

CONTRIBUTIONS
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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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331. A REVIEW OF AMERICAN SPECIES OF MIOGYPSINIDS
(LARGER FORAMINIFERA)

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ABSTRACT

Twenty-one specific names have been proposed for American miogypsinids (Foraminifera) since Cushman in 1918 described the first species, *Heterosteginoides panamensis*. Several authors (Drooger, 1952, 1963; Cole, 1957a, 1964; Hanzawa, 1962; Barker, 1965) have analyzed these species and proposed different classifications. This article expands the postulate (Cole, 1964) that the recognition of only three species is sufficient to account for the biologic development as well as the geographic and stratigraphic distribution of American miogypsinids.

Miogypsinoides complanata (Schlumberger) has a stratigraphic range from the marine Frio into the *Heterostegina* zone of the Anahuac Formation of the Gulf Coast of the United States. The uniserial (Cole, 1964, p. 142) *Miogypsina panamensis* (Cushman) is restricted to the *Heterostegina* zone of the Anahuac Formation and to stratigraphically equivalent sediments in Florida, Mexico, Panama, Puerto Rico and other Caribbean localities. The biserial (Cole, 1964, p. 144) *Miogypsina antillea* (Cushman) occurs in the *Discorbis* zone of the Anahuac Formation, the Culebra and La Boca Formations of Panama, stratigraphically equivalent sediments in Florida, and at various other Caribbean localities.

Miogypsinoides complanata occurs below the *Globorotalia kugleri* planktonic zone, *Miogypsina panamensis* is restricted to the *G. kugleri* zone, and *M. antillea* has a stratigraphic range from the *Catapsydrax dissimilis* into the *Globigerinatella insueta* planktonic zone.

The status of the subgenera (*Heterosteginoides*, *Lepidosemicyclina*, *Miolepidocyclina* and *Miogypsinita*) of *Miogypsina* is discussed. All of these subgenera are regarded as synonyms of *Miogypsina* s.s.

INTRODUCTION

Although numerous authors (see summary: Vaughan and Cole, 1941, p. 77-80) described species of American miogypsinids previous to 1952, and the origin of this kind of larger Foraminifera had been suggested (Barker and Grimsdale, 1937), the first extensive analysis devoted to American miogypsinids was that of Drooger (1952). This was followed by two articles by Cole (1957a; 1964) and one by Barker (1965). In 1963 Drooger published an expanded account of his concept of the classification and evolution of miogypsinids in general in which he cited numerous American examples.

The first attempt to use American miogypsinids and planktonic Foraminifera obtained primarily from samples from deep wells for stratigraphic correlation over an extensive geographic area in the United States was by Akers and Drooger (1957). Previous to 1957 several authors, including Drooger in his detailed statement (1956), suggested stratigraphic correlation between America and Europe,

not only by planktonic Foraminifera, but also by miogypsinids.

Hanzawa (1940) developed a general classification of miogypsinids which he refined and expanded in 1957. At that time he was concerned largely with Indo-Pacific miogypsinids. In 1962 after he had the opportunity of studying additional American specimens, he devoted a section of his article on "three-layered larger Foraminifera" to miogypsinids and discussed many American species. In 1965 Hanzawa gave a summary of his concept of the classification and relationship of species of miogypsinids.

Drooger (1952) by statistical analysis of specimens of *Miogypsina* from 50 American localities recognized 14 species (of which 4 were new). In addition, some 7 kinds were given hyphenated names under the designation *exemplum intercentrale*, a notation for specimens "... which are near the border-line of two adjoining species." Cole (1957a) recognized 5 valid species (*Miogypsinoides complanata*, *Miogypsina antillea*, *gunteri*, *panamensis* and *staufferi*).

In 1964 Cole (p. 138) presented "... another classification based on the development of the embryonic apparatus..." of miogypsinids. He recognized only two genera, *Miogypsinoides* with one species, and *Miogypsina* with two species, in the Americas. In this article he corrected his misidentification of certain specimens of uniserial *Miogypsina* which he had referred to the biserial *M. antillea*.

Barker in 1965 published a competent review of American miogypsinids. It is evident that this article had been in press for considerable time, as Barker refers to a number of articles from 1956 to 1963 on American miogypsinids in an "addenda" (p. 339) to his excellent bibliography which were not mentioned in the text.

Barker (1965, p. 312, 313) listed 21 specific names which had been applied to American miogypsinids, of which he considered 14 represented valid species. However, Barker expressed considerable doubt concerning the status of some of the species. He referred to *M. cushmani* as a probable synonym of *M. antillea* (p. 315), *M. basraensis* as "... a minor early variation of *M. gunteri* Cole" (p. 316), *M. bronnimanni* as a variation of *M. mexicana* (p. 317), *M. ecuadorensis* as a variety of

M. panamensis (p. 321), and *M. thalmanni* as possibly the same as *Miogypsinoides complanata*.

If these questioned species are deleted there remain 9 valid species, two assigned to *Miogypsinoides* (*M. cf. bermudezi* and *M. complanata*) and 7 to *Miogypsina* (*M. antillea*, *M. globulina*, *M. gunteri*, *M. intermedia*, *M. mexicana*, *M. panamensis* and *M. tani*). To this list should be added *M. colei*, a new species described by Barker (1965, p. 331). The classification developed by Barker (1965) is intermediate between that of Drooger (1952; 1963) and Cole (1957a; 1964) in regard to the number of valid species recognized.

This article is an enlargement of the thesis proposed in 1964 (Cole) that there are only 3 American species of miogypsinids, *Miogypsinoides complanata* (Schlumberger), the uniserial *Miogypsina*, *M. panamensis* (Cushman), and the biserial *Miogypsina*, *M. antillea* (Cushman).

It is recognized that a number of objections will be raised concerning this radical reduction of the number of species, as it is entirely possible to recognize differences between specimens. At first inspection it would seem that the "*M. tani*" kind (Plate 8, fig. 1) is entirely distinct from the *M. panamensis* kind (Plate 8, fig. 7). However, when large numbers of specimens are studied, it can be shown that "*M. tani*" is at one end of a specific series which interconnects through the American specimens referred to *M. globulina* (Plate 9, fig. 10), *M. gunteri* (Plate 8, fig. 2; plate 9, fig. 1, Cole, 1964) and *M. basraensis* to *M. panamensis* (Plate 8, fig. 7) at the other end of the series.

All of these supposed species occur at the same or nearly the same stratigraphic horizon, and various combinations of them have been found in association in samples. Of the numerous samples which have been examined, specimens of typical *M. panamensis* have been reported from few localities, as specimens with a smaller number of chambers around the embryonic apparatus are more commonly encountered (Table 1). Cole (1964, p. 144) wrote "Since the basic pattern of development is similar, such differences may be assigned to ecological rather than genetic control."

This discourse which attempts to elaborate on the concept (Cole, 1964) that there are only three American species of miogypsinids emphasizes the geographic and stratigraphic occurrence of American miogypsinids as well as the development of the test of these organisms. Analysis of the structure of the test is the best means of determining species, but species which are recognized should be tested against known geographic and stratigraphic relationships. Moreover, associated species of similar as well as different organisms must be considered. Other larger Foraminifera which occur with Amer-

ican miogypsinids have been given previously (Cole, 1964) and these data will not be repeated.

LOCALITIES OF THE FIGURED SPECIMENS

Georgia

Loc. 1—Carpenter Oil Co., C. T. Thurman No. 2 well, Land District 1, Land Lot 189, 450 feet northwest of the center of the SE¼ of Land Lot 189, Coffee County, at a depth of 460-470 feet. (Reference: Cole and Applin, 1961, p. 127). Oligocene.

Florida

Loc. 2—Port St. Joe Test well no. 3, Port St. Joe, Gulf County at depths of 890-911 and 996-1017 feet. (Reference: Cole, 1938, pl. 8, figs. 2, 3). Suwannee Limestone, Oligocene.

California

Loc. 3—From the vicinity of the locality described by Graham and Drooger, 1952, p. 22 as follows: "Calcareous grit outcrop on C. H. Williams Ranch, central part of N½ Sec. 1, T. 7 S., R. 4 W., Santa Cruz Quadrangle, California;" specimens sent through the courtesy of Earl E. Brabb.

Mexico

Loc. 4—500 meters east of Rancho Abajo which is near kilometer 9 on the Huasteca Petroleum Company's narrow gauge railroad between San Geronimo and Cerro Azul, Tampico Embayment Area. (References: Cole, 1957a, p. 319; 1964, p. 145). Meson Formation, Oligocene.

Loc. 5—Papantla-Tajin Road, bend in road northeast of Finca de los Tremari, Veracruz. (References: Nuttall, 1933, p. 176; Cole, 1952, p. 36; 1964, p. 140, 146). Tuxpan Formation, Miocene.

Trinidad

Loc. 6—Kugler loc. 11399, Morne Diablo Quarry; collected by Hans G. Kugler. (References: Cole, 1957a, p. 326; 1957b, p. 32; 1964, p. 147). Morne Diablo Limestone.

Panama Canal Zone

Loc. 7—Low garden islet 0.25 mile northeast of landing, Barro Colorado Island; 53, collected by S. M. Jones and W. P. Woodring, 1947. (References: Cole, 1952, p. 6; 1964, p. 146; Woodring, 1957, p. 116; 1958, p. 34). Middle member of Caimito Formation.

Loc. 8—Panama Railroad, east side of second cut southeast of Bohio Peninsula. Soft calcareous tuffaceous sandstone. USGS locality 6025, type locality of *M. panamensis* = locality 55, collected by S. M. Jones and W. P. Woodring, 1947. (References: Cushman, 1918, p. 97, 98; Vaughan and Cole, 1932, p. 510; Cole, 1952, p. 6, 7; 1964, p. 139, 146; Woodring, 1957, p. 116; 1958, p. 34).

TABLE 1
Data on Selected Localities with Uniserial *Miogypsina*

Locality	Kind	Number of chambers around embryonic chambers													Mean	No. of specimens	Per-cent	Stated mean values (Drooger, 1952)		
		20	18	17	16	15	14	13	12	11	10	9	8	7					6	5
A	All specimens							1	3	3		4	1				9.5	12	100	
	<u>"gunteri"</u>							1	3	2							10.8	6	50	9-12.5
	<u>"tani"</u>										1	4	1				8.1	6	50	6- 9
B	All specimens							1		3	4	3	6	4	1		7.9	22	100	
	<u>"gunteri"</u>							1		3	3						9.9	7	32	9-12.5
	<u>"tani"</u>										1	3	6	4	1		6.9	15	68	6- 9
1 (text)	All specimens									1		3		4			7.3	8	100	
	<u>"gunteri"</u>									1		1					9.0	2	25	9-12.5
	<u>"tani"</u>											2		4			6.7	6	75	6- 9
2 (text)	All specimens							2	2	2		3					10.0	9	100	
C	<u>"basraensis"</u>							3									13	3		12.5-15
	<u>panamensis</u>							1	1								12.5	2		
8 (text)	<u>panamensis</u>	1	2	2	2	2	2	3									15.6	14	100	15

A - Stream east of Shannon Trail, about 335 meters southeast of Shannon 1, Barro Colorado Island, Panama Canal Zone (Cole, 1957a, p. 313) - Bohio formation, Oligocene.

B - Stream crossing Standley Trail at Standley 11 plus 60 meters, about 30 meters downstream from trail, Barro Colorado Island, Panama Canal Zone (Cole, 1957a, p. 316) - Caimito formation, Oligocene.

C - Fossiliferous marl from a cut on the San Sebastian-Lares Road (Rte. 111) where it crosses Quebrada Collazo at Km. 26.8, Puerto Rico (Sachs, 1959, pl. 36, figs. 1, 3-6) - Oligocene.

CLASSIFICATION OF
AMERICAN MIOGYPSINIDS

Genus *Miogypsinoides* Yabe and Hanzawa, 1928

General statement.—The type of *Miogypsinoides* Yabe and Hanzawa, 1928, is *Miogypsina dehaartii* van der Vlerk, 1924, from Tertiary *e* of Larat, East Malay Archipelago. The excellent illustration (Van der Vlerk, 1924, p. 431, text fig. 2) of the embryonic apparatus shows the bilocular embryonic chambers so situated that the second embryonic chamber is adjacent to the periphery of the test and is not separated from the periphery by periembrionic chambers. There are eight chambers which partially surround the embryonic chambers.

The embryonic apparatus of the type of *M. dehaartii* has essentially the same appearance as that found in certain species of *Miogypsina* (compare text fig. 2, p. 431, Van der Vlerk, 1924 with fig. 6, pl. 9, Cole, 1964). Although the embryonic apparatus of certain specimens of *Miogypsinoides* is similar to that of *Miogypsina*, *Miogypsinoides* does not have distinct, well developed lateral chambers as *Miogypsina* does. However, some specimens of *Miogypsinoides* may develop vacuoles in the walls covering the equatorial layer (Drooger, in Drooger *et al.*, 1955, p. 19), but these cavities are not typical lateral chambers.

Hanzawa (1940, p. 773; 1957, p. 94-96; 1962, p. 154) postulated that the orientation of the embryonic chambers and the position of the periembrionic chambers within specimens of a species of *Miogypsinoides* are constant. By these criteria he recognized numerous species of *Miogypsinoides*, several of which occurred in the same sample (Hanzawa, 1957, tables 2, 3).

Cole (1957c, p. 339) wrote "Although the number of coils and the number of periembrionic chambers are significant in specific classification, it does not appear that the position of the periembrionic chambers, with regard to the apical part of the test has any special significance." Drooger (1963, p. 344) stated "Hanzawa's (1957) pronounced splitting of *Miogypsinoides* into species... completely disregards the existing variation in every sample."

Hanzawa (1940, p. 782, 783) recognized two species of *Miogypsinoides* from a sample in the Kita-Daitō-Zima (North Borodino Island) test well. One of these, *M. lateralis* (Hanzawa, 1940, pl. 39, figs. 13, 14) has an embryonic apparatus similar to that of the type of *M. dehaartii* (Van der Vlerk, 1924, p. 431, text fig. 2) except the axis across both embryonic chambers is at nearly right angles to the axis between the proximal and distal apexes of the test instead of parallel to this axis.

From this sample Hanzawa (1940, pl. 39, figs. 16-19) identified other specimens as *Miogypsinoides bantamensis* Tan. These specimens have the second

embryonic chamber oriented toward the distal margin of the test, and the embryonic chambers are separated from the periphery of the test by periembrionic chambers.

Hanzawa (1940, p. 783) noted in the description of *M. lateralis* "In its external form and transverse section alone, the present form is almost indistinguishable from *Miogypsinoides bantamensis* Tan Sin Hok... But, the former is easily distinguishable from the latter by the characteristics of its juvenarium."

Cole (1957c, p. 339) suggested that *M. lateralis* did not differ sufficiently in the development of the embryonic apparatus from *M. bantamensis* to be regarded as a valid species. "Therefore, *M. lateralis* Hanzawa is combined with *M. bantamensis*," an opinion accepted by Drooger (1963, p. 346).

In the sample immediately overlying the one from which Hanzawa (1940, p. 780) identified *M. bantamensis* and *M. lateralis*, he recovered typical specimens of *Miogypsinoides dehaartii* (his *M. dehaartii pustulosa*). The embryonic apparatus of these specimens is identical with that of type *M. dehaartii*.

Another species commonly recognized in the Indo-Pacific area should be mentioned. *Miogypsinoides formosensis* Yabe and Hanzawa [described as *Miogypsina (Miogypsinoides) dehaartii* van der Vlerk *formosensis* Yabe and Hanzawa, 1928, p. 535] has an embryonic apparatus in the type (Hanzawa, 1964, pl. 5, fig. 7) which resembles that of *M. bantamensis*, except the axis across the embryonic chambers is at right angles to the long axis, connecting the apexes of the test instead of parallel to this axis. Certain topotypes of *M. formosensis* (Cole, 1957c, pl. 111, fig. 10), however, are identical with *M. bantamensis*.

Cole (1957c) published illustrations of several specimens from locality B391, Saipan Island, which by a strict adherence to types could be separated into three species: *M. bantamensis* Tan (pl. 110, fig. 12; pl. 111, fig. 2); *M. lateralis* Hanzawa (pl. 110, fig. 15); and *M. formosensis* Yabe and Hanzawa (pl. 111, fig. 3). From locality S701 Cole (1957c) illustrated two equatorial sections, one (pl. 111, fig. 6) represents the "*lateralis*" kind, and the other (pl. 111, fig. 7) the "*dehaartii*" kind.

Although Cole (1957c, p. 339) combined *M. lateralis* with *M. bantamensis* and *M. formosensis* with *M. dehaartii*, he inconsistently maintained *M. bantamensis* as a valid species. Drooger (1963, p. 346) arranged *M. formosensis*, *M. bantamensis*, and *M. dehaartii* stratigraphically on a chronostratigraphic scale of the miogypsinids of the Indo-Pacific area. Hanzawa (1964, p. 157; 1965, p. 253) maintained these four as valid species.

From the illustrations which have been cited, it can be demonstrated that the "*lateralis*" kind of

specimen occurs with the "*bantamensis*" and "*dehaartii*" kinds, and the "*bantamensis*" kind occurs with the "*formosensis*" kind. It is reasonable to expect that these four kinds should occur in association if a sufficient number of specimens were examined.

Hanzawa (1957, Tables 2, 3) reported the following species were associated with *M. dehaartii* at one or more localities on Saipan Island: *M. bantamensis*, *M. borodinensis*, *M. lateralis*, and *M. mauretanicus*. Although Hanzawa (1957, p. 92) recognized *M. formosensis* on Saipan Island, he recorded it as occurring with *M. borodinensis*, *M. complanatus*, and *M. lateralis*, but not with *M. dehaartii*.

In a study just completed of samples from a deep well drilled on Midway Atoll in which large numbers of specimens of *Miogypsinoides* were sectioned, the following kinds could be recognized: *M. bantamensis*, *M. dehaartii*, *M. lateralis* and *M. mauretanicus*. In addition, many specimens had embryonic apparatuses which were intermediate between the four typical kinds.

If published illustrations of these species are studied, it will be observed that the coil of peri-embryonic chambers becomes progressively longer as the orientation of the embryonic chambers shifts from a position in which the second embryonic chamber faces the proximal apex of the test to the one in which the second embryonic chamber is directed toward the distal margin of the test. The following illustrations exemplify this: 1) *M. dehaartii* kind, (Cole, 1957c, pl. 111, fig. 7), 2) *M. lateralis* kind (Cole, 1957c, pl. 111, fig. 6), 3) *M. mauretanicus* kind (Cole, 1957c, pl. 110, fig. 15), 4) *M. formosensis* kind (Cole, 1957c, pl. 111, fig. 3), and *M. bantamensis* kind (Cole, 1957c, pl. 110, fig. 12; pl. 111, fig. 2).

As it has been demonstrated that these supposedly valid species occur in association, and represent a gradational sequence, only one species should be recognized, namely, *Miogypsinoides dehaartii* (van der Vlerk).

Cole (1966, p. 240) postulated that many species of *Camerina* if they were arranged in a gradational series could be combined. He stated "This decision is based first on the evidence which may be obtained by the study of numerous specimens from a given locality arranged in a series, and secondly on the biology of species of Foraminifera. They have both an asexual and a sexual mode of propagation. In sexual reproduction gametes fuse to produce the zygotes. The gametes are not necessarily from one individual but may come from different individuals. If one assumes there are more than one species in a population such as this, then one must assume that the gametes of one species will not unite with those

of another, otherwise each species will not retain its individual characteristics.

"In the population under discussion all the specimens are essentially the same. The differences between individual specimens are those of degree, not kind, and if a sufficient number of specimens are analyzed there is complete intergradation. Therefore, it is doubtful if the gametes from one individual would repel those from another. If the gametes from individuals, regardless of the relative differences between two reproducing individuals, fuse, only one species is present in such a population."

As the reproduction of the miogypsinids seemingly is parallel to that of the camerinids, the numerous species reported either from single samples, or occurring at the same stratigraphic position within a faunal province must be based upon minor variations within the embryonic apparatus of specimens which represent only one species.

Specific names of American *Miogypsinoides*

1900. *Miogypsina complanata* SCHLUMBERGER (p. 330, pl. 2, figs. 13-16; pl. 3, figs. 18-21). American specimens from Mexico were assigned first to this European species by Nuttall (1933, p. 176, 177, pl. 24, figs. 7, 9, 11, 13, 14), and later by Barker and Grimsdale (1937, p. 162, 163, pl. 5, fig. 6; pl. 6, figs. 1-6, 8; pl. 7, fig. 1; pl. 8, fig. 6).
1940. *Miogypsinella sanjosensis* HANZAWA (p. 766, text fig. 3). A new specific name for American specimens from Mexico previously assigned to *Miogypsinoides complanata* (Schlumberger) by Nuttall (1933) and Barker and Grimsdale (1937).
1951. *Miogypsina (Miogypsinella) bermudezi* DROOGER (p. 357-359, figs. 1-6). Specimens obtained from a well at a depth of 3,687-3,689 feet near Baños in Pinar del Río Province, Cuba.
1952. *Miogypsina (Miogypsina) thalmani* DROOGER (p. 15, 16, pl. 1, figs. 1-5; pl. 2, figs. 1-5; pl. 3, figs. 1a, b). Tabera formation (Bermudez, 1949, p. 12), Río Yaque del Norte at Baitao, Santiago Province, Dominican Republic.

Analysis of the specific names of American Miogypsinoides.—The assignment of certain American specimens to *Miogypsinoides complanata* (Schlumberger), a European species, has been accepted (Nuttall, 1933, p. 176; Barker and Grimsdale, 1937, p. 162; Cole, 1938, pl. 8, fig. 10; Drooger, 1951, p. 360; Cole, 1957a, p. 318; Barker, 1965, p. 317). In 1940 Hanzawa (p. 766) proposed that certain American specimens assigned to *M. complanata* should be designated *Miogypsinella sanjosensis*. Cole (*in* Cushman, 1948, p. 376) considered that *Miogypsinella* Hanzawa, 1940, was a synonym of *Miogypsinoides* Yabe and Hanzawa, 1928, a con-

clusion accepted by Drooger (1953, p. 120). There is general agreement (Drooger, 1951, p. 360; Cole, 1957a, p. 319; Barker, 1965, p. 318), even by Hanzawa (1962, p. 157), that *M. sanjosensis* is a synonym of *Miogypsinoides complanata* (Schlumberger).

Drooger (1963, p. 346) and Barker (1965, p. 316) retained *Miogypsinoides bermudezi* Drooger (1951, p. 357) as a valid species although Cole (1957a, p. 319) placed this species in the synonymy of *M. complanata*. Drooger (1951, p. 359) stated "*M. bermudezi* is more easily separable from *M. complanata* Schlumberger, which, in addition to generally still thicker outer walls than *M. borodiniensis*, is different from the other two species for its usually higher average number of coils." Later Drooger (1963, p. 336) wrote "The validity of thickening of the sidewalls as a rigorous evolutionary trend must now be doubted."

Four specimens (Plate 9, figs. 1, 3, 5, 8) of *M. complanata* from the Meson Formation of Mexico are illustrated. The average length of these specimens is 1.18 mm.; the average number of coils of periembryonic chambers is 1.55; and the average number of periembryonic chambers is 17.2. Type specimens of *M. bermudezi* (Drooger, 1951, p. 357) have a maximum diameter of 1.0 mm. and 15-19 periembryonic chambers in 1.5-2 whorls. As there does not seem to be any valid criterion by which *M. bermudezi* can be recognized, it must be a synonym of *M. complanata*.

Barker (1965, p. 316) gave the stratigraphic range of specimens identified as *Miogypsina* (*Miogypsinoides*) cf. *M. bermudezi* as "... throughout the upper part of the marine Frio in the Gulf Coast subsurface." *Miogypsinoides complanata* according to Barker (1965, p. 318) occurs in the marine Frio of Louisiana and in Mexico in the "... upper Palma Real and in sandy beds termed lower Meson which occur below the typical upper Palma Real in Acontitla well no. 4 near Poza Rica, Veracruz." Cole (1964, p. 145) demonstrated that *M. complanata* in Mexico occurs with *Heterostegina antillea* Cushman, *Camerina panamensis*, and two species of *Lepidocyclina*.

Barker (1965, p. 330) observed concerning *M. thalmani* "The median section figured by Drooger (1952, pl. 3, fig. 1a) shows great similarity to *M. complanata* Schlumberger... and is also superficially similar to some sections of *M. gunteri*..." Cole (1957a, p. 321) previously had referred to *M. thalmani* as a synonym of *M. gunteri*. Barker (1965, p. 331) emphasized "The only difference between *M. thalmani* and *M. complanata* appears to be the presence of rudimentary lateral chambers observed in transverse section of *M. thalmani*..."

M. thalmani was based on specimens from the Tabera Formation, Dominican Republic, in association with *Heterostegina antillea* Cushman and

Almaena alavensis (D. K. Palmer) (Bermudez, 1949, p. 12). *M. complanata* occurs in Mexico in association with *Heterostegina antillea* (Cole, 1964, p. 145). Certain of these Mexican specimens (Plate 9, fig. 1) have median sections which are identical with those of *M. thalmani*. Moreover, the vertical sections (Cole, 1964, pl. 11, fig. 10) demonstrate the presence of a "... distinctly trochoid embryonic nepionic stage" (Drooger, 1952, p. 16), and these Mexican specimens have a few, poorly developed, vacuoles in the covering walls.

Drooger (1955, p. 19) stated concerning European specimens which he referred to *M. complanata* "Occasionally, single, irregular cavities occur in the side walls, especially near the nepionic spiral." Therefore, there is not any valid criterion by which *M. thalmani* can be distinguished from *M. complanata*.

Genus *Miogypsina* Sacco, 1893

Status of the subgenera: *Miolepidocyclina*,
Miogypsinita, *Lepidosemicyclina* and
Heterosteginoides

Miolepidocyclina Silvestri, 1907: type, *Orbitoides* (*Lepidocyclina*) *burdigalensis* Gümbel, 1870, is based upon European specimens in which the embryonic apparatus both in the megalospheric and microspheric forms is subcentrally located. *Miogypsinita* Drooger, 1952: type *Miogypsina mexicana* Nuttall, 1933, was erected for American specimens in which the embryonic apparatus in the megalospheric form was separated from the periphery of the test by rows of equatorial chambers, but in the microspheric form the embryonic apparatus was peripherally located.

Barker (1965) retained both of these names as subgenera of *Miogypsina*, assigning *M. ecuadorensis* and *M. panamensis* to *Miolepidocyclina*, and *M. bronnimanni* and *M. mexicana* to *Miogypsinita*. Drooger (1963, p. 317) placed the last mentioned species under *Miogypsinita*, but assigned *M. ecuadorensis* and *M. panamensis*, to *Heterosteginoides* Cushman, 1919.

Cole (1958, pl. 27, fig. 2) illustrated a microspheric specimen from Carriacou, British West Indies, identified as *M. (Miolepidocyclina) panamensis* which occurred in association in the same sample with megalospheric specimens (Cole, 1958, pl. 27, fig. 1) of *M. panamensis*. This microspheric specimen has a peripheral embryonic apparatus. Among topotypes of *M. panamensis* there are infrequent microspheric specimens, one of which is illustrated as figures 2, 4, Plate 9. The embryonic apparatus is located at the periphery.

A microspheric topotype of *M. mexicana* with a peripherally located embryonic apparatus is illustrated as figure 6, Plate 9. Similar specimens were found associated with topotypes of *M. bronniman-*

ni. Specimens from the Port St. Joe test well 3, Gulf County, Florida, at a depth of 700-721 feet had rare microspheric specimens (Cole, 1938, pl. 11, fig. 8) associated with abundant megalospheric specimens identified by Cole (1938, p. 43, 44) as *M. hawkinsi* and *M. venezuelana*. Drooger (1952, p. 22) referred these specimens to his intermediate category *M. ex interc. cushmani-mexicana*.

As the embryonic apparatus of the microspheric form of *M. panamensis* (a species commonly assigned to *Miolepidocyclina*) has a peripherally situated embryonic apparatus similar to that of species assigned to *Miogypsinita*, the position of the embryonic apparatus of the microspheric form can not be used to define these subgenera insofar as American specimens are concerned.

In the megalospheric generation certain specimens of *M. panamensis* have subcentrally located embryonic apparatuses similar in position to the embryonic apparatuses of certain specimens of *M. mexicana*. However, the embryonic apparatus of *M. panamensis* is uniserial (Cole, 1964, p. 142) whereas that of *M. mexicana* is biserial (Cole, 1964, p. 144).

Drooger (1952, p. 58), in proposing the subgenus *Miogypsinita*, recognized that the position of the embryonic apparatus within the test was not the absolute criterion for defining this subgenus. Therefore, he correctly based its definition largely on the more highly developed embryonic apparatus of *M. mexicana*. Drooger (1952, p. 58) emphasized that the embryonic apparatus of *M. cushmani*, although peripherally located, was similar to that of *M. mexicana*. However, he assigned *M. cushmani* to the subgenus *Miogypsina*, thereby indirectly stressing the position of the embryonic apparatus within the test, as both *M. mexicana* and *M. cushmani* are biserial *Miogypsina*.

Miolepidocyclina is based on European specimens which have a subcentrally located embryonic apparatus in the megalospheric and microspheric specimens (Schlumberger, 1900, pl. 3, fig. 22). The embryonic apparatus of microspheric specimens of *Miolepidocyclina burdigalensis*, except for its subcentral position, is similar to that of specimens assigned to *Miogypsina irregularis* (= *M. globulina*) (Schlumberger, 1900, pl. 3, fig. 17) and the same similarities are found if the embryonic apparatuses of megalospheric specimens are compared.

Drooger (1955, p. 24) reported *M. burdigalensis* in association with *M. tani* and *M. irregularis* (= *M. globulina*) in a fauna which he considered was a mixed fauna. Brönnimann (1940, p. 81, 88) identified these two species as occurring in the same sample.

Cole (1964, p. 145) concluded with regard to a similar association of Indo-Pacific miogypsinids in which certain specimens had a subcentrally located

and others a peripherally situated embryonic apparatus "Under the classification presented in this article the specimens would represent superficially different development of the embryonic apparatus within individuals of the same species... and the subgenus *Miolepidocyclina* would be a synonym of *Miogypsina*."

The Indo-Pacific specimens were described by Tan (1937) from Madoera under the names *M. excentrica* (pl. 3, figs. 2a, b) and *M. thecideaformis* (pl. 3, figs. 11a, b) and are similar to the American kinds *M. mexicana* and *M. cushmani*. The Indo-Pacific specimens are biserial. *M. excentrica* has a subcentrally located embryonic apparatus, and that of *M. thecideaformis* is peripherally located. Drooger (1963, p. 317) assigned the Indo-Pacific specimens to one subgenus, *Lepidosemicyclina* Ruttén, 1911, and American specimens to two subgenera.

Lepidosemicyclina Ruttén, 1911: type, *L. thecideaformis* Ruttén, 1911, is an Indo-Pacific species in which some of the equatorial chambers especially at the distal periphery of the test, are hexagonal in shape. Galloway as early as 1928 (p. 68) had placed *Lepidosemicyclina* in the synonymy of *Miogypsina*. Mohan (1958, p. 375) wrote "On the basis of the hexagonal chambers, the subgenus *Lepidosemicyclina* Ruttén, 1911, is reinstated as a subgenus of *Miogypsina* Sacco..."

Drooger (1953, p. 110) restudied the types of *M. thecideaformis*. He observed "The equatorial chambers are successively ogival, rhombic and hexagonal in shape. Most hexagonal chambers are about isodiametric; only occasionally they have the elongate shape, which is dominant in *M. polymorpha*. In some sectioned specimens of *M. thecideaformis* the latter kind of equatorial chamber is not present, in the others they occur only near the frontal margin. Short, hexagonal chambers become dominant after 10-20 rows of alternating ogival and rhombic equatorial chambers."

Although the presence of hexagonal equatorial chambers has not been emphasized in American miogypsinids, Cole (1938, pl. 7, figs. 2, 3, 6, 7) illustrated four thin sections in which toward the distal periphery distinct hexagonal equatorial chambers occur interspersed between arcuate and diamond-shape equatorial chambers. Other American specimens (Cole, 1961, pl. 8, fig. 8) have a partial row of hexagonal chambers at the distal periphery of the test. The shape and arrangement of the equatorial chambers in these American specimens are similar to the description given by Drooger and to the shape and arrangement in specimens of *M. thecideaformis* illustrated by Ruttén (1912, pl. 12, fig. 4).

In specimens assigned to *M. polymorpha* (Cole, in Cole *et al*, 1960, pl. 11, figs. 6-8) the hexagonal

equatorial chambers are more numerous and have a longer axis, but they are interspersed between arcuate and diamond-shape equatorial chambers.

Drooger (1953, p. 119) wrote "If it can be proved that in single assemblages populations of the *M. polymorpha*-group are morphologically distinctly separable from populations of *Miogypsina s. str.*, in which hexagonal chambers do not dominate, a subgeneric name for the former group may be introduced, for which is available *Lepidosemicyclina* L. Rutten, 1911."

There is abundant evidence to demonstrate that in many species of miogypsinids at least three major shapes of equatorial chambers develop in a single individual. Even in specimens in which numerous elongate hexagonal chambers occur, these are interspersed with chambers of other shapes (Cole, 1954, pl. 219, figs. 4, 5, 7, 10; Cole in Cole *et al.*, 1960, pl. 11, figs. 6-8). Drooger (1963, p. 333) observed "Chambers of somewhat hexagonal shape frequently occur towards the frontal margin in larger specimens of younger species all over the world."

The shape of any equatorial chamber must be governed by the mass of protoplasm from the surface of which the chamber walls form. If the mass of protoplasm has a semicircular front, an arcuate wall will develop. A slight radial elongation of the mass will produce diamond-shape walls, and slightly greater radial expansion will result in hexagonal shapes. It is logical, therefore, that several shapes of equatorial chambers should occur in a single individual. Moreover, under this concept more hexagonal chambers should occur toward the distal periphery of the test, and generally arcuate shape chambers should be more frequent in the proximal zone of the test.

The development of more or less elongate protrusions of protoplasm at the distal or growing margin of the test may depend on the rapidity with which the entire mass of protoplasm within the test increases. If the bulk of protoplasm is large, more will be extruded at the distal margin. The availability of food may be a factor in certain situations, as a smaller supply of food may result in longer extension of the protoplasm.

Although exceptions occur, species of larger size, such as *M. thecideaformis* (2.1-4.5 mm. in diameter) and *M. polymorpha* (3.5-10 mm. in diameter) (Drooger, 1953, p. 107, 109) develop more hexagonal chambers, and of these two species the larger, *M. polymorpha*, has the more numerous and better developed hexagonal chambers.

If this concept is the correct one to explain the development of equatorial chambers, the occurrence, variation in shape, or position in the equatorial layer of these chambers can not be used as a distinct structure on which to base a subgenus.

Therefore, *Lepidosemicyclina* is a synonym of *Miogypsina*.

M. mexicana, the type of *Miogypsinita*, and *M. thecideaformis*, the type of *Lepidosemicyclina*, are both biserial *Miogypsina*. If it is desirable to separate subgenerically uniserial and biserial *Miogypsina*, *Lepidosemicyclina* should be used, as it has priority. However, it is doubtful if the genus *Miogypsina* should be subdivided into subgenera.

The generic name *Heterosteginoides* Cushman, based upon *Miogypsina panamensis*, must be a synonym of *Miogypsina*, as the type of *Heterosteginoides* does not have any distinctive structure which would differentiate it from other uniserial *Miogypsina* (Cole, 1964, p. 143).

Uniserial *Miogypsina*

General statement.—Various methods of statistical analysis have been used to recognize species of miogypsinids. Drooger (1952, p. 50) suggested that one approach to the analysis of uniserial *Miogypsina* should "... be based on the differences of the calculated values of M_x [mean values of the number of periembryonic chambers] for the separate samples." Drooger (1952, p. 45) stated "... we assume that each sample only contains specimens of a single, homogenous population, unless it can be proved from the distribution of the numerical values of the individual features in the sample, that this supposition was not justified."

This assumption is accepted. However, the application of this postulate to individual samples may be interpreted differently. Drooger (1952, p. 51) defined three species on the "Ranges of the mean values of $X...$ " as *M. tani* (6-9), *M. gunteri* (9-12.5) and *M. basraensis* (12.5-15). In addition, he (Drooger, 1952, p. 72; 1963, p. 346) arranged these three species on a chronostratigraphic scale which implies both an evolutionary and a time separation of these species.

Recently, Cole (1964, p. 144) suggested that "... specimens classified into several species, such as *Miogypsina tani* Drooger, *M. gunteri* Cole and *M. panamensis* (Cushman), must represent only one species." Barker (1964, p. 312, 329) accepted *M. tani*, *M. gunteri*, *M. basraensis* and *M. panamensis* as valid species. However, he wrote under the discussion of *M. tani* "Median sections show great similarity to *M. gunteri* and *M. basraensis*... this species is arbitrarily separated on the evidence of median sections which show the presence of fewer than 9 chambers in the nepionic spiral... Available evidence indicates that *M. tani* has a range overlapping that of *M. gunteri*, commencing higher in the section and continuing later than *M. gunteri* has been found to date."

At locality B (Table 1) (Caimito Formation) 7 (32%) specimens with a mean number of cham-

bers surrounding the embryonic chambers of 9.9 (Table 1) are identical with the type illustration of *M. gunteri* (compare pl. 8, fig. 1, Cole, 1938, with pl. 11, fig. 4, Cole, 1964). Fifteen (68%) specimens with a mean number of chambers surrounding the embryonic chambers of 6.9 are identical with the type of *M. tani* (compare pl. 3, fig. 2a, Drooger, 1952 with pl. 9, fig. 6, Cole, 1964). All specimens from this locality give a mean value of the number of chambers surrounding the embryonic chambers of 7.9.

Similar data are shown in Table 1 for 4 localities at all of which the "gunteri" and "tani" kind of specimens occur. This association has been demonstrated at other localities. Sachs (1959) illustrated from a locality in Puerto Rico a specimen (pl. 34, fig. 8) which is identical with *M. tani*, and another specimen (pl. 34, fig. 11) which is entirely similar to one of the types of *M. gunteri* illustrated as fig. 2, Plate 8.

Specimens identical with *M. tani* and *M. gunteri* occur in association. If the mean value of the number of chambers surrounding the embryonic chambers for all of the specimens in each of the samples (Table 1) is used as the criterion, the specimens at locality B (mean 7.9) and locality 1 (mean 7.3) should be assigned to *M. tani*, whereas those at locality A (mean 9.5) and at locality 2 (mean 10) should be assigned to *M. gunteri*.

Unfortunately, relatively few adequate photomicrographs have been published whereby the total range of variation between specimens of a population can be evaluated. Even in the case where there are a sufficient number of photomicrographs different interpretations have been made. When the fauna from locality 1 (Table 1) was analyzed first (Cole and Applin, 1961) two species were recognized. Specimens (identified as *M. antillea*) with the *M. tani* kind (Plate 8, fig. 1; Cole and Applin, 1961, pl. 7, figs. 1, 2, 4, 5, 6) of embryonic apparatus occur with others of the *M. gunteri* kind (compare fig. 1, pl. 11, Cole, 1964, with fig. 1, pl. 26, Cole, 1957a, a topotype of *M. gunteri*).

Drooger (1962, p. 39) correctly criticized this treatment and wrote "... there is no reason to recognize more than one species, probably *M. tani*, for these figured specimens."

However, the illustrations cited prove that at all localities at which there are adequate data specimens of the *M. tani* and *M. gunteri* kind occur together. Moreover, at these localities there are other specimens which are intermediate between the two "typical" kinds. Should one species be recognized based on the dominance of one kind, or should two or more species be recognized by an analysis of selected specimens? At locality A 50% of the specimens are well within the limits of *M. tani*, whereas the others are within the limits of *M. gunteri* (Table

1). Should these specimens be referred to *M. tani-gunteri*?

If there is strict adherence to the concept of type specimens, a minimum of two species should be recorded. If the mean value of the number of chambers is used, each locality would have only a single species, but the specimens at localities B and 1 would be designated *M. tani*, those at locality 2 *M. gunteri*, and those at locality A *M. gunteri-tani*.

As neither of these methods of designation appeared to be realistic, Cole (1964, p. 142) suggested that recognition be given to the development of the test. Certain specimens may develop a small number of chambers around the embryonic chambers, whereas other specimens may develop a larger number. In certain environments specimens with a small number of chambers may dominate, whereas at other localities specimens with a greater number of chambers may be prevalent. However, at each of these localities, if a sufficient number of specimens are sectioned, a gradational series occurs from specimens with relatively few chambers around the embryonic chambers to those with a larger number of chambers.

There is the additional consideration that equatorial chambers have been included in the count of the spirally arranged chambers around the embryonic chambers (Table 2). Although typical *M. panamensis* has a large number of spirally arranged chambers (Cole, 1964, text fig. 1 E; Text fig. 1) only a limited number of these are perie embryonic chambers. If only the perie embryonic chambers are counted, specimens of the *M. gunteri* kind (Cole, 1964, pl. 9, fig. 1) may have the same number of perie embryonic chambers as topotypes of *M. panamensis* (Plate 8, fig. 7) (also Table 2).

As the specimens at a locality (for example, B, Table 1) may have a wide range of spiral cham-

TABLE 2
Illustrations of the *M. panamensis* series

Reference	Kind of embryonic apparatus	Perie embryonic chambers	Spiral chambers
Pl. 8, fig. 1	"tani"	4	7
*pl. 9, fig. 6	"tani"	4	7
Pl. 8, fig. 2	"tani-gunteri"	6	9
*pl. 9, fig. 4	"tani-gunteri"	8	10
*pl. 9, fig. 1	"gunteri"	9	11
‡pl. 36, fig. 3	"basraensis"	9	13
Pl. 8, fig. 3	"gunteri-panamensis"	6	12
Pl. 8, fig. 7	panamensis	9	16
*pl. 9, fig. 5	panamensis	10	15
†pl. 27, fig. 7	panamensis	10	17
Pl. 8, fig. 6	"ecuadorensis"	8	20
Pl. 9, fig. 7	"ecuadorensis"	8	15

* Cole, 1964; † 1957a; ‡ Sachs, 1959.

bers (5 to 12), arranged either as the "*M. tani*" kind or "*M. gunteri*" kind, several interpretations may be made. On types alone two species could be recognized. If the mean number of chambers (7.9) is used, the specimens would be assigned to *M. tani*. However, if these specimens are regarded as a part of the *M. panamensis* series (Cole, 1964), they would be identified as that species even if "typical" specimens of *M. panamensis* were not found at this locality.

Sachs (1959, pl. 36, figs. 1, 3, 4) illustrated three specimens (identified as *M. gunteri*) with a sufficient number (mean 12.6) of chambers surrounding the embryonic apparatus to be slightly over the arbitrary line (mean 12.5) separating *M. gunteri* and *M. basraensis*. From this same locality he (Sachs, 1959, pl. 36, figs. 5, 6) illustrated two specimens with subcentrally located embryonic apparatuses which are similar to certain specimens of *M. panamensis* (compare pl. 36, fig. 6, Sachs, 1959, with the specimen illustrated as fig. 7, Plate 8). Cole identified a specimen (1938, pl. 8, fig. 3; Plate 8, fig. 3) from the same sample from which the types of *M. gunteri* were obtained as *M. gunteri*. Later, this specimen was assigned to *M. panamensis* (Cole, 1957, p. 321).

From the few recorded occurrences which are available, it would appear that "*M. tani*" and "*M. gunteri*" occur in association, and "*M. gunteribasraensis*" and typical *M. panamensis* are associ-

ated at certain other localities. All of these supposedly valid species occur at the same, or nearly the same, stratigraphic horizon.

To demonstrate the concept that several supposedly valid species can be arranged in an intergrading series, additional illustrations are given (Plate 8, figs. 1, 2, 3, 7) at the same enlargement and oriented in the same manner as those published previously (Cole, 1964, pl. 9, figs. 1-6, text fig. 1). Table 2 lists critical illustrations which should be compared and the order in which this should be done. For each specimen the kind of embryonic apparatus, the number of perie embryonic chambers (see: Cole, 1964, text fig. 1), and the total number of chambers (perie embryonic and others) around the embryonic chambers are given.

The specimens illustrated by figures 2, 3, Plate 8 and figure 1, plate 9 (Cole, 1964) are enlargements of illustrations of specimens on which the type description of *M. gunteri* was based (Cole, 1938, p. 42).

The development of intercalary chambers (Drooger, 1952, text fig. 2) in *M. panamensis* is variable. Some specimens (Cole, 1964, pl. 10, fig. 5) lack these chambers. Others (Plate 8, fig. 7) have a few, and still others have numerous well developed intercalary chambers (Cole, 1964, pl. 27, fig. 7). The position of the embryonic apparatus within the test shifts from nearly marginal (Plate 8, fig. 7) to subcentral (Cole, 1952, pl. 25, fig. 4).

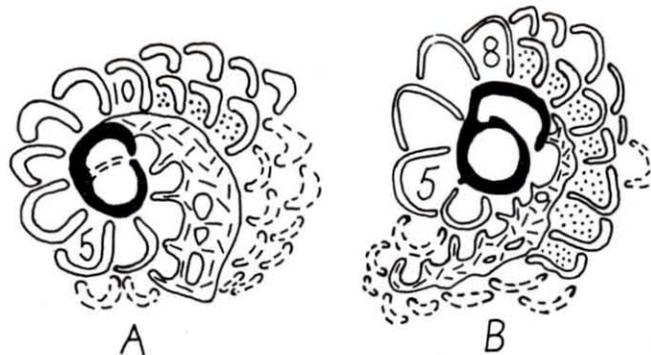


FIGURE 1

Diagrams of the embryonic apparatuses of uniserial *Miogypsina* (perie embryonic sequence indicated by numbers; spiral equatorial chambers stippled).

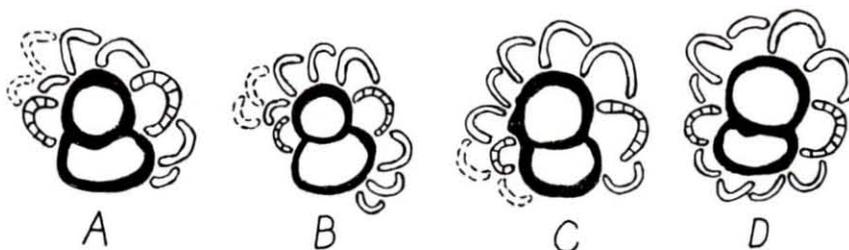


FIGURE 2

Diagrams of the embryonic apparatuses of biserial *Miogypsina* with incomplete (A-C) and complete (D) closure of the embryonic chambers by perie embryonic sequences (initial perie embryonic chambers lined).

Two specimens (Plate 8, fig. 6; Plate 9, fig. 7) of the kind which have been identified as *M. ecuadorensis* by Graham and Drooger (1952) are illustrated, and the embryonic apparatus of one of these (Plate 8, fig. 6) is shown diagrammatically (Text fig. 1B) for comparison with a toptype of *M. panamensis* (Text fig. 1A; Cole, 1957a, pl. 27, fig. 7).

From the analysis which has been presented concerning the development of the test (Cole, 1964, p. 142-144), the association of certain of the supposedly valid species, and the stratigraphic occurrence of these, it seems logical that *M. tani*, *M. gunteri*, *M. basraensis*, *M. panamensis* and *M. ecuadorensis* are names which have been applied to variants of a single species, *M. panamensis* (Cushman). To this list of names should be added *M. colei* Barker (1965, p. 331), and, at least some of the American specimens which have been identified as *M. globulina*.

Specific names of American uniserial *Miogyopsina*

1841. *Nummulina globulina* MICHELOTTI (p. 297, pl. 3, fig. 6). La collina di Torino, Italy. Several authors have identified American specimens with this European species. Although the specific name *Miogyopsina irregularis* (Michelotti) 1841, has been used commonly, Drooger and Socin (1959, p. 420) demonstrated that the correct name of this European species should be *M. globulina* (Michelotti), as *Nummulites irregularis* Michelotti (1841) is a homonym of *Nummulites irregularis* Deshayes (1838), a true *Camerina*. Barker and Grimsdale (1937, p. 163-166, pl. 5, figs. 4, 5, 7-10; pl. 7, figs. 2, 3) were the first to compare specimens from Mexico with *M. cf. M. irregularis*. These specimens later were referred by Cole (1938, p. 42) to *M. gunteri*. Drooger (1952, p. 32-34) assigned other American specimens from the Jaruco Formation of Habana Province, Cuba, and from the subsurface of Monroe County, Florida, to *M. irregularis* (= *M. globulina*). Moreover, Drooger (1952, p. 34) considered *M. bracuensis* Vaughan was a synonym of *M. irregularis* (= *M. globulina*).
1918. *Heterosteginoides panamensis* CUSHMAN (p. 97, pl. 43, figs. 3-8, not figs. 1, 2). Caimito Formation (Woodring, 1957, p. 117), Panama Canal Zone.
1928. *Miogyopsina bracuensis* VAUGHAN (p. 283, 284, pl. 45, figs. 1-3). Montpelier white limestone, Trelawny, Jamaica, West Indies.
1933. *Miogyopsina bramlettei* GRAVELL (p. 32-34, pl. 6, figs. 5-10). Specimens from the Rodriguez no. 23 well at a depth of 2,482 feet, Ambrosia field, District of Bolivar, Falcon, Venezuela.
1936. *Miopleidocyclina ecuadorensis* TAN (p. 59).
- A new specific name for specimens from near San Pedro, Ecuador, assigned by Barker (1932, v. 69, p. 280, pl. 16, fig. 7) to *Miogyopsina cf. panamensis* (Cushman).
1938. *Miogyopsina (Miogyopsina) gunteri* COLE (p. 42, 43, pl. 6, figs. 10-12, 14; pl. 8, figs. 1-9). Specimens from the Port St. Joe well T. 3 at a depth of 890-911 feet, Gulf County, Florida.
1940. *Miogyopsina basraensis* BRÖNNIMANN (p. 86-88, pl. 6, figs. 2, 4; pl. 8, figs. 13-17; text figs. 27, 28). Upper Oligocene and lower Miocene, northwest Morocco. American specimens from the *Globigerina dissimilis* zone of Kapur quarry, Trinidad were referred to this African species by Drooger (1952, p. 21).
1952. *Miogyopsina (Miogyopsina) tani* DROOGER (p. 26, 27, pl. 2, figs. 20-24; pl. 3, figs. a, b). Río Reventazon, Costa Rica.
1965. *Miogyopsina (Miogyopsina) colei* BARKER (p. 331, 332, pl. 3, figs. 7, 8, 10). *Heterostegina* zone of the Anahuac formation from the Shell Oil Company, Kratzer no. 1 well at a depth of 8,194 and 8,204 feet, Jefferson Davis Parish, Louisiana.

Analysis of the specific names of American uniserial Miogyopsina.—Nine specific names have been proposed for American *Miogyopsina* with uniserial embryonic apparatuses. Two of these species are accepted by Drooger (1952) and Barker (1965) as synonyms. *M. bracuensis* Vaughan (1928, p. 283) and *M. bramlettei* Gravel (1933, p. 32) are placed in the synonymy of *M. irregularis* (= *M. globulina*) (Drooger, 1952, p. 34, 55; Barker, 1965, p. 312).

Barker (1965, p. 315, 330) suggested that *M. basraensis* Brönnimann may be a synonym of *M. gunteri* Cole, and that *M. ecuadorensis* "... is extremely close to *M. panamensis* and has been considered here as a variety of that species, *q. v.*" Cole (1957a, p. 323) placed *M. ecuadorensis* in the synonymy of *M. panamensis*, and in 1964 (Cole, p. 142-144) postulated that *M. tani*, *M. gunteri*, and *M. panamensis* were based upon specimens which form a continuous, intergrading series representing only one species, *M. panamensis*.

Drooger (1952, p. 51) had previously arranged *M. tani* (9 or less spiral chambers), *M. gunteri* (9 to 12.5 spiral chambers), and *M. basraensis* (12.5 or more spiral chambers) in a series, but maintained each as a separate species. Cole (1964, p. 142) added *M. panamensis* to Drooger's original series and combined the 4 species under one specific name.

Authors commonly have reported only single species of *Miogyopsina* from a given locality. There is a tendency to arrange these species in time with distinct stratigraphic ranges (Drooger, 1952, p. 72;

1956, p. 188; 1963, p. 346) for each species. However, certain of these species may occur in association in a single sample.

Barker (1965) recorded four (*M. colei*, p. 332; *M. gunteri*, p. 323; *M. panamensis*, p. 328; and *M. tani*, p. 329) species of uniserial *Miogypsina* as occurring in the *Heterostegina* zone of the Anahuac formation. Although Barker did not specifically assign *M. basraensis* and *M. ecuadorensis* to the *Heterostegina* zone, he did state that *M. basraensis* was a minor variant of *M. gunteri* (p. 316) and *M. ecuadorensis* was probably a variety of *M. panamensis* (p. 321).

M. colei (Barker, 1965, p. 331), based on specimens from a well in Jefferson Davis Parish, Louisiana, is a uniserial *Miogypsina* which resembles topotypes of *M. tani* (compare fig. 7, pl. 3, Barker, 1965, with figs. 8, 9, pl. 8, Cole, 1961). Therefore, *M. colei* is based upon small specimens of *M. panamensis* and is another synonym of that species.

American specimens similar to the specimen illustrated as figure 10, Plate 9 have been referred to *M. globulina* (= *M. irregularis*). Drooger (1952, p. 33) and Barker (1965, pl. 3, fig. 9) have noted that some specimens have a uniserial embryonic apparatus, but others seemingly have a biserial embryonic apparatus. However, it is doubtful if these specimens are actually biserial with two initial perieembryonic chambers.

An enlargement of the embryonic apparatus (Cole, 1964, pl. 9, fig. 2) of a specimen of *M. panamensis* (which is similar in all other respects to specimens previously referred to *M. tani*) shows a small chamber on the right side of the embryonic chambers which might be mistaken for a second initial perieembryonic chamber. However, this small chamber interconnects by a stolon with the lower chamber of the first tier of normal equatorial chambers that develop from the last perieembryonic chamber of the true perieembryonic whorl. As this chamber is not developed from a stolon in the second embryonic chamber, it can not be an initial perieembryonic chamber.

Many specimens identified as *M. globulina* (= *M. irregularis*) have a uniserial embryonic apparatus and should be referred to *M. panamensis* (Cushman). It seems probable that specimens associated with these uniserial specimens that have been reported to have a biserial embryonic apparatus actually are uniserial.

Specimens identified by Barker (1965, p. 341) as *M. globulina* were reported both from the *Heterostegina* and *Discorbis* zones of the Anahuac Formation. This was the only uniserial *Miogypsina* that apparently ranged above the *Heterostegina* zone. The specimens from the *Discorbis* zone were probably misidentified, and they should have been referred to the biserial *M. antillea*.

Biserial *Miogypsina*

Miogypsina antillea series.—The biserial *Miogypsina* (Cole, 1964, p. 144) have embryonic apparatuses in which the perieembryonic coils develop from two initial perieembryonic chambers (text fig. 2, lined ones) formed from two stolons in the wall of the second embryonic chamber. In certain specimens these coils of perieembryonic chambers do not completely surround the embryonic chambers (text fig. 2, A, B, C), whereas in other specimens they enclose both embryonic chambers (text fig. 2, D). Specimens of both kinds occur together although in any population one kind dominates.

Thus, on superficial examination specimens might be assigned to two species, those with incomplete closure (*M. antillea* kind, Cole, 1938, pl. 7, fig. 2) of the embryonic chambers by perieembryonic chambers, and those with the perieembryonic chambers completely around the embryonic chambers (*M. staufferi* kind, Cole, 1938, pl. 7, fig. 7). Another example of these two kinds of specimens occurring in association is shown by figures 4, 7, plate 9 (Cole, 1961) and by the specimens illustrated as figure 4, Plate 8, and figure 9, Plate 9.

The diagrams (text fig. 2) were constructed from the following:

Text figure 2	Illustrated specimen	Identification
A	pl. 29, fig. 8, Cole, 1957a	Topotype of <i>M. cushmani</i>
B	pl. 29, fig. 1, Cole, 1957a	Topotype of <i>M. antillea</i>
C	Plate 8, fig. 4	
D	Plate 9, fig. 9	Topotype of <i>M. bronnimanni</i>

The illustrations and the diagrams demonstrate that the basic arrangement and development of the perieembryonic chambers is the same. Cole (1964, p. 145) concluded that such specimens "... represent superficially different development of the embryonic apparatuses within individuals of the same species."

Certain specimens (Cole, 1961, pl. 9, fig. 3) of biserial *Miogypsina* in which the equatorial section is not absolutely centered, or in which one of the initial perieembryonic chambers is poorly developed may have an embryonic apparatus which resembles that of the uniserial *Miogypsina*. However, careful examination of a number of specimens from any locality should enable one to identify the species.

Specific names of American biserial *Miogypsina*

1919. *Heterosteginoides antillea* CUSHMAN (p. 50, pl. 5, figs. 5, 6). Anguilla Formation, Anguilla, West Indies.
1924. *Miogypsina cushmani* VAUGHAN (p. 813, pl. 36, figs. 4-6). Culebra Formation (Woodring, 1957, p. 122), Panama Canal Zone.

1926. *Miogypsina staufferi* KOCH (p. 751-753, pl. 28, figs. 1-3). Falcon, Venezuela (February).
1926. *Miogypsina hawkinsi* HODSON (p. 28, 29, pl. 7, fig. 9; pl. 8, figs. 1, 2). District of Buchivacoa, Falcon, Venezuela (December).
1926. *Miogypsina venezuelana* HODSON (p. 29, 30, pl. 8, figs. 3-6). District of Buchivacoa, Falcon, Venezuela (December).
1933. *Miogypsina mexicana* NUTTALL (p. 175, 176, pl. 24, figs. 1-6, 8, 10, 12). Papantla-Tajin road, bend in road northeast of Finca de los Tremari, Veracruz, Mexico.
1952. *Miogypsina (Miogypsinita) bronnimanni* DROOGER (p. 28-30, pl. 1, figs. 35-39; pl. 3, figs. 3a-c, not fig. 3b). Morne Diablo quarry, Trinidad.
1952. *Miogypsina (Miogypsina) intermedia* DROOGER (p. 35, 36, pl. 2, figs. 30-34; pl. 3, figs. 4a, b). Paso Real Formation, Pinar del Rio Province, Cuba.

Analysis of the specific names of American biserial Miogypsina.—Barker (1965, p. 315) wrote "The writer has noted the very close similarity of *M. cushmani* to topotype *L. antillea* as far back as 1937, but owing to lack of topotype *M. cushmani* has not been able to establish positive synonymy. It seems highly probable, however, that both *M. hawkinsi* and *M. cushmani* should be referred to the synonymy of *M. antillea* . . ."

Although Drooger (1952, p. 61) considered that *M. mexicana* and *M. bronnimanni* were distinct species, Barker (1965, p. 317) concluded ". . . *M. bronnimanni* is very close indeed to *M. mexicana* and not markedly more primitive. It can even be considered as a variation of *mexicana*, and in the type area of the last named, the two forms are associated."

Although Cole (1941, p. 47, pl. 17, figs. 3-5) was the first to refer specimens from Florida to *M. cushmani* Vaughan, similar specimens (Cole, 1941, p. 47, pl. 17, figs. 1, 2) were identified as *M. hawkinsi*. Previously, Cole (1938) had assigned other specimens (1938, pl. 7, figs. 5-7) from Florida to *M. hawkinsi* and to *M. venezuelana* (1938, pl. 7, figs. 1-4). Drooger (1952, p. 41, 56) was the first to state that *M. hawkinsi* was probably a synonym of *M. cushmani*. Specimens which Cole (1938, pl. 7) had assigned to *M. hawkinsi* and *M. venezuelana* were identified by Drooger (1952, p. 22) as *M. ex interc. cushmani-mexicana* to which category he (Drooger, 1952, p. 41) also tentatively referred *M. staufferi*. Drooger (1952, p. 58) recognized ". . . *M. mexicana* is linked to *M. cushmani* by samples among our material, which are intermediate in character between the two species."

Cole (1952, p. 35) definitely placed *M. cushmani* in the synonymy of *M. antillea* and in 1957a (Cole, p. 321, pl. 29, figs. 1, 8, 9) published new illustra-

tions of topotypes of *M. antillea* and *M. cushmani*. However, Cole (1957a, p. 320) incorrectly assigned specimens from the Caimito Formation of Panama to *M. antillea*, but in 1964 (Cole, p. 145), these specimens were restudied and referred to *M. panamensis*.

All of the specimens on which these species are based are biserial *Miogypsina* (Cole, 1964, p. 144). The embryonic apparatus of *M. antillea*, *M. cushmani* and *M. hawkinsi* is located at the periphery of the test, whereas that of *M. bronnimanni*, *M. mexicana*, *M. staufferi*, and *M. venezuelana* is separated from the periphery of the test by equatorial chambers. Although Cole (1957a, p. 317) considered that the position of the embryonic apparatus could be used as a stable character for the recognition of species, he (1964, p. 144) later abandoned this concept.

M. intermedia Drooger (1952, p. 35) was based on specimens from the Paso Real formation of Cuba. Other specimens assigned to this species came from a well at Marathon, Monroe County, Florida and from USGS loc. 6505, Panama Canal Zone. Barker (1965, p. 324) wrote "Median section shows *M. intermedia* to be intermediate between *M. globulina* (Michelotti) and *M. cushmani* Vaughan, with one or perhaps occasionally two principal auxiliary chambers." The drawing of the embryonic apparatus (Barker, pl. 5, fig. 8) and the stratigraphic position of the samples from which *M. intermedia* was obtained suggests that these specimens represent *M. antillea*.

STRATIGRAPHIC IMPLICATIONS

Drooger (1963, p. 346) arranged 15 American species of miogypsinids on a chronostratigraphic scale which implied these species are distributed from Rupelian-Chattian to the Helvetian. The assignment of a few of these species follows: *M. panamensis* is placed in the Rupelian-Chattian, *M. guntereri* and *M. tani* are shown in the Aquitanian, *M. bronnimanni* occurs near the base of the Burdigalian with *M. mexicana* toward the top of this stage, and *M. cushmani* and *M. antillea* are referred to the Helvetian.

Woodring (1960, p. 31) several years ago stated "It may be pointed out that the type locality of *Miogypsina cushmani*, shown by Akers and Drooger (1957, fig. 1) as a Helvetian (middle Miocene) species, is in the Culebra formation, which is assigned to the early part of the early Miocene on the basis of its molluscan fauna." As the type locality of *M. antillea* is in the Anguilla Formation, it should also be placed in the early part of the early Miocene, as Woodring (1957, p. 37) correlated the Anguilla formation with the Culebra Formation. Moreover, *M. cushmani* is without question a synonym of *M. antillea*.

Although it may be inferred from the placement of *M. antillea* on this chronostratigraphic scale (Drooger, 1963, p. 346) that *M. antillea* is stratigraphically the youngest American species of *Miogypsina*, Barker (1965, p. 334) stated "The final stage was reached. . . with the appearance of *Miogypsinita mexicana* in beds of late lower Miocene age (top of Oligocene 'Discorbis' . . .). It persisted throughout the lower Miocene and probably into the middle Miocene. It is the latest and most symmetrical of the Miogypsinidae in the region."

In Panama, biserial *Miogypsina* with a subcentrally located embryonic apparatus (identified as *M. staufferi*) occur in the Culebra and La Boca Formations (Cole, 1961, p. 139). In Trinidad, similar biserial *Miogypsina* have been reported from the Morne Diablo Quarry in a zone which ". . . represents the *Globigerinatella insueta* zone or slightly older" (Cole, 1957, p. 32). Brönnimann and Rigassi (1963, p. 442) were of the opinion that "*Miogypsina* apparently became extinct at the end of the *Globigerinatella insueta* zone."

Stainforth (1960, p. 221) and Bandy (1964, p. 11) placed the *Globigerinatella insueta* zone at the top of the Aquitanian, but McTavish (1966, p. 11, table 4) assigned this zone to the Burdigalian. Even with these differences, the data available suggest that *Miogypsina* in the Americas would not range higher than Burdigalian.

Woodring (1958, p. 27; 1960, p. 27) not only referred the Caimito Formation of the Gatún Lake area to the late Oligocene, but also assigned it to the *Globorotalia kugleri* zone on the basis of planktonic Foraminifera identified by Bolli (Woodring, 1958, p. 22, 23). Abundant specimens of *Miogypsina* occur at certain localities in this formation which have been identified as *M. gunteri*, *M. tani*, and *M. panamensis* (Cole, 1964, p. 142-144, 146).

Barker (1965, p. 332-334) assigned *M. gunteri* and *M. tani* to the *Heterostegina* zone of the Anahuac Formation and noted (p. 328) concerning *M. panamensis* "A single occurrence was recorded by Akers and Drooger (1957, p. 671, 676) from near

the top of the *Heterostegina* zone in a well in . . . Louisiana."

Akers and Drooger (1957) reported on the occurrence of miogypsinids in samples from 34 wells from Louisiana to Florida. They definitely established that the stratigraphically oldest species are *Miogypsinoides*. They found *M. complanata* in 2 wells and *M. cf. M. bermudezi* in 2 other wells. As the stratigraphically youngest species, they reported *M. brönnimanni* from 5 wells in Louisiana, and *M. mexicana* (1 well), *M. cushmani* (4 wells) and *M. cushmani-mexicana* (2 wells) from Florida. In samples intermediate between these two extremes such species as *M. tani*, *M. gunteri*, *M. irregularis* and others were recorded.

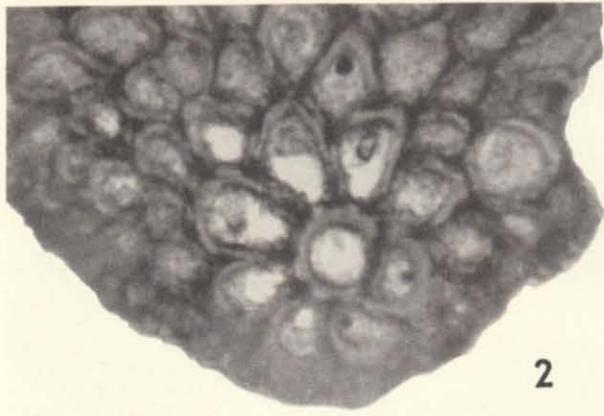
If the numerous names used by Akers and Drooger (1957) are plotted, the miogypsinids seemingly fall into three distinct zones which even on the incomplete data available extend from Louisiana to Florida. But, one would hesitate to draw correlation lines across the entire area because of the many specific names that were used. This difficulty disappears if only three species are recognized. However, such manipulation of names is certainly open to challenge.

If the argument advanced elsewhere in this article that most of the specific names given to American miogypsinids are based on minor variants is accepted, the reduction in names becomes more logical, as all the supposed species are found to be grouped in three limited stratigraphic zones.

If three species of American miogypsinids are recognized as proposed by Cole (1964), *Miogypsinoides complanata* ranges in the Gulf of Mexico area from the marine Frio (Barker, p. 334) into the *Heterostegina* zone of the Meson Formation of Mexico (Cole, 1964, p. 142, 145). The uniserial *Miogypsina panamensis* (including all the supposedly valid species here considered to be synonyms) is confined to deposits equivalent to the *Heterostegina* zone of the Anahuac Formation. The biserial *Miogypsina antillea* (including supposedly valid species with a subcentrally located embryonic

EXPLANATION OF PLATE 8

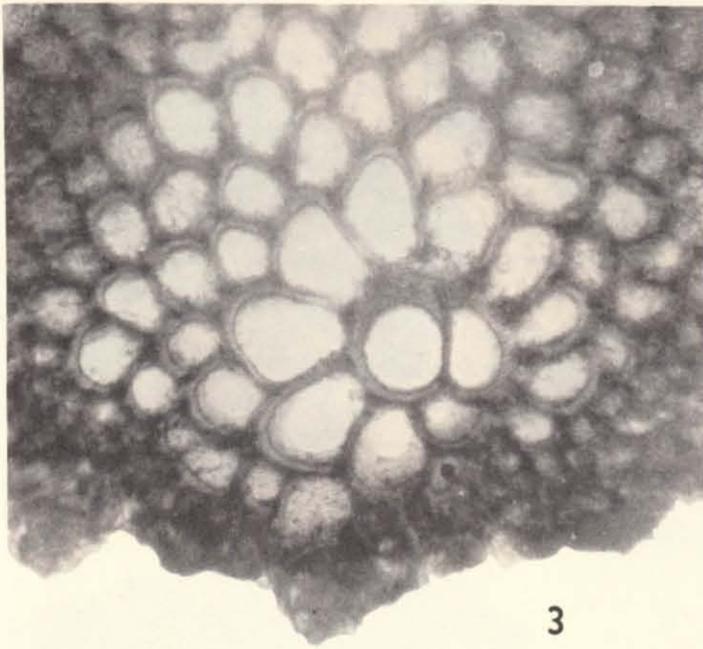
FIGS.	PAGE
1-3, 5-7. <i>Miogypsina panamensis</i> (Cushman)	104 - 110
1. Enlargement, $\times 80$, of the embryonic apparatus of a specimen (Cole and Applin, 1961, pl. 7, fig. 1) of the " <i>M. tani</i> " kind; loc. 1.	107, 108
2, 3. Enlargements, $\times 80$, of the embryonic apparatuses of type specimens (Cole, 1938, pl. 8, figs. 2, 3) of " <i>M. gunteri</i> ," loc. 2.	107, 108
5. Vertical section, $\times 40$, of a specimen of the " <i>M. ecuadorensis</i> " kind; loc. 3.	109
6. Equatorial section, $\times 40$, of a specimen of the " <i>M. ecuadorensis</i> " kind; loc. 3.	109
7. Enlargement, $\times 80$, of the embryonic apparatus of a topotype (Cole, 1952, pl. 25, fig. 2) of <i>M. panamensis</i> ; loc. 8.	107, 108
4. <i>Miogypsina antillea</i> (Cushman)	110
Part of an equatorial section, $\times 40$, of a specimen with a peripheral embryonic apparatus associated with " <i>M. brönnimanni</i> ," fig. 9, Plate 9; loc. 6.	110



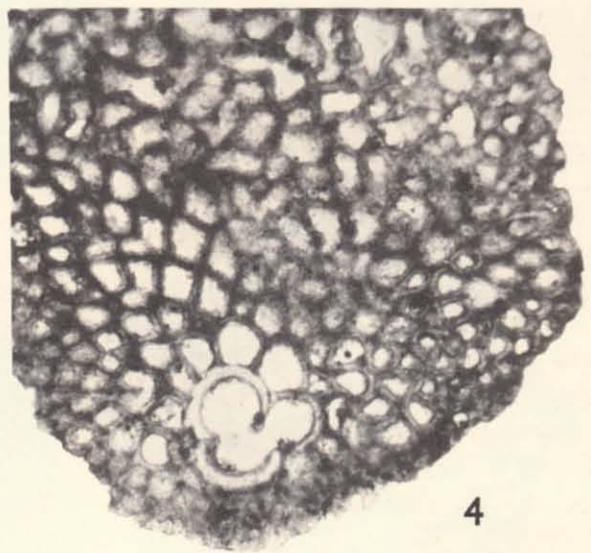
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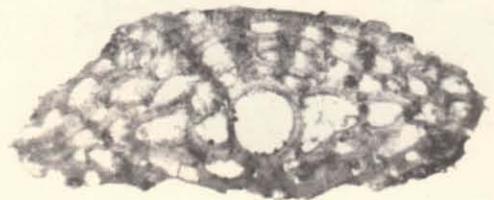
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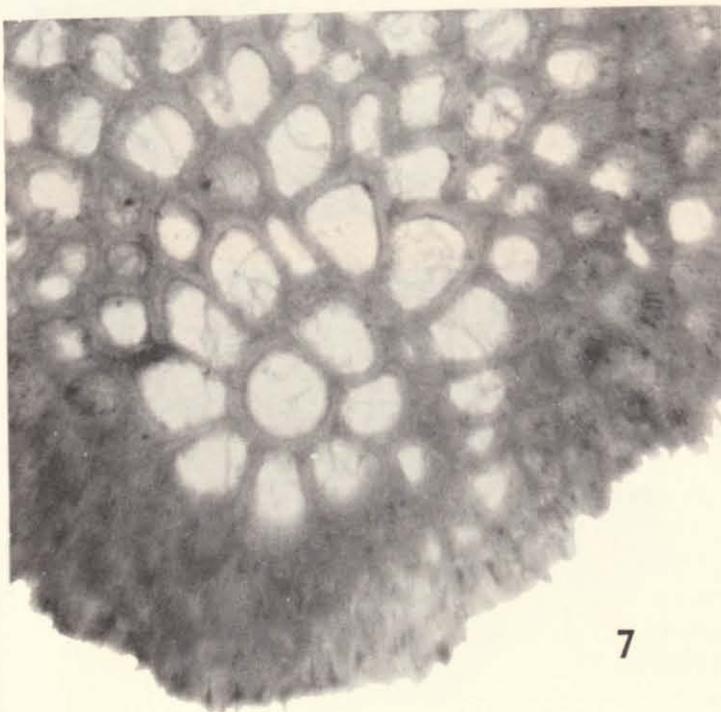
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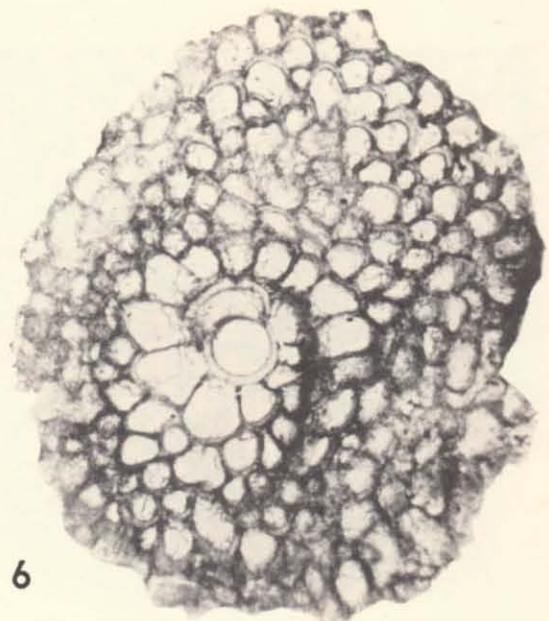
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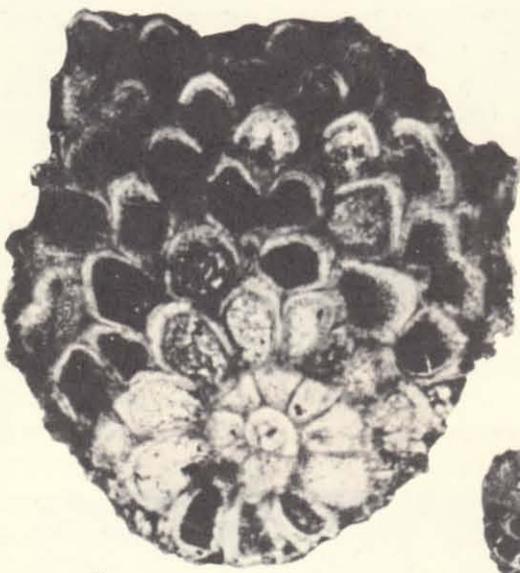
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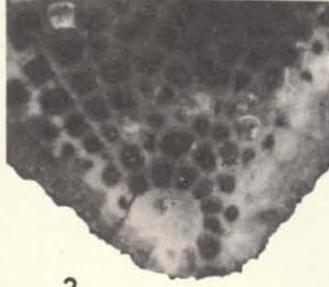
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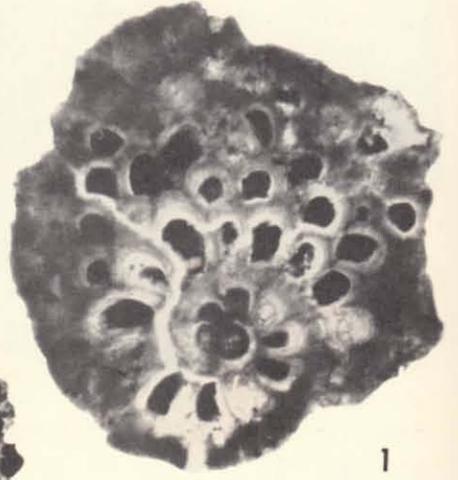
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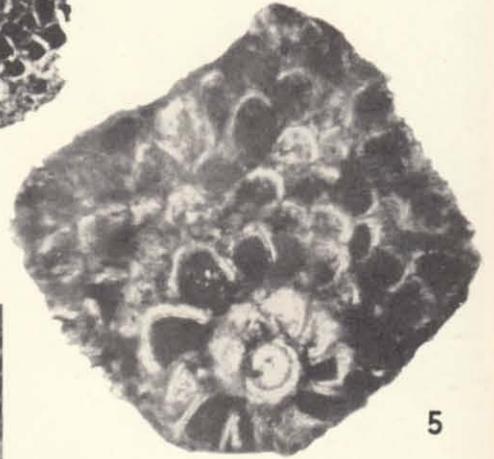
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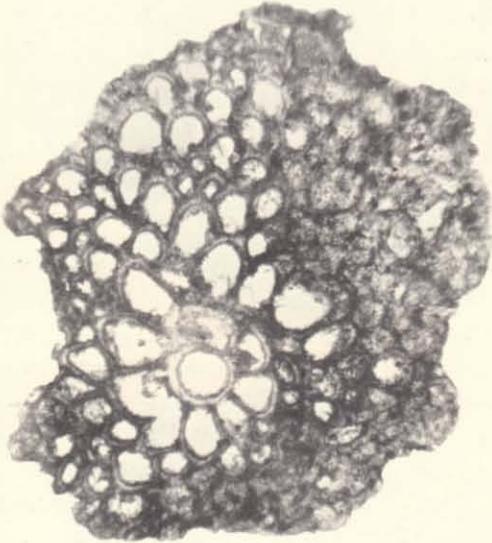
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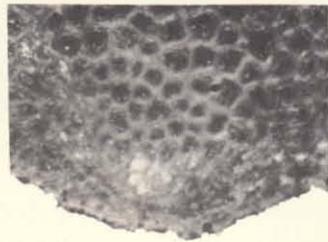
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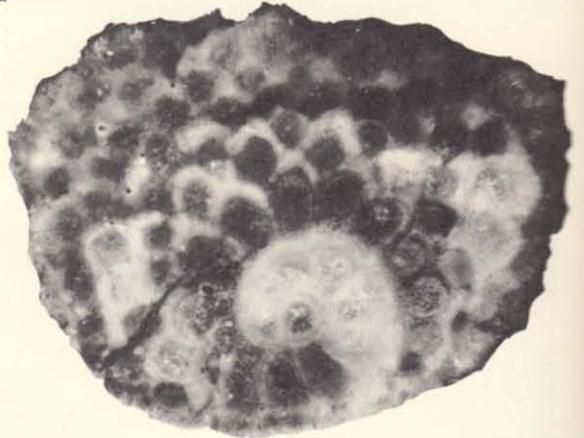
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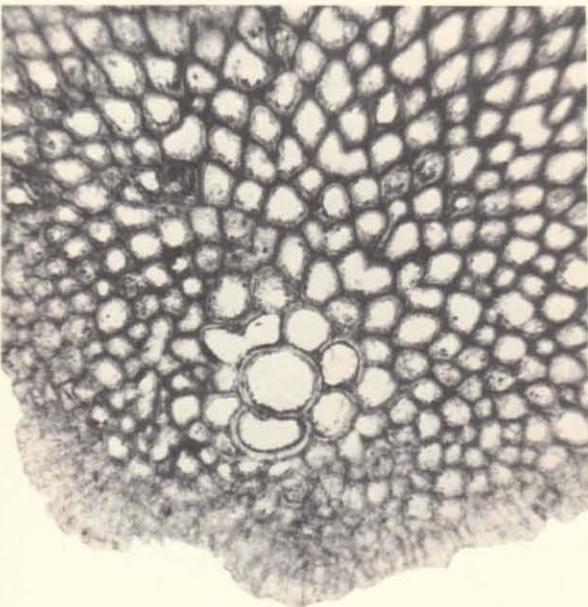
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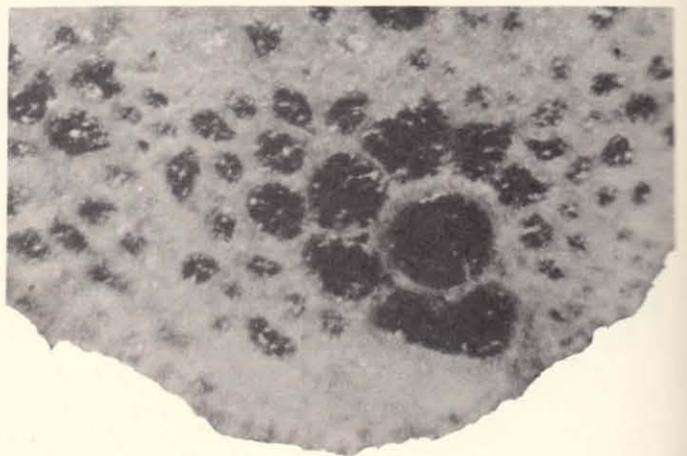
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apparatus) characterizes the so-called *Discorbis* zone of the Anahuac Formation, or ranges from the base of *Catapsydrax dissimilis* planktonic zone to the top of the *Globigerinatella insueta* zone. The additional stratigraphic data which follows, although not as complete as one could wish, tend to confirm the fact that three miogypsinid zones would allow more precise correlation between areas than do multiple zones each of which is based on the occurrence of different species.

Cole (1938) established that biserial *Miogypsina* (identified as *M. hawkinsi* and *M. venezuelana* by Cole, and later as *M. cushmani-mexicana* by Drooger, 1952, p. 22) occurred in Florida at least 170 feet above the first appearance of *Heterostegina* (identified as *H. texana*, later (Cole, 1957a, p. 327) assigned to *H. antillea*). At the same time Gravell and Hanna (1938, p. 989) traced a zone which they designated the *Miogypsina-Heterostegina* zone from southwest Texas to Alabama.

The *Miogypsina-Heterostegina* zone of Gravell and Hanna (1938, p. 996) occurred stratigraphically above their *Lepidocyclina* (*Eulepidina*) zone. They stated the interval between the top of their *Miogypsina-Heterostegina* zone and their *Lepidocyclina* (*Eulepidina*) zone was approximately 125-200 feet in western Alabama. Cole (1938, p. 19) recorded this interval in the Port St. Joe Test well 3 as about 160 feet. These relationships suggest that the zones recognized at that time by Gravell and Hanna are the same as those observed by Cole in Florida.

In southern Florida Cole (1941, p. 11, 12) found specimens of *Heterostegina antillea* (identified as *H. texana*) approximately 200 feet below specimens identified as *M. hawkinsi* (later assigned to *M. cushmani* by Drooger, 1952, p. 38). Although the *Lepidocyclina* (*Eulepidina*) zone was not found in

this well, the occurrence of biserial *Miogypsina* above *Heterostegina* strongly suggests that the *Miogypsina-Heterostegina* zone of Gravell and Hanna extends from Texas to southern Florida.

Specimens of uniserial *Miogypsina* of which *M. gunteri* is one of the supposed species have been cited by several authors as characteristic of the so-called *Heterostegina* zone of the Anahuac Formation of Texas and the Caimito Formation of Panama. Wherever data are available, this zone of uniserial *Miogypsina*, *Heterostegina* and *Eulepidina* is overlain by a zone of biserial *Miogypsina* (in Texas the *Discorbis* zone of the Anahuac Formation and in the Panama Canal Zone by the Culebra and La Boca Formations) and underlain by deposits containing *Miogypsinoides*. These relationships are constant elsewhere. In Mexico Barker (1965, p. 323) recorded uniserial *Miogypsina* of the *M. gunteri* kind in association with *Heterostegina* in the Meson Formation and biserial *Miogypsina* represented by the *M. mexicana* kind (p. 326) occurring in stratigraphically younger deposits, a relationship which was demonstrated previously by Butterlin (1958, p. 597).

Table 3 summarizes in a general manner the stratigraphic position of the miogypsinids in comparison with certain selected genera of other larger Foraminifera and with some of the major planktonic zones.

Although most of these data have been available for many years, interpretation has been difficult because of problems of nomenclature. *Heterostegina antillea* Cushman has been identified as *H. israel-skyi*, *H. panamensis* and *H. texana*. Cole (1961, p. 373) wrote "As many specific names designate a 'form' group within a variable species, they do not express a natural relationship. It is entirely possible to identify these 'form' groups of individ-

EXPLANATION OF PLATE 9

FIGS.	PAGE
1, 3, 5, 8. <i>Miogypsinoides complanata</i> (Schlumberger)	104
1, 3, 5, 8. Equatorial sections, $\times 40$, to illustrate the variable orientation of the embryonic chambers; 1, 3, 5 by transmitted light; 8, by reflected light; loc. 4	104
2, 4, 7, 10. <i>Miogypsina panamensis</i> (Cushman)	104
2. Enlargement, $\times 40$, by reflected light of the embryonic apparatus of the toptype microspheric specimen, figure 4; loc. 8.	104
4. Equatorial section, $\times 20$, by transmitted light of a microspheric toptype specimen; loc. 8.	104
7. Equatorial section, $\times 40$, of a specimen of the " <i>M. ecuadorensis</i> " kind; loc. 3.	109
10. Enlargement, $\times 40$, by reflected light of a specimen of the " <i>M. globulina</i> " kind; loc. 7.	110
6, 9. <i>Miogypsina antillea</i> (Cushman)	104, 110
6. Part of an equatorial section, $\times 40$, by reflected light of a toptype of <i>M. mexicana</i> ; loc. 5.	104
9. Part of an equatorial section, $\times 20$, of a toptype of " <i>M. bronnimanni</i> ;" loc. 6.	110

TABLE 3
A Stratigraphic Zonation by Larger and Planktonic Foraminifera

Age	Larger Foraminifera		Planktonic zones
	Major zones	Subzones	
Miocene	<u>Camerina cojimarensis</u>		<u>Globorotalia fohsi</u>
	<u>Lepidocyclina s.s.-Miogypsina</u>	<u>Miogypsina</u> (biserial)	<u>Globigerinatella insueta</u> <u>Catapsydrax dissimilis</u>
Oligocene	<u>Eulepidina</u>	* <u>Miogypsina</u> (uniserial) ----- <u>Miogypsinoides</u> -----	<u>Globorotalia kugleri</u> ----- <u>Globigerina ciproensis</u> <u>Globorotalia opima</u> -----
		<u>Lepidocyclina s. s.</u>	<u>Globigerina ampliapertura</u>
Eocene (upper)		<u>Pseudophragmina-Asterocyclina</u>	<u>Globorotalia cerroazulensis</u>
Eocene (middle)	<u>Polylepidina</u>	<u>Discocyclina</u>	

**Heterostegina antillea* is particularly characteristic of the uniserial *Miogypsina* subzone in the Gulf Coast of the United States, Mexico, Trinidad, Puerto Rico, Panama and elsewhere in the Caribbean region. However, in Mexico (Cole, 1964, p. 145) *H. antillea* occurs with *Miogypsinoides* and in Cuba it may occur with biserial *Miogypsina* (Brönnimann and Rigassi, 1963, p. 444).

uals to which specific names are given. However, the problem arises that another group of specimens may have characteristics which are intermediate between two species. The tendency is to assign another specific name to such specimens, and, finally the literature contains so many specific names that one becomes bewildered."

The nomenclatural confusion illustrated by *Heterostegina* is encountered in the miogypsinids as well as other Foraminifera. Until agreement is reached concerning the classification, the precise use of species in correlation will be difficult.

Drooger (1963, p. 346) placed *M. brönnimanni* on a chronostratigraphic scale below (Burdigalian) *M. mexicana*, *M. venezuelana*, *M. cushmani* and *M. antillea*, whose position is stratigraphically higher (Helvetian). These are all biserial *Miogypsina*. If all these species and their stratigraphic relationships are valid, deposits containing *M. brönnimanni* can not be correlated with those containing the other species. Even sediments in which *M. cushmani* and *M. antillea* are found are not stratigraphic equivalents, as *M. antillea* is assumed to occur stratigraphically above *M. cushmani*. However, *M. mexicana* and *M. cushmani* could occur together, as their ranges as shown on this scale overlap.

The type locality of *M. mexicana* is in the vicinity of Papantla, Vera Cruz, Mexico. Drooger

(1952, p. 79, 80) identified specimens near Papantla from two localities as *M. brönnimanni* and from another locality close to Papantla he assigned specimens to *M. mexicana*. He (Drooger, 1952, p. 80) wrote "These latter three occurrences of *M. brönnimanni* and *M. mexicana*, geographically close together, entail the conclusion that both species may be closely related in Mexico... Morphologically identical populations of *M. brönnimanni* possibly originated independently of one another in different geographic provinces." There is abundant evidence, however, to demonstrate that the faunas of the Gulf of Mexico area developed in one geographic province and that these faunas occur throughout this geographic area in sequence.

Barker (1965, p. 317) decided that *M. brönnimanni* might "... even be considered a variation of *M. mexicana*..." and he (p. 326) noted "The nepionic arrangement is generally similar in *M. cushmani* and in *M. brönnimanni*..." Drooger (1952) and Akers and Drooger (1957) identified specimens from various wells in Florida as *M. cushmani*, *M. mexicana* and *M. ex. interc. cushmani-mexicana*, all of which occur at nearly the same stratigraphic horizon.

Although the geographic and stratigraphic distribution of these specimens does not necessarily prove that only one species should be recognized,

it does reinforce nomenclatural studies, inasmuch as minor variants should occur at the same or nearly the same stratigraphic horizon. Barker (1965, p. 326) admitted that *M. bronnimanni* might be a variant of *M. mexicana* and that "... intermediates exist between *M. cushmani* and *M. mexicana*... These might possibly be confused with *M. mexicana*, but such misidentification would not cause any serious age determination, since the range of such intermediates appears to be almost coextensive with the lower range of *M. mexicana*."

The fact remains that the species will be arranged on a chronostratigraphic scale. If one finds *M. bronnimanni* placed stratigraphically below *M. mexicana*, different ages are not only implied but accepted, and correlation is impossible.

Drooger (1963, p. 346) and Barker (1965) recognize numerous species, but reach different stratigraphic conclusions. Drooger arranged his species as separate entities on an expanded chronostratigraphic scale, whereas if my interpretation of Barker's conclusions is correct the species must be grouped into a few zones.

The stratigraphic distribution of species of American miogypsinids presented by Barker (1965) is more in agreement with that given by Cole (1964) than with the interpretations given by Drooger (1952, 1963) and by Akers and Drooger (1957). Although Barker (1965) recognized more species than are accepted in this article, data available suggest that a further reduction of specific names is defensible both on biologic and stratigraphic evidence. If this reduction of specific names is accepted, the American miogypsinids can be used more satisfactorily in stratigraphic correlation within a geographic province.

American species of miogypsinids, properly interpreted, are valuable stratigraphic indices for a limited part of the American mid-Tertiary section. Whether they occur in the Oligocene, Miocene, or both is not debated. The essential fact is that species of miogypsinids can assist in establishing correlation over wide geographic areas within a faunal province.

Gravell and Hanna (1938, p. 989) wrote "If the terms Miocene and Oligocene must be used in the Gulf Coast, we believe it more logical to consider the *Heterostegina* zone and associated beds... as Oligocene..." The stratigraphic distributions of the miogypsinids as well as other larger Foraminifera which have been investigated since 1938 suggests that the postulate of Gravell and Hanna still holds. Woodring (1960, p. 27) after reviewing the molluscan as well as the foraminiferal faunas of the Caribbean region stated "The age assignments and correlations outlined... have the advantage of agreeing, so far as known with Bolli's planktonic scheme... [and] the further advantage of agreeing

with age assignments of correlated formations in the southeastern United States." Woodring's investigation substantiates the suggestion made by Gravell and Hanna.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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332. DISTRIBUTIONAL ANALYSIS OF NORTH ATLANTIC FORAMINIFERA
COLLECTED IN 1961 DURING CRUISES 17 AND 21 OF THE R/V CHAIN

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ABSTRACT

In 1961 planktonic Foraminifera were collected from cruise 17 of the R/V CHAIN along a traverse extending from Cape Cod to the Equator. Later in the year 3 additional tows were taken from cruise 21 of the R/V CHAIN in the Canaries Current and Sargasso Sea. Considerable differences in numerical abundances, amounting to 4 orders of magnitude, were manifested by the various water bodies of the North and Equatorial Atlantic. Highest concentrations were in the slope waters, lowest in the southern Sargasso Sea. The one well-defined faunal boundary was encountered in the vicinity of the Gulf Stream. The fauna of the Sargasso Sea was very similar to that of the equatorial waters, the principal differences being an increase in frequency of *Globorotalia menardii* and a slight increase in species diversity in the equatorial waters. A faunal boundary at the southern edge of the Sargasso Sea was hard to define. However, *Globigerina bulloides* showed a disjunct distribution, being dominant in the slope waters, virtually absent in the Sargasso Sea, and ubiquitous south of the Sargasso Sea. Distributional patterns in the North and Equatorial Atlantic showed many similarities to those in the North and Equatorial Pacific described by Bradshaw (1959).

INTRODUCTION

Most of the modern published data on the distribution of planktonic Foraminifera in the Atlantic are limited to the northwestern Atlantic (Bé, 1959, 1960; Cifelli, 1962, 1965) and the eastern Equatorial Atlantic (Boltovskoy, 1964). In an attempt to rectify this imbalance, we have for a number of years been participating in cruises of the Woods Hole Oceanographic Institution with the purpose of obtaining planktonic foraminiferal collections from the whole of the North Atlantic, with as wide seasonal coverage as possible, and using uniform collecting procedures. Recently, a comparison was made of planktonic foraminiferal and radiolarian abundances along a traverse extending from the Nova Scotia Shelf to the Caribbean Sea (Cifelli and Sachs, 1966). For the greater part of the North Atlantic, however, distributional data on planktonic Foraminifera are completely lacking.

The first opportunity to fill some of this gap was afforded by cruise 17 of the R/V CHAIN in the winter and spring of 1961. The track of this cruise, which was devoted mainly to a study of the Romanche Trench, extended from the coast of Cape Cod to the vicinity of the Equator, at about longitude 16°W. Plankton tows were taken on both the outgoing and return legs. In addition, plankton tows from three stations were collected in Decem-

ber, 1961 during cruise 21 of R/V CHAIN. The track of CHAIN 17 with the plankton stations as well as those of CHAIN 21 are shown in text fig. 1. Reports from these cruises already have been made on the distribution of Acantharia (Massera Bottazzi and Vannucci, 1964) and mesopelagic fishes (Backus *et al.*, 1965).

All of the plankton tows were taken with a number 10 mesh nylon net having a $\frac{3}{4}$ meter opening at the mouth. A flow meter to measure the amount of water filtered was fixed at the mouth of net. The net was towed obliquely for periods of about one hour. In order to make uniform comparisons between stations, the nets were towed to depths of approximately 200 meters, except at the shelf stations (CH9, CH8) where the nets were lowered to about half the distance of the bottom.

The samples were preserved in 5 percent buffered formalin and aliquoted, with $\frac{3}{8}$ of the sample used for foraminiferal analysis. This study was completed in 1963, before development of the ignition technique (Sachs *et al.*, 1964), and the method of laboratory analysis was similar to that described by Bradshaw (1959, p. 27). Specimens were examined and picked directly from the wet samples. Since many Foraminifera are obscured by entanglement with other plankton, specimen counts obtained this way tend to be less than the actual total. This probably accounts in part for the generally lower numerical abundances recorded here than those from comparable parts of the North Atlantic recorded from CHAIN 25 (Cifelli and Sachs, 1966) where the samples were prepared by the ignition technique.

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This is contribution number 1940 from the Woods Hole Oceanographic Institution.

TABLE 1
Station Localities and Dates of Collections of
Planktonic Foraminifera

CHAIN 17		
CONTINENTAL SHELF		
Station	Location	Date of Tow
CH 17-9 ¹	40°-45'N; 70°30'W	16-5-61
CH 17-8 ²	40°-31'N; 70°10'W	16-5-61
¹ Water depth 29 fathoms		
² Water depth 32 fathoms		
SLOPE WATERS		
CH 17-7	39°51'N; 69°46'W	16-5-61
CH 17-6	39°07'N; 69°14'W	15-5-61
CH 17-5	38°35'N; 68°50'W	15-5-61
CH 17-4	38°00'N; 68°26'W	15-5-61
GULF STREAM		
CH 17-3	37°20'N; 67°51'W	15-5-61
SARGASSO SEA		
CH 17-2	36°05'N; 67°06'W	15-5-61
47	32°32'N; 64°38'W	14-5-61
46	31°07'N; 61°38'W	12-5-61
44	27°34'N; 54°20'W	11-5-61
43	25°44'N; 50°56'W	10-5-61
3	25°30'N; 49°44'W	23-2-61
4	23°24'N; 45°46'W	24-2-61
42	23°22'N; 47°16'W	8-5-61
41	22°13'N; 45°14'W	7-5-61
5	20°59'N; 42°01'W	25-2-61
40	19°44'N; 41°28'W	6-5-61
6	18°16'N; 38°29'W	26-2-61
39	18°10'N; 39°12'W	6-5-61
38	16°09'N; 36°30'W	5-5-61
7	15°32'N; 35°19'W	27-2-61
NORTH EQUATORIAL CURRENT		
37	13°37'N; 33°03'W	4-5-61
8	12°59'N; 32°15'W	28-2-61
36	10°52'N; 29°26'W	1-5-61
9	10°16'N; 29°13'W	1-3-61
35	09°23'N; 27°41'W	1-5-61
EQUATORIAL COUNTER CURRENT		
10	07°15'N; 26°00'W	2-3-61
34	06°43'N; 25°01'W	29-4-61
33	05°14'N; 23°31'W	29-4-61
SOUTH EQUATORIAL CURRENT		
28	04°12'N; 16°01'W	21-4-61
11	04°03'N; 22°52'W	3-3-61
32	03°05'N; 21°24'W	28-14-61
29	02°19'N; 16°43'W	22-4-61
12	00°51'N; 19°52'W	4-3-61
30	00°12'S; 18°47'W	25-4-61
13	00°32'S; 17°05'W	5-3-61
CHAIN 21		
21-2	30°14'N; 23°49'W	3-12-61
21-3	29°08'N; 31°15'W	5-12-61
21-4	30°35'N; 55°20'W	12-12-61

NUMERICAL ABUNDANCES

Numerical abundances of total planktonic foraminiferal assemblages at the various stations, where such data were available, are shown in text fig. 1. The numerical data are given in orders of magnitude. Considerable differences in numerical abundances, amounting to four orders of magnitude, were manifested by the various water bodies. Richest in planktonic Foraminifera were the outer slope waters, where over 10,000 per 1,000 m³ were recovered at stations CH5 and CH4. The Gulf Stream,

inner slope waters and northernmost Sargasso Sea were also rich, all yielding between 1,000-10,000 specimens per 1,000 m³. The innermost shelf station (CH 17-9) was barren, but possibly that station, at a depth of 29 fathoms, was beyond the limits of planktonic foraminiferal distribution.

In the Sargasso Sea, at about the latitude of Bermuda (32° 32' N), abundances dropped sharply, and the southern Sargasso Sea, to about the latitude of 20°N was a foraminiferal "desert," with stations yielding fewer than 10 specimens per 1,000 m³. Below latitude 20°N abundances again increased and in the southernmost Sargasso Sea, through the North Equatorial Current, numerical abundances were between 1,000 and 10,000 specimens per 1,000 m³, values comparable to those of the inner slope waters and Gulf Stream. Farther south, the waters were relatively impoverished, with numerical abundances ranging between 10-1,000 and 100-1,000 specimens per 1,000 m³ in the South Equatorial Current.

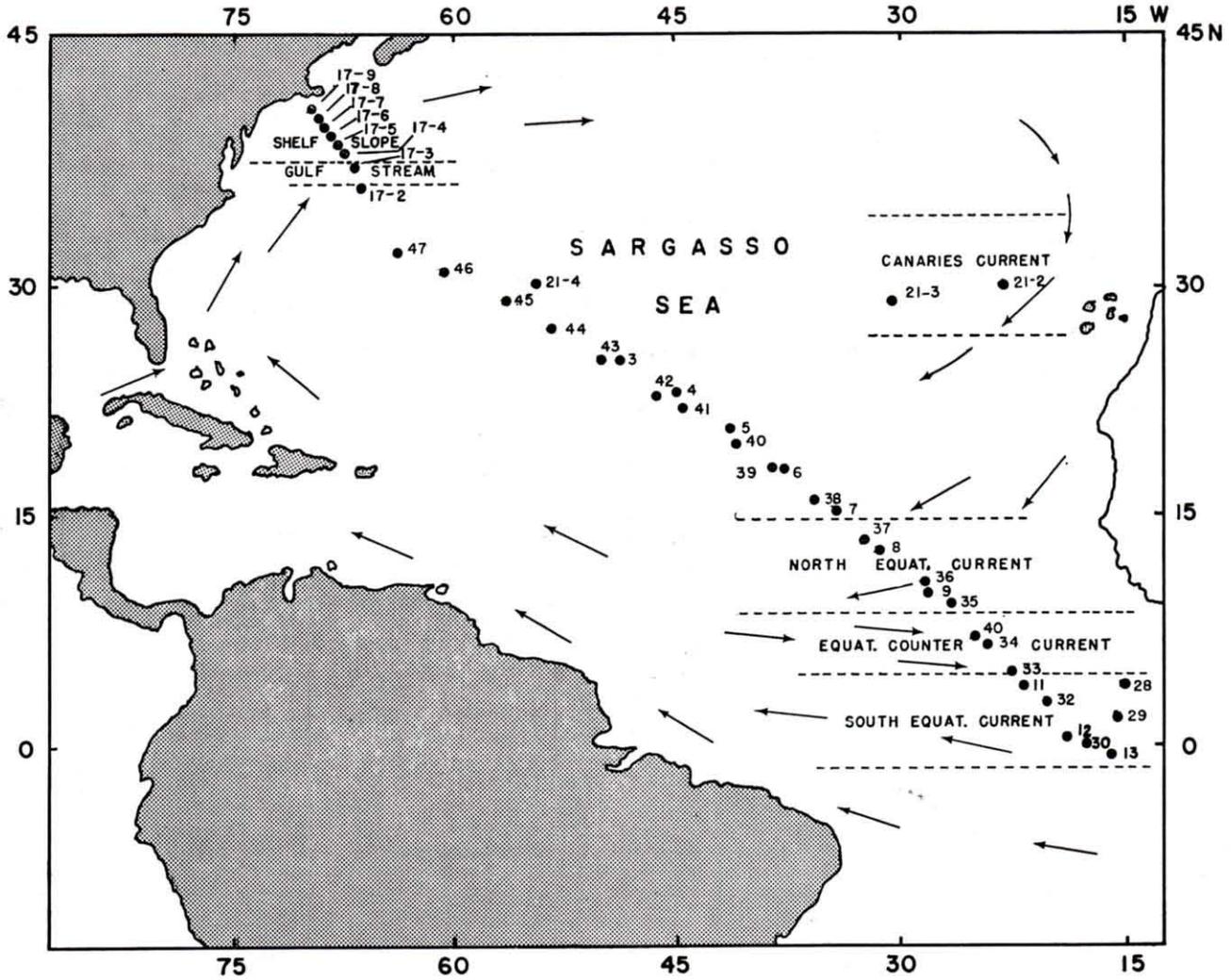
SPECIES DISTRIBUTION

In general, species exhibited long ranges, extending across the greater part of the traverse. The most ubiquitous were *Globigerinoides ruber*, *G. trilobus*, *Globigerinella aequilateralis* and *Globigerinita glutinata*, which were recorded at almost all of the stations from the slope waters to the South Equatorial Current. The few species that were geographically restricted in range were, for the most part, rare forms, limited to the southern latitudes. *Sphaeroidinella dehiscens* and *Hastigerinella rhumbleri* were recorded only from the North Equatorial Current while *Globorotalia tumida*, *G. unguolata* and *G. scitula* were encountered no farther north than station 38 (latitude 16°N). *G. scitula*, however, has been observed considerably farther north on other occasions (unpublished data).

SLOPE-WATER FAUNA AND THE GULF STREAM BOUNDARY

Because of the long ranges of most of the species, faunal boundaries are more discernible on the basis of relative abundance and of diversity rather than presence or absence of species. Frequencies of species at each of the stations along the traverse are shown on the chart, text fig. 2.

It is interesting to note that the traverse, ranging over 42° of latitude, crossed only one well-defined faunal boundary. This was encountered in the vicinity of the Gulf Stream where the cool, temperate assemblages of the slope waters to the north contrasted sharply with the warm assemblages of the Sargasso Sea to the south. The boundary is associated with the sharp thermal gradient of the Gulf Stream, but is rarely coincident with it. On previous occasions (Cifelli, 1962) the faunal



TEXT FIGURE 1
Plankton stations of CHAIN 17 and 21.

boundary was encountered mostly north of the Gulf Stream and is believed to reflect a mixture of surface waters across the Gulf Stream. This is evidenced by the transitional nature of the faunal boundary area where the fauna is composed of a mixture of slope water and Sargasso Sea species. Like the Gulf Stream, the faunal boundary is dynamic, varying throughout the year in breadth, position and faunal composition (Cifelli, 1962).

Characteristic temperate assemblages are seen in the two northernmost stations (text fig. 2) where only four species, all belonging to *Globigerina*, were recorded. By contrast, the Sargasso Sea assemblages, which may be considered subtropical rather than subtemperate, are composed, in most cases, of thirteen or more species, belonging to several genera. Representatives of *Globigerina*, however, are scarce or absent.

The boundary fauna is seen in slope-water stations CH6, CH5 and CH4, where ten of the Sargasso Sea species occur in association with the *Globigerina* slope-water assemblages. At all of the slope-water stations, however, species of *Globigerina* comprised over 80 percent of the combined fauna.

SARGASSO SEA FAUNA

Distributional patterns of individual species in the Sargasso Sea are complex and showed considerable variations in frequencies along the traverse. Owing to the limitations of the data, the significance of these variations cannot be meaningfully estimated and the distributional patterns are not fully clear. Nevertheless, the data do allow for some generalizations concerning the nature of the Sargasso Sea fauna.

First, it can be seen that despite the wide latitudinal range of the Sargasso Sea (approximately 21° or more) the plankton foraminiferal fauna throughout its entirety shows a close affinity with that of the equatorial region (text fig. 2). With few exceptions, to be discussed later, this Central Water Mass is characterized by the same suite of species as are the waters of the various equatorial currents to the south. There are no indications of a latitudinal gradient in the Sargasso Sea and the southern faunal boundary with the North Equatorial Current is rather vaguely defined. The close faunal affinity with the equatorial waters is, perhaps, not surprising, as the Sargasso Sea is a rel-

CHAIN 17																																	CHAIN 21												
STATION	NORTH ATLANTIC SLOPE WATERS SHELF						GULF STREAM	SARGASSO SEA															NORTH EQUATORIAL CURRENT	EQUATORIAL COUNTER CURRENT	SOUTH EQUATORIAL CURRENT					CH21 4	CH21 3	CH21 2													
	CH 9	CH 8	CH 7	CH 6	CH 5	CH 4		CH 3	CH 2	CH 47	* 46	45	44	* 43	* 3	4	42	41	5	* 40	* 6	39			38	7	37	8	36				9	35	10	34	33	28	* 11	32	29	12	30	13	
No. specimens per M ³ water	0	—	n·10 ³	n·10 ³	n·10 ⁴	n·10 ⁴	n·10 ³	n·10 ³	n·10 ²	n·10 ¹	n·10 ¹	n·10 ¹	n·10 ¹	—	n·10 ¹	n·10 ¹	n·10 ¹	—	n·10 ¹	—	n·10 ²	n·10 ³	n·10 ³	n·10 ³	n·10 ³	n·10 ³	n·10 ³	n·10 ³	n·10 ²	n·10 ²	n·10 ²	n·10 ²	—	n·10 ¹	n·10 ¹	n·10 ²	n·10 ²	n·10 ²							
<i>Candeina nitida</i>																																													
<i>Globigerina bulloides</i>	43	29	37	28	49		01																																						
<i>dutertrei</i>				<1			2																																						
<i>pachyderma incompta</i>	14	29	26	34	22		<1	01																																					
<i>inflata</i>	29	17	19	26	10		<1	01	01																																				
<i>quinqueloba</i>	14	25	06	03	03																																								
<i>rubescens</i>							<1	01																																					
<i>sp.</i>																																													
<i>Globigerinella aequilateralis</i>				03	<1	02	30	60	16	+	06	+	+	32	35	11	+	32	+	13	04	13																							
<i>Globigerinita glutinata</i>	Z			02	05	06	06		<1	+	+			05	05	19		04	+	13	02																								
<i>Globigerinoides conglobatus</i>	W																																												
<i>elongatus</i>	α																																												
<i>ruber</i>	α			03	04	03	38	22	05	+				+	45	40	29	+	14	+	12	02	50																						
<i>trilobus</i>	Δ			<1	02	10	06	<1	+						11	15	11	+	16	+	36	62	20																						
<i>Globorotalia hirsuta</i>	⊖			<1			<1	04	⊕					18	⊕																														
<i>menardii</i>							<1	<1	01																																				
<i>punctulata</i>				01	<1		<1	<1																																					
<i>scitula</i>																																													
<i>truncatulinoides</i>				<1	02		<1	02	08	⊕				71	⊕																														
<i>tumida</i>																																													
<i>ungulata</i>																																													
<i>Hastigerina pelagica</i>				<1			01																																						
<i>Hastigerinella rhumbleri</i>																																													
<i>Orbulina universa</i>				<1			03	02	02	+				02	+																														
<i>Pulleniatina obliquilocutata</i>				02			06	01																																					
<i>Sphaeroidinella dehiscentis</i>																																													
<i>Tretomphalus concinnus</i>																																													

+ PRESENT ⊕ DOMINANT
 * LESS THAN 50 SPECIMENS IN THE EXAMINED SAMPLE

TEXT FIGURE 2

Frequencies and numerical abundances of planktonic Foraminifera. Numerical abundances are given in order of magnitude, where n=1-9. At those stations where numerical abundances are not given, samples were poor, showing signs of solution.

atively homogeneous, warm body of water without a well-defined thermal gradient at its southern edge. The North Equatorial Current is largely a surficial, wind-driven feature and the southern boundary of the Sargasso Sea is rather arbitrarily defined, either at about 20°N or about 15°N, depending on the criteria used (Iselin, 1936; Worthington, 1959; Istoshin, 1961; Backus *et al.*, 1965; Bowen and Sugihara, 1966). In any case, the planktonic foraminiferal fauna, despite its temperate latitudinal range, is appropriately a subtropical one. It is misleading to refer to the Sargasso fauna as temperate, as has become the convention.

In the Sargasso Sea four species, *Globigerinella aequilateralis*, *Globigerinoides ruber*, *G. trilobus* and *Globorotalia truncatulinoides*, were observed to achieve dominance. *Globigerinella aequilateralis* was best represented in the northernmost part of the Sargasso Sea, where it was recorded at 60 percent at station CH2. It was also strongly dominant with respect to the eupelagic assemblage at the adjacent station 47, but was largely overshadowed there by *Tretomphalus concinnus*. The latter hemipelagic form which spends but a brief part of its life cycle in the pelagic state (Myers, 1943, p. 27) was apparently captured at a time of reproductive activity and comprised 61 percent of the total assemblage. Station 47, close by to Bermuda, was the only station at which this species was recorded. If the frequencies at station 47 are recalculated without *T. concinnus*, *Globigerinella aequilateralis* comprised 41 percent of the eupelagic population.

Globigerinoides ruber showed strong dominances in the central and southern Sargasso Sea, with a maximum frequency of 50 percent at station 7 (latitude 15°N). *G. trilobus* dominated only in the southern Sargasso Sea, with a maximum frequency of 62 percent at station 38 (latitude 16°N). *Globorotalia truncatulinoides* dominated in the central Sargasso Sea at three stations, with an unusually high maximum, 71 percent at station 44 (latitude 27°N). It was also high at station 47, comprising 8 percent of total population and 20 percent of the eupelagic population. Oddly, this species was relatively scarce throughout the remainder of the traverse.

Common (10 percent or more), though never dominant, species in the Sargasso Sea were: *Globorotalia hirsuta*, *Globigerinoides elongatus*, *G. conglobatus*, and *Globigerinita glutinata*. The latter species, however, was recorded in about equal percentages in all water bodies, showing no apparent preferences. Ubiquitous, but relatively scarce species (less than 10 percent) recorded from all, or most stations in the Sargasso Sea were *Orbulina universa*, *Hastigerina pelagica*, *Globorotalia punctulata* and *G. menardii*. Species that were both scarce and recorded rarely in the Sargasso Sea include representatives of *Globigerina*, *Globorotalia*

tumida, *G. unguolata*, *G. scitula*, *Pulleniatina obliquiloculata* and *Candeina nitida*.

In the Canary Current the two CHAIN 21 stations (CH21-2, -3) showed close faunal affinities with the Sargasso Sea stations farther to the west. *Globigerinella aequilateralis* was dominant and *Globigerinoides ruber* was common.

EQUATORIAL FAUNAS AND BOUNDARY CONDITIONS

As previously mentioned, the southern limits of the Sargasso Sea are not well-defined, and the boundary with the North Equatorial Current is usually variously placed, according to the criteria used to recognize the boundary. For the present traverse the boundary is rather arbitrarily placed at about 15°N (V. T. Bowen, personal communication). Surficially, this boundary is weakly defined, being largely effected by the direction and intensity of the trade winds, with no appreciable gradient in surface temperatures. At relatively shallow depths, however, a major hydrographic change occurs in the vicinity of this latitude (Schroeder, 1963, pl. 4; Backus *et al.*, 1965, figure 5). It is here that the isotherms begin to steepen and converge sharply towards the south, forming the shallow, well-defined thermocline in the vicinity of the Equator. For example, at 15°N the 20° and 15° isotherms occur at depths of 80 and 175 meters respectively, while near the Equator the same isotherms are found at depths of less than 50 to 100 meters (Backus *et al.*, 1965, figure 5). Because of the shallow equatorial thermocline, there is a disjunct temperature distribution in the North Atlantic at depths of 200 meters (Schroeder, 1963, plate 4), being warmest at 20°N and cooling both toward the pole and the Equator. As emphasized by Backus *et al.* (1965, p. 155) this hydrographic feature of the North Atlantic is of great importance in the study of pelagic organisms and may, in part, explain disjunct species distributions.

A disjunct distribution was noted, in fact, both among Foraminifera and fishes during the traverse of CHAIN 17. *Globigerina bulloides*, the dominant species in the slope waters but virtually absent in the Sargasso Sea, was ubiquitous in the equatorial waters, being recorded at all stations (although in low frequencies) in the North Equatorial Current, Equatorial Counter-Current and South Equatorial Current. Boltovskoy (1964, p. 5) also recorded this species in equatorial waters, although at depths only 300 meters or greater. Backus *et al.* (1965, p. 155) reported disjunct distributions for several species of fish and suggested a relationship with the disjunct temperature distribution. An alternate explanation, of course, is that these organisms arrive from the north via the eastern part of the North Atlantic Gyre. If this were the case, however, some

contribution would be expected from the Canary Current. The absence of *Globigerina bulloides* from the two CHAIN 21 stations in the Canary Current (CH21-2, -3) would appear to argue against this latter explanation.

Aside from the occurrence of *Globigerina bulloides* in the equatorial waters the planktonic Foraminifera showed no dramatic change across the Sargasso Sea-North Equatorial boundary, particularly less so when compared with the change seen in the vicinity of the Gulf Stream. The faunas of the equatorial waters were, for the most part, of similar composition to those of the Sargasso Sea, being characterized by the same major constituents. *Globigerinella aequilateralis*, *Globigerinoides ruber* and *G. trilobus*, for example, were about as equally well represented in the southern Sargasso Sea as they were in the equatorial waters.

The most notable change in frequency of a species involved *Globorotalia menardii*. North of 18°N this species was rare or absent, while to the south of that latitude it was recorded in appreciable, though variable, frequencies. In the South Equatorial Current, particularly, *G. menardii* was common and at station 32 dominated the assemblage with a frequency of 50 percent. The increase in relative abundance of *G. menardii* in the equatorial waters, however, does not appear to be closely, if at all, related to the hydrographic boundary of the southern edge of the Sargasso Sea.

The other distinguishing feature between the Sargasso Sea and equatorial faunas is the slight increase in diversity in the equatorial waters. In the Sargasso Sea the maximum number of species per station was fourteen and the average for all stations (exclusive of those which contained less than 50 specimens) was eleven. In the equatorial waters the maximum was eighteen and the average fourteen. Responsible in part for the increased diversity in the equatorial waters was the disjunct distribution of *Globigerina* species, particularly *G. bulloides*, which were virtually absent in the Sargasso Sea but ubiquitous in the equatorial waters. Also accounting for the increased diversity were the restricted occurrences of *Candeina nitida*, *Globorotalia scitula*, *G. tumida*, *G. unguolata*, *Hastigerinella rhumbleri* and *Sphaeroidinella dehiscens*. The restricted ranges of these species appear to correlate reasonably well with the Sargasso Sea-North Equatorial Current boundary at about latitude 15°N.

In summary, then, on the CHAIN 17 traverse the planktonic foraminiferal fauna of the Sargasso Sea showed much in common with that of the equatorial waters. There appeared to be some faunal change related to the hydrographic boundary, chiefly the recurrence of temperate species, such as *Globigerina bulloides*, and a small increase in diversity, but the change was of relatively small signifi-

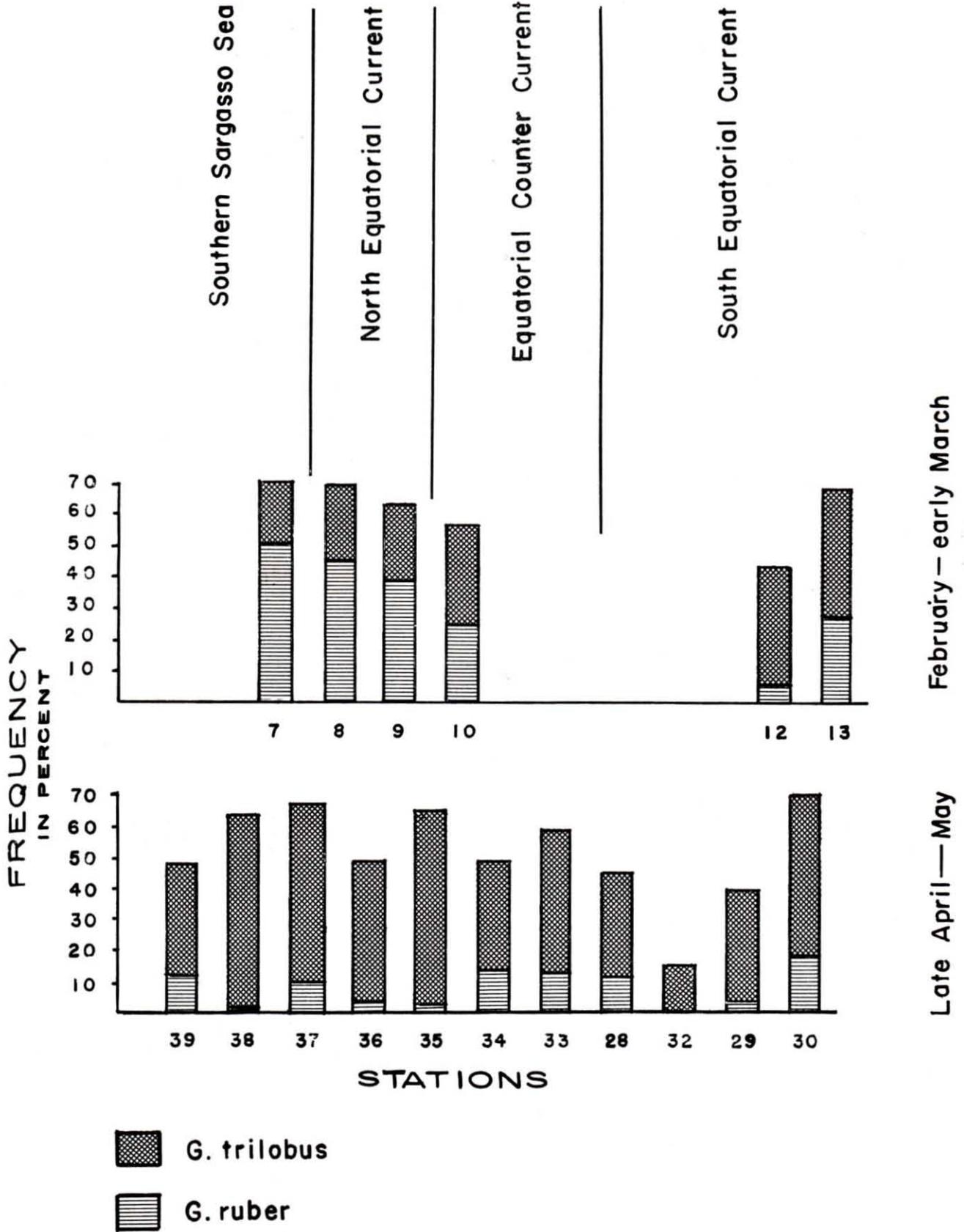
cance. It is interesting to note that the distribution of Acantharia (Massera Bottazi and Vannucci, 1964) and Sr⁹⁰ surface concentrations (Bowen and Sugihara, 1966, p. 135) also failed to show a significant change across this boundary. On the other hand, Backus *et al* (1965) recognized a change in the distribution of mesopelagic fish associated with the boundary which they considered of major significance. The method of analyzing faunal distribution used by Backus *et al* is different from that employed here. Their method, more formal and quantitative, derives from a mathematical formulation based on first and last captures of fish species. Basically, it takes into account total range of species but does not allow for changes in the frequencies of species occurrences. Despite the differences in methods of analysis, similar kinds of changes associated with the boundary show up in both planktonic Foraminifera and fishes. In both groups the most apparent changes across the boundary are the increase in diversity and the occurrence of temperate species to the south. However, with the Foraminifera, the magnitude of the change, or at least the significance attached to it, is considerably less than with the fishes.

SEASONAL FAUNAL CHANGES

The most suitable part of the traverse for discerning possible seasonal changes in faunal composition is south of latitude 19°N. Here, nearby stations yielding relatively good samples were occupied on both the outgoing (February-early March) and return (May) legs of the voyage. Perhaps the most conspicuous change involves the relative frequencies of *Globigerinoides ruber* and *G. trilobus* in the southern Sargasso Sea and North Equatorial Current (text fig. 3). During the February traverse the three stations occupied in these waters all showed a pronounced dominance of *G. ruber* over *G. trilobus*. During the May traverse the situation was reversed, with *G. trilobus* heavily outnumbering *G. ruber*. An unfortunate gap in winter stations exists in much of the Equatorial Counter-Current and South Equatorial Current, but it would appear that in the southernmost waters of the traverse there is no temporal shift in relative frequencies of *G. ruber* and *G. trilobus*.

The February-early March station in the Equatorial Counter-Current showed a slight dominance of *G. trilobus* over *G. ruber*, while in the two stations in the South Equatorial Current the former was strongly dominant over the latter. All of the May stations in the Equatorial Counter-Current and South Equatorial Current showed a pronounced dominance of *G. trilobus* over *G. ruber*.

Globigerinella aequilateralis had consistently higher frequencies in the southern Sargasso Sea, North Equatorial Current and Equatorial Counter-



TEXT FIGURE 3

Seasonal change in relative frequencies of *Globigerinoides ruber* and *G. trilobus*.

Current during the February part of the traverse than the May part of the traverse (text fig. 4). The differences in frequencies, however, are relatively small.

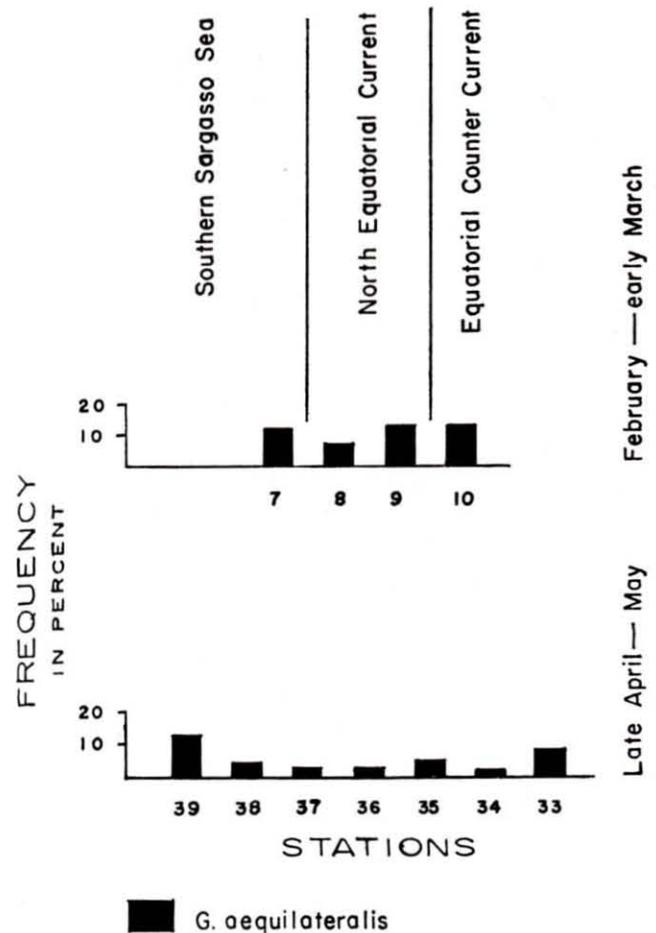
Globorotalia tumida was recorded only during the May part of the traverse in the southern Sargasso Sea, North Equatorial Current and Equatorial Counter-Current. However, in the South Equatorial Current it was recorded only during the February-early March part of the traverse.

COMPARISON WITH THE PACIFIC DISTRIBUTION

The distribution of planktonic Foraminifera in the Pacific has been studied over a considerably more extensive area (Bradshaw 1959; Parker 1960) than in the Atlantic. However, the Pacific data were compiled from a number of cruises collected at different times over a period of several years, utilizing several kinds of nets. The present Atlantic data, on the other hand, derive mostly from a single cruise, using a single collection procedure. Thus the data from the two oceans are not strictly commensurate and allow for only limited comparisons.

As in the Atlantic, the various water bodies of the North Pacific show differences in numerical abundances that amount to several orders of magnitude (Bradshaw, 1959, text figs. 36, 37, p. 54). Both oceans show very low minima in the Central Water Masses (e.g. Pacific Central Water, Sargasso Sea). Differences in methods of measuring amount of water filtered perhaps prohibits meaningful comparisons of actual abundance numbers. Yet it is interesting to note that in both oceans minima are of about the same order of magnitude, ranging between 1-100 specimens per 1,000 m³. Maxima in both oceans occur in the northern regions, although numerical values cannot be compared, as the data of northernmost Pacific stations are from the small, fine-meshed nets which appear to give values about an order of magnitude higher than the large, coarse-meshed net (Bradshaw, 1959, text figs. 36, 37). There is, however, a difference between the two oceans in the occurrence of maximum abundance with respect to faunal composition. In the Pacific the maximum abundance was found in the subarctic region and is associated with the *Globigerina* fauna, characterised by few species. In the Atlantic the maximum abundance was south of the "pure" *Globigerina* fauna, in the boundary slope waters which were composed of a mixture of *Globigerina* and Sargasso Sea species. The difference may be owing to the close proximity of the Atlantic slope waters to the land mass of eastern North America, as contrasted to the open ocean conditions of the Pacific.

To the north and south of the minima in the Central Water Masses similar patterns are shown in both oceans, with concentrations of about 100-1,000 specimens per 1,000 m³. In the equatorial water, the situation is more complex. Considerable lateral patchiness is revealed in the Pacific, but to what extent this occurs in the Atlantic is not known yet. In general, the numerical values in the Equatorial Pacific are of the order of 1,000 specimens per 1,000 m³ or greater. These seem to be comparable to those of the North Equatorial Current where numerical abundances of 1,000-10,000 specimens were recorded. In the Atlantic, however, the CHAIN 17 traverse showed a decrease in abundance south of the North Equatorial Current, and numerical values in the South Equatorial Current were of the order of 100-1,000 specimens per 1,000 m³. There does not appear to be a similar trend in the Pacific of a decrease to the south.



TEXT FIGURE 4
Seasonal change in frequency of
Globigerinella aequilateralis.

Some parallelisms between the North Pacific and North Atlantic can be seen also in relationship between water masses and faunal composition. However, because of hydrographic differences in the two oceans as well as differences in extent of areas and sampling, comparisons of boundary conditions are not possible.

The Pacific Subarctic fauna of Bradshaw (1959, p. 51) bears a close relationship to the temperate fauna found in the inner slope water stations of the CHAIN 17 traverse. Both faunas contain few species, virtually all belonging to *Globigerina*. The principal difference in the faunas is in the occurrence of *Globigerinoides* cf. *G. minuta* in the Pacific Subarctic. This species has not been recognized in the Atlantic. Also, in the North Atlantic *Globigerina inflata* was associated with this fauna, while in the North Pacific it occurred with the Central fauna.

The Central fauna of Bradshaw, like the Sargasso fauna, is characterized by a diverse group of species, but with few representatives of *Globigerina*. The Central fauna of the Pacific showed a much greater development of *Hastigerina pelagica* than did the Sargasso fauna when traversed by CHAIN 17. *Orbulina universa*, also, is seemingly better represented in the Pacific than the Atlantic. Otherwise, it would appear that in Pacific Central Water and Atlantic Sargasso Sea the best represented species are *Globigerinoides ruber*, *Globorotalia truncatulinoides* and *Globigerinella aequilateralis*. In both oceans *Globigerinoides trilobus* increases in importance with respect to *G. ruber* towards the south.

Moreover, the data of Bradshaw would seem to indicate that there is little to distinguish the Equatorial fauna from that of the Central fauna. As in the Atlantic, the chief distinguishing features of the equatorial waters are, first, the increased relative abundance of *Globorotalia menardii* and the restricted occurrence of rare species such as *Globorotalia tumida*, *Sphaeroidinella dehiscens* and *Hastigerinella rhumbleri*. The data of Bradshaw, however, give no indication of a disjunct distribution.

The Transition fauna of Bradshaw seems somewhat analogous to the North Atlantic boundary fauna between the slope-water and Sargasso Sea faunas. The Transition fauna in part, at least, appears to be a mixture of the Subarctic and Central Water species. However, the area occupied by this fauna is considerably larger than that of the boundary fauna in the North Atlantic and the hydrographic conditions undoubtedly more variable and complex. *Orbulina universa* and *Globigerina dutertrei* are far better represented in the Transition fauna than any where seen along the CHAIN 17 traverse in the Atlantic.

Parker (1960) showed the general distributional patterns of planktonic Foraminifera in the Southwest Pacific. However, the differences in southern hemispheric circulation do not allow for comparison with North Atlantic distribution at the present time.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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333. *GLOBOROTALIA CAVERNULA*, A NEW SPECIES OF PLANKTONIC
FORAMINIFERA FROM THE SUBANTARCTIC PACIFIC OCEAN*

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ABSTRACT

A new species of planktonic Foraminifera, *Globorotalia cavernula*, has been recognized from Subantarctic waters of the Pacific Ocean north of the Antarctic Polar Front. Its diagnostic features are the extraordinarily large, open umbilicus resembling a crater-like depression and the imbricated final chambers that form a twisted test. It occurs most abundantly in the upper 250 meters of water and is distributed most extensively in October and November, when water temperatures are between 4.0° and 6.0° C.

INTRODUCTION

During our zoogeographic investigations of living planktonic Foraminifera in Antarctic and Subantarctic waters of the Pacific Ocean (Bé, in press), we encountered one species that was unlike any other in our world-wide plankton collection.

We have examined thousands of plankton tows from various depth ranges within the upper 2000 m. of water and from almost all water-masses and oceanic regions of the world. Our data indicate that nearly every planktonic foraminiferal species exhibits a bipolar or anti-tropical distribution in reciprocal latitudinal zones with similar temperature regimes, so that with few exceptions each southern hemisphere population has a counterpart in the northern hemisphere.

Planktonic Foraminifera possess morphological differences that are associated with geographic variations. Left-coiling populations of *Globorotalia truncatulinoides* occur in the central North Atlantic, while right-coiling populations live predominantly in the surrounding region of the northeastern Atlantic, equatorial Atlantic and Gulf Stream system (Ericson, Wollin, and Wollin, 1954). South Atlantic specimens of *G. truncatulinoides* have tests with relatively low spires, more lobate peripheries and less angular chambers (see Boltovskoy, 1959, plate 3) in contrast to the North Atlantic variety, which has a high spire, circular periphery and sharply angular chambers. The test sizes of *Orbulina universa*, *Globigerinoides ruber* and *Globigerinoides sacculifer* vary in relation to latitude and other oceanographic factors along a line parallel to the coasts of North and South America (Stone, 1956). An example of an adaptive morphological change is the shell-thickening of many species that is apparently associated with their living at bathypelagic depths (Bé, 1965). Other subtle differences in morphological characters among planktonic Fo-

raminifera are probably also subject to geographic variation, but comprehensive biometric studies of modern species have not yet been attempted on a global scale.

MATERIAL

The plankton samples used in this study were collected from USNS ELTANIN during Cruises 10, 11, 13, 15, 17, 18 and 19, between November 1963 and July 1965 in the Pacific sector of the Antarctic Ocean. The new species was also found in two samples obtained by R/V CONRAD and one haul by R/V VEMA in the Pacific region south of Australia and New Zealand (Table 1, text fig. 1).

Surface (0-10 m) and oblique (0-250 m) plankton tows were gathered with nets having a mesh aperture of 202 μ , mouth opening of 0.25 m², and length of 2.8 m. A multiple opening-and-closing sampler with 3 nets of identical mesh size and 0.5 m² mouth openings was used to obtain serial vertical hauls from 500-250 m, 250-100 m, and 100-0 m. The instrument described by Bé (1962) was modified for sampling during ascent. The amount of water filtered by each net haul was measured by a Tsurumi-Seiki Kosakusho flowmeter mounted within each net opening.

Globorotalia cavernula appeared in 38 out of a total of 1442 plankton samples from 328 stations that have been examined in the Atlantic and Pacific sectors of the Antarctic Ocean. These 38 samples were collected at 29 stations in the Pacific Ocean and are shown in text fig. 1 and Table 1. The description is based on a total of 121 specimens (hypodigm).

SYSTEMATICS

Family GLOBOROTALIIDAE Cushman, 1927

Genus *Globorotalia* Cushman, 1927

Globorotalia cavernula, n. sp.

Plate 10, figures 1-6

Diagnosis:—Test moderate in size compared with many species of *Globorotalia*; low, trochospiral coiling; biconvex, the umbilical side more convex than the spiral side; equatorial periphery ovate in juveniles, becoming nearly circular in adults; peripheral outline lobate; axial periphery sharply angled with thin keel; chambers angular-rhomboid, numbering about 13 to 18 and arranged in 2 to 3 whorls; early whorl often raised above subsequent whorls; 5 to 6 chambers usually make up the final whorl; chambers offset from each other, producing

* Lamont Geological Observatory, Contr. No. 1043.

TABLE 1

Plankton Samples containing *Globorotalia cavernula* collected in Subantarctic Region of Pacific Ocean by USNS ELTANIN (=EL), R/V VEMA (=V) and R/V CONRAD (=RC).

Ship Cruise & Station Sample no.	S. Lat.	W. Long.	Date	Local Time	Depth range (m)	Surface Temp. (°C)	Vol. water filtered (m ³)	<i>G. cavernula</i> specimens/1000 m ³ of water	% of Total Planktonic Foraminifera
1963									
EL 10-1-130	55°09'	82°43'	Oct. 13	0835-0926	0-437	5.1	422	2	trace
EL 10-1-131	55°09'	82°43'	Oct. 13	0940-1020	0-950	5.1	309	3	trace
EL 10-2-133	55°56'	82°44'	Oct. 14	1605-1630	0-100	5.1	253	4	trace
EL 10-3-136	58°02'	82°40'	Oct. 17	0812-0831	0-156	4.8	151	7	0.1
EL 10-4-139	59°20'	82°35'	Oct. 18	1345-1419	0-303	4.9	361	3	trace
EL 10-4-139	59°20'	82°35'	Oct. 18	1427-1442	0-88	4.9	148	7	trace
EL 10-5-141	59°56'	82°56'	Oct. 19	1947-2013	0-305	4.0	185	16	0.4
EL 10-19-186	57°55'	74°54'	Nov. 10	1538-1600	0-100	5.1	409	2	trace
EL 10-19-187	57°55'	74°54'	Nov. 10	1511-1538	100-250	5.1	594	7	0.1
EL 10-20-190	56°58'	75°02'	Nov. 11	1537-1555	100-250	4.9	159	6	trace
EL 10-24-208	62°18'	78°57'	Nov. 18	0621-0642	100-250	3.7	712	1	trace
EL 10-28-219	59°53'	79°02'	Nov. 22	1117-1255	0-490	4.7	1364	3	trace
EL 10-29-221	58°07'	79°11'	Nov. 24	1529-1622	0-1000	5.5	273	117	1.7
EL 10-31-225	56°05'	79°06'	Nov. 27	1725-1751	100-250	5.5	334	6	0.1
EL 10-31-226	56°05'	79°06'	Nov. 27	1703-1725	250-522	5.5	929	2	0.1
EL 10-31-227	56°05'	79°06'	Nov. 27	1551-1640	0-883	5.5	312	13	0.2
EL 10-32-230	55°22'	78°26'	Nov. 29	1431-1508	250-486	5.8	643	2	trace
1964									
EL 11-5-249	58°58'	114°47'	Jan. 2	0132-0233	500-1000	4.0	—	10	14.3
EL 13-1-443	54°59'	89°49'	May 17	1455-1531	0-100	6.2	248	40	1.6
EL 13-2-449	56°05'	90°10'	May 20	1609-1616	0-100	5.0	106	75	9.1
EL 13-3-456	57°03'	89°36'	May 21	0124-0139	0-200	5.3	178	11	0.6
EL 13-6-474	59°32'	89°39'	May 24	1955-2015	0-10	4.7	110	73	5.0
EL 14-4-594	54°57'	159°38'	Aug. 7	0135-0205	0-10	4.1	132	61	8.3
EL 15-5-751	58°03'	99°54'	Oct. 17	1404-1433	0-10	4.4	195	41	0.1
EL 15-5-752	58°05'	99°51'	Oct. 17	1610-1615	100-250	4.4	669	12	0.4
EL 15-5-752	58°05'	99°51'	Oct. 17	1610-1620	0-250	4.4	953	44	0.7
EL 15-17-806	54°50'	129°46'	Nov. 7	1704-1740	0-500	6.0	211	9	trace
EL 15-23-843	55°54'	139°56'	Nov. 14	0637-0652	250-500	4.5	2280	4	0.2
EL 15-26-864	54°00'	145°17'	Nov. 18	1007-1058	500-1000	7.0	867	9	5.5
1965									
EL 17-34-1112	57°05'	94°49'	Apr. 28	1146-1151	0-100	6.2	103	621	2.6
EL 18-1-1137	54°46'	99°11'	June 5	0720-0753	0-220	5.8	230	16	trace
EL 18-2-1138	56°00'	99°22'	June 6	2110-2115	0-100	5.9	45	5772	5.0
EL 18-3-1150	57°01'	99°26'	June 8	0625-0642	0-250	4.9	147	35	trace
EL 19-1171	60°40'	100°20'	July 15	0547-0605	0-240	3.1	168	86	trace
EL 19-13-1233	56°09'	109°33'	July 29	0155-0228	0-500	4.9	351	22	1.2
1960									
V 16-202	52°52'	158°54'E	Mar. 31	1852-1922	0-300	8.0	212	5	0.6
1965									
RC 9-80	46°00'S	154°00'E	Apr. 15	1745-1815	0-10	12.5	78	13	0.1
RC 9-92	49°38'	125°35'E	May 3	1850-1915	0-10	7.3	—	—	1.1

imbricate arrangement; sutures step-like depressions and curved on spiral side, depressed and radial on umbilical side; umbilicus very deep and broad, rimmed by angled umbilical shoulder; aperture arched, interiomarginal, extraumbilical-umbilical with a lip or rim projecting at the top of the aperture; wall thin and finely perforate.

Spiral side:—Large specimens have 3 or more whorls with a total of 18 or more chambers. In typical specimens the last few chambers are each attached below the level of the anterior margin of the preceding one, producing a step-like sutural depression and an imbricate appearance. The early whorl is frequently raised above the later whorls, leaving an offset margin between whorls. Thus, the imbricate chambers and offset whorls give a characteristically twisted appearance to adult test.

Apertural side:—Angular-rhomboid, strongly convex chambers with depressed, radial sutures. The

deep, open umbilicus is so prominent as to give it a semblance of a crater-like depression. This is produced by the arrangement of loosely coiling chambers and the large, sharply angled umbilical shoulder (rim). The early whorl is often visible within the umbilicus, owing to the tendency for the final whorl to become evolute. The specific name of our new species refers to the cave-like depression of the prominent umbilicus.

Wall:—Thin and smooth surface; finely perforate; pustulate and more coarsely crystalline on the earlier chambers on the spiral side and around the umbilical region and base of the aperture. (The coarse pustules in globorotaliids have been termed "spinose" by some authors. This is misleading, because they are not homologous to the very elongate, true spines possessed only by globigerinids).

Coiling direction:—The tests of all specimens in our collection are sinistral.

Dimensions:

	Total no. Chambers	Diameter (μ)			Whole test thickness	Umbilicus diameter (μ)	Sample no. (See Table 1)
		1st whorl	2nd whorl	whole test			
Holotype USNM no. 686929	17	72	193	419	281	90	EL 15-23-843
Paratype 1 USNM no. 686930	18	75	182	364	241	84	EL 10-24-208
Paratype 2	15	74	171	319	132	82	RC 9-92
Paratype 3 USNM no. 686931	17	77	191	414	239	80	EL 10-5-141
Paratype 4 USNM no. 686932	15	54	133	255	136	45	EL 18-1-1137
Paratype 5 USNM no. 686933	13	54	122	182	91	27	EL 18-2-1143

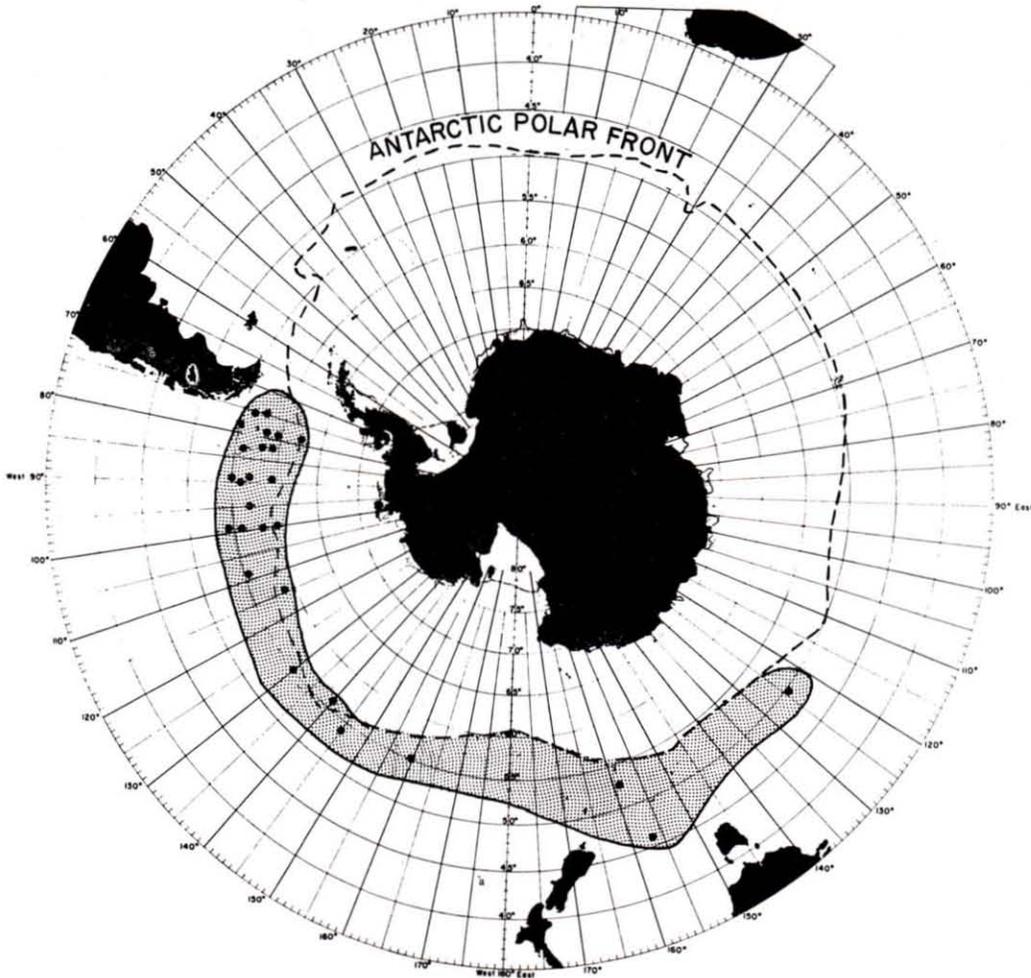
The holotype and four paratypes are deposited in the national collection of Foraminifera, U. S. National Museum, Washington, D. C.

Comparison:—Certain morphological variants of our new species do somewhat resemble *Globorotalia truncatulinoides* in having rhomboid chambers and an umbilical shoulder. Specimens referable to *Globorotalia cavernula* have not been reported in Antarctic surface and subsurface sediments studied by Blair (1965 and personal communication) and hence its phylogenetic derivation and stratigraphic distribution remain unknown.

Distribution:—*Globorotalia cavernula* is sparsely distributed in Subantarctic waters of the South Pacific Ocean. It occurs in a belt about 400 miles wide north of the Antarctic Polar Front and is found only occasionally south of this major water-mass boundary. We encountered it most frequently in the region east of the Drake Passage; it appeared to diminish in frequency and quantity westward to New Zealand, where only scattered occurrences have been noted. However, our sample coverage in

this latter region is less extensive. The most northerly occurrence is at 46° S and 154° E and the most westerly at 49°38' S and 125°35' E. It has not yet been found in the Indian Ocean and is probably absent from the Atlantic Ocean.

This species lives predominantly in the upper 250 m of water but is occasionally collected in opening-and-closing tows from the depth ranges of 250-500 m and 500-1,000 m. The highest frequencies of occurrence (23 out of 38 samples) were noted during October and November 1963 (ELTANIN Cruise 10) and again during October and November 1964 (ELTANIN Cruise 15). The concentrations of *G. cavernula* in all except one of these samples are less than 100 specimens/1,000 m³ of water. In three stations only does the absolute abundance exceed this concentration; the highest density is observed at ELTANIN 18 station 2 (June 1965) with 5772 specimens/1,000 m³.



TEXT FIGURE 1

Locations of stations and general region (stippled) where *Globorotalia cavernula* has been found. It occurred in only 29 out of a total of 328 plankton stations in the area of investigation bounded by 10°E to 160°E Long. and 50°S to 70°S Lat.

Globorotalia cavernula is also rare in relation to the total planktonic Foraminifera, making up usually less than one per cent of the population. Its relative abundance exceeds 5% in six samples.

The observed temperature range in the upper 250 m of water in which it occurs is 12.5° to 3.3°C. The highest concentrations coincide with temperatures between 4.0° and 6.0°C and salinities between 34.2 to 34.3 ‰.

The holotype (USNM no. 686929) is from 55° 54'S and 139° 56'W, collected between 250 and 500 meters on November 14, 1964.

ACKNOWLEDGMENTS

The plankton samples on which this study is based were collected under the National Science Foundation's Antarctic Research Program (Grant GA-118 and GA-212); laboratory analysis was made possible through the National Science Foundation (Grant GB-4219). The author gratefully acknowledges the help of James Hubbard and Michael Smiles in sample collecting aboard USNS ELTANIN. Dee Breger illustrated the species. Diane

Miller and Connie Harmon helped in sorting the Foraminifera from the samples. The critical review of the manuscript by Richard Cifelli, David B. Ericson, Frances L. Parker, Tsunemasa Saito and Douglas Tolderlund is also highly appreciated.

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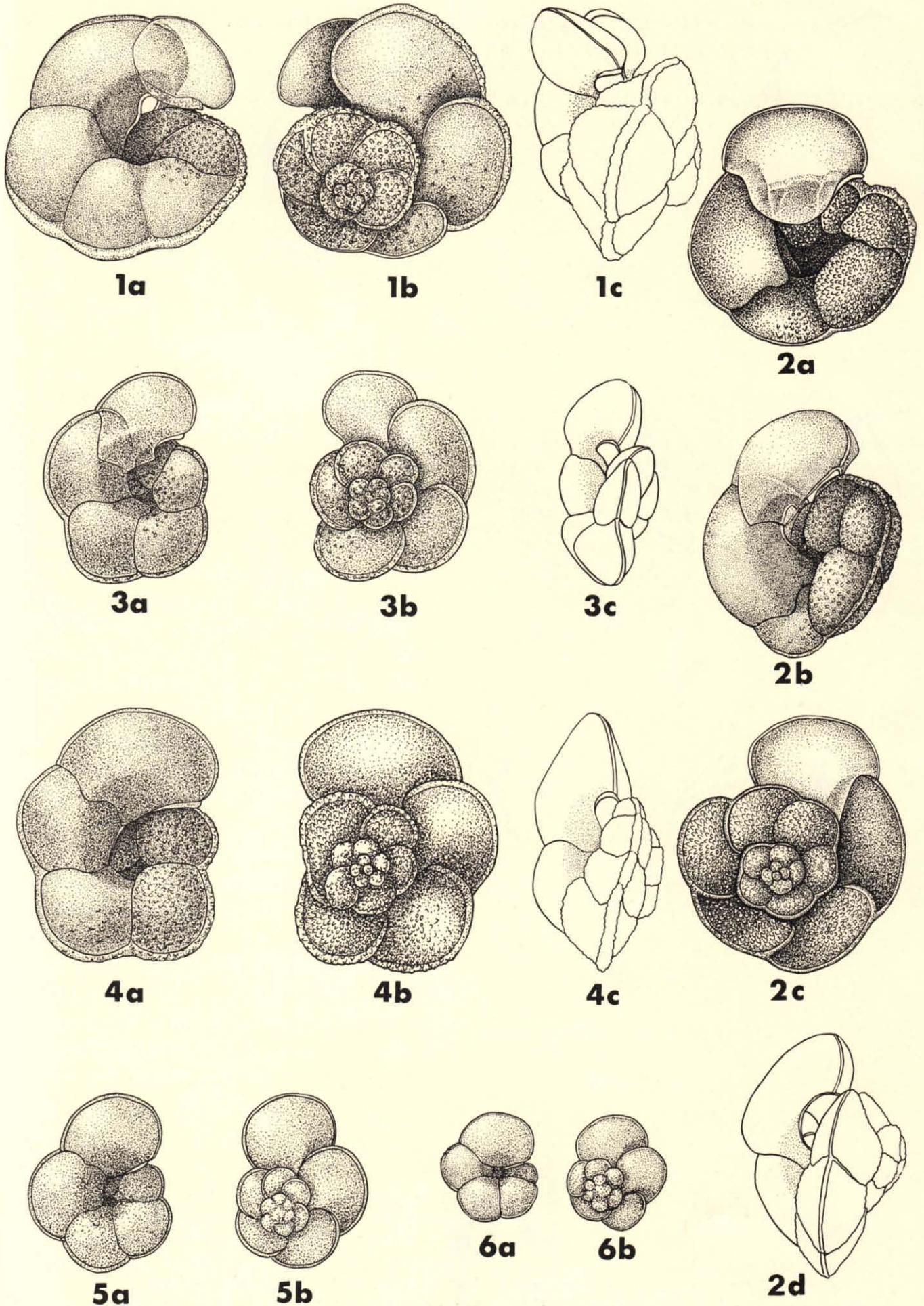
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EXPLANATION OF PLATE 10

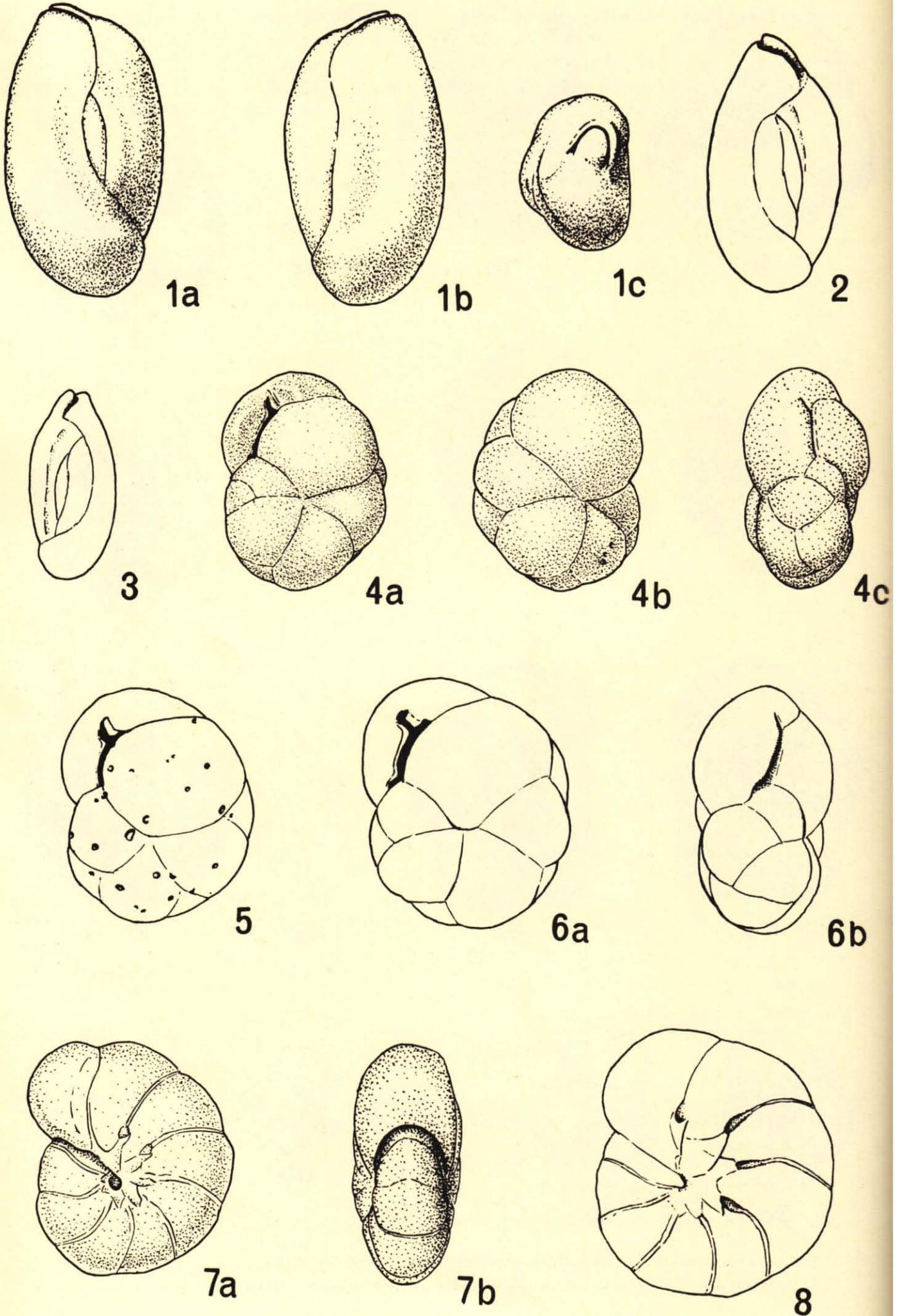
FIGS.

PAGE

- | | |
|--|-----|
| 1-6. <i>Globorotalia cavernula</i> Bé, n. sp. | 128 |
| 1. Holotype, U.S.N.M. no. 686929; a, umbilical side; b, spiral side; c, edge view. Magnification \times 85. | |
| 2. Paratype 1, U.S.N.M. no. 686930; a, umbilical side; b, oblique view; c, spiral side; d, edge view. Magnification \times 97. | |
| 3. Paratype 2, a, umbilical side; b, spiral side; c, edge view. Magnification \times 98. | |
| 4. Paratype 3, U.S.N.M. no. 686931; a, umbilical side; b, spiral side; c, edge view. Magnification \times 90. | |
| 5. Paratype 4, U.S.N.M. no. 686932; a, umbilical side; b, spiral side. Magnification \times 103. | |
| 6. Paratype 5, U.S.N.M. no. 686933; a, umbilical side; b, spiral side. Magnification \times 88. | |



Bé: New planktonic *Globorotalia*



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334. NEW FORAMINIFERA FROM THE ROSS SEA, ANTARCTICA

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ABSTRACT

Examination of surface sediment samples collected from the Ross Sea, Antarctica, disclosed two new species of Foraminifera, *Miliolinella antarctica* and *Astrononion echolsi*, and a new subspecies, *Globocassidulina crassa* (d'Orbigny) *rossensis*.

INTRODUCTION

In 48 surface sediment samples examined by the author from the Ross Sea, three new forms were found. Details of the associated foraminiferal assemblages, their distribution and aspects of their environment, have already been discussed elsewhere (Kennett, 1966; in press). The samples were collected by the New Zealand Oceanographic Institute between 1959 and 1961 during three cruises on H.M.N.Z.S. *Endeavour*.

The holotypes are deposited in the United States National Museum. Figured paratypes and additional paratypes are deposited in the micropaleontological collections of the Allan Hancock Foundation, University of Southern California, Los Angeles. Additional paratypes are deposited in the foraminiferal collections of the New Zealand Geological Survey, Lower Hutt.

The type localities given in the systematics are New Zealand Oceanographic Institute sample locations and are shown on a map elsewhere (Kennett, in press).

This work was in part supported by N.S.F. Grant No. GA-448, a part of the U. S. Antarctic Research Program of the National Science Foundation. Many thanks are due Mrs. Mary E. Echols for illustrating the specimens of Foraminifera.

SYSTEMATICS

Family MILIOLIDAE

Subfamily MILIOLINELLINAE

Genus *Miliolinella* Wiesner

Miliolinella antarctica Kennett, n. sp.

Plate 11, figures 1-3

Description.—Test free, moderately small, elongate, subovate, compressed, triloculine in chamber arrangement in adult form, quinqueloculine in young forms, periphery rounded. Chambers long, narrow, increasing rapidly in size as added; final chamber little wider at the base and tapering toward the aperture. Wall calcareous, smooth, imperforate, white and porcelaneous in appearance. Sutures almost flush, often indistinct. Aperture large, high and arched, almost completely filled with solid flap which leaves only a narrow slit.

<i>Dimensions</i> .—	Length	Width	Thickness
Holotype (fig. 1)	1.01 mm	0.57 mm	0.39 mm
Paratype (fig. 2)	0.09 mm	0.45 mm	0.25 mm
Paratype (fig. 3)	0.65 mm	0.29 mm	0.20 mm

Variability.—The degree of compression varies somewhat, and the apertural flap protrudes from the aperture in some specimens.

Types.—Holotype (U.S.N.M. 686794) and 2 figured paratypes (U.S.C.-MFS307). Two additional paratypes (U.S.C.-MFS308) from A468, and one (N.Z.Geological Survey Cat. No. TF 1556) from A468.

Type Localities.—Holotype and 3 paratypes, A468, east of Beaufort Island, Ross Sea, Antarctica; 110 meters; 76°59'S; 167°36'E. Two paratypes, A463, northern Ross Sea; 466 meters; 72°20'S; 174°50'E.

Type Level.—Recent.

EXPLANATION OF PLATE 11

FIGS.	PAGE
1-3. <i>Miliolinella antarctica</i> Kennett, n. sp.	133
1a. front view of holotype; 1b. rear view of holotype; 1c. apertural view of holotype; 2. paratype (A463); 3. paratype (A463); × 40.	
4-6. <i>Globocassidulina crassa</i> (d'Orbigny) <i>rossensis</i>	134
4a. ventral view of holotype; 4b. dorsal view of holotype; 4c. side view of holotype; × 51; 5. paratype (A533), × 100; 6a. ventral view of paratype (A530); side view of same paratype, × 72.	
7-8. <i>Astrononion echolsi</i> Kennett, n. sp.	134
7a. side view of holotype; 7b. peripheral view of holotype; 8. paratype (A449), × 99.	

Remarks.—Distinguished by the compressed, elongate test and the high, arched aperture almost completely filled by a solid flap. Differs from *M. williamsoni* (Terquem) by having a less elongate, less narrow test and a less protruding apertural flap. Found only in the two type samples.

Family CASSIDULINIDAE

Genus *Globocassidulina* Voloshinova, 1960
Globocassidulina crassa (d'Orbigny) *rossensis*
 Kennett, n. sub. sp.

Plate 11, figures 4-6

Description.—Test free, oval to circular in outline, involute, moderately compressed, periphery broadly rounded, slightly lobulate, chambers biserially arranged in a planispiral coil, inflated, very gradually increasing in size as added, usually five, sometimes four pairs making up the last whorl. Sutures almost flush, often indistinct. Wall fairly thin, calcareous, smooth, finely perforate, granular in structure. Aperture consists of an elongate narrow slit at the base of the last formed chamber, with a distinct aerial branch at right angles extending about halfway up face of final chamber; has narrow rim, which is considerably widened at one side of the aerial portion, forming a projecting tooth-like plate.

Dimensions.—

	Max. Diameter	Min. Diameter	Thickness
Holotype (fig. 4)	0.61 mm	0.47 mm	0.36 mm
Paratype (fig. 5)	0.32 mm	0.25 mm	0.20 mm
Paratype (fig. 6)	0.49 mm	0.38 mm	0.27 mm

Variability.—Apart from variation in length of the test and in the numbers of chambers making up the final whorl, *Globocassidulina crassa rossensis* exhibits little variability.

Types.—Holotype (U.S.N.M. 686795) and 2 figured paratypes (U.S.C.-MFS309). Ten additional paratypes (U.S.C.-MFS310) from A533, and 2 (N.Z.Geological Survey Cat. No. TF 1557) from A533.

Type Localities.—Holotype and 13 paratypes, A533, off Cape Barnes, McMurdo Sound, Ross Sea, Antarctica; 90 meters; 77°35'S; 166°10'E. One paratype, A530, Pennell Bank, Ross Sea; 269 meters; between 74°03'30" and 74°05'S; between 179°21'E and 179°19'E.

Type Level.—Recent.

Remarks.—This subspecies is very similar to the typical form of the species, but differs from d'Orbigny's type figures and descriptions in being much smaller, slightly less compressed; it also appears to have different apertural characteristics. *Globocassidulina crassa* is interpreted by most previous workers (Parker, 1958; Marks, 1951) as being a form with no obvious aerial branch to the aperture. However,

Nørvang (1958) showed that some specimens from N. Atlantic-Arctic areas, which he identified as *G. crassa*, possessed a very low aerial apertural branch. In others he examined, the aerial branch is completely closed and indicated only by the presence of a more or less distinct groove, or there is no trace of even a groove. Of the many specimens of *Globocassidulina crassa rossensis* examined by the author from the Ross Sea, there is an open aerial apertural branch which in all cases extends well up the face of the final chamber and possesses a simple plate to one side. Therefore, this subspecies is distinguished from the typical form and from forms identified as *G. crassa* by previous workers on the basis of the distinctive and consistent apertural characteristics described above.

Cassidulina braziliensis has a somewhat similar aperture to that of *Globocassidulina crassa rossensis*, but its test is smaller, more compressed and shows a tendency to uncoil.

Widespread and abundant throughout the Ross Sea in depths ranging from 90 to 470 meters. Rare at greater depths.

Family NONIONIDAE

Subfamily NONIONINAE

Genus *Astrononion* *echolsi* Kennett, n. sp.

Plate 11, figures 7, 8

Description.—Test free, of moderate size, planispiral and involute, compressed, periphery rounded. Chambers increasing gradually in size as added, 8 or 9 in final whorl in adult, slightly inflated. Sutures moderately limbate, flush to slightly depressed, gently curved. Supplementary chambers small, somewhat indistinct, usually tube-like, extending from umbilical region about one-third of the distance to the periphery, the outer ends of the tubes opening into slightly sunken pits on the sutural lines. Supplementary apertures typically forward slanting. Surface smooth, glossy, densely and finely perforate. Primary aperture is a low, simple, arched slit at the base of the terminal face, extending laterally into the umbilicus.

Dimensions.—

	Max. Diameter	Min. Diameter	Thickness
Holotype (fig. 7)	0.34 mm	0.27 mm	0.16 mm
Paratype (fig. 8)	0.38 mm	0.32 mm	0.18 mm

Variability.—Varies somewhat in the amount of depression of the umbilical region. The supplementary chambers are somewhat irregular in shape and size, ranging from parallel-sided and tube-like to triangular and plate-like.

Types.—Holotype (U.S.N.M. 686793) and figured paratype (U.S.C.-MFS 311). Seven additional paratypes (U.S.C.-MFS 312) from A450, 2 (U.S.C.-MFS 313) from A449, and 2 (N.Z.Geological Survey Cat. No. TF 1558) from A449.

Type Localities.—Holotype and seven paratypes, A450, central Ross Sea, Antarctica; 395 meters; between 76°42'S and 76°36'S; between 179°44'E and 179°53'E. Five paratypes, A449, central Ross Sea; 362 meters; 177°05'S; 77°12'E.

Type Level.—Recent.

Remarks.—This species is easily distinguished from others of the genus by its short, somewhat indistinct, irregularly shaped supplementary chambers with forward slanting apertures, and by the relatively compressed test.

Widespread and often abundant in the calcareous faunas of the Ross Sea, ranging from 90 to 1000 meters, but most abundant between 250 and 350 meters. Found in the Scotia Sea most abundantly between 250 and 1000 meters (Mr. Ronald J. Echols, personal communication). Deeper than 1000 meters in the Scotia Sea it is less persistent and abundant, but living specimens were found as deep as 2000 meters.

Named after Mr. Ronald J. Echols.

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NOMENCLATURAL NOTE

335. *BOLIVINOIDES CULVERENSIS*, NEW NAME FOR THE
CAMPANIAN FORAMINIFER *B. HILTERMANNI* BARR

F. T. BARR

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Recently, the author (Barr, 1966, *Palaeontology*, vol. 9, pt. 2, pl. 36, figs. 7, 8; pl. 37, figs. 1-3) proposed the name *Bolivinoides hiltermanni* for a new species from the Upper Cretaceous Chalk of southern England. The type locality for this stratigraphically important species is located in the lower part of the *Actinocamax quadratus* Zone (Lower Campanian) at Culver Cliff, Isle of Wight. While this paper was in press, Goel (1965, *Bull. Bur. Rech. Géol. Min.*, no. 5, p. 83, pl. 7, figs. 17, 18) pub-

lished a study on certain Upper Cretaceous foraminifers from the Paris Basin in which he proposed the name *B. hiltermanni*. Therefore, as Goel's species has priority, the name *B. culverensis* is here proposed as a new name for *B. hiltermanni* Barr.

The holotype and paratypes are located in the British Museum (Natural History), London, under the numbers P45724 to P45727. Additional paratypes have been deposited in the U. S. National Museum, Washington, D. C.

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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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.

- ADSHEAD, PATRICIA C. Collection and laboratory maintenance of living planktonic Foraminifera.—*Micropaleontology*, v. 13, No. 1, January 1967, p. 32-40, pls. 1, 2, text-figs. 1, 2 (photos of equipment).—Description of shipboard collection, transfer to laboratory, and successful maintenance for as long as 3 months.
- ALIYULLA, KH. New genus *Edhemia* (Foraminifera) from the Cenomanian of the Little Caucasus (Azerbaijan).—*Internat. Geol. Review*, v. 8, No. 9, Sept. 1966, p. 1123-1125, text figs. 1, 2.—A Cenomanian polymorphinid, 2 new species.
- ANSARY, S. E., and EMARA, MADIHA MOHAMED. A new foraminiferal fauna from El Minshera area, North Sinai.—*Journ. Geol. U.A.R.*, v. 6, No. 2, 1962 (1966), p. 85-101, pls. 1-3, text figs. 1-3 (map, columnar section, check list).—Eighteen species and 3 varieties, all new, are described from a section extending from Turonian to upper Paleocene.
- ARNI, P. A comprehensive graph of the essential diagnostics of the nummulites.—*Micropaleontology*, v. 13, No. 1, January 1967, p. 41-54, pls. 1-4, text-fig. 1 (graphs), tables 1-11.—Four features are graphed over the same abscissa: (1) winding curve, (2) number of chambers per whorl, (3) height of chamber, and (4) height plus thickness of spiral cord. As examples, 6 species and 4 varieties (1 new) of *Nummulites* from the Sirte Basin, north-central Libya, are graphed and described and illustrated.
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- cold-water and a warm-water fauna are recognized. A fauna transitional between the other two is characterized by abundant *Globorotalia inflata* and mixing of subarctic and subtropical species. Absolute and relative abundances of 18 species are plotted on maps.
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