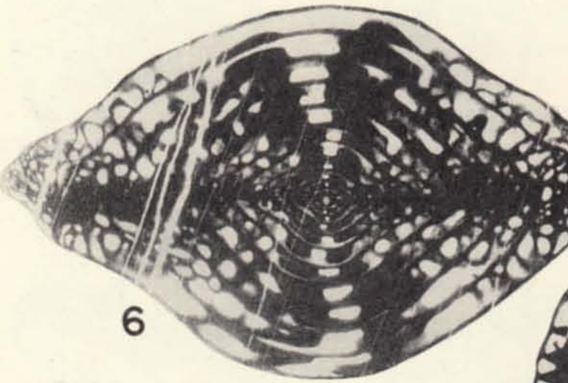
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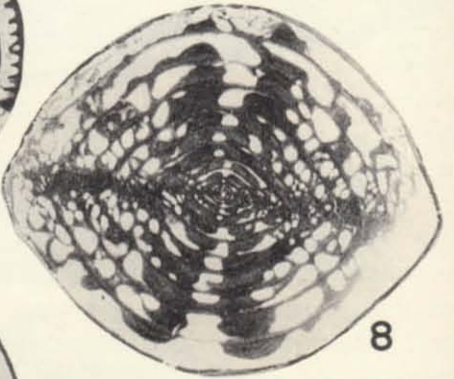
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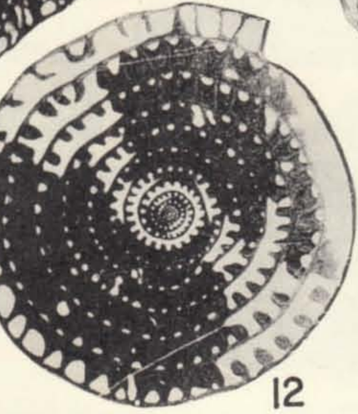
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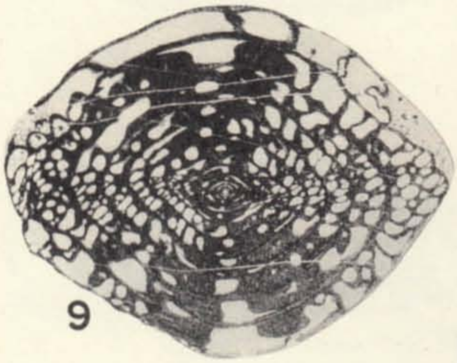
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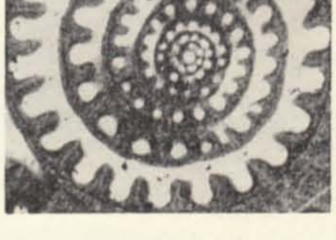
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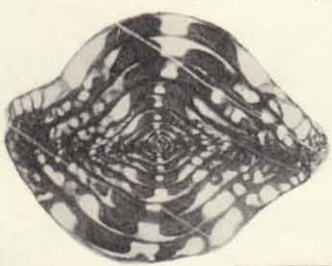
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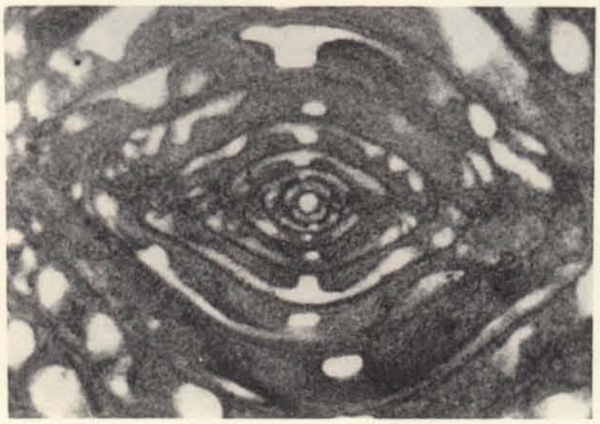
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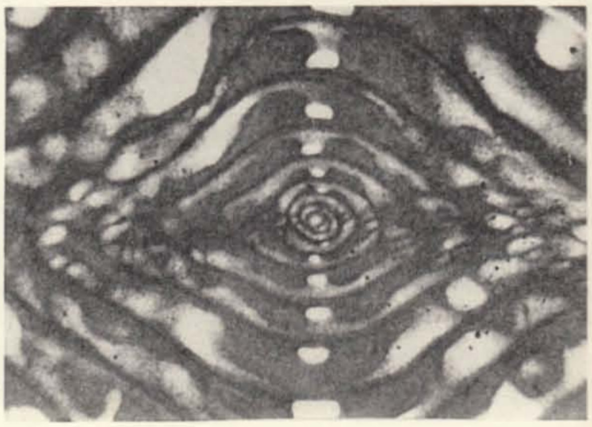
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Skinner and Wilde: Wolfcampian Fusulinids from New Mexico

Rugosochusenella differs from *Pseudofusulina* Dunbar and Skinner in its tightly coiled juvenarium, small proloculus for size of shell, spirothecal thickness for shell size, and presence of distinctive axial fillings. It is similar to *Chusenella* Hsu, but differs in the presence of a "rugose" or furrowed wall, and the septal folding in *Rugosochusenella* is much more irregular than in *Chusenella*. *Rugosochusenella* is strikingly similar to the Pennsylvanian genus *Dunbarinella* Thompson except for its strongly "rugose" spirotheca. Possibly *Dunbarinella* is the ancestral form of the new genus.

Presumably several species previously referred to other genera actually belong in *Rugosochusenella*. Stewart (1963), for example, placed in *Chusenella* certain previously described species which may have "rugose" walls. Assignment of such species to *Rugosochusenella*, however, involves re-examination of the specimens.

Geologic age and distribution.—Lower Permian (Wolfcampian) of the southwestern United States, possibly Europe and Asia.

Rugosochusenella zelleri Skinner and Wilde, n. sp.

Plate 15, figures 1-12

Shells of medium size, elongate fusiform with a straight to slightly curving axis of coiling. The first 3 to 5 whorls are tightly coiled, after which the shell expands regularly. This change from a tightly coiled portion is not abrupt, but such is the impression at first glance. Mature shells of 6 to 8 volutions vary from 6.36 to 7.24 mm. in length, and 1.73 to 2.43 mm. in diameter. The form ratio varies from 2.80 to 3.83.

The spirotheca is composed of a tectum and a rather coarsely alveolar keriotheca. The entire wall is strongly furrowed both axially and transversely, and the septal furrows are deep. This gives the shell surface for any given whorl a rough pebblestone appearance. Thickness of the spirotheca in the sixth whorl varies from 46 to 73 microns.

The septa are strongly and irregularly folded throughout the length of the shell, and the folds commonly reach the tops of chambers. Septal counts for seven whorls vary from 8 to 9 in the first, 13 to 15 in the second, 14 to 16 in the third, 14 to 21 in the fourth, 17 to 21 in the fifth, 20 to 23 in the sixth, and 25 to 29 in the seventh.

Proloculus is small and spherical and varies from 97 to 161 microns in outside diameter. The tunnel is rather wide and nearly half as high as the chambers. The tunnel angle varies from 44 to 60 degrees in the sixth volution. Chomata deposits are quite evident in the earlier volutions, but they are either absent or only sporadically developed in later whorls.

Secondary axial filling is present along the axis throughout the length of the shell. This filling gradually spreads beyond the axial region in a poleward direction in later whorls, so that the equatorial region has an open appearance, in contrast to that near the poles.

Discussion.—*Rugosochusenella zelleri* is not closely similar to previously described species, so that comparisons are unnecessary. A smaller undescribed species occurs in other Big Hatchet material, but it differs distinctly in size and in the distribution of axial fillings.

This species is named for Dr. Robert A. Zeller, Jr., who has contributed so much to knowledge of the geology of southwestern New Mexico.

Occurrence.—*Rugosochusenella zelleri* is present in collection NM-150 of the New Wells Peak section where it is associated with species of *Schwagerina* and *Pseudoschwagerina*. Some specimens were obtained from collection NM-404 of the Bugle Ridge section associated with species of *Schubertella, Schwagerina, Paraschwagerina,* and *Pseudoschwagerina*. *R. zelleri* is found also in collections NM-428, NM-429, and NM-450 of the Borrego section in association with *Schwagerina, Pseudofusulina,* and *Paraschwagerina*. NM-150 was collected from the upper half of Zeller's bed 150 of the New Wells Peak section; NM-404 comes from the lower portion of bed 110 in the Bugle Ridge section; NM-428 is from bed 39 and NM-429 is from the base of bed 40 of the Borrego section.

EXPLANATION OF PLATE 14

Leptotriticites

FIGS.		PAGE
1-5.	*Triticites* (*Leptotriticites*) *gracilitatus* Skinner and Wilde, n. subgen., n. sp. .... 1, axial section of the holotype; 2, 3, axial sections of paratypes; 4, 5, sagittal sections of paratypes. All figs. × 10. Horquilla Limestone, Big Hatchet Mountains, Hidalgo County, New Mexico (loc. NM-389).	101
6-15.	*Triticites* (*Leptotriticites*) *hatchetensis* Skinner and Wilde, n. subgen., n. sp. .... 6, axial section of the holotype, × 10; 7-9, axial sections of paratypes, × 10; 10, axial section of a microspheric individual, × 10; 11, 12, sagittal sections of paratypes, × 10; 13, part of same specimen as fig. 8, enlarged, × 40; 14, part of same specimen as fig. 10, enlarged, × 40, to show the asymmetrical juvenarium; 15, part of same specimen as fig. 12, enlarged, × 40. Horquilla Limestone, Big Hatchet Mountains, Hidalgo County, New Mexico (loc. NM-151).	101

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302. *GLOBIGERINOIDES QUADRILOBATUS* (D'ORBIGNY) AND RELATED FORMS: THEIR TAXONOMY, NOMENCLATURE AND STRATIGRAPHY

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ABSTRACT

The lectotype of **Globigerina quadrilobata** d'Orbigny, selected from the d'Orbigny collection, is discussed and vindicated. The "substitute lectotype" proposed by Bandy is shown to be unnecessary, unavailable and invalid. The nomenclature of the **Globigerinoides quadrilobatus** (d'Orbigny) group is outlined; its taxonomy and stratigraphy are discussed, taking into consideration all available proposed names and their application to taxa of stratigraphical and probably ecological significance. The evolution of the group follows three major trends from the prototypical **G. quadrilobatus primordius** and **G. quadrilobatus s.s.**: one (to **G. quadrilobatus altiaperturus**) is short-lived within the Aquitanian, another (to **G. quadrilobatus trilobus**) persists from the Lower Miocene to Recent, while a third (to **G. quadrilobatus fistulosus**) undergoes more complex evolution in late Tertiary and Quaternary. The hazards of lectotypic selection are discussed, with especial additional regard to **Globorotalia crassata** (now a synonym of **G. spinulosa**), the practical value of the rules of the International Commission of Zoological Nomenclature is upheld, and a plea for stability is made.

INTRODUCTION

Up to the time of this writing, nineteen different specific and infraspecific names have been applied to taxa which, it is generally agreed, are closely related to the forms originally named *Globigerina quadrilobata* d'Orbigny, 1846 (lectotype), *Globigerina triloba* Reuss, 1850, and *Globigerina sacculifera* Brady, 1877. Of these nineteen names, one is a *nomen nudum* and another is almost certainly to be considered an objective junior synonym; seventeen are available, and most of these are currently used by authors in a variety of combinations, frequently with different morphological connotations. In order to try to clarify the nomenclatorial confusion, we (1960) re-examined all the primary type material available to us in London and Paris, and carefully selected, figured and described lectotypes from series which, in the opinion of both ourselves and the authorities in the Museums and neighbouring Institutes, were genuinely syntypic. This was an attempt to bring studies, of some of the taxa at least, within the disciplines explicit in Article 61 (*et seq.*) of the International Code of Zoological Nomenclature (as adopted by the XV Congress), to reduce the amount of polyonomy in current literature (both published and, within commercial enterprises, unpublished), and, by judicious use of the senior available names, to suggest a nomenclature of real or possible significance to the stratigrapher and ecologist which would also reflect the biological affinities of the taxa, as currently understood.

Owing to the length of the original paper (1960), we were obliged, in the case of each and every taxon, to be concise in our explanations and comments; it appears that even our subsequent brief explanatory note (1962) was inadequate as additional information and explanation, especially in the case of *Globigerina quadrilobata* d'Orbigny, 1846, for Bandy (1964a) has recently argued that the designated lectotype of this taxon is invalid, that another must be proposed, and that the specimen in the A. d'Orbigny collection "is actually a *Globigerinoides triloba* (Reuss)." Each of these points must be answered and explained.

THE VALIDITY OF THE LECTOTYPE OF *GLOBIGERINA QUADRILOBATA* D'ORBIGNY, SELECTED BY BANNER AND BLOW, 1960

1. The syntypic series extant in the A. d'Orbigny collection in the Museum de l'Histoire Naturelle, Paris, was vouched for by M. J. Sornay of that Museum. The base of the tube, which contained the mounted specimens, was clearly labelled "*Globigerina quadrilobata* d'Orb., Tortonien, Nussdorf (Autriche)" and (referring to the published work of d'Orbigny, 1846) "p. 164, pl. 9, figs. 7-10." It was the only series of specimens so labelled in the A. d'Orbigny collection, it did not form a part of the display collections or those subsequently gathered together by the "disciples of d'Orbigny," and no other specimens of Globigerinids in the d'Orbigny collection could, as far as we could tell, have been confused with them. All the specimens labelled "*G. quadrilobata,*" by nature of their preservation and known stratigraphical occurrence, were typical of those to be found in the plastic clays (so-called "Tortonian") of Nussdorf, and there is no reasonable doubt of their geological provenance. D'Orbigny published only one study of the foraminifera of the Vienna Basin; this material was never collected by himself, but was sent to him by Joseph de Hauer in 1844. It is, therefore, as certain as can be that these specimens were the ones studied by d'Orbigny prior to his publication of 1846. No authentic d'Orbigny types exist in Vienna (Flugel, 1961, p. 68), and the ones described by us in 1960 are present in the only authentic collection known to exist.

2. No specimen in the syntypic series of *Globigerina quadrilobata* d'Orbigny measured as little as the "¼ millim." diameter noted by d'Orbigny for his figured specimen (1846, p. 164). However, as we have previously noted (1960, p. 17), clear traces exist which indicate that three of d'Orbigny's original eleven specimens have been lost. The specimen figured by d'Orbigny (1846, pl. 9, figs. 7-10, here reproduced, pl. 16, figs. 1, a-d) must be presumed to have been among these. Nevertheless, specimens clearly specifically and infraspecifically identical to that selected as lectotype, but which measure only 0.25 mm. in diameter, and which are even more clearly "quadrilobate" than the larger, more fully grown specimens similar to the lectotype, occur in the clays at Nussdorf; one such is illustrated here (pl. 16, fig. 2), and it agrees with the original description given by d'Orbigny (quoted by us, 1962, p. 98, for reference) as well as could reasonably be expected. It measures precisely 0.25 mm. in maximum diameter; the test is ovate-convex, gibbous, punctate, ventrally umbilicate, and consists of four, subequal, nearly spherical chambers in the final whorl. It is important to note that d'Orbigny observed a test "se compose de quatre loges sphériques presque égales en grosseur . . . sans former de spire régulière" (1846, p. 164); it is characteristic of the species now represented by the lectotype that its wall is thick and coarsely pitted, and that the dorsal wall, over the early whorls, is so strongly thickened as to obscure the early intercameral sutures. Such a form, as seen through an early nineteenth-century microscope with contemporary artificial illumination, could well appear to lack a dorsal spiral coil, the chambers of the penultimate whorl not being clearly differentiated from the first chamber of the last whorl (see pl. 16, figs. 1c and 2d). This lapse of accurate observation could not have occurred, in so highly trained an observer as d'Orbigny, with specimens conspecific with the smooth, thin-walled, deeply-sutured, finely perforate form figured by Bandy (1964a, text-figure 2), which occurs at Nussdorf but which was almost certainly included by d'Orbigny in 1846, in his species *G. bulloides*. This last point is confirmed by the fact that the specimen figured as *G. bulloides* from Nussdorf (1846, p. 163, pl. 9, figs. 4-6 reproduced in Bronn, 1856, as pl. 35 (2), fig. 19, and renamed *G. bulliformis* by Mayer-Eymar, 1887, p. 123) possessed a finely perforate wall, was composed of two distinct whorls (seven chambers in all were observed by d'Orbigny), the last whorl only consisting of four spherical chambers, and that it possessed a narrow, almost closed umbilicus and a small, lipped, intra-umbilical aperture; all these characters are very similar to those of the specimen illustrated by Bandy (*cit.*, text-fig. 2), which is very probably referable to *G. bulliformis* Mayer-Eymar. We know of no species, other than the one represented by the lectotype selected by us, which occurs at Nussdorf and yet which agrees well with d'Orbigny's original description of *G. quadrilobatus*. As the specimen was a syntype, this is not surprising. The dorsal supplementary sutural apertures of the lectotype were not figured by d'Orbigny, but d'Orbigny did not illustrate a true dorsal view (figures 1b and 1c, reproduced here on pl. 16, are clearly both oblique views); d'Orbigny did not mention the presence of such apertures in any species he recorded from Nussdorf (specimens of adult *G. quadrilobatus, G. quadrilobatus immaturus, G. quadrilobatus sacculifer* and *G. quadrilobatus trilobus* have all been found to occur there), and the dorsal apertures in small specimens are slit-like and are not easily seen even in true dorsal view (pl. 16, fig. 2e). Only the "last" aperture of *Planorbulina mediterranensis* d'Orb., from Nussdorf, was illustrated by d'Orbigny (1846, pl. 9, figs. 15-17), even though this genus and species is now well known to have two subequal apertures in each chamber of the last annulus — as d'Orbigny's own specimens reveal on examination. Dorsal apertures in *Globigerinoides* have not always been indicated in drawings even by recent authors — for example, in the original illustrations of the type specimens of *"Globigerinoides triloba* var. *aspera"* of Petri (1954, pl. 12, fig. 12) and of *"Globigerina fistulosa"* Schubert (1910, text-fig. 2) — and are often far from clear in photographs (e.g., *"Globigerinoides sacculifer* var. *spinulosus"* of Christodoulou, 1960, pl. 1, fig. 25). We must conclude that there are no reasonable grounds for disputing the authenticity of the d'Orbigny collection specimens, including the lectotype.

3. The syntypic series contained specimens which we, today, would not consider conspecific with the lectotype. It would be remarkable if the refinement in taxonomy of the foraminifera over the last 120 years had not resulted in a modern subjective division of d'Orbigny's old type-series. It is for this reason that lectotypic designation for classical species-names is now very important. By modern standards, d'Orbigny must have been a "lumper" at specific level, for all the species of *Globigerina* present in the Vindobonian of the Vienna Basin were covered by four specific names in his work; these we would now refer to four different genera (*Baggina regularis* (d'Orb.), *Globigerina bulloides* d'Orb., *Globigerinoides quadrilobatus* (d'Orb.), and *Biorbulina bilobata* (d'Orb.)). D'Orbigny was a catastrophist, who preferred not to record the same species at different geological horizons (see, for example, the account given by Davitashvili, 1962, p. 17) although he was sometimes compelled by his own observations to do so (e.g., 1846, pp. xi-xxxvii), and he was clearly amazed at "l'immense nombre de *deux cent-vingt-huit* éspèces" even he was forced to

record from the Vienna Basin. Article 72 (b) of the I.C.Z.N. refers to the inclusion, in the type-series, "of all the specimens on which an author bases his species, except any that he" (note: the original author only) "refers to as variants, or doubtfully associates with the nominal species, or expressly excludes from it." Not only did d'Orbigny not exclude the lectotype from his taxon, we believe that all the evidence shows that he clearly included it. The species *Globigerina quadrilobatus,* as based upon the lectotype chosen by us in 1960, is clearly not a subjective synonym of any other species named in 1846 or in earlier years by d'Orbigny or by any other author; neither is it (as we shall show below) a senior synonym at subspecific level of any other commonly used and subsequently proposed name.

BANDY'S PROPOSAL FOR A SUBSTITUTE LECTOTYPE

This proposal (Bandy, 1964a) is doubly invalid. First, the already selected, figured and described lectotype (Banner and Blow, 1960) came from a series of specimens whose syntypy is not in reasonable doubt. Secondly, the "lectotype" proposed by Bandy (1964a, p. 36: "the original specimen which served for the illustration by d'Orbigny") has already been shown to have been lost. It is not available for lectotypic selection (if it had been, we ourselves would have selected it in 1960), and, if all the syntypes were to be lost, neotypy would then have to be invoked, as under Article 75 of the I.C.Z.N. Code. This, of course, is as yet neither necessary nor possible.

THE NOMENCLATURE OF *GLOBIGERINOIDES QUADRILOBATUS* (D'ORB.) *SENSU LATO,* AND RELATED FORMS

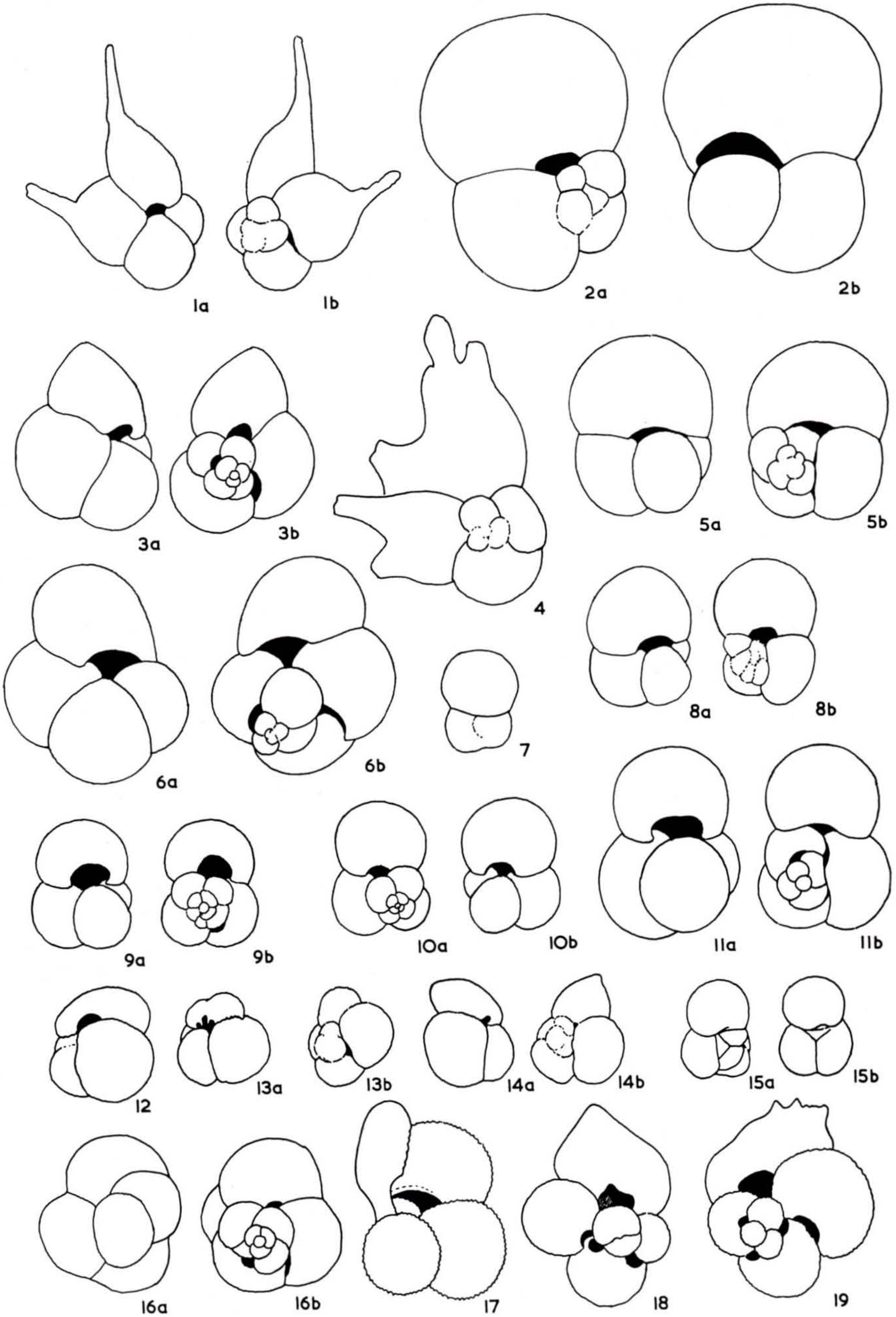
The primary types of all the named species, subspecies and "varieties" considered here to be closely related to *G. quadrilobatus* (d'Orb.) are illustrated in text figures 1-19 by outline drawings, traced from the original figures with their magnifications adjusted where desirable for their ready comparison.

Six of the available names were originally proposed at species level. These were *Globigerina quadrilobata* d'Orbigny, 1846 (figs. 11, a-b), *Globigerina triloba* Reuss, 1850 (figs. 2, a-b), *Globigerina sacculifera* Brady, 1877 (figs. 3, a-b), *Globigerina fistulosa* Schubert, 1910 (fig. 4), *Globigerina tricamerata* Tolmachoff, 1934 (fig. 7) and *Sphaeroidinella cellata* Subbotina, 1958 (figs. 5, a-b).

Of the remainder, two were originally proposed as subspecies of *Globigerinoides quadrilobatus* (d'Orb.); these were *G. quadrilobatus hystricosus* Belford, 1962 (figs. 1, a-b) and *G. quadrilobatus primordius* Blow and Banner, 1962 (figs. 10, a-b). Three were originally attached infraspecifically to *Globigerinoides trilobus* (Reuss): *G. trilobus* (Rss.) var. *aspera* Petri, 1954 (figs. 15, a-b), *G. triloba* (Rss.) *altiapertura* Bolli, 1957 (figs. 9, a-b), and *G. trilobus* (Rss.) *bullatus* Chang and Chang, 1962 (figs. 16, a-b). One was originally described as *Globigerina bulloides* d'Orbigny var. *recumbens* Rhumbler, 1901 (fig. 17), but this was almost certainly subsequently revised by Rhumbler (1911) and referred to as a variety of *Globigerina sacculifera* Brady (Rhumbler's figure of 1901 was republished by him in 1911 as pl. 31, fig. 11 of the "Plankton-Expedition"; this figure, with that reproduced here as text figure 19, was then referred to as "*Globigerina sacculifera* Brady variante *recumbens*" in the MS plate-explanations, according to Wetzel, 1949, p. 39).

The greatest number of infraspecific names proposed in this group were originally referred to as subspecies or "varieties" of *Globigerina sacculifera* Brady (= *Globigerinoides sacculifer* (Brady), *auct.*, or *G. sacculiferus* (Brady), *auct.*). These comprise the three "subspecies" (*brachysacculifer, minimus* and *spinulosus*) proposed by Christodoulou, 1960 (figs. 12, 13 a-b and 14 a-b respectively), the *nomen nudum* "var. *galeata*" of Rhumbler, MS (published in Wetzel, 1949), and the two "varieties" *immatura* LeRoy, 1939 (figs. 8, a-b) and *irregularus* LeRoy, 1944 (figs. 6, a-b). The name "*Globigerinoides sacculiferus* (Brady) var. *immaturus*" was republished for ideotypes by LeRoy in 1941 (pp. 44, 87, 118), but by 1944 (although he still retained the taxon-name "*G. sacculiferus* (Brady) var. *irregularus,*" 1944, p. 40) he had revised his opinion and stated that his variety *immaturus* was a full junior synonym of "*Globigerinoides trilocularis* (d'Orbigny)" (1944, pp. 40, 91).

Cushman (1941, pp. 39-40, pl. 10, figs. 14-17) figured and briefly described specimens from Miocene deposits at "various localities" in the region of Bordeaux (the "Bordelais") which he referred to as "topotypes" of *Globigerina trilocularis* d'Orbigny, 1826 = *Globigerinoides trilocularis* (d'Orb.). However, the name *Globigerina trilocularis* was *nomen nudum* when originally published by d'Orbigny in 1826 (p. 277, list no. 2), for no description, illustration or any other indication of the nature of the species was given. Deshayes (1832, p. 170, list no. 3), to whom the name must now be credited, was the first to publish a formal diagnosis of the species, and this (and his discussion of its characters) was based upon specimens obtained (like d'Orbigny's) from the environs of Bordeaux. Deshayes did not illustrate specimens of *G. trilocularis* (the first illustration, of a hypotype from Tertiary marine sands at Osnabruck, was published by Roemer, 1838, pl. 3, fig. 41a, and is without status), but d'Orbigny's previously unedited drawings were published by Fornasini (1898, p. 12, text-fig.) as outline draw-



TEXT FIGURES 1-19

ings, and these may be considered probably to represent syntypes, although they may have been of ideotypes. In any case, the specimens so represented are no longer extant in the d'Orbigny or Deshayes collections in the Museum de l'Histoire Naturelle, Paris, and must be presumed to have been lost. When d'Orbigny later (1852, p. 157) recorded *G. trilocularis* from the "26th stage," or the "Falunian," near Bordeaux, he made no implication that this "very globose" species was in any way similar to the previously described *G. triloba* Reuss or to *G. quadrilobata*. Owing to the inadequacy of the original descriptions and figures, subsequent usage of the name *G. trilocularis* has varied widely, some authors, from Roemer (1838, *loc. cit.*) to Bolli (1957, p. 110, pl. 22, figs. 8, 9; 1957a, p. 163, pl. 36, fig. 3), being of the opinion that it is a species of *Globigerina*, while others (e.g., Cushman, *op. cit. sup.*, and Sacal and Debourle, 1957, p. 56, pl. 24, fig. 7) considered it to be a *Globigerinoides*. Until *Globi-*

EXPLANATION OF TEXT FIGURES 1-19

FIGS.

1 a-b. *Globigerinoides quadrilobatus hystricosus* Belford, 1962; after Belford, 1962, pl. 4, figs. 11, 13; holotype, × 50; specimen CPC 4092, Canberra, Australia.

2 a-b. *Globigerina triloba* Reuss, 1850; after Reuss, 1850, pl. 47, figs. 11b, 11a; syntype, probably × ca. 65; probably in Naturhistorische Museum, Vienna (see Flugel, 1961, p. 68).

3 a-b. *Globigerina sacculifera* Brady, 1877; after Banner and Blow, 1960, pl. 4, figs. 16, 1a; lectotype, × 50; specimen P.44033, British Museum (Natural History), London.

4. *Globigerina fistulosa* Schubert, 1910; after Schubert, 1910, text-fig. 2; syntype, probably × ca. 50; depository unknown.

5 a-b. *Sphaeroidinella cellata* Subbotina, 1958; after Bikova, *et al.*, 1958, pl. 11, figs. 5b, 5a; holotype, × 50; specimen 440-60, VNIGRI collection, Leningrad.

6 a-b. *Globigerinoides sacculiferus* (Brady) var. *irregularus* LeRoy, 1944; after LeRoy, 1944, pl. 3, figs. 42, 43; "cotype" (i.e., syntype), × 52; deposited in collection of the Nederlandsche Pacific Petroleum Maatschappij, Medan, Sumatra.

7. *Globigerina tricamerata* Tolmachoff, 1934; after Tolmachoff, 1934, pl. 41, fig. 21, syntype × 50; specimen no. 7040, collection of section of Invertebrate Paleontology, Carnegie Museum, Pittsburgh, Pennsylvania (Note: this name is a junior synonym of *Sphaeroidina* (?) *peruviana* Berry, 1932, *teste* Tolmachoff, *op. cit.*, p. 324).

8 a-b. *Globigerinoides sacculiferus* (Brady) var. *immatura* LeRoy, 1939; after LeRoy, 1939, pl. 3, figs. 19, 20; holotype, × 50; no. P.S.1077a, Government Geological Museum, Bandoeng, Java.

9 a-b. *Globigerinoides triloba* (Reuss) ssp. *altiapertura* Bolli, 1957; after Bolli, 1957, pl. 25, figs. 7b, 7a; holotype, × 34; no. P.5632, U. S. National Museum, Washington, D.C.

10 a-b. *Globigerinoides quadrilobatus* (d'Orb.) ssp. *primordius* Blow and Banner, 1962; after Eames, *et al.*, 1962, pl. 9, figs. Dd, Ff; holotype × 50; no. P.44515, British Museum (Natural History), London.

11 a-b. *Globigerina quadrilobata* d'Orbigny, 1846; after Banner and Blow, 1960, pl. 4, figs. 3b, 3a; lectotype, × 50; A. d'Orbigny collection, Muséum Nationale de l'Histoire Naturelle, Paris.

12. *Globigerinoides sacculifer* (Brady) ssp. *brachysacculifer* Christodoulou, 1960; after Christodoulou, 1960, pl. 1, fig. 31; syntype (?), × 30; no. 1069, Bavarian State Coll. for Palaeontology and Historical Geology, Munich, Germany.

13 a-b. *Globigerinoides sacculifer* (Brady) ssp. *minimus* Christodoulou, 1960; after Christodoulou, *loc. cit.*, figs. 28, 27; syntypes, × 30; nos. 1068 and 1068a, Bav. State Coll. Palaeont. Hist. Geol., Munich, Germany.

14 a-b. *Globigerinoides sacculifer* (Brady) ssp. *spinulosus* Christodoulou, 1960; after Christodoulou, *loc. cit.*, figs. 26, 25; syntypes, × 30; nos. 1070 and 1070a, Bav. State Coll. Palaeont. Hist. Geol., Munich, Germany.

15 a-b. *Globigerinoides triloba* (Reuss) var. *aspera* Petri, 1954; after Petri, 1954, pl. 12, figs. 13, 12; holotype, × 60; no. 1-58, Laboratorio de Paleontologia do Conselho Nacional do Petróleo, Belém, State of Pará, Brazil.

16 a-b. *Globigerinoides trilobus* (Reuss) ssp. *bullatus* Chang and Chang, 1962; after Chang, 1962, pl. 2, figs. 2b, 2a; holotype, × 50; probably deposited in the collection of the Geological Survey of Taiwan.

17. *Globigerina bulloides* d'Orbigny var. *recumbens* Rhumbler, 1901; after Rhumbler, 1901, text-fig. 27, spines omitted; syntype, × 35; depository unknown; the same figure re-published by Rhumbler, 1911, as pl. 31, fig. 11, and referred to in Rhumbler's MS (Wetzel, 1949) as *Globigerina sacculifera* Brady var. *recumbens* Rhumbler.

18. *Globigerina sacculifera* Brady var. *galeata* Rhumbler, 1949, *nom. nud.;* after Rhumbler, 1911, pl. 31, fig. 15, spines omitted; hypotype, × 30; depository unknown.

19. *Globigerina sacculifera* Brady var. *recumbens* (Rhumbler), Rhumbler, 1949; after Rhumbler, 1911, pl. 31, fig. 12, spines omitted; hypotype, possible syntype of *G. bulloides* d'Orb. var. *recumbens* Rhumbler, 1911; × 40; depository unknown.

gerina trilocularis Deshayes (ex. d'Orbigny) becomes a nominal species, by neotypy, it is not possible to use the name without increasing the amount of synonymy and polyonymy already present in the literature. In this case, neotypy would be ill-advised, for most of the common "trilocular" species present in the Miocene of the environs of Bordeaux already bear well-defined names. One of these species (observed by us to occur commonly in a sample collected by Dr. F. W. Anderson, H. M. Geological Survey of Great Britain, from the Burdigalian of Pont Pourquey, Commune de Saucats, approximately 10 miles south of Bordeaux) would agree well with what is known of *Globigerina trilocularis* Deshayes, but is also identical to *Globigerina woodi connecta* Jenkins. As the latter has been adequately figured and described in current literature (Jenkins, 1964, p. 72), we believe it to be in the interests of nomenclatorial stability to recommend that *Globigerina trilocularis* Deshayes (ex. d'Orbigny) be declared *nomen dubium, non conservandum,* and that it is certainly not to be considered a senior synonym of its virtual paronym, *Globigerina triloba* Reuss.

Of the other available names considered in this paper, almost all identify taxa which are now represented by primary type specimens, including holotypes or lectotypes. Their nature is thus objectively defined, and can be rationally discussed. One exception is *Globigerina triloba* Reuss, 1850; this may prove to be represented by primary type specimens in the Naturhistorischen Museum in Vienna, but they have not yet been identified (Flugel, 1961, p. 68) and thus cannot yet be redescribed. However, Reuss's original description and illustrations were excellent (1850, p. 374, pl. 47, figs. 11, a-e) and permit unambiguous interpretation even by modern standards. Reuss obtained his original specimens from a Tertiary "Salzthon" at Wieliczka, 8 miles south-east of Krakow, in what is now Poland; for comparison with *Globigerinoides quadrilobatus* (d'Orbigny) we here illustrate a specimen of *G. trilobus* (Reuss) from the Lower Amphistegina Marl of Kików, Gora Kadrzyna, Poland, a geological horizon of approximately the same age as that sampled by Reuss (Vindobonian). The depository of the type specimens of *Globigerina fistula* Schubert, 1910, is not known to us, and the original figure (reproduced here as text fig. 4) is rather poor; the current interpretation of this taxon must depend, to some extent, on ideotypes later figured by Schubert (but see below) and near-topotypes recently described and illustrated by Belford (1962, pp. 16-17, pl. 4, figs. 7-10), until the original syntypic series of Schubert is located and redescribed. Rhumbler's specimens of *Globigerina bulloides* var. *recumbens* may be present in the collections of the Forstzoologischen Institut, Göttingen, but these have not yet been located; however, Rhumbler's name *recumbens* has been little if at all used since its original publication (Rhumbler, 1901, p. 25) and, being of relatively recent proposal, would not affect the nomenclature of the taxa named by d'Orbigny, Reuss or Brady at specific level, although it may well prove to be a synonym of *"Globigerinoides sacculifer* (Brady) *brachysacculifer"* Christodoulou, 1960 (see below).

THE TAXONOMY AND STRATIGRAPHY OF *GLOBIGERINOIDES QUADRILOBATUS* (D'ORBIGNY) AND RELATED FORMS

The available means discussed above can now be shown to be applicable to recognisable morphological stages in the phylogenesis of *Globigerinoides quadrilobatus,* its ancestor and its descendants. Many of the forms, which can be named with strict reference to the established types of the taxa involved, have already been demonstrated to be of stratigraphical value. Others may well prove to be ecologically significant when ecologists and palaeoecologists trouble to distinguish these recognisably different forms. For example, the samples studied by us from Nussdorf are dominated by *G. quadrilobatus s. s.;* the sample, of approximately the same age, from Kików was dominated by *G. quadrilobatus immaturus* and *G. quadrilobatus trilobus.* Such relative abundances are of frequent occurrence in samples which contain this species, and palaeoecological factors must, almost certainly, be responsible; these factors are not yet understood, nor can they be until the autecology is known. Even forms which occur together in the same thanatocoenose may well have been bathymetrically separated during life.

Globigerinoides quadrilobatus primordius has been shown to have arisen directly from advanced forms of *Globigerina praebulloides occlusa* in the *Globorotalia kugleri* zone of the Aquitanian Lower Miocene (Blow and Banner, 1962, pp. 136-139). *Globigerinoides quadrilobatus primordius* is believed to be confined to this zone, which does not occur at the base of the Aquitanian (as stated, without reasons, by Bandy, 1964b, pp. 7-8), but in about the middle part of the Aquitanian; this has been directly demonstrated in Aquitaine by the presence of the older *Globigerina ouachitaensis ciperoensis* within the lower part of the stratotype Aquitanian (Blow and Banner, 1962, p. 75) and by the first appearance of *Globigerinoides quadrilobatus* (*s. l.*), accompanied by *G. quadrilobatus* cf. *G. primordius,* in about the middle of the stratotype Aquitanian (Jenkins, 1964, pp. 28-29).

In the upper part of the *Globorotalia kugleri* zone, virtually contemporaneously with the extinction of *Globigerinoides quadrilobatus primordius, G. quadrilobatus s. s.* appears to have differentiated into a group of forms showing continuous variation between the extremes of (1) rapid chamber enlargement, depression of the later chambers, reduction in size of the umbilicus, and tighter coiling, producing the form known as *G. quadrilobatus immaturus* and (2) slower chamber enlargement, looser coiling, and increasingly asymmetric chamber shape later in growth, characterising the form which may be called *G. quadrilobatus irregularus.* At or near the top of the *Globorotalia kugleri* zone, the variation widens, so that trend (1) above produces the tightly coiled *G. quadrilobatus trilobus,* with three chambers only being visible ventrally, and trend (2) above results in the evolution of early forms of *G. quadrilobatus sacculifer,* in which the asymmetric form of the later chambers is combined with elongation (Bolli, 1957, pp. 99, 112-113; Blow, 1959, pp. 186-188; Banner and Blow, 1960, pp. 17-19; Blow and Banner, 1962, pp. 136-137). All these forms (*G. quadrilobatus s. s., G. quadrilobatus immaturus, G. quadrilobatus trilobus, G. quadrilobatus irregularus* and *G. quadrilobatus sacculifer*) have persisted up to Recent times, but, as indicated above, are apparently differently influenced ecologically; they have also undergone separate and different evolutionary development in the past, phenomena which may have been due to early ecological separation.

Immediately following the *Globorotalia kugleri* zone, the *Globigerinita* (*vel "Catapsydrax"*) *dissimilis* zone and the lower part of the *G. stainforthi* zone contain the short-lived direct descendant of *Globigerinoides quadrilobatus s. s.* named *"Globigerinoides triloba altiapertura"* by Bolli, 1957 (pp. 112-113). The chamber shape, coiling mode and wall surface and structure of *G. quadrilobatus altiapertturus* (Bolli) are so closely similar to those of *G. quadrilobatus s. s.* that there can be no doubt of its immediate ancestry; however, *altiaperturus* has developed such high, broad primary and supplementary apertures that it may readily be distinguished, and its relatively short stratigraphical range indicates that its morphology resulted from possession of a particular gene-complex of short duration in geological time—that it was biologically distinct from, and not merely a random variant of, *G. quadrilobatus s. s.* It seems probable that the genetic control which had led to the development of single, small supplementary apertures in *Globigerina praebulloides occlusa* to produce the primitive root of the new stock, *Globigerinoides quadrilobatus primordius,* had continued in *G. quadrilobatus s. s.* with larger, more numerous supplementary apertures, and had then produced, in *G. quadrilobatus altiaperturus,* a short-lived extreme expression of the same trend. The more conservative, less extreme form (*G. quadrilobatus s. s.*) was, however, able to survive, and later (see below) to give rise to forms of *G. quadrilobatus sacculifer* with supplementary apertures as large as those in *G. quadrilobatus altiaperturus* but which were, from their geological range, apparently more viable. It is clearly incorrect for Bandy (1964b, p. 8) to consider that *G. quadrilobatus primordius* is merely a synonym of *G. quadrilobatus altiaperturus,* for these forms are different both morphologically and stratigraphically; if Bandy (*op. cit.*) had attempted to demonstrate a "Cenozoic planktonic foraminiferal zonation" at a level of refinement similar to that proposed, for example, by Bolli (1957, p. 99), the error would have been immediately obvious.

The remaining history of the *Globigerinoides quadrilobatus* stock may be summarised as follows. *G. quadrilobatus s. s.* was the precise morphological intermediate between, and the immediate ancestor of, two distinct descendant stocks. On the one hand, the tightly coiled forms, typified in extreme morphology by *G. quadrilobatus trilobus,* persisted until the Recent with little apparent change but for the production of variants from *G. quadrilobatus immaturus* which were characterised by an extremely thick, coarsely pitted wall, with both primary and supplementary apertures reduced to narrow slits: these are referable to *G. quadrilobatus cellatus* (Subbotina), are known to occur commonly but sporadically in post-Burdigalian deposits, and may well prove to be an ecologically controlled geographical subspecies, perhaps developing in colder waters than in the tropics. The trend to increasingly tight coiling in the *G. quadrilobatus* stock reached its culmination in the development of *Globigerinoides sicanus* de Stefani (a senior objective synonym of *G. bispthericus* Todd, 1954, *teste* Bermudez, 1961, p. 1240) from *G. quadrilobatus trilobus* in the high Aquitanian (*Globigerinatella insueta* zone). *"G. bisphericus"* itself continued the trend to tight coiling and increasing test sphericity by rapidly giving rise to early Orbulininae (e.g., *"Porticulasphaera" glomerosa,* etc.) by the introduction of ontogenetic changes in the coiling-axes, and by the addition of further, smaller sutural apertures; these forms soon gave rise to the completely spherical *Orbulina* itself, the ultimate in the trend to tight coiling and test sphericity (Blow, 1956, pp. 57-70; Blow and Banner, 1962, pp. 123-124).

On the other hand, the group with relatively loose coiling, characterised by umbilicate tests and asymmetric, elongate chambers, which has its prototype in typical *G. quadrilobatus sacculifer,* underwent at least two broad lines of development. The typical *G. quadrilobatus sacculifer* (text fig. 3), of which the forms termed *"brachysacculifer," "minimus"* and *"spinulosus"* by Christodoulou (text figs. 12-14) are probably absolute junior synonyms, produced more loosely coiled descendants, with much higher primary and supplementary apertures, in the Pliocene or Pleistocene, and these persist until the Recent (Banner and Blow, 1960, pl. 4, figs. 2a-b); the "var. *recumbens*" of Rhumbler (1901, 1949) may prove to be applicable to these forms, but this depends on its lectotypic designation. Other forms of *sacculifer,* which retained relatively tight coiling and low apertures, developed elongate digit-like processes in their later growth-stages (rather than higher, broader sac-like chambers); these occurred as early as Upper Miocene or Pliocene (Belford, 1962, pp. 17-18), and the extreme forms, with several processes on sac-like chambers, may be called *G. quadrilobatus fistulosus* (Schubert) (text fig. 4). This form has been claimed to be of short stratigraphical range within the upper part of the Pliocene only (Ericson, *et al.,* 1963, pp. 732-733), but these same occurrences have been considered by other authors (e.g., Bandy, 1963, pp. 1290-1292) to be of Upper Miocene age, and well developed forms of typical *G. quadrilobatus fistulosus* have also been illustrated from Recent deposits (e.g., Cushman, Todd and Post, 1954, pl. 91, fig. 13). As the recognition of "Upper Miocene" and "Pliocene" European standard stages, in terms of their microfaunas, has not yet been established by direct correlation outside Europe, such stratigraphical difficulties are to be expected. However, the form named *G. quadrilobatus hystricosus* Belford, 1962, (text fig. 1) may prove to be the immediate ancestor of *fistulosus,* evolving in Upper Miocene or Pliocene, the latter form persisting to the Recent with increasing geographical restriction. The picture is complicated, however, by the fact that another "fistulate" (more properly, digitate) form of *G. quadrilobatus s. l.* appears to have evolved separately, directly from *G. quadrilobatus s. s.;* this form possesses elongate processes arising from subspherical chambers which possess none of the characters of *G. quadrilobatus sacculifer,* and is the form which was illustrated as an ideotype by Schubert (1911, text fig. 13b) and as a hypotype by Belford (1962, pl. 4, figs. 7-10) of *fistulosus* itself. This form may be responsible for some of the older records of *fistulosus,* and it does not appear to have been described yet from Pleistocene or Recent deposits.

Such appears to be the simplest form of the phylogeny of the *G. quadrilobatus* stock. It is not suggested that the evolution outlined above was strictly orthogenetic; some of the events (for example, the change from *G. quadrilobatus s. s.* to *G. quadrilobatus immaturus* and the separate developments of *cellatus* and *trilobus* from *immaturus*) may have occurred repeatedly and indistinguishably at many geological horizons. The end-forms as recognised here are, however, morphologically distinct, often have restricted geological ranges as compared to the parent stock, and may well be of potentially great ecological and palaeoecological significance. The detailed phylogeny of the stock is unrecognisable without them. Some names which have been proposed may yet prove to be synonymous with earlier names (e.g., *Globigerina tricamerata* Tolmachoff may be senior to *Globigerinoides quadrilobatus immaturus* LeRoy, and *"Globigerinoides trilobus aspera"* Petri may be junior to it) and some refer to forms of uncertain taxonomic position (e.g., *"G. trilobus bullatus"* Chang may be a true bulla-bearing *Globigerinoita* or merely a *Globigerinoides* with an aborted end-chamber), but the remainder, as used above, are available to denote, simply and adequately, separate morphological developments, and we can see no good reason why they should not be so used. For so long as the distinctions outlined above are not recognised by students, information of unknown value will be left unrecorded, unavailable and unassessed.

NOTE ON THE SELECTION OF LECTOTYPES

From the above, it will be seen that the selection of lectotypes is necessary in order to establish firmly the precise morphology of a taxon, but that lectotypic selection, and the assessment of lectotypes already selected, is not to be undertaken lightly. Lectotypic selection and description is only necessary, in the majority of cases, where the original syntypic series includes forms beyond the limits of taxa as currently restricted, and redescription is needed only when the original description of the type-specimens was vague and ambiguous by modern standards. From this it follows that such taxa have, in the past, been poorly understood, and their names used variously and differently. Fixing and redescribing a type, therefore, almost always results in changes of nomenclatorial usage by some authors, at least, but it should provide a firm basis for future work and provides no excuse for future, deliberate and unnecessary polyonymy and synonymy.

Such a case has occurred very recently, as Bandy (1964) has selected, described and excellently illustrated a lectotype for *Pulvinulina crassata* Cushman, 1925 (=*Globorotalia crassata* (Cushman), *auct.*); this species was originally so briefly described and poorly figured (Cushman, 1925, p. 300, pl. 7, fig. 4) that it was never really recognisable until Bandy's redescription. Unfortunately, the name *Globorotalia crassata* (Cushman) has almost always been used, by all authors, for a species quite different from the newly designated lectotype. Cushman and Renz (1948, p. 40, pl. 8, figs. 5, 6) figured a hispid, unkeeled *Turborotalia* as *G. crassata,* and this usage was clearly followed by the great majority, at least, of all subsequent workers (e.g., Beckman, 1955, p. 396, pl. 26, figs. 10, 11; Graham and Classen, 1955, p. 29, pl. 5, figs. 3, 4; AGIP Mineraria, 1957, pl. 48, fig. 2). Bolli (1957a, p. 168) was not confident that this usage was, in fact, correct, and he doubtfully suggested that such forms were referable, in part, to his new species *Globorotalia bullbrooki* (1957a, p. 167, pl. 38, figs. 4, 5). Bandy's lectotype shows that Bolli's fears were justified, for not only is the lectotype different, even subgenerically, from this common usage, but it is virtually identical to Bolli's hypotypes of *Globorotalia spinulosa* (Bolli, 1957a, p. 168, pl. 38, figs. 6, 7) and is very similar indeed to the holotype of *G. spinulosa* as originally figured by Cushman, 1927. Thus, as a result of Bandy's work, it can be seen that *G. crassata* (Cushman, 1925) is a prior synonym of *G. spinulosa* Cushman, 1927, that all correct records of *G. spinulosa* must now be revised to read *Globorotalia* (*G.*) *crassata,* and that all records of a *Turborotalia* as *G. crassata* have been incorrect, some to be now included within *G.* (*T.*) *bullbrooki* and others to be wholly renamed. This must, at first, cause some complication, as the stratigraphical records of the various forms have been confused as a result of the confused nomenclature; for example, the range of *G. crassata* given by Bandy (1964, p. 35) is a synthesis of old and incorrect records, which do not apply to the lectotype, and must be revised to be that of the better known *G. spinulosa* (which was given correctly by Bandy, 1964b, as "Middle Eocene only," but which must there be renamed, of course, *G. crassata*).

Although the revision of *G. crassata,* by selection of its lectotype, must cause revision of past work, we believe that the selection by Bandy was fully justified; now, at last, the name may be used uniformly and unambiguously for the first time. The fact that much past usage has proved to be incorrect is of little consequence relative to the future stability of the nomenclature. We agree whole-heartedly with Loeblich and Tappan (1964) on this subject, when they stated that "what stability has been achieved has been due solely to the strict application of the rules . . . 'Usage itself' cannot be a primary consideration . . . Usage can never become stable, as long as knowledge of a group increases, but a strict application of priority and other stipulations of the Code of Nomenclature will result in the fewest changes and greatest possible degree of stability."

ACKNOWLEDGMENTS

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POST-SCRIPT

In order to provide authoritative but independent opinion as to the authenticity of the one and only syntype series of *Globigerina quadrilobata* d'Orbigny which exists in the A. d'Orbigny collection in the Muséum de l'Histoire Naturelle, Paris, M. M. Lys, of the Institut Français du Pétrole, long a student of the collection (see, e.g., *Internat. Geol. Congr., Sess.* 18, 1948, Pt. 15, *Proc. Internat. Palaeontological Union,* pp. 15-13), has kindly written the following (letter dated 20th July, 1964).

"Le type (syntype) [of *Globigerina quadrilobata* d'Orbigny] *existe bien* (voir photographie de la fiche) en effet dans la collection originale du Muséum de Paris et je n'ai aucune raison de croire qu'il n'est pas authentique, d'autant qu'il provient du Miocène de Nussdorf dont la collection a été assez bien préservée."

The "fiche" referred to is No. 247 of the "fichier d'Orbigny," the complete catalogue of the A. d'Orbigny collections edited by M. Lys; the fiche No. 247 was prepared in 1948 and contains a photograph, made at that time, of one of the syntypes (now a paralectotype) which is clearly consubspecific with the lectotype selected by Banner and Blow 1960, from the same and only syntype series. There can be no reasonable doubt of the authenticity of these specimens.

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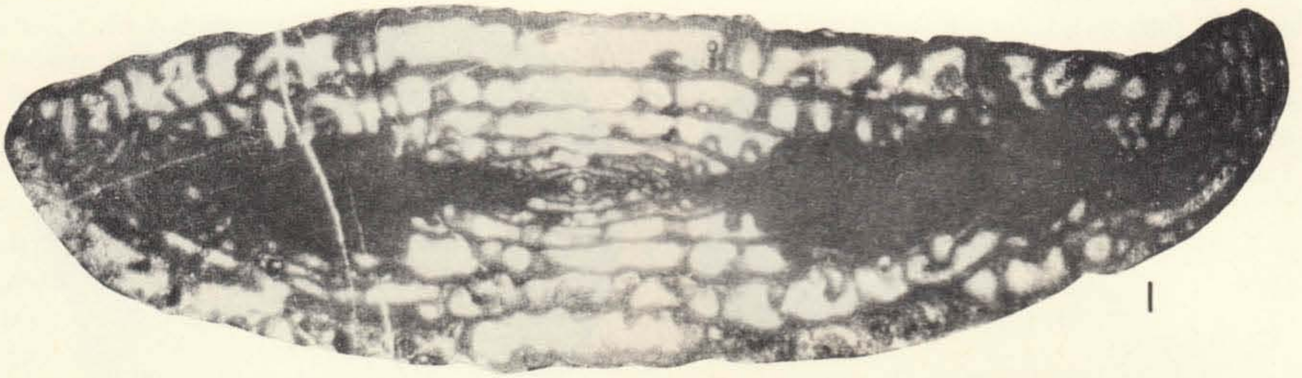
EXPLANATION OF PLATE 15

Rugosochusenella

FIGS.		PAGE
1-12.	*Rugosochusenella zelleri* Skinner and Wilde, n. gen., n. sp.	103

1, 2, axial section of the holotype, × 20 and × 10, respectively; 3-6, axial sections of paratypes, × 10; 7, 8, sagittal section of a paratype, × 20 and × 10, respectively; 9, sagittal section of a paratype, × 10; 10, tangential section, × 10; 11, part of same specimen as fig. 10, enlarged, × 40; 12, part of same specimen as figs. 1 and 2, enlarged, × 40. 4 from loc. NM-429; all others from NM-150. Horquilla Limestone, Big Hatchet Mountains, Hidalgo County, New Mexico.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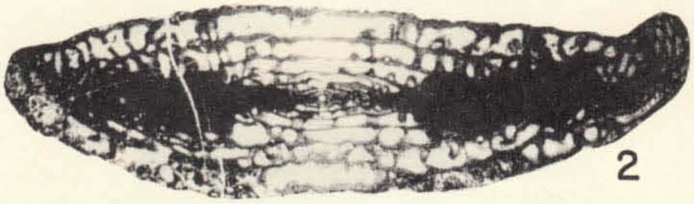
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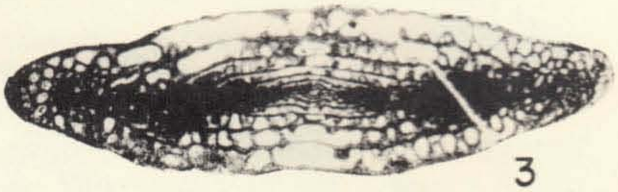
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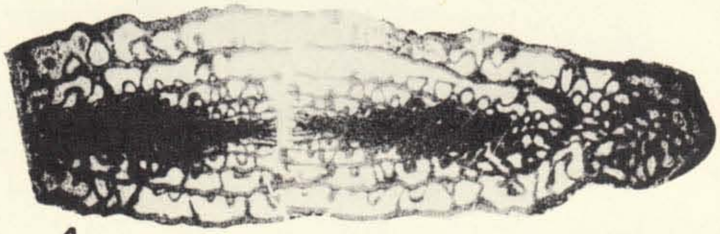
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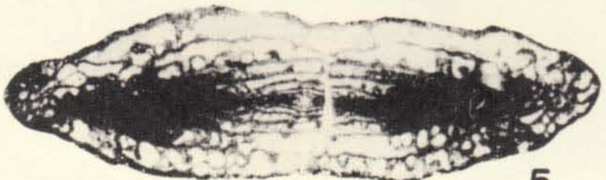
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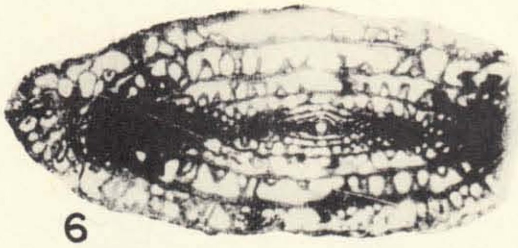
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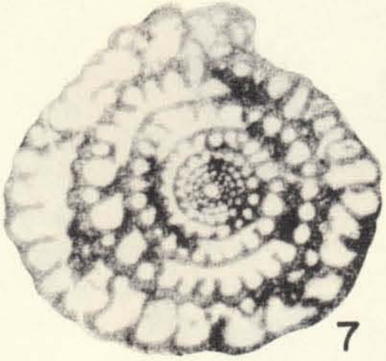
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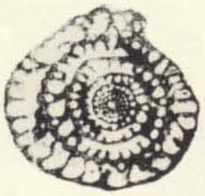
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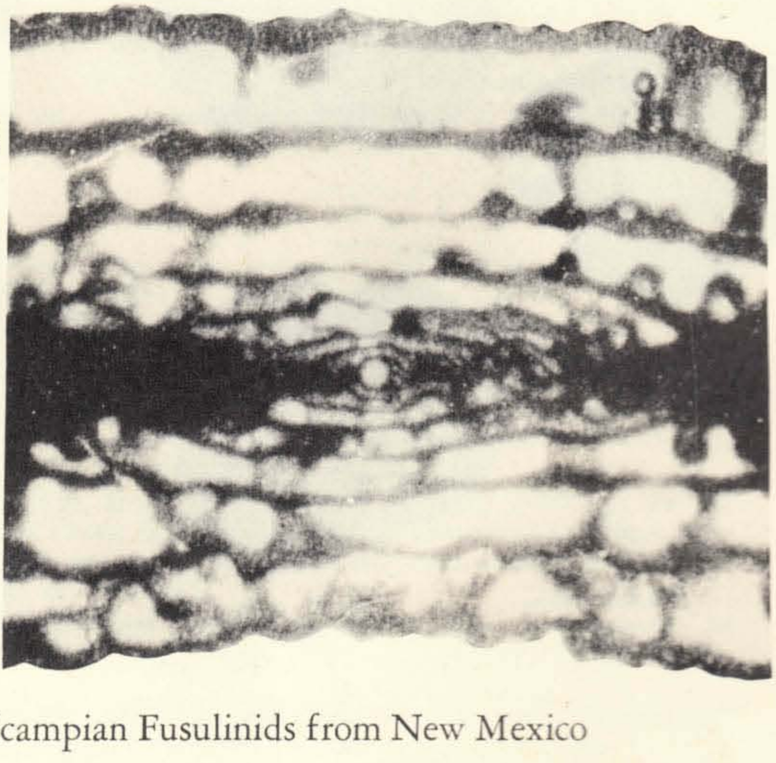
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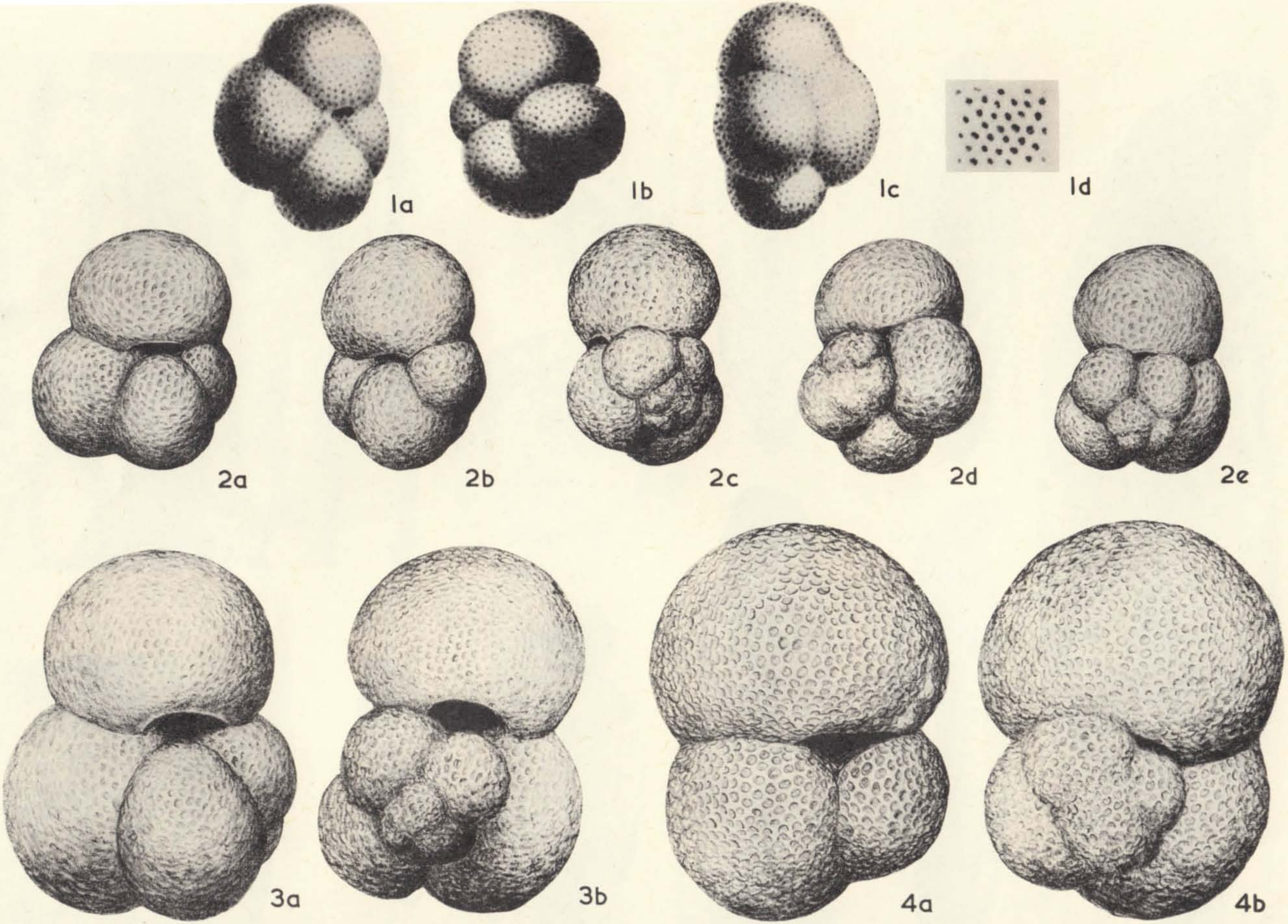
Skinner and Wilde: Wolfcampian Fusulinids from New Mexico



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EXPLANATION OF PLATE 16

FIGS.

1. *Globigerina quadrilobata* d'Orbigny, after d'Orbigny, 1846, pl. IX; fig. 1a. d'Orbigny's fig. 8; fig. 1b, d'Orbigny's fig. 9; fig. 1c, d'Orbigny's fig. 7; fig. 1d, d'Orbigny's fig. 10. ~~Same size as original~~; magnification ~~× 50~~, if the specimen was the same as that measured by d'Orbigny, 1846, p. 164. From Nussdorf, Vienna Basin, Austria. Specimen now lost.
2. *Globigerina quadrilobata* d'Orbigny, topotype, from Nussdorf, Vienna Basin, ~~× 50;~~ figs. 2a, 2c, 2e, ventral, peripheral and dorsal standard views; figs. 2b, 2d, oblique ventral and oblique dorsal views, for comparison with d'Orbigny's figs. 9 (1b, above) and 7 (1d, above) respectively. British Museum (Natural History) Coll., no. P.45645.
3. *Globigerina quadrilobata* d'Orbigny, topotype, from Nussdorf ~~× 50;~~ specimen intermediate ~~indeterminate~~ in size between that figured above (fig. 2) and the lectotype (Banner and Blow, 1960) B. M. (N. H.) Coll. no. P.45646.
4. *Globigerina triloba* Reuss, near topotype, ~~× 50;~~ from the *Amphistegina*-marl, "Tortonian," Kików, Góra, Kadrzyna, Poland. B. M. (N. H.) Coll. no. P.45647.

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303. THE ORIGIN OF THE SPECIES *GLOBIGERINOIDES TRILOBUS* (REUSS) IN NEW ZEALAND

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ABSTRACT

The origin of the species **Globigerinoides trilobus** (Reuss) has been studied in a sequence of lower Miocene rock samples from the Parengarenga section, New Zealand. The hypothesis that **Globigerina woodi woodi** Jenkins - **Globigerina woodi connecta** Jenkins - **Globigerinoides trilobus** (Reuss) is an evolutionary lineage is supported by a study of the coiling directions of their tests. A theory suggesting a different origin for **G. trilobus** is discussed.

INTRODUCTION

Seven rock samples from a lower Miocene section from between Paratoetoe and Takiwhetu, Parengarenga Harbour, Northland, have been examined (text fig. 1). These samples represent a rock sequence of Waitakian - Awamoan age which can be broadly correlated with the *Globigerina ciperoensis ciperoensis* Zone - lower *Globigerinatella insueta* Zone of Trinidad (Bolli, 1957a). The stratigraphic ranges of the planktonic Foraminifera in the section have been determined (Table 1) and a study has been made of the evolutionary lineage *Globigerina woodi* Jenkins - *Globigerinoides trilobus* (Reuss).

ACKNOWLEDGMENTS

I wish to thank the following members of the New Zealand Geological Survey:

Dr. C. A. Fleming, Mr. N. de B. Hornibrook and Mr. G. H. Scott for reading the original manuscript, and Mr. R. C. Brazier who made the drawings for Plate 17. Mr. B. N. Thomson provided stratigraphic information with footage intervals between the 8 samples which are recorded in text figure 3. (Mr. Thomson has a paper in manuscript describing the Parengarenga section in detail.)

EVOLUTIONARY LINEAGE *G. WOODI* - *G. TRILOBUS*

In previous publications (Jenkins, 1960, 1964, MS) it has been stated that a subspecies of *G. woodi* gave rise to *G. trilobus*. The intermediate form between the two species from the Parengarenga section has been recently described and named *Globigerina woodi connecta* Jenkins (1964).

Globigerina woodi connecta is found in the six samples F14852 to F14847 of the Parengarenga Section (Table 1). It is distinguished from *G. woodi woodi* by having a very low arched aperture and a more compact test (Plate 17). In sample F14848, single supplementary apertures are developed on the spiral side at the base of the final chamber in some specimens; these tests are referred to *Globigerinoides trilobus* (Reuss) *s. l.* Concommitant with the development of this supplementary aperture is a slight change in coiling form so that the final chamber tends to envelope part of the test. This trend is maintained and eventually gives rise to *Orbulina universa* d'Orbigny later in the Miocene.

In the Parengarenga rocks a form similar to *Globigerinoides primordius* Blow and Banner has been found in samples F14852 and F14851 (Plate 17). Three specimens were found in each of these samples in well developed planktonic faunas and appear to be related to the *G. woodi woodi* populations. The specimens have distinct lipped umbilical apertures, a feature not found in the holotype of *G. primordius* (Blow and Banner, *in* Eames *et al.*, 1962).

Twelve specimens of *Globigerinoides altiaperturus* Bolli were found in sample F14849 and appear identical with type specimens from Trinidad which were made available by Dr. H. M. Bolli. *G. altiaperturus* again appears to be an offshoot of the *G. woodi woodi* populations.

A series of outline drawings has been made to illustrate the variation of the aperture size and the test morphology to be found within the *G. woodi* population (Plate 17). Specimens of *G. praebulloides* Blow, *G.* cf. *G. primordius* and *G. altiaperturus* have also been illustrated to show the differences in their morphology. The shape of the aperture and the finely perforate test easily distinguish *G. praebulloides* from *G. woodi woodi.*

TEST COILING DIRECTION

Bolli (1957c) has stated in his comments on the direction of coiling in the tests of fossil planktonic Foraminifera that "distinct changes in ratios occur during the evolution of many species." The direction of coiling of the tests of *G. praebulloides, G. woodi woodi, G. woodi connecta, G. trilobus* and *G.* cf. *primordius* has been worked out in the Parengarenga section (text fig. 2).

The percentage of dextral specimens of *G. praebulloides* is seen to fall within 37.5 - 55% and for *G. woodi woodi* it falls within the range 17 - 34%. These two species thus have distinctly different coiling ratios. *G. woodi connecta,* which is closely related morphologically to *G. woodi woodi,* has dextral specimens falling within the range 9 - 35%; *G.*

TABLE 1

Stratigraphic ranges of the planktonic Foraminifera in 8 Lower Miocene samples from the Parengarenga section, New Zealand. Lw = Waitakian Stage; Po = Otaian Stage; Ph = Hutchinsonian Stage; Pa = Awamoan Stage.

NEW ZEALAND STAGES	Lw	Po		Ph	-	Pa	-	Sa
SAMPLE NUMBERS	F14853	F14852	F14851	F14850	F14849	F14848	F14847	F14846
PLANKTONIC FORAMINIFERA								
Cassigerinella chipolensis (Cushman and Ponton)		x		x	x	x		
Catapsydrax dissimilis (Cushman and Bermudez)	x							
C. unicavus Bolli, Loeblich and Tappan			x	x	x			
Globigerina angustiumbilicata Bolli	x	x	x	x	x	x	x	x
G. bradyi Wiesner		x		x	x		x	
G. ciperoensis ciperoensis Bolli		x	x					
G. eamesi Blow						x	x	x
G. praebulloides Blow	x	x	x	x	x	x	x	x
G. cf. *G. tripartita* Koch	x							
G. woodi connecta Jenkins		x	x	x	x	x	x	
G. woodi woodi Jenkins	x	x	x	x	x	x	x	x
Globigerinita incrusta Akers	x	x		x	x	x	x	
Globigerinoides altiaperturus Bolli					x			
G. cf. *G. apertasuturalis* Jenkins		x			x			
G. cf. *G. primordius* Blow and Banner		x	x					
G. trilobus (Reuss)						x	x	x
Globoquadrina dehiscens (Chapman, Parr and Collins)	x	x	x	x	x		x	
Globorotalia kugleri Bolli			x	cf.x				
G. cf. *G. minutissima* Bolli				x	x	x	x	
G. obesa Bolli							x	
G. opima continuosa Blow			x	x				
G. opima nana Bolli	x	x	(?)x	(?)x				
G. praescitula Blow						x	x	x
G. semivera (Hornibrook)		x	x					
G. siakensis (LeRoy)							x	x
G. zealandica Hornibrook						x	x	x
Globorotaloides suteri Bolli	x							

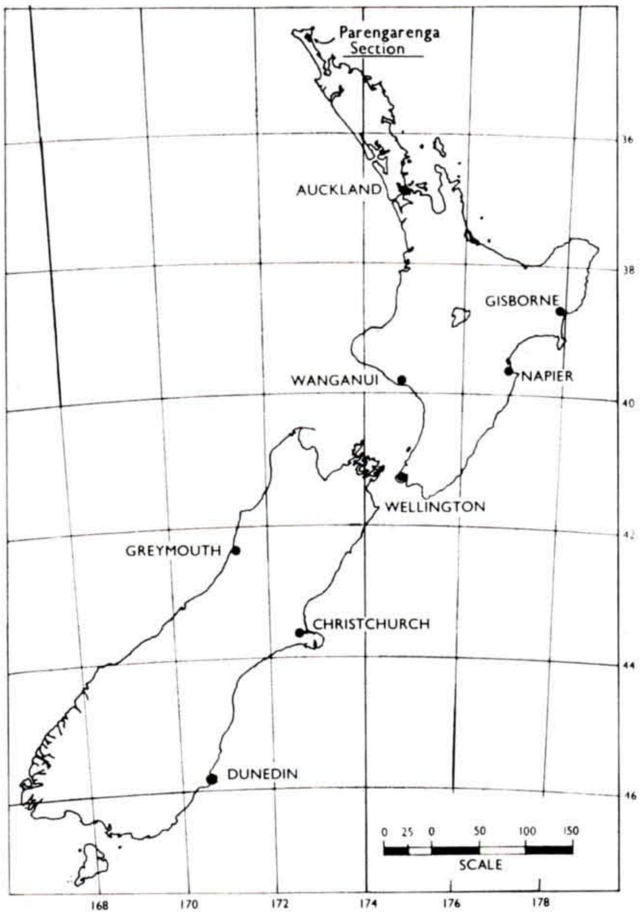
trilobus, which evolved from *G. woodi connecta,* has the range of 33 - 48%. In sample F14848 *G. woodi connecta* has 35% dextral specimens and *G. trilobus* has 34%, but in the succeeding sample *G. trilobus* tests have a greater proportion of dextral tests while *G. woodi connecta* has less (text fig. 2). At this level the proportion of specimens of *G. woodi connecta* in the sample has decreased markedly.

The numbers of specimens of *G.* cf. *primordius* are too few for adequate discussion, but the plot of the coiling direction of the tests indicates a possible relationship with *G. woodi woodi.* This species bears no relation to *G. trilobus* which appears much later (text fig. 3).

DISCUSSION OF RESULTS

Bolli (1957a) stated that in the *Globorotalia kugleri* Zone of the Cipero formation, Trinidad, it appeared probable that *Globigerina* cf. *G. trilocularis* d'Orbigny gave rise to *Globigerinoides trilobus* (Reuss), and, according to Bolli, "Specimens of *Globigerina trilocularis* and *Globigerinoides triloba immatura* LeRoy were found to be indistinguishable in this zone, except that the latter showed a supplementary sutural aperture in the last chamber." Specimens of *G. woodi woodi* have been sent to Dr. H. M. Bolli and he has stated (personal communication) that *G. woodi woodi* is the same species as *G.* cf. *trilocularis* of the Cipero Formation. Therefore, it was then assumed that the sequence of forms within the evolutionary lineage *G. woodi - G. trilobus* was the same in the two areas.

Blow and Banner (in Eames *et al.,* 1962) have given another interpretation of this lineage based on the study of fossils from Trinidad and eastern Falcon, Venezuela, namely, that *Globigerina prae-*



TEXT FIGURE 1
Map of New Zealand showing the locality of the Parengarenga section.

bulloides occlusa Blow and Banner gave rise to *Globigerinoides quadrilobatus primordius* Blow and Banner, and it was this form which was the root of the succeeding *Globigerinoides quadrilobatus* stock (Blow and Banner, *ibid.*). They included in the *G. quadrilobatus* stock the forms *Globigerinoides sacculifer* (Brady), *Globigerinoides trilobus altiaperturus* Bolli and *Globigerinoides trilobus* (Reuss). A previous interpretation of this lineage by Banner and Blow (1960) also showed *Globigerinoides sacculifer irregularis* LeRoy and *Globigerinoides sacculifer immaturus* LeRoy as being subspecies of *G. quadrilobatus.* They did not clearly state what they considered the main taxonomic differences between *G. quadrilobatus, G. trilobus* and *G. immaturus* and gave no information regarding the coiling ratios of the forms in the *G. occlusa - G. quadrilobatus* lineage. This has led to taxonomic confusion and possible duplication of names and has drawn criticism of the present nomenclature (Todd, 1961; Parker, 1962; Bandy, 1964).

Although Blow and Banner (1962, *ibid.*) have placed their subspecies *G. praebulloides occlusa* in synonymy with Bolli's *G.* cf. *G. trilocularis* (Bolli, 1957a, pl. 22, fig. 9a-c; 1957b, pl. 36, fig. 3a-b) these two forms appear to have different test wall ornamentation. The type description and figure of *G. praebulloides occlusa* (Blow and Banner, *ibid.*), indicates that it has a finely perforate and hispid test wall. The illustrations of the Miocene specimen of *G.* cf. *G. trilocularis* (Bolli, 1957a, *ibid.*) show a distinctly perforate wall structure as in *G. woodi woodi* and a higher arched aperture than that of *G. praebulloides occlusa.* It is therefore concluded that *G. praebulloides occlusa* has a significantly different test morphology from *G.* cf. *G. trilocularis* (Bolli, *ibid.*) and *G. woodi woodi.*

CONCLUSION

In the Parengarenga section *Globigerina woodi connecta* evolved into *G. trilobus s. l.* and is in accordance with Bolli's (1957a) original interpretation of this lineage in Trinidad, but differs considerably from the more recent interpretation of this lineage given by Blow and Banner (in Eames *et al.*, 1962).

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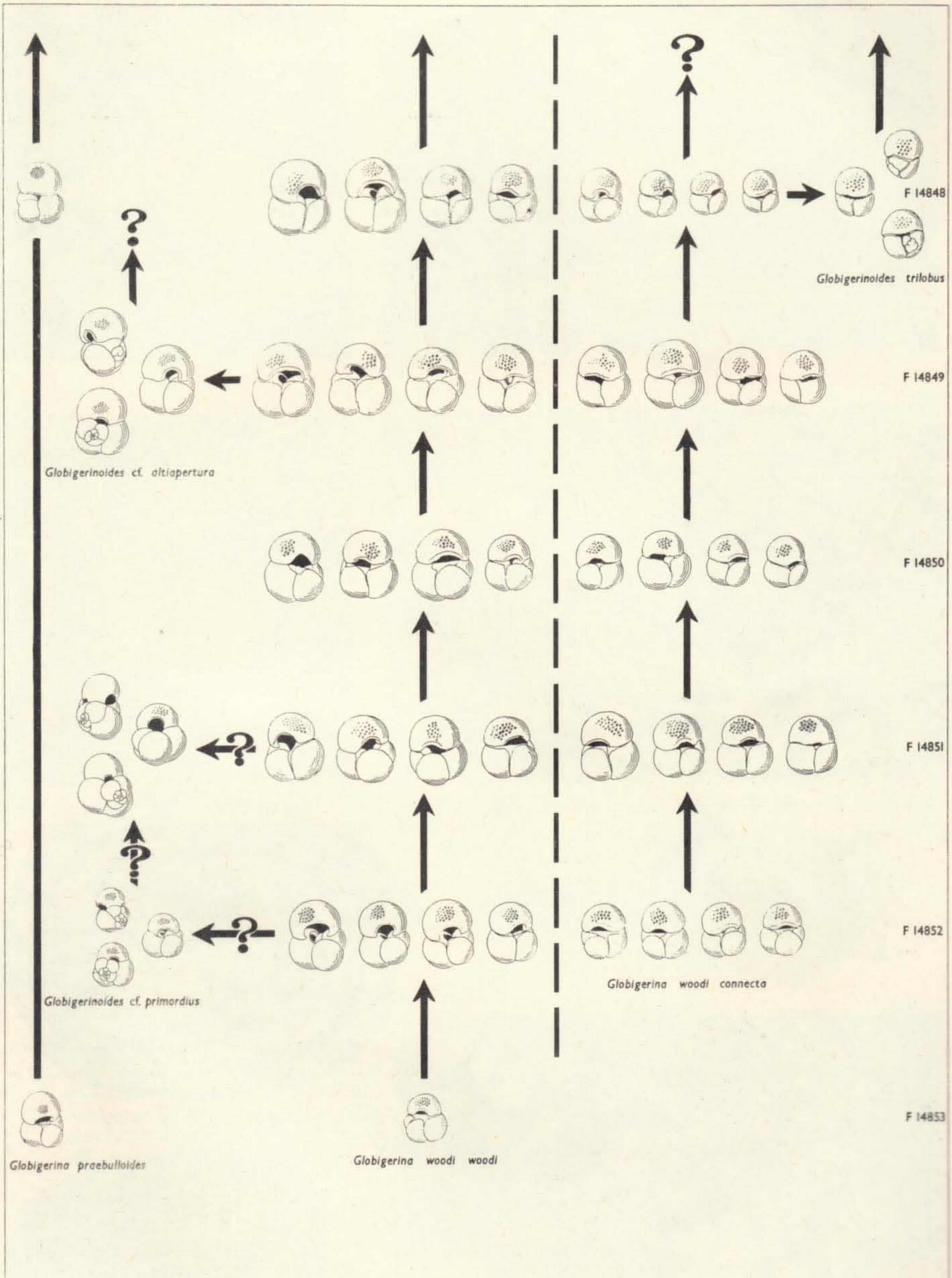
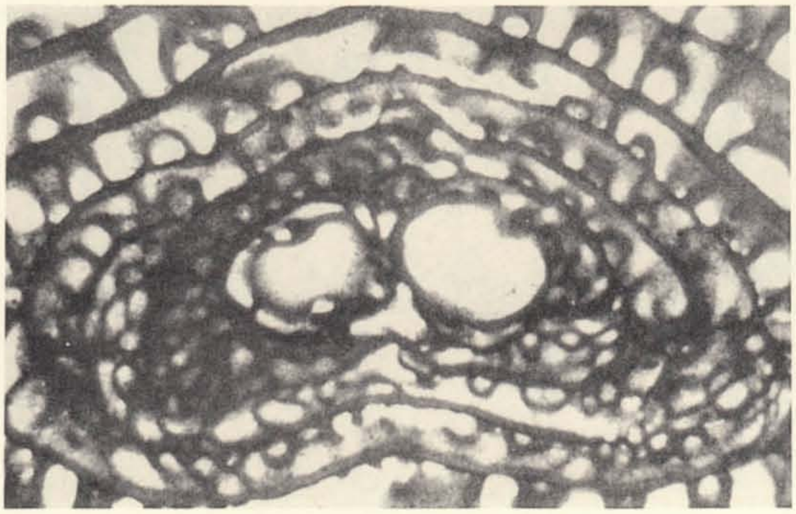
EXPLANATION OF PLATE 17

Outline drawings of selected specimens from 6 successive samples from the Parengarenga section, illustrating the evolutionary lineage *Globigerina woodi - Globigerinoides trilobus.* Also illustrated is *Globigerina praebulloides* to show its morphology, although it is not part of this lineage at this particular level. All specimens magnified × ca. 25.



Jenkins: Origin of *Globigerinoides trilobus* (Reuss)



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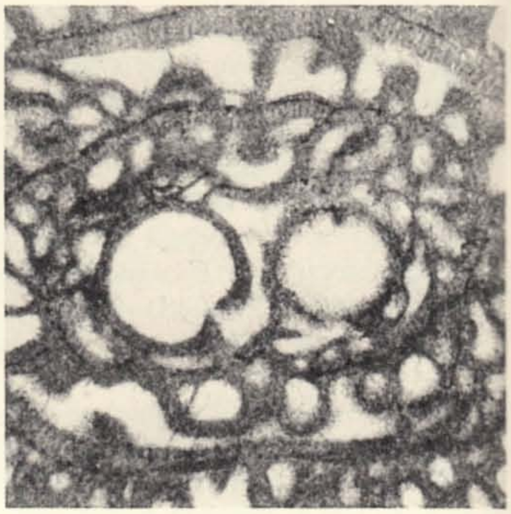

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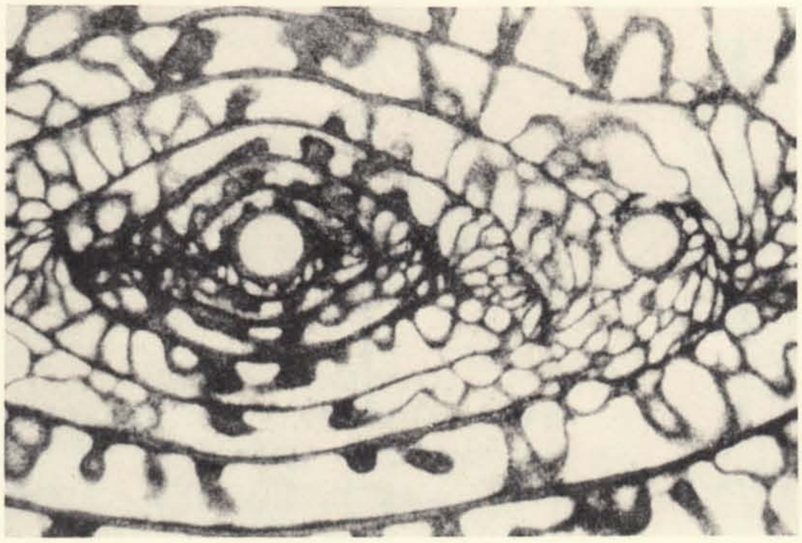

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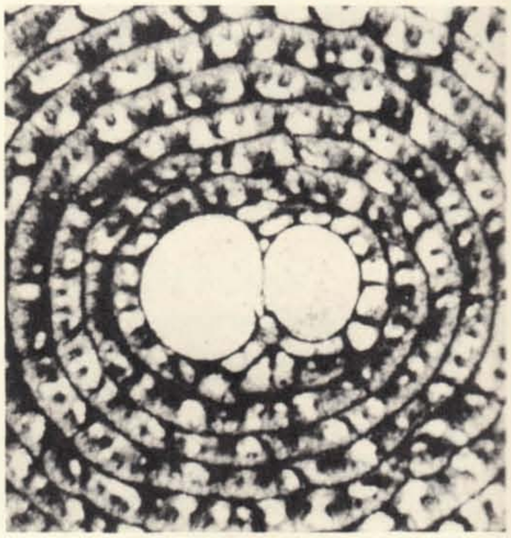

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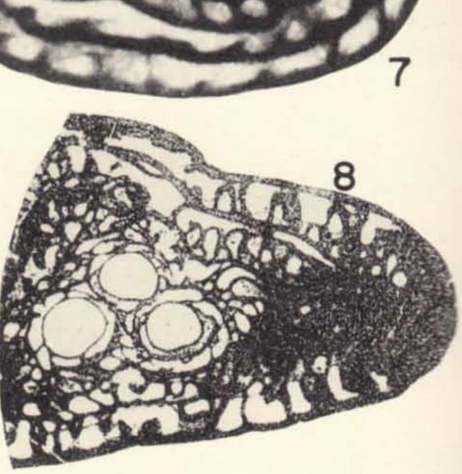

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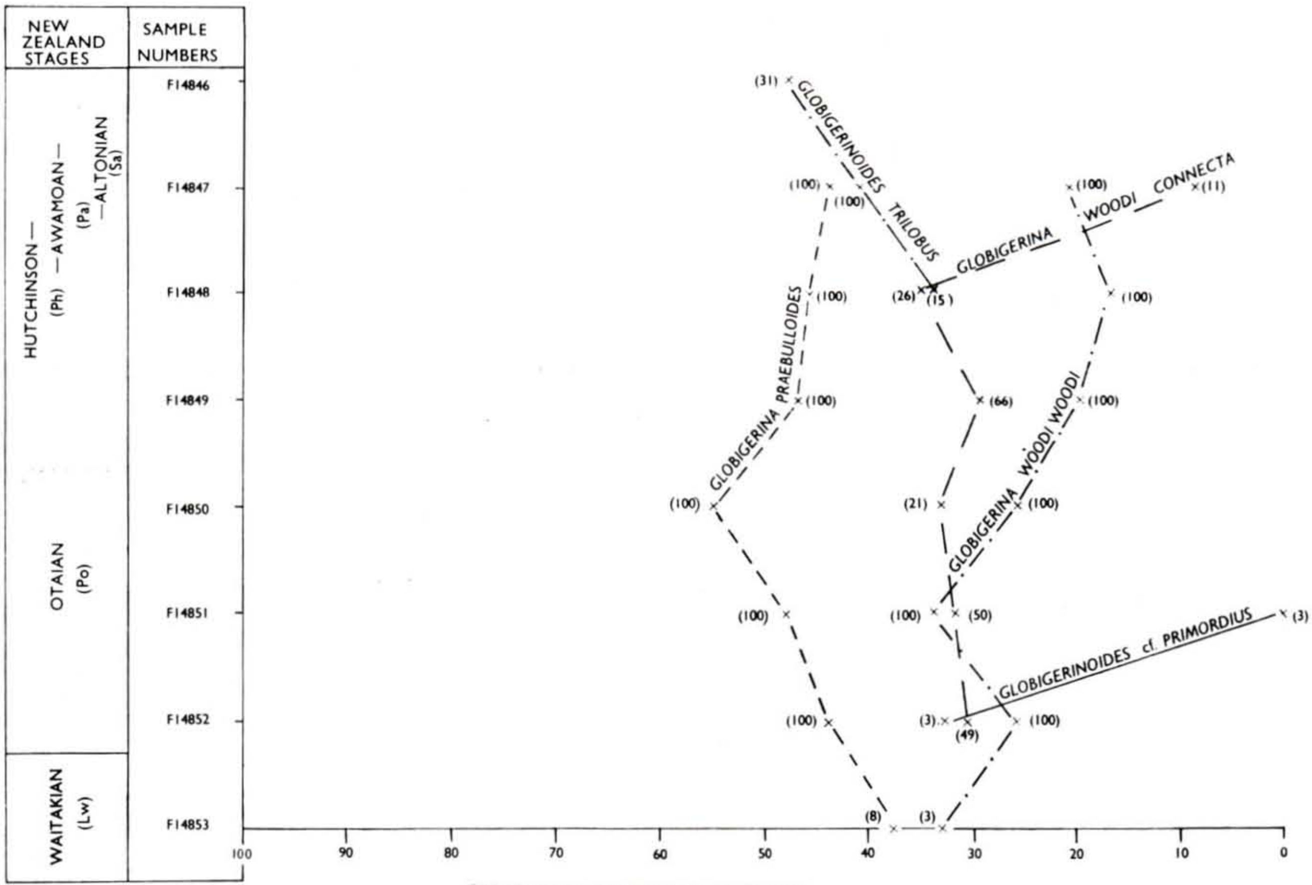
Wilde: Abnormal growth in fusulinids



TEXT FIGURE 2

Coiling directions in 5 planktonic foraminiferal species and subspecies from the Parengarenga section, New Zealand. Numbers in parenthesis indicate the numbers of specimens counted per sample.

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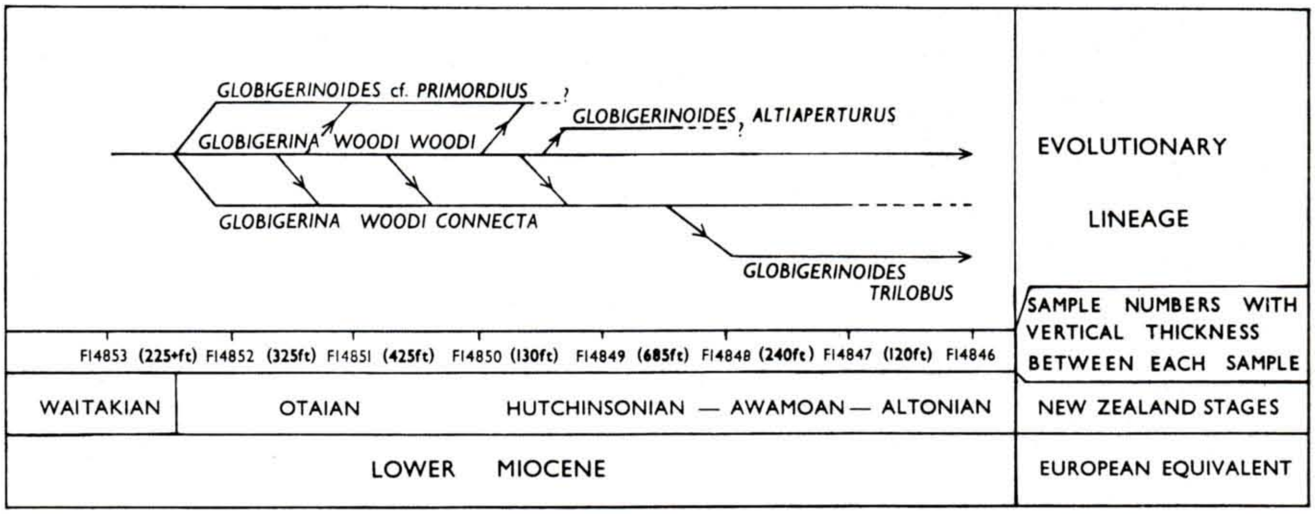
EXPLANATION OF PLATE 18

(Figs. 5, 8, × 10; all others × 40)

Figs.		Page
1.	*Parafusulina* sp. Portion of an axial section. Word Formation, Permian (Lower Guadalupian), about 150 feet below top of Permian in Pinto Canyon, Presidio County, Texas.	121
2.	*Schwagerina hessensis* Dunbar and Skinner. Portion of an axial section of a topotype. Leonard Formation, Permian (Leonardian), Dugout Mountain, Brewster County, Texas.	121
3.	*Fusulina* sp. Portion of an axial section showing a second proloculus trapped in the axial region of the outer whorls. East Mountain Shale, Pennsylvanian (Desmoinesian), Palo Pinto County, Texas.	121
4.	*Lepidolina multiseptata* (Deprat). Portion of a sagittal section of a topotype showing double proloculi in close contact. Permian, Sisophon, Cambodia.	121
5, 6.	*Fusulina* sp. 5, axial section; 6, portion of specimen shown in fig. 5, enlarged. Note the two erratic, but distinct, tunnels. Pennsylvanian (Desmoinesian), Franklin Mountains, El Paso County, Texas.	122
7.	*Polydiexodina* sp. Portion of a sagittal section showing multiple proloculi; one may be microspheric. Capitan Limestone, Permian (Upper Guadalupian), "Trail of the Golden Stairs," south wall of Calamity Cove, Eddy County, New Mexico.	121
8.	*Schwagerina* sp. Portion of an axial section, showing triple proloculi (from Gubler, 1935). Permian, Pong Oua, Laos.	121



TEXT FIGURE 3

The lineage *Globigerina woodi* Jenkins - *Globigerinoides trilobus* (Reuss).

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304. ABNORMAL GROWTH CONDITIONS IN FUSULINIDS

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ABSTRACT

Abnormal growth features were common among the fusulinids. Cellular fusion, multiple proloculi, engulfment, teratogenesis, and shell repair were not restricted normally to any particular genus or species. Recognition of these phenomena and their possible causes is important to a better understanding of the group.

INTRODUCTION

Numerous workers have described several types of abnormalities observed in the fusulinids, but few have attempted to treat any of them in very great detail. Staff (1910) was the first to give much attention to the subject; Dunbar and Henbest (1942), Kahler (1942), and Thompson (1948) have discussed particular features, and recently Bradley (1956) has dealt briefly with teratoid forms. The present review, also, is not intended as a complete treatment of the subject. During the analysis of many tens of thousands of thin sections of fusulinids over a span of more than ten years, however, hundreds of specimens showing abnormal characteristics have been observed. Those specimens which were considered to be unusually instructive are discussed.

The material summarized here is part of a series of lectures presented at Western Reserve University in February 1963. Thanks are given to John W. Skinner and Russell M. Jeffords for critically reading the manuscript and to Humble Oil and Refining Company for permission to publish this paper. The figured specimens are deposited in the files of Humble Oil and Refining Company, Midland, Texas.

CELLULAR FUSION, MULTIPLE PROLOCULI

Many examples showing double proloculi are available in fusulinid literature, and Gubler (1935) has even shown a fine example of triple proloculi. Dunbar and Henbest (1942, p. 38) stated ". . . it appears evident that the twinning is due to the fusion of two young individuals after they had already started to form their shells." For want of a better descriptive terminology, this phenomenon is here called *cellular fusion.*

Fusion of two or more separate individuals to form one adult was not confined necessarily to any particular generic or specific group. In the case of those genera characterized by an endothyrid juvenarium (e.g., *Schubertella, Boultonia, Codonofusiella, Paradoxiella*), however, multiple proloculi are unknown. Megalospheric shells are unknown among this group, and seemingly only the microspheric generation ever existed. Among those genera that display both microspheric and megalospheric generations (dimorphism) multiple proloculi are well known, but even here the microspheric shells are not involved normally.

The specimens shown on Plate 18 have either double or triple proloculi and represent the genera *Fusulina, Schwagerina, Parafusulina, Polydiexodina,* and *Lepidolina.* Not only do they represent a relatively good cross section of fusulinid types, but some are of individual interest for various other reasons. For example, the sagittal section of *Polydiexodina* (pl. 18, fig. 7) appears to have at least two, possibly three, megalospheric proloculi and one microspheric proloculus. Presence of the latter is somewhat doubtful because of the thickness of the section. If present, however, this fusulinid is the only one known having an apparent combination of the two types of shells and such an association would represent a startling exception to the principle of alternation of generations. Presence of three megalospheric proloculi also is doubtful because the central one might represent the first chamber outside the large proloculus. Large first chambers are typical of *Polydiexodina.* Regardless of the proper interpretation, this section certainly is notable.

Commonly, fused individuals began their joint growth in the very early stages of development because fusion apparently occurred at the time or very shortly after the amoebulae were released by the adult fusulinid. Less commonly, however, a mature fusulinid engulfed the proloculus of a young individual (pl. 18, fig. 3). In such instances, the adult apparently encountered little resistance and its growth continued in a normal fashion. The proloculus of the adult *Fusulina* in this case is the same size as the captured proloculus, so the individuals most probably were conspecific. Another example (pl. 20, fig. 3) is of a specimen of *Pseudoschwagerina* which engulfed the juvenarium of an individual belonging probably to the same species. Because of the relatively large size of the engulfed specimen in this case, there is a pronounced bulge developed in the mature specimen.

The data given above may lead to the impression that fusion took place only between individuals of the same species. Engulfment, however, was not restricted to the same species, nor was it necessarily restricted to the same genus. A fine example of this type is a specimen of *Triticites* which engulfed a mature specimen of *Schubertella* (pl. 20, fig. 2). Whether the *Schubertella* died as it was engulfed, or whether it continued to live, is not known. Although difficult to discern in every case, engulfment is not to be interpreted as indicating necessarily that protoplasmic fusion occurred. Furthermore, protoplasmic fusion cannot be demonstrated adequately, even when proloculi came together at a very early stage of growth. For example, one specimen of *Fusulina* (pl. 18, figs. 5, 6) contains double proloculi which fused after about the first whorl, but double tunnels may be noted for a number of whorls. It may be concluded, therefore, that each individual acted as a unit for some time, even though fused with the other. How this could have occurred calls for the wildest speculation.

Rarely two mature individuals of the same species are observed which have fused to become one (pl. 19, fig. 5), but such occurrences are very unusual. It is possible that enough differentiation of the protoplasm had already taken place by maturity to make fusion difficult.

TERATOGENESIS

According to strict definition, *teratogenesis* includes the development of any grotesque or misshapen individual. In the fusulinids, this would include, theoretically, the forms with multiple proloculi discussed above. For purposes of this discussion, however, such forms have been treated separately.

Bradley (1956) discussed teratoid fusulinids and illustrated one specimen. This was a Y-shaped representative of *Parafusulina* having a normal proloculus and three volutions prior to damage. Five more whorls developed after the injury. No good reason can be offered here to explain the Y-shape of many terata, but the pattern is not uncommon. Good examples are shown in *Sumatrina, Parafusulina,* and *Paradoxiella* (pl. 20, figs. 1, 4, 7, respectively). The specimen of *Fusulina* (pl. 20, fig. 5) probably represents a Y-shaped individual, but this cannot be determined with certainty.

Viên (1959) described the genus *Codonoschwagerina* with *Schwagerina thuanae* (Viên) as the type species. This species was considered by Viên as an uncoiled form, hence the generic name. The holotype of *Codonoschwagerina* obviously represents a Y-shaped teratoid individual cut through the proloculus; therefore, *Codonoschwagerina* should not be considered a valid genus.

At least one genus of fusulinid has been described as being characterized by abnormal growth features. The genus *Akiyoshiella* (= *Eofusulina* Rauser, 1951) was described by Toriyama (1953) from Japan as being an aberrant form. Thompson, Pitrat, and Sanderson (1953) followed Toriyama's understanding of the generic features of "*Akiyoshiella*" in describing a new species from British Columbia. Obviously the two localities contain a high percentage of abnormal individuals, but studies of topotypes of these, as well as the type species of *Eofusulina* Rauser, reveal that the abnormal shells are not characteristic of the genus.

Many instances of teratogenesis are undoubtedly attributable to shell damage, but such was probably not always the case. Possibly abnormal growth occurred in some individuals as a result of diseased sarcode which would not have been the result necessarily of broken shells. This may have been the case locally in Japan and British Columbia for the species discussed above.

One specimen which should be mentioned here is a microspheric form of *Fusulinella* (pl. 19, fig. 1) which is sagittal in the juvenarium, axial in the middle whorls, and sagittal once again in the outer volutions. This double change in axis of coiling is most unusual and probably reflects some kind of shell damage.

SHELL REPAIR

Abundant information is available regarding shell damage and repair in the fusulinids. Again, as has been noted, considerable overlap exists between teratogenesis and shell repair. Kahler (1942) perhaps has written more about the subject of shell repair than anyone else. He pointed out that the fusulinid shell underwent the greatest damage in the region of the aperture (or tunnel), and that, generally speaking, the wider the aperture, the more dangerous the possibility became. He further concluded that an aggressor probably would have attacked the tunnel area because this was the weakest part of the shell. In the same manner, the shell would also have been more susceptible to mechanical breakage in that area.

Of considerable interest also was the ability of fusulinids to repair damage by a healing-over process. This was not true regeneration of parts because rarely did individuals repair themselves in such a way that they resembled their old selves. Again, this ability evidently was not confined to any particular group of fusulinids; it is known in practically all genera. Interesting examples of shell damage and subsequent repair may be cited. A specimen of *Triticites* (pl. 19, fig. 2) was broken after gaining only three whorls, but repaired the damaged portion and added three more volutions. In this instance the shape of the species was retained fairly well. One specimen of *Fusulinella* (pl. 19, fig. 3) repaired itself so well after having been broken that following the whorls precisely is difficult. A close examination of this sagittal section betrays the damage and repair.

The specimen of *Pseudoschwagerina* (pl. 19, fig.

4) is of interest for more than one reason. This individual was broken in a wedge-shaped fashion and then healed itself over to continue its growth; moreover, the specimen is microspheric. Microspheric examples of *Pseudoschwagerina* are extremely rare, so much so that microspheric generations are considered generally to be lacking among most species of the genus.

Part of the sagittal section of *Schwagerina* (pl. 20, fig. 6) displays a broken portion of wall which has been strengthened by the addition of a thin lamellar portion above the broken area. Kahler (1942) discussed this phenomenon at length, and examples are abundant in the stratigraphic record.

A specimen of *Wedekindellina* (pl. 19, fig. 6) is of more than passing interest. The proloculus was lost when the shell was broken; even so, more whorls were added subsequently. This observation tends to dispel any remaining argument that the fusulinids were uninucleate and had a nucleus that resided in the central chamber. They are considered to have been polynucleate. Dunbar and Skinner (1937) reported a similar example in *Parafusulina rothi* in which only a fragment of one end of a shell developed nine more volutions after injury. Shells of this type are rare but knowledge of their existence is important for a better understanding of fusulinid development.

Kahler (1942) observed several kinds of shell damage and repair among Permian fusulinids from Austria. In one instance he noted that a specimen of *Pseudoschwagerina* continued living following heavy damage, but showed a marked increase in the number of septa through a given portion of the shell. The opposite condition, in which septa are lacking for as much as one-half of a whorl, also has been observed.

In other examples, Kahler found a marked shortening of the septa for some distance in a given whorl. This phenomenon is not that which is seen in the last volution of many species and which is attributable to senility. Kahler suggested that the plasma may have been weakened from some outside cause. The possibility exists, however, for some sort of analogy between the weakened plasma of the growing shell and that of the senile stage. For instance, were the physiochemical changes which caused the loss of vitality of the plasma among injured or diseased fusulinids actually very different from those which were incurred in old age?

Reference is made in the discussion of teratogenesis, above, to the change in direction of growth due to outside influences such as shell damage (pl. 19, fig. 1). Kahler also discussed this alteration of the direction of growth in fusulinids and made analogies with Tertiary camerinids. He concluded that the "life tenacity" of these large foraminifers must have been great, inasmuch as some individuals added numerous chambers after the reversal had occurred. This change of the direction of growth should always be kept in mind in studying fusulinid suites. The genus *Hayasakaina* Fujimoto and Kawada (1953) is reported to be characterized by an abrupt change in the axis of coiling in the gerontic stage. Otherwise, *Hayasakaina* differs little from *Ozawainella* (or *Nankinella*). Whether these features in *Hayasakaina* are of generic stability can only be answered by careful observations from further collecting (see Igō, 1956). *Hayasakaina* is cited here only as a possible example; no position is intended as to the validity of this genus without first studying type material.

Lee (1924) described the genus *Grabauina* from the Lower Permian Taiyuan Series, Lincheng Basin, south Chihli, China. The figures of Lee's types are drawings of two crushed specimens of *Triticites,* very similar to the group of *Triticites ventricosus.* The sagittal section is of a specimen so badly crushed that only the innermost whorls were left intact. The outer volutions were squeezed flat so that the sagittal section appeared to be discoidal; hence the name *Grabauina disca* for the type species. Lee (1924, p. 51) stated, "The first four volutions are generally fusiform while the last two flatten out in the median region so that the external appearance of the test becomes distinctly discoid or lenticular."

Grabauina, until recently, has been considered by fusulinid workers a junior synonym of *Triticites* Girty. Recently, however, Miklukho-Maklai (1959) resurrected the genus to include a number of species of *Triticites* which appear to differ considerably in morphological features, and seemingly do not constitute a distinct genetic type (e.g., *Triticites acutus* Dunbar and Condra, *T. beedei* Dunbar and Condra, *T. plummeri* Dunbar and Condra, *T. osagensis* Newell, T. *powwowensis* Dunbar and Skinner).

Grabauina does not fall into the class of fusulinids displaying abnormal growth conditions because the shells were crushed after incorporation in the sediment. The abnormal shape ascribed to *Grabauina* was considered erroneously by Lee to be of generic significance. Abnormalities in fusulinids were produced in various ways; however, introduction of new names based on such features, regardless of the cause, can only result in taxonomic confusion.

Numerous instances are known of fusulinid shells which have become partially recrystallized in such a way that a very thin line is the only thing that remains of the spirotheca and septa. Superficially such forms appear to be quite different from fusulinids having normal preservation. Extreme caution must be used in classifying shells of this type. A good rule of thumb is to question any feature that does not follow generally the known phylogenetic trends among the fusulinids.

CONCLUSIONS

Multiple proloculi, shell repair, and teratogenesis were common among the fusulinids. Recognition of such abnormalities is important to a fuller understanding of these foraminifers. An awareness of such occurrences, moreover, could be of help in preventing the proposal of additional taxa based on deformed or abnormal specimens.

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305. FURTHER COMMENTS ON PLANKTONIC FORAMINIFERA IN THE TYPE THANETIAN

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The writer wishes to offer some comments on a recent paper by Haynes and El-Naggar (1964) dealing with planktonic foraminifera in the type Thanetian and to clarify what appear to be some misinterpretations by these authors of views expressed by him in a previous work (Berggren, 1962).

In their paper Haynes and El-Naggar (*op. cit.*) recognize the derived nature in the Reculver Silts of the previously determined *Globorotalia velascoensis* aff. *acuta* Toulmin as "possibly a single-keeled species of *Globotruncana*" (*op. cit.*, p. 354). In addition they list several planktonic foraminiferal species from the Reculver Silts: globotruncanids and other forms of Cretaceous affinities, probably derived from the Campanian in the vicinity, and globigerinids and non-keeled globorotaliids which they also interpret as being derived. These latter include: *Chiloguembelina* cf. *C. morsei, Globigerina daubjergensis, G. triloculinoides, Globorotalia pseudobulloides, G. quadrata* and *G. trinidadensis.* No derived species of definite Maestrichtian age were found according to the authors; this agrees well with observations by Barr and Berggren (1964, *in press*).

The authors believe that *G. daubjergensis, G. quadrata, G. trinidadensis* and *Chiloguembelina* cf. *C. morsei* "appear to represent species derived from Danian deposits" (*op. cit.*, p. 355). Berggren (1963) and Barr and Berggren (1964, *in press*) have not observed these forms in the Reculver Silts but have described three species of planktonic foraminifera which they interpret as being indigenous to the Reculver Silts: *Globigerina chascanona, G. triangularis* and *Globorotalia perclara.* It is possible, in the absence of an opportunity to make direct comparison between the materials used in our respective studies, that a difference or overlap in species concepts exists. It is regrettable that Haynes and El-Naggar (1964) did not illustrate the planktonic forms from the Reculver Silts for purposes of documentation. *G. trinidadensis*—a robust 5-7 chambered form—is primarily a Tethyan species but has been recorded in the Danian and Dano-Montian of Austria and in the lower part of the Montian of Belgium by Gohrbandt (1963). It occurs in the *G. daubjergensis/G. trinidadensis* Zone of Danian Age (*s. s.*) and becomes extinct within the *G. uncinata/ G. spiralis* Zone of Dano-Montian Age, or Danian Age (*s. l.*). Similarly *G. quadrata* is primarily a Tethyan form and is found in post-Danian (*s. s.*) strata.

The authors question whether the rest of the planktonic fauna, i.e., *G. pseudobulloides* and *G. triloculinoides,* is also reworked. It will be recalled that Haynes (1956, p. 99, pl. 17, figs. 12, 12b; 1958, fig. 4) recorded *Globorotalia pseudobulloides* (Plummer) from the Reculver Silts of Pegwell Bay and the Reculver section. In their present publication Haynes and El-Naggar (1964) list *G. pseudobulloides* from the Reculver Silts again. But Berggren (1963) and Barr and Berggren (1964, *in press*) have demonstrated that the three specimens of *G. pseudobulloides* deposited by Haynes in the British Museum (Natural History) in London (Brit. Mus. No. P42633) actually belong to a species of *Rugoglobigerina* (cf. Barr and Berggren, 1964, pl. 3, figs. 1a-2d). Barr and Berggren (*op. cit.*) questionably redetermined *G. triloculinoides* of Haynes (1956, p. 99, 100, pl. 17, figs. 15, 15b; 1958, text-fig. 1) as *G. triangularis* White. In their study of the Reculver Silts they found numerous specimens of this species.

We come now to some points which this writer believes may lead to misunderstanding unless clarified. In questioning whether these two forms may not also be reworked, Haynes and El-Naggar (1964) suggest that the key may lie in specimens formerly referred to *Globigerinella aspera.* They point out that their specimens from the Reculver Silts are identical to those described from the Campanian of California by Graham and Church (1963) and from the Senonian of the Isle of Wight by Barr (1962). They conclude that "it would seem that species intermediate between *Planomalina* and *Pseudohastigerina* were present in the Campanian, and it is likely that the Thanet specimens are derived" (Haynes and El-Naggar, 1964, p. 355). This statement is based on an opinion expressed by Banner and Blow (1959) that the Reculver Silts specimens may belong to *Pseudohastigerina.* The statement above by Haynes and El-Naggar would appear to be without foundation, however. The planispiral forms of the Cretaceous variously described under *Planomalina* or *Globigerinelloides* constitute an homogeneous group which became extinct at the end of the Maestrichtian. The Lower Tertiary planispiral forms included under *Pseudohastigerina* (or *Globanomalina*) arose in the Lower Eocene *Globorotalia rex* Zone from non-keeled globorotaliids such as *G.*

elongata of Bolli, Loeblich and Tappan (*non* Glaessner) (which is probably to be correctly redetermined as *Globorotalia chapmani* Parr). There is no relationship between the Cretaceous species of *Globigerinelloides* and Lower Tertiary species of *Pseudohastigerina* (cf. Banner and Blow, 1959, p. 10).

The authors continue (*op. cit.*, p. 355), "The earliest known species of *Pseudohastigerina* in the Tertiary is *P. eocenica* (Berggren), from the Lower Eocene of northwest Germany. This differs from *Planomalina*? *aspera* in being less inflated and smooth with a different rate of chamber-size increase. According to Berggren (1962), the specimens described by Dain in Subbotina (1953) as *G.* ex. gr. *aspera* belong to his species. However, the illustrations of the form from the Palaeocene of the Caucasus seem to show a number of disparate specimens, at least one of them identical with the Thanet species (plate 13, figure 2) and, presumably, likewise derived." Several points need clarification here:

1) The specimens of *"Globigerinella aspera* (Ehrenberg)" illustrated in Subbotina (1953, pl. 13, figs. 2-12) are from the Maestrichtian with the exception of fig. 2 which is from the Senonian of Northern Kazakhstan, Temirskii region, Djaksy-Bai, not from the Paleocene as the authors state (Haynes and El-Naggar, 1964, p. 355). This was made clear both in the Russian text, in the plate descriptions and in this writer's translation of a part of the text discussion (Berggren, 1962, p. 45). This writer would agree that "a number of disparate specimens" are illustrated in Subbotina (1953, pl. 13, figs. 2-12; cf. Berggren, 1962, p. 44, synonymy). The specimen illustrated as fig. 2 on pl. 13 in Subbotina (1953) may well be *Globigerinelloides aspera* and does indeed agree well with forms found in the Reculver Silts; the remark by the authors that the specimens in Subbotina are, "presumably, likewise derived" is superfluous and meaningless. *Globigerinelloides messinae* (Bronnimann) (which may prove to be a junior synonym of *Globigerinella aberranta* Netskaya, 1948, p. 220; cf. Subbotina, 1964, p. 252) is primarily a middle and upper Maestrichtian species and should be distinguished from the Coniacian-lower Maestrichtian *Globigerinelloides aspera* (*fide* Barr, personal communication). Berggren (1962, p. 44) excluded from the synonymy of *G. messinae* (*G. aspera* of Dain *in* Subbotina, 1953) the specimen figured as fig. 12 on pl. 13 because it is low-trochospiral, perhaps referable to *Hedbergella*.

2) Berggren (1962, p. 47) stated that "the Paleogene form mentioned under *G.* ex. gr. *aspera* may well be a *Pseudohastigerina eocenica* (Berggren), a lower Eocene species which apparently develops a double row of chambers and bipartite primary aperture in some forms." [Haynes and El-Naggar have apparently interpreted this to mean that Berggren (*loc. cit.*) considered the *described* and *illustrated specimens* (italics mine) in Subbotina, 1953, to be referable to *P. eocenica*. But this is manifestly impossible because a) the synonymic list of *G. messinae* in Berggren, 1962, p. 44, included these same illustrations of *G. aspera* by Dain and b) this writer presented in translation a part of the pertinent discussion on the stratigraphic position and morphologic details of the specimens of *G. aspera* used in Subbotina, 1953.] The reference above is to a statement in Subbotina (1953, p. 86; and, again, translated by Berggren, 1962, p. 47) that she had previously (1947) recorded similar forms under the name *G.* ex. gr. *aspera* from the upper part of the Foraminiferal Beds and from the Khadumsk Formation of the northern Caucasus. These strata are of Eocene age and this writer has suggested that they may belong to his species *Pseudohastigerina eocenica* (= *P. wilcoxensis* (Cushman and Ponton)). Unfortunately in this writer's translation of Subbotina (1953, p. 86), "In Lower Paleogene strata of the North Caucasus a very similar form was recorded by the authors under the name of *G.* ex. gr. *aspera* (1947)", the word *Paleogene* was rendered as *Paleocene*. This does not affect the present discussion, however.

Thus the writer would agree with Haynes and El-Naggar (1964) that the specimens of *Globigerinelloides aspera* in the Reculver Silts are derived from the Campanian of the surrounding area. He merely wishes to point out that the discussion by Haynes and El-Naggar (1964, p. 355) to justify this thesis is superfluous and based on some misinterpretations.

It should be pointed out that Barr and Berggren have observed two of the three planktonic foraminiferal species found in the Reculver Silts—*G. chascanona* and *G. triangularis*—in the lower part of the type Landenian in Belgium. This writer considers the evidence for the origin of the Thanetian planktonic foraminiferal species in Danian deposits in the eastern Kent area to be inconclusive.

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RECENT LITERATURE ON THE FORAMINIFERA

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

ADAMS, C. G. The age and foraminiferal fauna of the Bukit Sarang limestone, Sarawak, Malaysia.—Ann. Rept. Geol. Survey, Borneo Region, Malaysia, 1963 (1964), p. 156-162, pls. 46, 47, text figs. 46, 47.—Foraminifera studied in random thin section permit correlation with Tertiary *c* (lower Oligocene).

ADAMS, T. D., and HAYNES, J. Foraminifera in Holocene marsh cycles at Borth, Cardiganshire (Wales).—Palaeontology, v. 8, pt. 1, Feb. 1965, p. 27-38, text figs. 1-3 (map, frequency charts).—Frequency study of Foraminifera in 11 shallow borings around an estuary shows that deposition, beginning under estuarine conditions, evolved through salt marsh to fen carr and finally pine and birch forest. With climatic change, fresh-water peat overwhelmed the forest, and renewed marine transgression initiated another estuarine phase and subsequent marsh cycle. The various stages of these cycles, dated and correlated by radiocarbon and pollen analysis, are recognized by their Foraminifera assemblages.

AKERS, W. H., and DORMAN, J. H. Pleistocene Foraminifera of the Gulf Coast.—Tulane Studies in Geol., v. 3, No. 1, Dec. 30, 1964, p. 1-93, pls. 1-15, text figs. 1, 2 (graph, occur. table).—Illustrated systematic catalog of 259 species and subspecies (5 species and 3 subspecies new) from a 4300-foot section of a well drilled at the mouth of the Mississippi River.

ALEKSEEVA, L. V. Foraminifery Nizhnego Mela Zapadnoj Turkmenii.—Akad. Nauk SSSR, Instit. Geol. i Razrab. Gor. Iskop., 1963, p. 3-56, pls. 1-9, text fig. 1 (columnar sections), 1 occur. and abund. table.—Fifty-five species and varieties (6 new) from the Lower Cretaceous of Turkmen SSR.

ANOSOVA, A. N. et al. Revizija Sistematiki Roda *Schwagerina* i Blizkikh k Nemu Rodov.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 60-75, pls. 1-3.

BARBIERI, FRANCESCO, and PETRUCCI, FRANCO. I Foraminiferi del Tortoniano di Casatico (Parma).—Boll. Soc. Geol. Ital., v. 82, fasc. 3, 1963 (1964), p. 119-180, pls. 1, 2, text fig. 1 (map), geol. map and section, check list.—A catalog of 88 species, with a few illustrated, and a check list comparing Tortonian assemblages from 14 areas.

BASHKIROV, L. V. Stroenie Rakovin i Ontogeneticheskoe Razvitie Paleogenovykh Orbitoidov.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 175-189, text figs. 1-9 (diagrams, chart).

BASOV, V. A. O sistematike i Printhipakh Razgranichenija Marginulin i Marginulinopsisov.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 76-83, 1 pl.—*Lenticulina* (*Marginulinopsis*) *chetae* sp. nov. from the Jurassic (upper Volgian).

BIZON, GERMAINE, DERCOURT, JEAN, and NEUMANN, MADELEINE. Données nouvelles sur l'âge de l'apparition du faciès flysch dans la zone de Gavrovo-Tripolitsa (Massif du Klokova, Acarnanie, Grèce).—Bull. Soc. Géol. France, ser. 7, tome 5, no. 7, 1963, p. 1100-1104, text figs. 1-3 (geol. section, photomicrograph, drawings).—Age determined by upper Eocene planktonics and Priabonian *Pellatispira*.

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CRESCENTI, UBERTO. *Praerhapydionina murgiana* n. sp. (Foraminifero) e *Neomacroporella cretacica* n. gen., n. sp. (Alga Calcarea-Dasicladacea), nuovi microfossili del Cretacico dell' Italia Meridionale.—Boll. Soc. Geol. Ital., v. 83, fasc. 1, 1964, p. 5-10, pls. 1, 2.

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DELANCE, JEAN-HENRI. *Meyendorffina* et *Orbitammina* dans les calcaires de Comblanchien au sud-ouest de Dijon.—Revue de Micropaléontologie, v. 7, No. 3, Dec. 1964, p. 219-222, pl. 1.—Age attributed to upper Bathonian.

DIENI, I., and PROTO DECIMA, F. *Cribrohantkenina* ed altri Hantkeninidae nell' Eocene superiore di Castelnuovo (Colli Euganei).—Riv. Ital. Pal. Stratig., v. 70, No. 3, 1964, p. 555-592, pls. 43-46, text figs. 1-8 (diagrams, graphs).—Descriptions and illustrations of 6 species (in *Pseudohastigerina, Hantkenina,* and *Cribrohantkenina*), none new. Paired primary apertures observed in *Pseudohastigerina micra.*

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1-2, 1962 (1964), p. 29-37, pls. 1-5, text fig. 1 (map).—Six species, one a new *Assilina*.

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A marine section from the Holocene of Talavera on Barentsöya in Spitsbergen with a record of the Foraminifera.—Vorträge des Fridtjof-Nansen-Gedachtnis-Symposions über Spitzbergen, 1964, p. 30-58, pls. 1-3, text figs. 1-5 (maps, columnar section, distrib. charts).—A varied Arctic fauna (57 species) is listed and illustrated in part.

Life cycle and classification in the Foraminifera (in Norwegian with English summary).—"Fauna," Oslo, Norway, arg. 17, hefte 4, 1964, p. 161-178, text figs. 1-8.—Evaluation of previous work.

FIERRO, GIULIANO. Contributo allo studio delle microfaune del Mare Jonio.—Atti Soc. Ital. Sci. Nat. Mus. Civico Storia Nat. Milano, v. 103, fasc. IV, Dec. 15, 1964, p. 381-389, table 1.—Numerical and percentage records of 62 species of Foraminifera (538 specimens) from 1 sample (500 meters) in the Ionian Sea.

FRANKEL, J. J. Terrestrial gastropods in Foraminifera-bearing sediments from the Burman Bush area, Durban.—South African Jour. Sci., v. 60, No. 12, Dec. 1964, p. 363-365, fig. 1 (pl.).—A coastal dune deposit of Plio-Pleistocene age, derived from beach sand.

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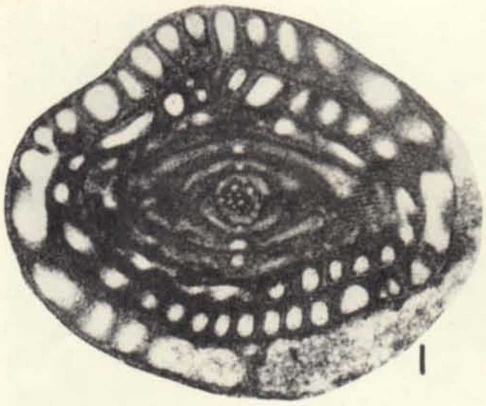

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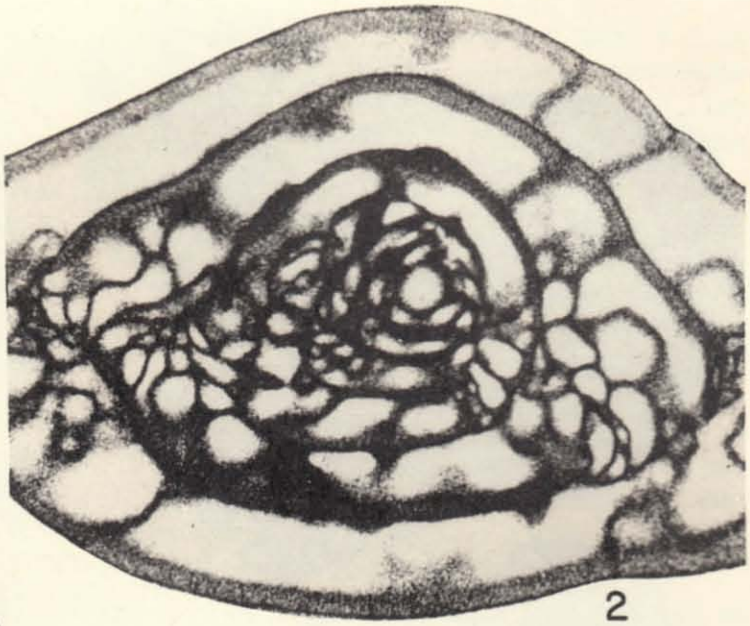

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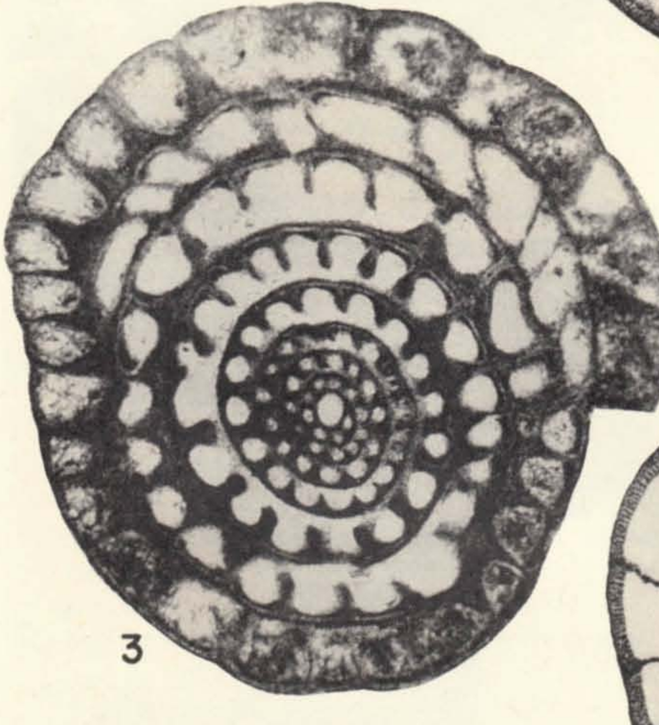

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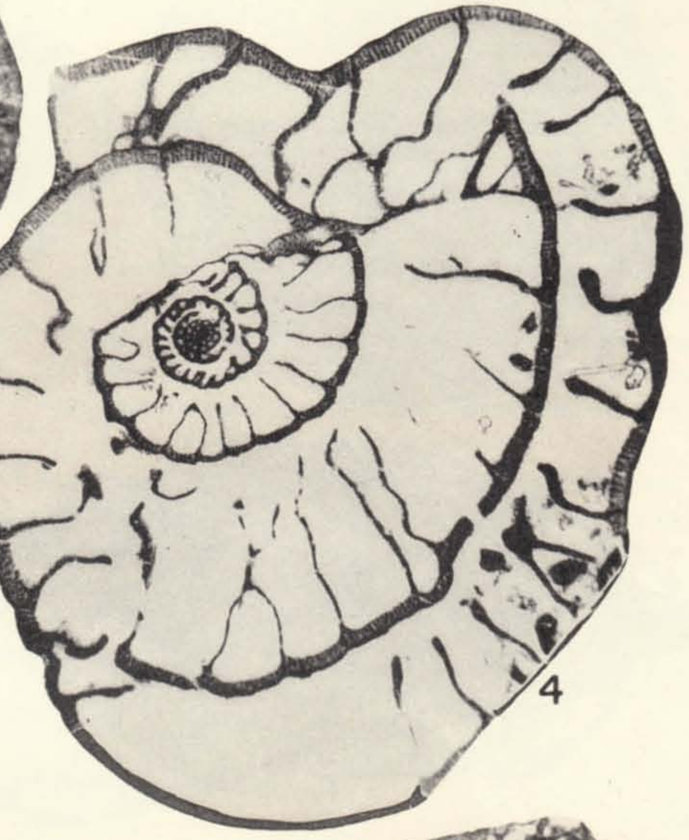

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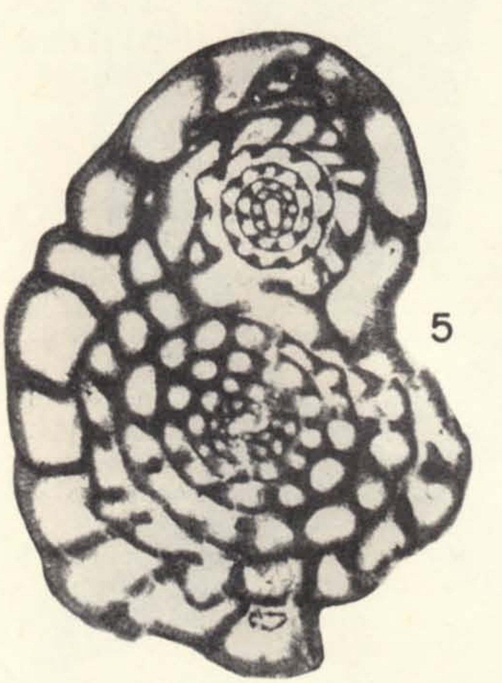

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Wilde: Abnormal growth in fusulinids

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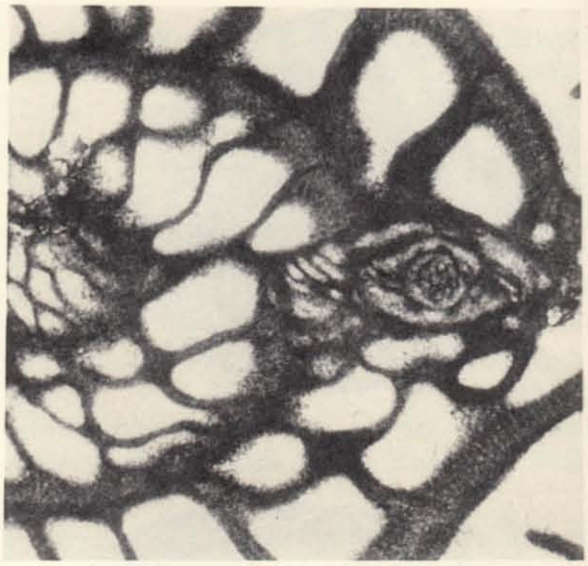

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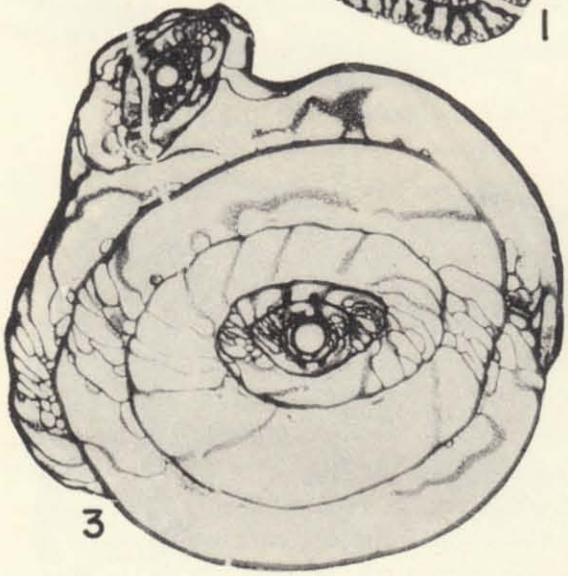

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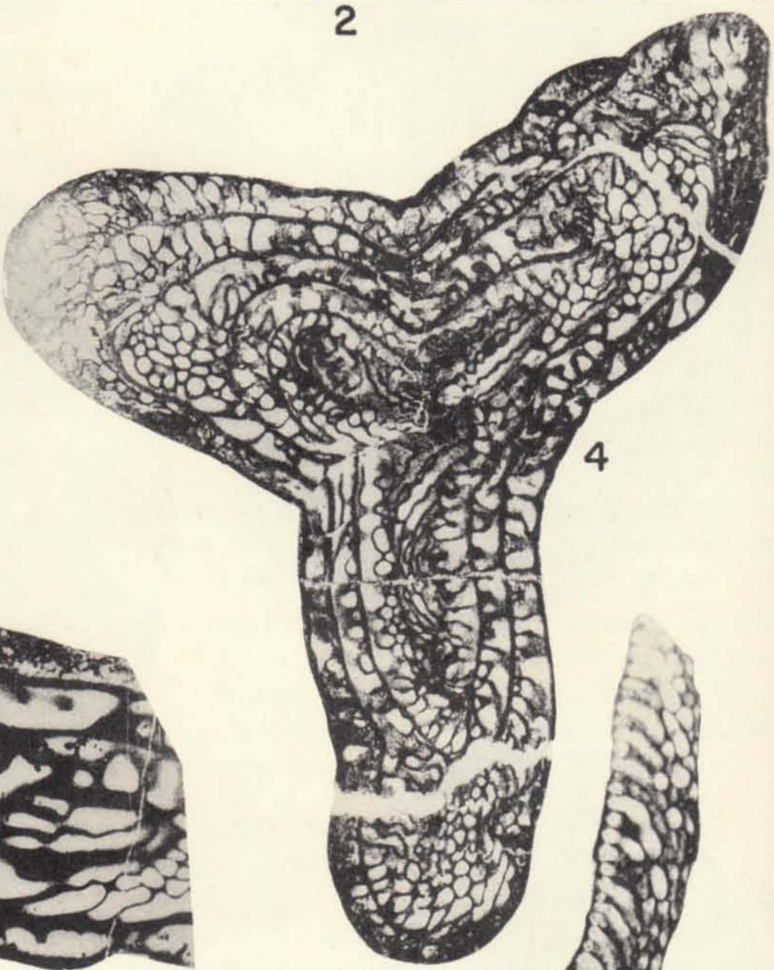

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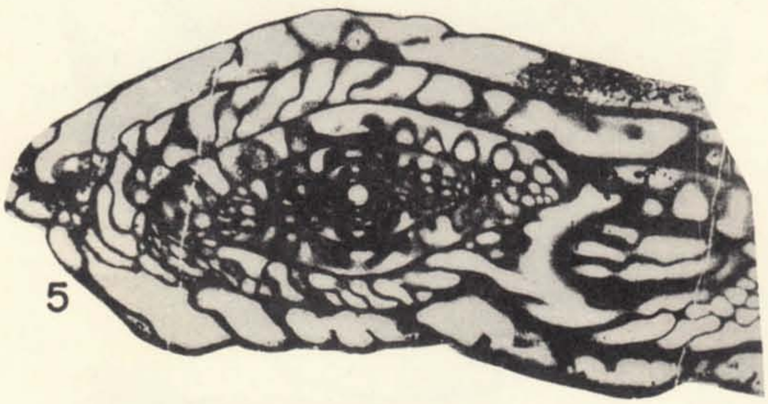

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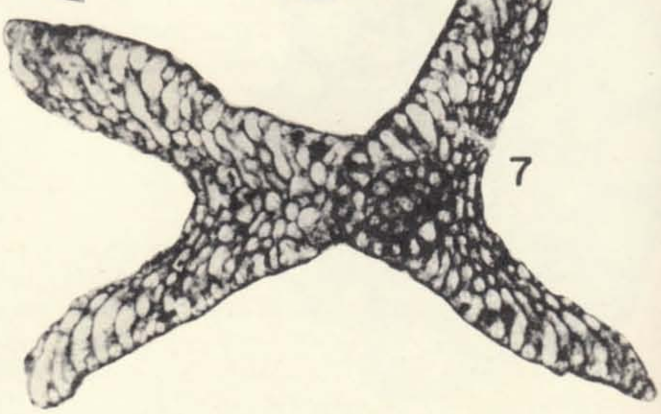

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Wilde: Abnormal growth in fusulinids

pls. 1, 2, text figs. 1-3 (diagrams).—Three peneroplids, 1 new: *Flabellocyclolina laevigata* n. gen., n. sp.

GOLEV, B. T. O Taksonomicheskom Znachenii Nekotorykh Morfologicheskikh Priznakov Predstavitelej Podsemejstva Nummulitinae.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 154-167, pls. 1-4, text figs. 1-4 (diagrams).—Includes diagrammatic drawings of internal structures of nummulites.

GUDINA, V. I. Some Elphidiidae from Quaternary deposits of northern part of West Siberian Lowland (in Russian).—Akad. Nauk SSSR, Sibirskoe Otdel., Geol. Geofiz., No. 9, 1964, p. 66-80, pls. 1, 2, text figs. 1-3, table 1.—Four species of *Elphidium* (3 new); 2 related to *E. clavatum*.

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HARTONO, H. M. S. Coiling direction of *Pulleniatina obliquiloculata trochospira* n. var. and *Globorotalia menardii*.—Bull. Geol. Survey Indonesia, v. 1, No. 1, Jan. 1964, p. 5-12, text figs. 3-6 (graphs, map), figs. a-c (drawings).—In a 200-meter drillhole section on the island of Bali the coiling of *P. obliquiloculata* within the upper Miocene-Pliocene section changes downward from dextral to random to sinistral and that of *G. menardii* from random to sinistral. A new variety, *trochospira*, of *P. obliquiloculata* is described.

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HEDLEY, R. H., HURDLE, C. M., and BURDETT, I. D. J. *Trochammina squamata* Jones and Parker (Foraminifera) with observations on some closely related species.—New Zealand Jour. Sci., v. 7, No. 3, Sept. 1964, p. 417-426, text figs. 1-3.—Discovery of Jones and Parker's holotype shows it to be different from that of Parker and Jones (renamed *T. arctica*) and that of Brady (renamed *T. challengeri*). Comparison table also includes 2 other related species: *T. ochracea* and *Tritaxis fusca*.

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HORNIBROOK, N. DE B. A record of *Globigerinatella insueta* Cushman and Stainforth from New Zealand.—New Zealand Jour. Geol. Geophys., v. 7, No. 4, Nov. 1964, p. 891, 892.—An isolated occurrence in the Clifdenian, indicating the Southern Pacific planktonic fauna is outside the usual limits of the characteristic Caribbean fauna.

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Igo, Hisayoshi. Permian fusulinids of Nyukawa, central Japan. Part 2. Some fusulinids from the lower part of the Sote formation.—Jour. Paleontology, v. 39, No. 2, March 1965, p. 210-223, pls. 29-32, text figs. 1-4 (map, columnar section, geol. section, diagram), tables 1-5. —Ten species, 5 new.

Ishii, Ken-ichi, and Nogami, Yasuo. Contributions to the geology and paleontology of Cambodia. Part 1. Permian Fusulinids.—Jour. Geosciences Osaka City Univ., v. 8, 1964, p. 9-68, pls. 1-8, text figs. 1-5d (maps, graphs), tables 1-8.—Six species and 2 subspecies, none new.

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Jartheva, M. V. Predstavniki rodu *Halkyardia* v Paleogeni Ukraini.—Akad. Nauk Ukrains. RSR, Geol. Zhurnal, tom 24, vyp. 6, 1964, p. 38-48, pls. 1, 2.—Illustrations (thin sections and free specimens) of 2 species, 1 new subspecies, and a forma, from upper Eocene.

O Nekotorykh Vidovykh Kriterijakh Nummulitov.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 168-174, 1 pl., text fig. 1 (graph), tables 1, 2.

Jell, J. S., Maxwell, W. H. G., and McKellar, R. G. The significance of the larger Foraminifera in the Heron Island Reef sediments.—Jour. Paleontology, v. 39, No. 2, March 1965, p. 273-279, pl. 44, text figs. 1-3 (graphs, distrib. map).—Six large genera of Foraminifera characterize the reef (a part of the Great Barrier) and 4 large genera, the deeper water surrounding it. Eight species are illustrated.

Jenkins, D. Graham. Foraminiferal evidence for the Oligocene-Miocene boundary in New Zealand.—New Zealand Jour. Geol. Geophys., v. 7, No. 4, Nov. 1964, p. 888-890, table 1 (chart).—Comparison with planktonics in the Aquitaine Basin.

Location of the Danian-Upper Paleocene-Eocene boundaries in North Canterbury.—New Zealand Jour. Geol. Geophys., v. 7, No. 4, Nov. 1964, p. 890-891.—By means of planktonic Foraminifera.

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Keij, A. J. The relative abundance of Recent planktonic Foraminifera in seabed samples collected offshore Brunei and Sabah.—Ann. Rept. Geol. Survey, Borneo Region, Malaysia, 1963 (1964), p. 146-153, text figs. 42-45 (distrib. and abund. maps, seabed profiles, graphs).—In a quantitative study based on 565 bottom samples from the inner (0-100 m.) and backreef parts of a shallow shelf of the South China Sea, the 40-50 meter isobath defines the inner limit of or a marked increase in various planktonic species. The planktonic-benthonic ratio reflects many complex factors and therefore is not a valid basis for interpretation of a single sample. Isopleth maps show frequency distribution for *Globorotalia menardii, Pulleniatina, Orbulina,* and *Globigerinoides conglobatus.*

Kireeva, G. D. K Taksonomicheskomu Analizu Stroenija Stenki Nekotorykh Rodov Fuzulinidij na Rubezhe Srednego i Pozdnego Karbona.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 53-56.

Krasheninnikov, V. A. Znachenie Foraminifer Otkrytykh Tropicheskykh Bassejnov Datskogo i Paleogenovogo Vremeni dlja Razrabotki Mezhdunarodnoj Stratigraficheskoj Shkaly.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 190-213, text figs. 1, 2 (columnar sections), tables 1, 2.—Includes correlated local planktonic zonation tables for the Danian to Oligocene.

Kristan-Tollmann, Edith. Die Foraminiferen aus den Rhätischen Zlambachmergeln der Fischerwiese bei Aussee im Salzkammergut.—Jahrb. Geol. Bundes., Sonderband 10, Sept. 1964, p. 1-189, pls. 1-39, text figs. 1-6 (map, outcrop diagrams, drawings).—Illustrated systematic catalog includes 245 species and subspecies (97 new). Three genera are new: *Ammobacularia* (genotype *A. triloba* n. sp.), *Kion* (genotype *K. canaliculata* n. sp.), and *Grillina* (genotype *G. grilli* n. sp.).

Kudrin, L. N., Buryndina, L. V., and Kirillova, T. A. Recent data on the age of layers enclosing *Candorbulina universa* (in Russian).—Doklady Akad. Nauk SSSR, tom 159, No. 2, 1964, p. 333-335.

Kurgalimova, G. G. On the problem of the *Gaudryina-Gaudryinella* phylogeny (in Russian). —Paleont. Zhurnal, 1964, No. 3, p. 121-123, text figs. 1-3.—*Belorussiella intermedia* sp. nov. from middle Eocene.

KUZNETHOVA, K. I. Ob Ehvoljuthii Nekotorykh Vidov Marginulin i Metodakh ikh Issledovanija.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 84-90, text figs. 1, 2 (graphs).—Evolution of *Marginulina robusta* in Upper Jurassic and Lower Cretaceous.

LIPINA, O. A., and PRONINA, T. V. A new subgenus of *Tournayella* from the Upper Frasnian of the Urals (in Russian).—Paleont. Zhurnal, 1964, No. 3, p. 125, 126, text fig. 1.—*Tournayella* (*Eotournayella*) *jubra* sp. nov.

LIPPS, JERE H. Revision of the foraminiferal family Pseudoparrellidae Voloshinova.—Tulane Studies in Geol., v. 3, No. 2, 1965, p. 117-147, pls. 1-3, text figs. 1-4 (range chart, drawings, graph). —Six genera (2 new) make up the family. New are *Ambitropus* (type species *Epistominella evax* Bandy) and *Concavella* (type species *Pulvinulinella gyroidiniformis* Cushman and Goudkoff). Seventeen species (1 given a new name) are described and illustrated from California. Another species is placed in a new genus of the Eponidae: *Eilohedra* (type species *Epistominella levicula* Resig).

LISZKA, STANISLAW. Occurrence of Lower Permian foraminifers in the Treskelodden beds of Hornsund, Vestspitsbergen.—Polska Akad. Nauk, Studia Geol. Polonica, v. 11, 1964, p. 169-172.

LUCZKOWSKA, EWA. Preliminary investigations of microfauna from the Fjord-bottom deposits in Hornsund, Vestspitsbergen.—Polska Akad. Nauk, Studia Geol. Polonica, v. 11, 1964, p. 217-220.—Eight species of Foraminifera recorded from clay at 22 meters; specimens of *Cibicides lobatulus* comprising more than 80% of the assemblage.

LUTERBACHER, HANSPETER. Studies in some *Globorotalia* from the Paleocene and lower Eocene of the Central Apennines.—Eclogae Geol. Helvetiae, v. 57, No. 2, Dec. 1964, p. 631-730, text figs. 1-134 (drawings, maps, columnar sections, range chart, correl. table).—Descriptions and illustrations of 22 species, with their distribution in the Gubbio section indicated in terms of the West Indian zonation, and their European occurrences and correlation with European stages discussed.

MAJZON, L. Stratigraphic range of planktonic Foraminifera in Hungary.—Acta Geologica, Budapest, Acad. Sci. Hungaricae, tom. 8, fasc. 1-4, 1964, p. 283-300, text figs. 1-3 (maps).—Summary of planktonic assemblages (including their benthonic associations) in Hungarian localities from Lower Cretaceous to Miocene.

MASLAKOVA, N. I. K Sistematike i Filogenii Globotrunkanid.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 102-117, text figs. 1-5 (graph, phylogenetic diagrams), 1 table.—New subfamily Globotruncanellinae.

MAYNC, WOLF. *Iberina praelusitanica* n. sp. from the upper Oxfordian of Israel.—Eclogae Geol. Helvetiae, v. 57, No. 2, Dec. 1964, p. 559-566, pls. 1, 2, text figs. 1, 2 (map, graph).

MONTANARI, L. *Orbitolites lehmanni,* nuova specie nel Cuisiano di Sicilia.—Riv. Ital. Pal. Stratig., v. 70, No. 3, 1964, p. 537-544, pls. 40, 41, text figs. 1, 2 (columnar section, photomicrograph).

Alveolina obtusa, nuova specie del Luteziano.—Riv. Ital. Pal. Stratig., v. 70, No. 3, 1964, p. 547-552, pl. 42, text fig. 1 (map).

MOSNA, S. Frequenti rinvenimenti di *Robulus brevispinosus* (Nuttall) in termini del Miocene inferiore (Aquitaniano e Langhiano) del Bacino Terziario Piemontese.—Boll. Soc. Geol. Ital., v. 83, fasc. 1, 1964, p. 63-71, pl. 1.

MOULLADE, MICHEL. Nouvelles propositions pour l'établissement d'une zonation micropaléontologique de l'Aptien et de l'Albien vocontiens.—C.R.S. Soc. Géol. France, fasc. 2, Feb. 8, 1965, p. 48-50, range chart.—Ranges shown for 25 species of Foraminifera, most of them planktonic. Seven zones and 13 subzones based on Foraminifera.

NEAGU, THEODOR. Large size agglutinated Foraminifera from the Campanian of Rumania.—Ann. Soc. Geol. Pologne, v. 34, fasc. 4, Année 1964, p. 579-588, pls. 26, 27, text figs. 1-5.—One new species of *Psammatodendron* and 2 of *Aschemonella.*

NOSOVSKIY, M. F., and SAVENKO, N. G. Stratigraphic position of the *Sphaeroidina* zone in Maykopian beds of the Black Sea Trough (translation). —Doklady Acad. Sci. USSR, Earth Sci. sec., v. 148, Jan.-Feb. 1963, (translation Nov. 1964), p. 75-76.—Associated Foraminifera listed.

PARKER, FRANCES L. Correction: Foraminifera from the experimental Mohole drilling near Guadalupe Island, Mexico.—Jour. Paleontology, v. 39, No. 2, March 1965, p. 304.

PERLMUTTER, NATHANIEL M., and TODD, RUTH. Correlation and Foraminifera of the Monmouth Group (Upper Cretaceous), Long Island, New York.—U. S. Geol. Survey Prof. Paper 483-I, April 2, 1965, p. I1-I24, pls. 1-6 (fossils), 7 (map), 8 (geol. sections), tables 1-6, (available U. S. Govt. Printing Office, $1.00).—Includes descriptions and illustrations of about 75 species of Foraminifera from cores and cuttings of 11 wells along the south shore of Long Island. The subsurface formation is correlated with the Monmouth Group of New Jersey, the Navarro Group of the Gulf Coast, and the Maestrichtian of Europe.

POZARYSKA, KRYSTYNA. On some Foraminifera from the Boryszew boring (Central Poland).—Acta Paleont. Polonica, v. 9, No. 4, 1964, p. 539-548, pls. 1-5.—Six species indicating lower Paleocene.

PREMOLI SILVA, I. Le Microfaune del Pliocene di Balerna (Canton Ticino).—Eclogae Geol. Helvetiae, v. 57, No. 2, Dec. 1964, p. 731-742, pl. 1.—Includes lists of Foraminifera and photomicrograph of a typical assemblage.

PUTRJA, F. S. On some new species of Miocene Foraminifera from the eastern Ciscarpathia (in Russian).—Paleont. Zhurnal, 1964, No. 3, p. 127-131, pl. 15.—Four species of *Streblus*, all new.

RASHEED, D. A. Some arenaceous and calcareous porcellaneous Foraminifera from the Cullygoody (Dalmiapuram) Limestone, Trichinopoly Cretaceous, Madras State, India, Part I.—Jour. Madras Univ., v. 32, sec. B, No. 1, April 1962, p. 21-47, pls. 1-6.—Illustrated systematic catalog includes 28 species, 2 new and 6 indeterminate.

Some calcareous Foraminifera belonging to Lagenidae, Ellipsoidinidae and Heterohelicidae from the Cullygoody (Dalmiapuram) Limestone, Trichinopoly Cretaceous of South India, Part II.—Jour. Madras Univ., v. 32, sec. B, Nos. 2-3, 1962, p. 199-266, pls. 1-13.—Illustrated systematic catalog includes 85 species and varieties, 1 species new and 13 indeterminate.

Some calcareous Foraminifera belonging to the families Rotaliidae, Globigerinidae, Globorotaliidae and Anomalinidae from the Cullygoody (Dalmiapuram) Limestone, Trichinopoly Cretaceous of South India, Part III.—Jour. Madras Univ., v. 33, sec. B, No. 3, Dec. 1963, p. 231-248, pls.1-4.—Illustrated systematic catalog includes 15 species, 2 new.

RATHUR, ANWARUL QADEER. A note on the taxonomic position of *Lenticulina* (*Marginulinopsis*) *radiata* (Terquem).—Bull. Min. Res. and Explor. Instit. Turkey, No. 63, 1964, p. 60-65, text figs. 1, 2 (graphs, photomicrographs).—A study of variability in length and number of ribs in specimens from the lower Lias of England.

REDMOND, C. D. Three new genera of Foraminifera from the Jurassic of Saudi Arabia.—Micropaleontology, v. 11, No. 2, April 1965, p. 133-140, pl. 1.—*Pseudomarssonella* n. gen. (type species *P. maxima* n. sp.) and *Riyadhella* n. gen. (type species *R. regularis* n. sp.) in the Ataxophragmiidae, and *Dhrumella* n. gen. (type species *D. evoluta* n. sp.) in the Rotaliacea. Eighteen species, all new.

REITLINGER, E. A. O Sostojanii Izuchennosti Otrjada Endothyrida.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 30-52, 1 pl., text figs. 1, 2 (graph, diagram), tables 1-3.

RICHTER, GOTTHARD. Zür Ökologie der Foraminiferen. I. Die Foraminiferen-Gesellschaften des Jadegebietes.—Natur und Museum (Frankfurt a. M.), Band 94, heft 9, Sept. 1964, p. 343-353, text figs. 1-14 (photomicrographs, maps, graphs).—Quantitative study of living communities in the Jade region around Wilhelmshaven. Major constituents of the region (*Nonion depressulum, Elphidium excavatum,* and *E. selseyense*) exist in greatly varying percentages at various localities.

Zür Ökologie der Foraminiferen. II. Lebensraum und Lebensweise von *Nonion depressulum, Elphidium excavatum* und *Elphidium selseyense.*—Natur und Museum (Frankfurt a. M.), Band 94, heft 11, Nov. 1964, p. 421-430, text figs. 1-4 (graphs, photomicrographs), tables 1-3.—Includes photomicrographs showing living specimens of *Elphidium excavatum* crawling over a fine sediment surface in an observation dish, and the digging tracks left by specimens creeping up through freshly deposited sediment against the glass wall of an observation tank.

RODIONOVA, M. K. Foraminifery Verkhneeothenovykh Otlozhenij Zapadnoj Turkmenii.—Akad. Nauk SSSR, Instit. Geol. i Razrab. Gor. Iskop., 1963, p. 57-92, pls. 1-7, text figs. 1-8 (columnar sections, maps), 1 occur. and abund. table. —Twenty-eight species and varieties (9 new) from the upper Eocene of Turkmen SSR.

ROSS, CHARLES A., and SABINS, FLOYD F., JR. Early and middle Pennsylvanian fusulinids from southeast Arizona.—Jour. Paleontology, v. 39, No. 2, March 1965, p. 173-209, pls. 21-28, text figs. 1-4 (map, stratigraphic sections, range chart), tables 1-10.—Forty-one species, 22 new and 7 indeterminate.

ROVEDA, V. Découverte de *Gabonella* dans le Crétacé Supérieur du Sahara Espagnol.—Revue de Micropaléontologie, v. 7, No. 3, Dec. 1964, p. 195-204, pls. 1-3, text figs. 1-3 (map, range chart, diagrams).—Eight species (6 new) from various parts of well sections between Campanian and Cenomanian.

SADA, KIMIYOSHI. *Neoschwagerina* from Joé Limestone, Hiroshima Prefecture, West Japan, with a note on *Neoschwagerina margaritae* Deprat.

—Geol. Rept. Hiroshima Univ., No. 12, March 1963, p. 541-552, pl. 58, text figs. 1, 2 (map, graph).

SAMANIEGO, REMEDIOS M. The occurrence of *Globorotalia velascoensis* in the Philippines.—The Philippine Geologist, v. 18, No. 3, Sept. 1964, p. 65-74, pls. 1, 2.—The Paleocene faunal association, listed and illustrated, is correlated with the *G. velascoensis* zone in Trinidad.

SCHROEDER, ROLF. Communication préalable sur l'origine des Orbitolines.—C.R.S. Soc. Géol. France, fasc. 10, Dec. 21, 1964, p. 411-413, text figs. A-C.—*Praeorbitolina* n. gen. and 2 new species from the Bedoulian (substage of the Aptian) of Spain.

SCHROEDER, ROLF, and POIGNANT, ALAIN. *Orbitolinopsis aquitanica,* eine neue Foraminifere der Unterkreide der Aquitaine (SW-Frankreich) (Studien über primitive Orbitolinidae I).—Eclogae Geol. Helvetiae, v. 57, No. 2, Dec. 1964, p. 553-558, pls. 1, 2, text fig. 1 (diagram).

SCHUTZKAJA, E. K. Vidovye Kriterii Nizhnepaleogenovykh Predstavitelej Roda *Globigerina.*—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 118-137, pls. 1, 2, text figs. 1-22.—Three species (*Globigerina pseudobulloides* and 2 new ones) comprise the "*Globigerina pseudobulloides* group." These and several other species are illustrated from upper Danian and lower Paleocene.

SEROVA, M. JA. Znachenie Nekotorykh Morfologicheskikh Priznakov Roda *Cyclammina* dlja Taksonomii na Primere *Cyclammina cancellata* Brady.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 13-29, pls. 1-7, text figs. 1-7 (graphs).—Illustrations of free specimens and thin sections.

SGANGA, P. La sezione stratigrafica calabriana di Naso (Messina).—Riv. Mineraria Siciliana, Anno 14, No. 82-84, July-Dec. 1963, p. 214-234, pls. 1-11, text figs. 1-4 (map, columnar section, photomicrographs of assemblages).—Occurrence and abundance of nearly 300 species of Foraminifera are recorded in 40 samples covering about 150 meters of section. Five lithologic subdivisions are recognized, each with its characteristic fossil assemblage, and the entire section is dated as upper Calabrian. Fourteen of the most significant Foraminifera are illustrated and discussed.

SHCHERBOVICH, S. F. O Rode *Orientoschwagerina* A. M.-Maclay, 1955.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 57-59, 1 pl.

STSCHEDRINA, Z. G. O Nekotorykh Izmenenijakh v Sisteme Otrjada Rotaliida (Foraminifera).—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 91-101, text figs. 1-6.—*Cribroeponides* gen. nov. (type species *Poroeponides cribrorepandus* 1952) is distinguished from *Poroeponides lateralis* (Terquem).

TAKAYANAGI, YOKICHI. Upper Cretaceous planktonic Foraminifera from the Putah Creek subsurface section along the Yolo-Solano County Line, California.—Sci. Repts. Tohoku Univ., 2nd Ser. (Geol.), v. 36, No. 2, Feb. 15, 1965, p. 161-237, pls. 20-29, text figs. 1-9 (maps, distrib. table, range charts, graph), table 1.—Includes an illustrated systematic catalog of 36 species, 1 new. Six zones, defined by overlapping ranges of planktonic forms, are correlated with the European stages from lower Turonian to Campanian.

TEDESCHI, D., and PAPETTI, I. On the occurrence of *Pseudolituonella* in Libya.—Revue de Micropaléontologie, v. 7, No. 3, Dec. 1964, p. 180-187, pls. 1, 2, text figs. 1, 2 (map, columnar section).—In the upper Lutetian.

THOMPSON, M. L. Pennsylvanian and Early Permian fusulinids from Fort St. James area, British Columbia, Canada.—Jour. Paleontology, v. 39, No. 2, March 1965, p. 224-234, pls. 33-35, text fig. 1 (map).—Thirteen species, 8 new.

UCHIO, TAKAYASU. Influence of the River Shinano on Foraminifera and sediment grain-size distributions.—Papers in Marine Geology, Shepard Commemorative Volume, The MacMillan Co., New York, 1964, p. 411-428, text figs. 19.1-19.10 (map, distrib. maps), table 19.1.—Maps show distribution by percentage of total population for some of the most abundant and locally restricted species.

UJIIÉ, HIROSHI. Larger Foraminifera from a guyot in the Cocos-Keeling Basin, eastern Indian Ocean.—Bull. Tokyo Nat. Sci. Mus., v. 7, No. 3, Oct. 1964, p. 307-321, pls. 1-9, text figs. 1, 2 (map, diagram).—A lower Miocene reef fauna (1 *Cycloclypeus* and 4 *Lepidocyclina*) from limestone blocks dredged from the top of the guyot at about 800 fathoms.

VELLA, PAUL. Oligocene-Miocene boundary.—Geol. Soc. America Bull., v. 76, No. 3, March 1965, p. 349-356, table 1.—Discusses need for an international committee to choose a type section where a complete sequence of planktonic forams exists across the boundary and includes the *Orbulina* bioseries. The boundary should be chosen to fall at an horizon whose world-wide isochroneity could be determined by means of the *Orbulina* bioseries.

VOLOSHINOVA, N. A. Stepen' Izuchennosti i puti Dal'nejshego Izuchenija Tretichnykh Lituolid. —Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 3-12, pls. 1-3, phylogenetic diagram. —Illustrations of various lituolid species.

VOLOSHINOVA, N. A., and KUZNETHOVA, V. N. Novye Dannye po Morfologii i Evoljuthionnomu Razvitiju Nekotorykh Predstavitelej Semejstva Elphidiidae.—Akad. Nauk SSSR, Otdel. Nauk o Zemle, Geol. Instit., Voprosy Mikropaleont., vyp. 8, 1964, p. 138-153, pls. 1-7, text figs. 1-3 (diagrams, evolution chart).—Includes illustrations of numerous species of *Elphidium, Elphidiella,* and *Cribroelphidium,* and a chart showing their evolutionary relationship.

WALTON, WILLIAM R. Ecology of benthonic Foraminifera in the Tampa-Sarasota Bay area, Florida.—Papers in Marine Geology, Shepard Commemorative Volume, The MacMillan Co., New York, 1964, p. 429-454, text figs. 20.1-20.8 (maps, distrib. maps), tables 20.1, 20.2.—Quantitative analysis of living and dead populations in 33 samples from depths between 1 and 33 feet, and recognition of 4 faunas. Contrast with faunas of the geographically similar Mobile Bay in Alabama demonstrates the effects of the difference in hydrographic climate.

WEAVER, D. W., and MOLANDER, G. E. The Eocene faunal sequence in the eastern Santa Rosa Hills, Santa Barbara County, California.—Univ. Calif. Publ. Geol. Sci., v. 41, No. 3, Jan. 6, 1965, p. 161-248, pls. 1-18, text figs. 1-4 (maps, columnar section, check list), tables 1, 2.—Illustrated systematic catalog includes 155 species and subspecies (1 species new).

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