

# Larger Foraminifera From Deep Drill Holes on Midway Atoll

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 680-C



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By W. STORRS COLE

GEOLOGY OF THE MIDWAY AREA, HAWAIIAN ISLANDS

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*Discussion of nine species, four of which are  
diagnostic of early Miocene (Tertiary e)*



**UNITED STATES DEPARTMENT OF THE INTERIOR**

**WALTER J. HICKEL, *Secretary***

**GEOLOGICAL SURVEY**

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## GEOLOGY OF THE MIDWAY AREA, HAWAIIAN ISLANDS

### LARGER FORAMINIFERA FROM DEEP DRILL HOLES ON MIDWAY ATOLL

By W. STORRS COLE

#### ABSTRACT

Nine species of larger Foraminifera were recovered from cores of two deep holes drilled on Midway atoll, Hawaiian Islands, in the summer of 1965. In the upper part of these holes, *Borelis melo* (Fichtel and Moll), *Heterostegina suborbicularis* d'Orbigny, *Marginopora vertebralis* Quoy and Gaimard, *Sorites marginalis* (Lamarck), and *Sorites orbiculus* (Forskål) were recovered. These species have a well-known rather long stratigraphic range in the Indo-Pacific region and are not especially diagnostic; they only suggest that the sediments in which they occur are early Miocene (Tertiary *e*) or younger.

In the lower part of the deeper hole, the Reef hole, two zones of larger Foraminifera were encountered. The upper zone contains abundant specimens of *Miogypsinoides dehaartii* (van der Vlerk) and *Austrotrillina striata* Todd and Post; it is underlain by a zone of *Spiroclypeus margaritatus* (Schlumberger), in which *A. striata* also occurs. A single specimen of *Flosculinella globulosa* L. Rutten was found in the *Spiroclypeus* zone. These four species are known markers for upper Tertiary *e* (Miocene) in the western Pacific. Small specimens of *Borelis* were found at intervals throughout both drill holes; all are referred to *Borelis melo* (Fichtel and Moll). Several supposedly valid species of *Borelis* are placed in the synonymy of *B. melo*. The section in this lower part of the Reef hole is correlated with sections in the Kita-daitō-jima, Bikini, and Eniwetok holes and with outcrops on Saipan, Guam, and Borneo. All the species of larger Foraminifera found on Midway atoll probably migrated there, on rafts of vegetation, from the western Pacific area.

All nine species are discussed and illustrated, except *Sorites marginalis* which is not figured.

#### INTRODUCTION

During the summer of 1965, two holes were drilled on Midway atoll at the northwestern end of the Hawaiian Islands (fig. 1). The drilling was sponsored by the Hawaii Institute of Geophysics with financial support (grant No. GP4728) from the National Science Foundation. In a preliminary report, Ladd, Tracey, and Gross (1967) described the drilling operations and the sediments and igneous material encountered, and a comparison was made with drill holes on other Pacific atolls. A fuller account of these matters is contained in Ladd, Tracey, and Gross (1969). The hole on Sand Island (fig. 2) penetrated 516 feet of sediments and was extended into the basaltic foundation to a depth of 568

feet. The second hole, Reef hole, drilled from a barge resting on the lagoon floor adjacent to the northern reef (fig. 2), penetrated 1,261 feet of sediments before encountering basalt. This hole was completed at a depth of 1,654 feet in basalt.

Larger Foraminifera recovered from the Sand Island hole are *Borelis melo* (Fichtel and Moll), *Heterostegina suborbicularis* d'Orbigny, *Marginopora vertebralis* Quoy and Gaimard, *Sorites marginalis* (Lamarck), and *S. orbiculus* (Forskål). These five species are still living in the lagoon at Midway, and four also occur in the upper part of the Reef hole (table 1). In addition, *M. vertebralis* and *S. orbiculus* were found in thin sections from certain cores in the part of the Reef hole assigned to Tertiary *e* (Miocene); matrix-free specimens of *B. melo* also occur in this zone.

*Heterostegina suborbicularis* and *Marginopora vertebralis* occur in samples from the upper part of the Alifan limestone of Guam. This part of the Alifan limestone with a "*Cycloclypeus-Operculina* fauna is seemingly post-Miocene in age and related to known Pleistocene faunas" (Cole, 1963, p. E9). Hanzawa

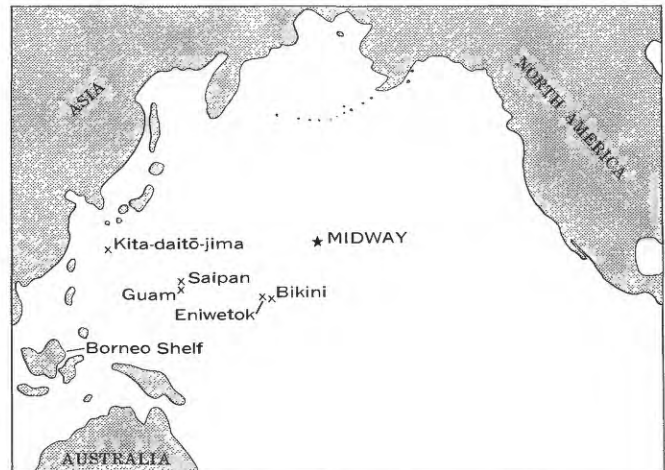


FIGURE 1.—Location of Midway and other Pacific localities which have related fossiliferous sections.

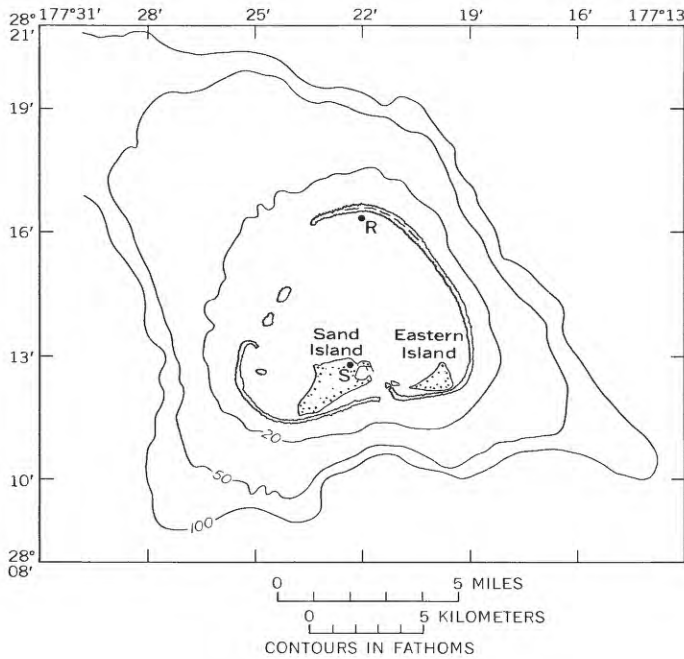


FIGURE 2.—Midway atoll, showing location of drill holes. S, Sand Island hole; R, Reef hole. From Ladd, Tracey, and Gross (1969).

TABLE 1.—Distribution of larger Foraminifera in the Midway drill holes

Species	Depth (ft)	
	Sand Island hole	Reef hole
<i>Marginopora vertebralis</i> Quoy and Gaimard <sup>1</sup>	0-233	0-911
<i>Sorites marginalis</i> (Lamarck) <sup>1</sup>	0-33	.....
<i>S. orbiculus</i> (Forsk.)	0-233	0-911
<i>Heterostegina suborbicularis</i> d'Orbigny <sup>1</sup>	0-412	0-401
<i>Borelis melo</i> (Fichtel and Moll) <sup>2</sup>	30-465	73-1,117
<i>Flosculinella globulosa</i> L. Rutten	.....	1,043
<i>Miogypsinooides dehaartii</i> (van der Vlerk)	.....	590-927
<i>Austrorillina striata</i> Todd and Post	.....	901-1,151
<i>Spiroclypeus margaritatus</i> (Schlumberger)	.....	960-1,126

<sup>1</sup> Still living in the lagoon at Midway.

<sup>2</sup> Still living in Hawaiian area.

(1940, p. 763) reported *Heterostegina depressa* (= *H. suborbicularis*) in the Kita-daitō-jima (North Borodino Island) hole in association with *Lepidocyclina* and *Miogypsina*, an upper Tertiary *e* (Miocene) association. *Marginopora vertebralis* has a stratigraphic range from Tertiary *e* (Miocene) to Holocene. The stratigraphic ranges of *Sorites marginalis* and *S. orbiculus* in the Indo-Pacific have not been determined, but specimens from the Miocene, which are commonly identified as *Sorites martini*, are probably *Marginopora vertebralis* or *Sorites orbiculus*.

The four species of larger Foraminifera in the upper section of the Midway atoll holes, therefore, do not serve as precise stratigraphic indices. At best, their occurrence in these holes only suggests that the sedi-

ments in which they occur are probably Miocene or younger. Likewise, *Borelis melo* has a long stratigraphic range, probably from Eocene to Holocene.

Larger Foraminifera that have more exact stratigraphic significance were first found in the Reef hole at a depth of 590 feet, where a few specimens of *Miogypsinooides dehaartii* (van der Vlerk), a well-known species diagnostic of late Tertiary *e* (Miocene), were recovered. This species was described by van der Vlerk (1924, p. 429) from Larat Island, in the Malay Archipelago. It has been reported from outcrop samples in Saipan (Cole, 1957a, p. 324) and Guam (Cole, 1963, p. E4) and in drill-hole samples on Bikini Atoll (Cole, 1954, p. 572) and Eniwetok Atoll (Cole, 1957b, p. 746). Hanzawa (1940, p. 780) reported specimens from the drill hole on Kita-daitō-jima as *Miogypsinooides dehaartii pustulosa*, which are without question typical *M. dehaartii* (van der Vlerk).

*Miogypsinooides dehaartii* occurs in the Reef hole cores, from 590- to 927-foot depths. In certain of these cores, this species is so abundant that the sediment can be described as a *Miogypsinooides* sand. Elsewhere, *M. dehaartii* is associated with other genera of larger Foraminifera—for example, *Miogypsina* and *Lepidocyclina*; however, *Miogypsinooides* was the only genus of larger Foraminifera found in this section of the Reef hole.

At depths between 901 and 927 feet in the Reef hole, the diagnostic smaller Foraminifera *Austrorillina striata* Todd and Post occurs in association with *Miogypsinooides dehaartii*. *A. striata*, a species seemingly restricted to the Tertiary *e* stage in the western Pacific, was formerly identified as *A. howchini*, a species characteristic of the Tertiary *f* stage.

The first specimen of *Spiroclypeus* was found at a depth of 960 feet in the Reef hole. At 1,029 feet, abundant specimens of this genus were obtained, and the cores between 1,029 feet and 1,126.3 feet contain *Spiroclypeus* in varying abundance. As in the overlying zone of *Miogypsinooides*, no other larger Foraminifera are associated with *Spiroclypeus*. In Bikini hole 2B (Cole, 1954, p. 572) and the Eniwetok (Cole, 1957b, p. 747) and Kita-daitō-jima (Hanzawa, 1940, p. 763) drill holes, the *Miogypsinooides dehaartii* zone is underlain by a zone of *Spiroclypeus margaritatus* (Schlumberger). This same zonal relationship occurs in the Reef hole of Midway atoll.

A single specimen identified as *Flosculinella globulosa* L. Rutten was found in the Reef hole at 1,043 feet. This species elsewhere in the Indo-Pacific region is another diagnostic species of Tertiary *e* (early Miocene) (Cole, 1957b, p. 747).

COMPARISON WITH OTHER PACIFIC ISLAND  
DRILL HOLES

Hanzawa (1940, p. 763) reported 12 species of larger Foraminifera from Zones 3-5 in the Kita-daitō-jima drill hole, between depths of 116.49 meters and 431.67 meters. Table 2 gives the species recognized by Hanzawa, and the zones in which these species were found. The final column of this table lists the species as they are interpreted in this report.

Previously, Cole (1954, p. 573) stated that the order of appearance of genera of larger Foraminifera in the Kita-daitō-jima drill hole was similar to that in Bikini hole 2B and that the Kita-daitō-jima drill hole ended "definitely in the Aquitanian, Tertiary *e*." Cole's interpretation is different from that given by Hanzawa (1940, p. 764), who assigned Zone 5 to the Chattian.

The parts of the Midway Reef hole in which *Miogypsinoides dehaartii* (590-927 ft) and *Spiroclypeus margaritatus* (960-1,126.3 ft) occur correlate with Zones 4 and 5 of the Kita-daitō-jima test hole and with the section in the Bikini and Eniwetok holes assigned to upper Tertiary *e* (Cole, 1957b, p. 747).

Although the upper *Miogypsinoides dehaartii* zone in the Reef hole is sharply delimited and separated from the lower *Spiroclypeus margaritatus* zone by an unfossiliferous zone, at certain localities elsewhere *M. dehaartii* and *Spiroclypeus* occur together (Cole, 1957b, p. 747). In part, the distinct separation of these two genera in the Reef hole may be the result of the geologic history of the atoll. The section between 911 and 955 feet contains such materials as reddish-brown and carbonaceous clay, which would develop in an environment unfavorable to larger Foraminifera.

## MIGRATION

As all the species of larger Foraminifera found on Midway atoll, either fossil or Holocene, are well-known Indo-Pacific species, the faunas of this atoll must have been derived by direct migration from the west. In the

migrations, however, only a few species of the more diversified western Indo-Pacific faunas were able to survive and become established in the mid-Pacific Hawaiian area.

In the western Pacific and the Malay Archipelago, *Miogypsinoides dehaartii* is associated with species of *Miogypsina* and *Lepidocyclina*. *Spiroclypeus* is usually found with *Lepidocyclina*, *Heterostegina*, and *Miogypsinoides*. On Midway, *Miogypsina* and *Lepidocyclina* were not found.

On many of the western Pacific islands *Calcarina* and *Baculogypsina* occur in such abundance that their tests form the beach sands. These two genera are usually associated with *Marginopora* and *Sorites*. Although *Marginopora* and *Sorites* were found (fossil and Holocene) on Midway, *Calcarina* and *Baculogypsina* were not recovered.

Cole (1960, p. 16) suggested that larger Foraminifera may become entangled in rather large masses of vegetation.

During exceptional storms or similar disturbances masses of this vegetation broke loose from the bottom, and, then drifted widely. Most of this vegetation would gradually disintegrate and drop any organisms which it contained. However, occasionally masses of the vegetation would come to rest in some favorable situation far from its source and the organisms which it contained would be able to establish themselves anew. \* \* \* The migration of the larger Foraminifera would be slow, erratic, and discontinuous. Moreover, under the conditions proposed many genera might not be transported to a favorable situation where a colony could be established.

Kita-daitō-jima is nearly on the same latitude as Midway. Tertiary *e* (Miocene) sediments on Kita-daitō-jima contain *Miogypsinoides dehaartii* and *Spiroclypeus margaritatus* (Hanzawa, 1940, p. 780, 789), as well as *Lepidocyclina* and *Miogypsina*.

If the current direction in the north Pacific was the same during Tertiary *e* (Miocene) as at present, rafts of vegetation containing larger Foraminifera could have moved from Kita-daitō-jima via the Kuroshio, Kuroshio Extension, and North Pacific Current to the Ha-

TABLE 2.—Reevaluation and distribution of selected Foraminifera from the Kita-daitō-jima test hole

Species identified by Hanzawa (1940, p. 763)	Zone			Revised list (this report)
	3	4	5	
<i>Operculina gaimardi</i> d'Orbigny	×			<i>Camerina ammonoides</i> (Gronovius).
<i>Heterostegina depressa</i> d'Orbigny	×			<i>H. suborbicularis</i> d'Orbigny.
<i>Cycloclypeus communis</i> Martin	×			<i>Cycloclypeus</i> sp.
<i>Nephrolepidina tournoueri</i> Lem. and R. Douvillé	×	×		<i>Lepidocyclina (Eulepidina) sumatrensis</i> H. B. Brady.
<i>N. plicomargo</i> Hanzawa	×	×		Do.
<i>Miogypsina polymorpha</i> (L. Rutten)	×			Microspheric specimen (?).
<i>M. borneensis</i> Tan	×	×		<i>Miogypsina thecideaformis</i> (L. Rutten).
<i>Miogypsinoides dehaartii pustulosa</i> Hanzawa		×		<i>Miogypsinoides dehaartii</i> (van der Vlerk).
<i>M. bantamensis</i> Tan		×		Do.
<i>M. lateralis</i> Hanzawa		×		Do.
<i>Spiroclypeus margaritatus</i> (Schlumberger)		×		<i>S. margaritatus</i> (Schlumberger).
<i>Miogypsinella borodinensis</i> Hanzawa			×	<i>Miogypsinoides ubaghsi</i> Tan.



waiian area (Sverdrup and others, 1942, chart 7). During the long transportation eastward across the Pacific, many species of the Indo-Pacific fauna were probably lost, but a few *Spiroclypeus*, *Austrotrillina*, and *Borelis* were able to survive the journey. In a similar fashion, at a slightly later time, a few *Miogypsinoides* became established. The arrival of *Marginopora vertebralis* and *Sorites orbiculus* in the Hawaiian area generally coincided with that of *Miogypsinoides dehaartii*, but *Heterostegina suborbicularis* and *Sorites marginalis* did not become established until the Holocene.

Under the postulated conditions of rafting, the Hawaiian faunas of larger Foraminifera, in which a single species may constitute the entire fauna, are entirely expectable. Moreover, migration east of the Hawaiian area is doubtful, as "The main part of the North Pacific Current does not, therefore, extend across the Pacific Ocean but turns back toward the west in the longitude of the Hawaiian Islands" (Sverdrup and others, 1942, p. 722).

One species of *Spiroclypeus* has been recorded in the Americas (Vaughan and Cole, 1941, p. 54) in the Oligocene. *Spiroclypeus* is known to occur in the Eocene of Europe and Indo-Pacific area. With our present understanding of migrations, it is easier to derive the American species of *Spiroclypeus* from a European source rather than by transportation across the eastern Pacific Ocean from the Hawaiian area.

#### DISCUSSION OF SPECIES<sup>1</sup>

##### Family MILIOLIDAE

##### Genus AUSTROTRILLINA Parr, 1942

##### *Austrotrillina striata* Todd and Post Plate 4, figure 27; plate 5, figures 4, 5

1960. *Austrotrillina striata* Todd and Post, U.S. Geol. Survey Prof. Paper 260-N, p. 555, pl. 198, fig. 9.  
1954. *Austrotrillina howchini* Cole [not Schlumberger, 1893], U.S. Geol. Survey Prof. Paper 260-O, p. 573, pl. 210, figs. 6-9.  
1957. *Austrotrillina howchini* Cole [not Schlumberger, 1893], U.S. Geol. Survey Prof. Paper 280-I, p. 329, pl. 101, figs. 4-6.  
1957. *Austrotrillina howchini* Hanzawa [not Schlumberger, 1893], Geol. Soc. America Mem. 66, p. 38, pl. 22, figs. 12, 13; pl. 34, figs. 1, 2.

This species was based upon specimens obtained from cuttings at depths of 2,049-2,059.5 feet in Bikini hole 2B, Marshall Islands. Although in the type description the internal structure was not illustrated, Cole (1954, pl. 210, figs. 7-9) figured thin sections of specimens from this hole at depths of 2,038.5-2,048 feet

<sup>1</sup>All figured specimens are in the collections of the U.S. National Museum (USNM).

and 2,049-2,059.5 feet under the name *Austrotrillina howchini* (Schlumberger), which are without question the same kind of specimens as those which were named *A. striata*.

*Austrotrillina striata* differs from *A. howchini* in possessing a single sequence of coarse alveoli which project inward from the thin external wall of the test. *A. howchini*, however, has a secondary sequence of short alveoli interposed between coarse large alveoli, thereby producing two distinct rows of inward projections (Parr, 1942, text fig. 1).

The stratigraphic range of *Austrotrillina howchini* has been given commonly as Tertiary *e* through *f*. However, certain specimens identified previously as *A. howchini* are in reality *A. striata*. Specimens from Saipan Island (Cole, 1954, pl. 210, figs. 6-9; Hanzawa, 1957, pl. 22, figs. 12, 13; pl. 34, figs. 1, 2) that were identified as *A. howchini* are *A. striata*.

In Bikini hole 2B (its type locality), *Austrotrillina striata* is associated with *Spiroclypeus* in sediments dated as Tertiary *e* (Cole, 1957b, p. 745, table 2). On Saipan Island (Cole, 1957a, tables 2, 3) *A. striata* occurs with *Spiroclypeus* and *Miogypsinoides dehaartii*, as well as other species of larger Foraminifera. These associations firmly establish the age of *A. striata* as Tertiary *e*. *A. howchini* seemingly replaces *A. striata* in Tertiary *f*.

*Austrotrillina striata* occurs infrequently in the Reef hole, Midway atoll, at depths of 901-906 feet and 926-927 feet with abundant specimens of *Miogypsinoides dehaartii*. At 906-911 feet *A. striata* is abundant, but *M. dehaartii* is rare. The two samples in which *M. dehaartii* is abundant represent shallow water of a reef flat, whereas the core with abundant *A. striata* represents deeper water lagoonal conditions.

At greater depths in the Reef hole, about 1,100-1,120 feet, *Austrotrillina striata* occurs in great abundance, and it continues to be present to a depth of 1,151 feet (Ruth Todd, written commun., Nov. 1966).

##### Family SORITIDAE Ehrenberg Genus SORITES Ehrenberg, 1839

##### *Sorites marginalis* (Lamarck)

1965. *Sorites marginalis* (Lamarck). Cole, Bulls. Am. Paleontology, v. 49, no. 219, p. 21, 22; pl. 4, figs. 3, 7, 9; pl. 6, figs. 6, 8 (references).

A few entirely typical specimens were found in dredgings from the lagoon and in a sample from the Sand Island hole at a depth of 25-30 feet. The external appearance and the internal structure of this species has been discussed and illustrated by Cole (1965, p. 21).

**Sorites orbiculus (Forskål)**

Plate 3, figures 7, 8, 16; plate 4, figures 3-7

1965. *Sorites orbiculus* (Forskål), Cole, Bulls, Am. Paleontology, v. 49, no. 219, p. 20, 21; pl. 6, figs. 1-5, 7, 9; pl. 7, figs. 1-8, 10-12; pl. 8, figs. 7-9 (references).

This species has been discussed and illustrated recently by Lehmann (19601, p. 641) and Cole (1965, p. 20). Oriented thin sections of specimens from dredgings in the lagoon and from the upper part of the drill holes are identical with the specimens illustrated by these two authors.

In thin sections from the Reef hole at a depth of 901-906 feet in the *Miogypsinoides dehaartii* zone (Tertiary *e*), several transverse sections and two partial equatorial sections were found of specimens which seem to be identical in internal structure with the stratigraphically younger specimens.

Miocene specimens elsewhere in the Indo-Pacific region have been referred commonly to *Sorites martini* (Verbeek) (Cole in Cole and Bridge, 1953, pl. 12, fig. 11; pl. 14, figs. 1, 2; Hanzawa, 1957, pl. 6, figs. 3, 4, 8, 9; pl. 35, fig. 16). However, Henson (1950 p. 55) illustrated specimens from the Segid No. 1 well, Farsan Islands, from "L. Miocene?" limestones which he identified as *S. orbiculus?* Forskål.

Although Hanzawa (1957, p. 55) placed the specimens which Henson identified questionably as *Sorites orbiculus* in the synonymy of *S. martini*, this assignment may not be correct. The type of *Orbitolites martini* is inadequately described and illustrated. The type transverse section (Verbeek and Fennema, 1896, pl. 9, fig. 134) of "*O.*" *martini* has chevron-shaped chamber walls of the kind found in certain specimens (Cole, 1954, pl. 211, figs. 10, 17) of *Marginopora vertebralis*. Therefore, "*O.*" *martini* may be this species.

Inasmuch as the specimens from Tertiary *e* of Saipan Island (Cole in Cole and Bridge, 1953, p. 27; Hanzawa, 1957, p. 55) and Guam (Cole, 1963, p. E5), which were referred to *Sorites martini*, are similar to the specimens from Midway identified as *S. orbiculus*, they are here referred to *S. orbiculus*.

If these assignments are correct, *Sorites orbiculus* has a stratigraphic range in the Indo-Pacific region from Tertiary *e* (Miocene) to Holocene. This stratigraphic range is similar to that of *Marginopora vertebralis*.

**Genus MARGINOPORA Quoy and Gaimard in Blainville, 1830*****Marginopora vertebralis* Quoy and Gaimard**

Plate 3, figures 6, 15, 17; plate 4, figures 1, 2

1830. *Marginopora vertebralis* Quoy and Gaimard in Blainville, Dict. Sci. Nat., v. 60, p. 377.

1965. *Marginopora vertebralis* Quoy and Gaimard. Cole, Bulls.

Am. Paleontology, v. 49, no. 219, p. 22-24; pl. 7, fig. 9; pl. 8, figs. 1-6; pl. 9, figs. 1-12; pl. 10, figs. 1-8 (references).

Typical but usually small specimens occur in the foraminiferal sands of the upper part of both holes and in certain samples from the floor of the lagoon. Specimens of the large size observed in collections from the reefs of the atolls in the western Pacific were not found at Midway.

Thin sections from a core at 901-906 feet in the *Miogypsinoides dehaartii* zone (Tertiary *e*) in the Reef hole contained several specimens of this species. *Marginopora vertebralis* was found at several localities in the Tagpochau limestone, Tertiary *e* (Miocene), of Saipan (Cole, 1957a, p. 335) also in association with *M. dehaartii*. The stratigraphic range of *M. vertebralis* in the Indo-Pacific region is from Tertiary *e* to Holocene.

**Family ALVEOLINIDAE****Genus BORELIS Montfort, 1808*****Borelis melo* (Fichtel and Moll)**

Plate 4, figures 8-23, 25; plate 5, figures 1-3, 6-8

1798. *Nautilus melo* var.  $\beta$  Fichtel and Moll, Testacea Microscopica, p. 123, pl. 24, figs. g, h.

1930. *Borelis (Fasciolites) pygmaea* Hanzawa, Tohoku Imp. Univ. Sci. Repts., 2d Ser. (Geology), v. 14, no. 1, p. 94, pl. 26, figs. 14, 15.

1937. *Neoalveolina pygmaea schlumbergeri* Reichel, Schweizer. Palaeont. Gesell. Abh., v. 59, p. 110-112, pl. 10, figs. 1-3; pl. 11, fig. 6b.

1949. *Borelis philippinensis* Hanzawa, Japanese Jour. Geology and Geography, v. 21, nos. 1-4, p. 155-157, pl. 4, figs. 1-7.

1957. *Borelis primitivus* Cole, U.S. Geol. Survey Prof. Paper 260-V, p. 766, 767, pl. 240, figs. 3-10.

1957. *Borelis parvulus* Hanzawa, Geol. Soc. America Mem. 66, p. 56, pl. 23, figs. 3a-c.

Several specific names have been given to small fossil specimens of *Borelis* in the Indo-Pacific region, but *Borelis pygmaeus* Hanzawa has been used most frequently for specimens from the Tertiary *e* (lower Miocene).

This species was described by Hanzawa (1930, p. 94) as *Borelis (Fasciolites) pygmaea* from a Tertiary *e* (lower Miocene) limestone in the vicinity of Pabeasan, Java. The types (Hanzawa, 1930, pl. 26, figs. 14, 15) are three axial sections, and Hanzawa's figure 14 is similar to the specimen (pl. 4, fig. 16) from the Reef hole at 1,117 feet. This specimen from the Reef hole has a length of 1.0 mm, a height of 0.49 mm, and about 20 chamberlets in the final volution. Hanzawa (1930, p. 94) stated the length of the types was 1.3 mm, the height, 0.5 mm, and the number of chambers in the final volution, 22-24.

Hanzawa (1930, p. 95) considered that the types had a "unilocular nucleocoench."

Bakx (1932, p. 237) identified specimens from Borneo and adjacent islands as *Borelis pygmaea*, but he recognized that the embryonic apparatus was not unilocular; therefore, he transferred this species to the genus *Neovalveolina*. Bakx (1932, pl. 3, fig. 19) illustrated a specimen which is slightly larger than, but otherwise similar to, the specimen (pl. 4, fig. 10) from the Reef hole at 1,126.3 feet. Later, Crespin (1938, p. 10) identified and illustrated this species under the name *Neovalveolina pygmaea* (Hanzawa) from a lower Miocene limestone from the Ok Ti River, Papua.

Cole (1939, pl. 24, fig. 8) illustrated a small specimen from the "Lowermost Miocene, Tertiary e" Guam. This specimen was smaller and less fusiform than the types, but it was otherwise similar.

Hanzawa (1947) published four excellent illustrations of specimens from Saipan Island, which he identified as *Borelis pygmaeus*. The average length of three of these specimens is 2.1 mm, and the average height is 0.83 mm. According to Hanzawa the Saipan specimens have 56 chamberlets in the last volution. Thus, Hanzawa disregarded size in identifying the Saipan specimens with the types.

Reichel (1937, p. 110) named Holocene specimens from Mayotte Island, northwest of Madagascar, *Neovalveolina pygmaea schlumbergeri*. Hanzawa (1947, p. 10) wrote: "Comparison of the foregoing features with the statistics following leads to the conclusion that *Neovalveolina pygmaea schlumbergeri* Reichel is similar to the fossil form of *Borelis pygmaea* (Hanzawa) from Saipan I. \* \* \*." However, Hanzawa concluded that "The living form, *Borelis pygmaea schlumbergeri* (Reichel), should be distinguished from the Aquitanian form."

Cole (1954) identified specimens from Tertiary *g* (Miocene) in the Bikini drill holes as *Borelis schlumbergeri* (Reichel); Cole (1954, p. 583) wrote: "It is entirely possible to distinguish these specimens [*B. pygmaeus*] from the Bikini specimens as the specimens from Saipan are larger, with fewer chambers per millimeter and more chambers in the final volution. However, it should be indicated that the differences may be caused by ecological conditions rather than specific or varietal change."

Hanzawa (1957, p. 56) named specimens from Saipan Island *Borelis parvulus*, and wrote, "This species stands close to *Borelis melo* (Fichtel and Moll, pl. 24) or *Borelis melo* var. *curdica* (Reichel, 1937, p. 109, pl. 10, figs. 4-7), but is easily distinguished from the latter by the mode of growth in its early stage." Hanzawa (1957, tables 2, 3) recorded the occurrence of *B. parvulus*, at

several stations in the Tagpochau limestone, with other specimens which he identified as *B. pygmaeus*.

Cole (1957a, p. 336) wrote: "Hanzawa named certain small specimens *B. parvulus* and compared this new species with *B. melo* (Fichtel and Moll). Similar specimens in the present collection are considered to be small *B. pygmaeus*."

In the Eniwetok drill holes, Cole (1957b, p. 766, 767) recognized *Borelis schlumbergeri* (Reichel), which first appeared at a depth of 800 feet (Tertiary *g*); *B. melo*, at 1,230 feet (Tertiary *e*); and *B. pygmaeus*, at 1,718 feet (Tertiary *e*). In addition, Cole named small specimens from the Eniwetok Atoll drill hole E-1, at a depth of 1,925-1,955 feet (Tertiary *e*), *B. primitivus*. Cole (1957b, p. 766) wrote: "This species differs from *B. pygmaeus* Hanzawa in its smaller size and the smaller number of chamberlets in the final chamber. Moreover, it has a smaller number of chambers in the adult test."

Cushman, Todd, and Post (1954, p. 348) recorded that rare specimens of *Neovalveolina pulchra* (d'Orbigny), a species described from the Holocene of the West Indies, occurred in the Holocene fauna of Foraminifera from the Marshall Islands. Earlier, Cushman (1917, p. 98) wrote concerning *Alveolina melo* (Fichtel and Moll): "Brady records this species from off the Hawaiian Islands and this stands as the only record for the North Pacific." *Borelis pulchrus* is without question a synonym of *B. melo*.

The specimens of *Borelis* recovered from the Midway drill holes are small and vary in shape from nearly globular to fusiform. These specimens were found in several limited zones; therefore they were grouped into depth zones for study (table 3). Although specimens in the uppermost zone are commonly globular (pl. 4, fig. 20), fusiform specimens (pl. 4, fig. 8) were associated with these globular specimens. In the lowermost zone specimens were generally fusiform, but occasional globular specimens were found.

In oriented thin sections (pl. 4, figs. 8-23, 25; pl. 5, figs. 1-3, 6-8), all these specimens had identical internal structures. One specimen (pl. 5, fig. 6) from a depth of 1,126.3 feet in the Reef hole is fusiform (pl. 4, fig. 10). Another specimen (pl. 5, fig. 7) from a depth of 140 feet in the Sand Island hole is globular (pl. 4, fig. 19). The internal arrangement and shape of the chambers are the same, though the shape of test is different.

The conclusion was reached that all these specimens represent only one species, but the problem remained concerning which specific name should be applied to these specimens.

Hanzawa (1947, pl. 5, figs. 1-4) published excellent illustrations of the internal structure of specimens from Tertiary *e* (lower Miocene) of Saipan Island which he identified as *Borelis pygmaeus*. Cole (1957a, pl. 102,

fig. 1; pl. 110, figs. 5-7) gave additional illustrations of this species from the same island. Reichel (1937, pl. 10, figs. 1-3) published clear illustrations of *Neoalveolina pygmaea schlumbergeri* from the Holocene, and Cole (1954, pl. 209, figs. 10-18) illustrated specimens, which he identified as *B. schlumbergeri*, from Tertiary *g* (Miocene) of the Bikini drill holes. The internal structure of Holocene specimens of *B. melo* from the Atlantic was shown by H. B. Brady (in Barker, 1960, pl. 17, figs. 14, 15), and Reichel (1937, pl. 10, figs. 8, 9) illustrated the internal structures of fossil specimens from the Tortonian (Miocene) "Leithakalk (Transylvania)." The types of *B. primitivus* from Tertiary *e* (lower Miocene) of the Eniwetok drill holes were also illustrated (Cole, 1957b, pl. 240, figs. 3-10).

TABLE 3.—Depth zones from which specimens of *Borelis* were recovered and the average size of specimens within each zone, Midway

Hole	Depth (ft)	Number of specimens	Average height (mm)	Average length (mm)	Height-length ratio
Sand					
Island----	0-145	6	0.42	0.45	1.07
Reef-----	0-88	4	.34	.5	1.47
	733-740	3	.43	.57	1.32
	1,042-1,075	7	.47	.7	1.51
	1,108-1,186	11	.4	.81	2.02

Hanzawa (1949, p. 155) described *Borelis philippinensis* from Tertiary *e* (lower Miocene) sediments of Luzon, Philippine Islands. Although Hanzawa stated this new species "shows some affinity to *Borelis pygmaeus* *Borelis pygmaeus schlumbergeri*, *Borelis parvulus*, *Borelis melo* (Fichtel and Moll), and *Borelis melo* var. *curdica*," he also stated "the following statistic study shows that it should be specifically distinguished from any of these." He suggested that such characteristics as the thickness of the test, the number of chamberlets in the final volution, the number of irregular volutions at the center of test, and similar features could be used to distinguish among these species.

Detailed study of the illustrations which have been cited in conjunction with the illustrations of the oriented sections (pl. 4, figs. 8-23, 25; pl. 5, figs. 1-3, 6-8) of specimens from the Midway drill holes proves conclusively that the internal structure of all these supposedly valid species is the same. There are slight differences in the dimensions of the test, in shape, in the number of volutions, and in the number of chamberlets per whorl; however, these features are variable, whereas the internal structure is constant. Thus, the conclusion was reached that only one species, *Borelis melo* (Fichtel and Moll), could be recognized.

The size and shape of the test of species of *Borelis*

may be influenced by the depth of the water. The kind which was named *B. schlumbergeri* (elongate, fusiform) was dredged from depths of 74-224 fathoms (Reichel, 1937, p. 112). Cushman, Todd, and Post (1954, table 3) reported 13 specimens identified as *Neoalveolina pulchra* (globular to slightly fusiform) from Holocene sediments of the Marshall Islands. Of these 13 specimens, 10 occurred in sediments above 50 fathoms.

Heron-Allen and Earland (1914-15, p. 607), in their analysis of Holocene Foraminifera of the Kerimba Archipelago, Portuguese East Africa, remarked that *Alveolina melo* "is most abundant and attains its best development at Stn. 11. At most of the Stns. two distinct forms occur together, one spherical (most frequent), and the other obtusely elliptical \* \* \*." Heron-Allen and Earland (1914-15, p. 369) wrote concerning station 11 "This sample covers a long range of inshore reef gatherings." Adjacent water is reported to have depths ranging from 0.25 to 4 fathoms. Although these few records do not necessarily prove that depth of water is a controlling factor in the size and shape of the test, they do suggest it.

The type of *Borelis melo* is from the Miocene of Transylvania. In an undoubted Eocene fauna of Saipan Island, Cole (1957a, p. 336) found a single specimen which he referred to *B. pygmaeus*. Previously, Bakx (1932, p. 254) gave the range of *B. pygmaeus* from upper Tertiary *a* through Tertiary *e*. Caudri (1934, p. 134) stated: "This species could be identified on Soemba in Tertiary *a* \* \* \* and further in a number of later rocks from Tertiary *c* age." Thus *Borelis melo* has an extensive stratigraphic range from Eocene to Holocene and a wide geographic distribution from Europe into the central Pacific area.

#### Genus FLOSCULINELLA Schubert, in Richarz, 1910

##### *Flosculinella globulosa* L. Rutten

Plate 4, figures 24, 26

1917. *Alveolinella* (*Flosculinella*) *globulosa* L. Rutten, Geol. Reichs-Mus. Leiden, Sammlungen, Neue Folge, v. 2, pt. 7, p. 277; pl. 5, figs. 140, 141.

Only one specimen was found in the Reef hole at a depth of 1,043 feet. The section made from this specimen is not centered, but the internal structure is entirely comparable to that in other nearly globular specimens referred to this species. (Compare pl. 4, fig. 24, with Cole, 1954, pl. 209, fig. 9.)

This species has been reported from Tertiary *e* of Bikini hole 2B (Cole, 1954, p. 584), of Eniwetok hole E-1 (Cole, 1957b, p. 767), and from outcrop samples on Saipan Island (Cole, 1957a, p. 336).

Family CAMERINIDAE<sup>2</sup>

## Genus HETEROSTEGINA d'Orbigny, 1826

*Heterostegina suborbicularis* d'Orbigny

Plate 3, figures 1-5, 18

1826. *Heterostegina suborbicularis* d'Orbigny, Ann. Sci. Nat., v. 7, p. 305.
1903. *Heterostegina suborbicularis* d'Orbigny. Fornasini, Soc. Geol. Italiana Boll., v. 22, p. 396, pl. 14, figs. 5-7.
1940. *Heterostegina depressa* Hanzawa [not d'Orbigny], Jubilee publication in commemoration of Professor H. Yabe, M.I.A., sixtieth birthday, v. 2, p. 762, 763.
1954. *Heterostegina suborbicularis* d'Orbigny. Cole, U.S. Geol. Survey Prof. Paper 260-O, p. 576, pl. 205, figs. 5-8 (references).

The types of this species probably are from the Hawaiian Islands. The types of *Heterostegina depressa* d'Orbigny are from the island of Sainte-Hélène in the South Atlantic Ocean. Although some authors considered *H. suborbicularis* a synonym of *H. depressa*, this relation has not been demonstrated. Therefore, for the present, the specific name *H. suborbicularis* is used for the Indo-Pacific specimens of this kind.

The specimens (pl. 3, figs. 3-5) from the Sand Island hole were recovered by crushing the compact limestone. These specimens (for example, pl. 3, fig. 3) have an inflated initial part bordered on the apertural edge by a broad thin flange. Thus, their external appearance is similar to that of certain specimens of *Camerina venosa* (Fichtel and Moll) (Cole, 1959, pl. 28, fig. 17; pl. 29, figs. 1, 13). Sections demonstrate that all these specimens are *Heterostegina*.

The specimens (pl. 3 figs. 1, 2, 18) from the Reef hole occurred in a foraminiferal sand that contained abundant specimens of *Amphistegina*. These specimens lack the flange but internally have the same structure as the specimens from the Sand Island hole.

*Heterostegina suborbicularis* may have an extended stratigraphic range in the western Pacific for Cole (1957b, p. 762) identified specimens, presumably from the Tertiary *b* (upper Eocene) in Eniwetok hole E-1, as *H. suborbicularis*.

## Genus SPIROCLYPEUS Douvillé, 1905

*Spiroclypeus margaritatus* (Schlumberger)

Plate 2, figures 1-20; plate 3, figures 9-14, 19

1902. *Heterostegina margaritatus* Schlumberger, Geol. Reichs-Mus. Leiden Sammlungen, ser. 1, v. 6, p. 252, 253, pl. 7, fig. 4.
1905. *Spiroclypeus orbitoides* H. Douvillé, Soc. Géol. France Bull., ser. 4, v. 5, p. 460-462, pl. 14, figs. 1-6.

<sup>2</sup> For discussion of this name, see Cole (1966, p. 236).

1905. *Spiroclypeus pleurocentralis* H. Douvillé, idem, p. 462-464, pl. 14, figs. 7-9, not *Orbiculina pleurocentralis* Carter, 1857.
1925. *Spiroclypeus leupoldi* van der Vlerk. Dienst Mijnbouw, Wetenschappelijke, Mededeel., no. 3, p. 14, 15, pl. 2, fig. 16; pl. 5, figs. 41, 48.
1925. *Spiroclypeus wolfgangi* van der Vlerk, idem, p. 15, 16, pl. 2, fig. 15; pl. 5, figs. 39, 49.
1925. *Spiroclypeus yabei* van der Vlerk, idem, p. 16, pl. 2, fig. 19; pl. 5, figs. 40, 50.
1925. *Spiroclypeus tidoenganensis* van der Vlerk, idem, p. 16, 17, pl. 1, fig. 12; pl. 5, figs. 42, 47.
1925. *Spiroclypeus margaritatus* (Schlumberger). Yabe and Hanzawa, Geol. Mijnb., Genootsch. Nederland en Kolonien, Verh. Geol. ser., v. 8, p. 627-630, pl. 2, fig. 10; pl. 3, figs. 8, 9; pl. 4, figs. 3-8; text figs. 1-4.
1939. *Spiroclypeus higginsii* Cole, Jour. Paleontology, v. 13, no. 2, p. 185, 186, pl. 23, figs. 10-15; pl. 24, fig. 13.

Douvillé (1905, p. 458) erected the generic name *Spiroclypeus*. type species *S. orbitoides* from the Miocene of Borneo, for specimens which are similar to *Heterostegina* in median section but develop lateral chambers on each side of this layer. In this same article Douvillé (1905, p. 462, pl. 14, figs. 7-9) referred other specimens from the Miocene of Borneo to *Orbiculina pleurocentralis* Carter, 1857, a species which he assigned questionably to the genus *Spiroclypeus*.

Previously, Schlumberger (1902, p. 253) described *Heterostegina margaritatus* from a single transverse section from Teweh, Borneo. Yabe and Hanzawa (1925, p. 627) transferred this species to *Spiroclypeus* after studying topotype material. Also, van der Vlerk (1925, p. 14-17) described four new species of *Spiroclypeus* from the Naintoepo beds of "Tidoengsche Landen," East Borneo. These were *S. leupoldi*, *S. tidoenganensis*, *S. wolfgangi*, and *S. yabei*.

The first comparative review of the species of Indo-Pacific *Spiroclypeus* was by Krijnen (1931). He recognized five valid species, *S. leupoldi*, *S. margaritatus*, *S. orbitoides*, *S. pleurocentralis*, and *S. tidoenganensis*. Krijnen (1931, p. 90) considered *S. yabei* to be a synonym of *S. pleurocentralis* and *S. wolfgangi* to be the microspheric form of *S. leupoldi*. In addition, Krijnen (1931, p. 105) assigned *S. globulus* Nuttall (Nuttall, 1926, p. 36) from the Miocene of Christmas Island and *S. bintoetensis* Zuffardi-Comerci (Zuffardi-Comerci, 1929, p. 146) from the Miocene of Borneo as synonyms of *S. leupoldi*.

Tan (1937) described a new Eocene species of *Spiroclypeus*, *S. vermicularis*, from the upper Eocene of East Borneo, and illustrated and commented on several of the Miocene species of *Spiroclypeus*. Tan (1937, p. 183) rejected Krijnen's suggestion that *S. yabei* was a synonym of *S. pleurocentralis* (Carter) and stated: "But we are not at all sure, whether Carter's species even belongs to *Spiroclypeus*."

Cole (in Cole and Bridge, 1953; Cole 1954; 1957a, b) illustrated and commented on *Spiroclypeus* found on Saipan Island and in samples from the drill holes on Bikini and Eniwetok Atolls. Earlier, Cole (1939, p. 185) described a new species, *S. higginsi*, from the Miocene (Tertiary *e*) of Guam Island, which he stated might prove to be synonymous with *S. leupoldi*.

The four species of *Spiroclypeus* which van der Vlerk (1925, p. 14-17) described from East Borneo were obtained from three localities in the Naintoepo beds of East Borneo. Krijnen (1931, p. 93, 94) and Tan (1937, p. 190) restudied specimens of *Spiroclypeus* from the original three localities of van der Vlerk, as well as other localities. The distribution of species of *Spiroclypeus* identified by van der Vlerk, Krijnen, and Tan at five localities in Borneo is shown in table 4.

Although six species names are shown on table 4, there are only four species represented, because specimens identified by Krijnen (1931, p. 89) as *Spiroclypeus pleurocentralis* are referred by Tan (1937, p. 183) to *S. yabei* and *S. wolfgangi* is based on microspheric specimens. The only other Miocene species of *Spiroclypeus* from Borneo, *S. orbitoideus*, was not recorded at these stations.

Krijnen recorded *S. leupoldi* at all five localities. At three of the localities, either Krijnen or Tan recorded *Spiroclypeus tidoenganensis*. Cole (1957a, p. 332) in a discussion of the occurrence of *S. orbitoideus*, remarked: "It is always associated on Saipan with *S. tidoenganensis* van der Vlerk. Although it is not as abundant as that species, it occurs commonly at certain localities." Hanzawa (1957, p. 45) identified as *S. leupoldi* specimens from Saipan Island, which are similar to those Cole recorded as *S. orbitoideus*; Hanzawa stated that at certain Saipan localities *S. leupoldi* occurred with *S. tidoenganensis*.

TABLE 4.—Distribution of *Spiroclypeus* at selected localities in the Naintoepo beds of East Borneo

[Species identification: V, by van der Vlerk (1925); K, by Krijnen (1931); T, by Tan (1937). 38L, locality number]

Species	Naintoepo beds									
	Lower middle					Upper				
	38L	42L	55L	1169L	633L					
	V	K	T	V	K	V	K	T	K	T
<i>Spiroclypeus leupoldi</i> .....	×	×	×	×	×	×	×	×	×	×
<i>S. tidoenganensis</i> .....	×	×	×	×	×	×	×	×	×	×
<i>S. yabei</i> <sup>1</sup> .....										
<i>S. wolfgangi</i> <sup>2</sup> .....										
<i>S. pleurocentralis</i> <sup>1</sup> .....										
<i>S. margaritatus</i> .....										

<sup>1</sup> Specimens identified by Krijnen as *S. pleurocentralis* are referred by Tan to *S. yabei*.

<sup>2</sup> *S. wolfgangi* is based on microspheric specimens.

Specimens which Douvillé (1905, p. 464, pl. 14, figs. 7, 8) identified as *Spiroclypeus pleurocentralis* from Hikun on the Tabalong River, SE. Borneo, were examined by Cole (1954, p. 579), and he (Cole, 1954, pl. 206, figs. 1, 2) illustrated their internal structure, concluding (p. 580): "It is almost certain these specimens should be referred to *S. tidoenganensis*." From this same locality Douvillé (1905, pl. 14, fig. 9) illustrated one transverse section of a small *Spiroclypeus*, which he identified also as *S. pleurocentralis*. Tan (1937, p. 183) and Cole (1954, p. 580) suggested this transverse section represented *S. leupoldi*. Finally, the type locality for *S. orbitoideus* H. Douvillé (Douvillé, 1905, p. 462) is in the vicinity of that from which the specimens identified by Douvillé as *S. pleurocentralis* were obtained.

Tan (1937) illustrated two transverse sections of *Spiroclypeus orbitoideus* from his locality 394Z. One of these specimens (Tan, 1937, pl. 4, fig. 1) is similar to the type illustrations, and the other is comparable to specimens illustrated by Cole (in Cole and Bridge, 1953, pl. 4, fig. 4; Cole, 1957a, pl. 95, fig. 7) as *S. orbitoideus* and by Hanzawa (1957, pl. 5, fig. 8) as *S. leupoldi*. If similar comparative studies are made of specimens which have been identified as *S. orbitoideus* and *S. leupoldi*, it will be observed that only one species can be recognized. Thus, *S. leupoldi* van der Vlerk, 1925, must be a synonym of *S. orbitoideus* H. Douvillé, 1905.

Krijnen (1931, p. 94) recorded *Spiroclypeus leupoldi*, *S. margaritatus*, and *S. tidoenganensis* in association within the upper Naintoepo beds (loc. 633L, table 4). Tan (1937, pl. 2, fig. 12; pl. 4, figs. 6, 7) illustrated transverse sections of three specimens from this locality, which he identified as *S. margaritatus* (Schlumberger).

If the illustration given by Tan (1937, pl. 4, fig. 7) is compared with the enlargement<sup>3</sup> of the type illustration of *Spiroclypeus margaritatus* (pl. 2, fig. 17) it will be seen that the structure of the tests is similar. Moreover, if these two illustrations are compared with the type transverse section of *S. tidoenganensis* van der Vlerk (1925, pl. 5, fig. 47), it is impossible to find any criterion by which these specimens could be separated into distinct species.

The illustration (Tan, 1937, pl. 4, fig. 6) of another specimen which Tan identified as *Spiroclypeus margaritatus* resembles specimens from Bikini hole 2B (Cole, 1954, pl. 206, figs. 20, 21), which were identified

<sup>3</sup> The magnification of the type illustration of "*Heterostegina*" *margaritatus* is given by Schlumberger (1902, p. 253) as five times. Yabe and Hanzawa (1925, p. 627), after studying topotypes, stated Schlumberger's "figure 4 can not be the same magnification and must be at least in eight times, as fig. 2 is, or even more." This assumption by Yabe and Hanzawa is probably correct. Therefore, the enlargement of the type illustration (Schlumberger, 1902, pl. 7, fig. 4) of "*H.*" *margaritatus* on pl. 2, fig. 17, is 13 times.

as *S. margaritatus*; however, all these specimens resemble others which Tan (1937, pl. 4, fig. 21) and Cole (in Cole and Bridge, 1953, pl. 3, fig. 11; pl. 4, fig. 10) identified as *S. tidoenganensis*. From these and other comparisons the conclusion has been made that *S. tidoenganensis* is a synonym of *S. margaritatus*.

The variation between the specimens which have been discussed is so wide that all the species of Miocene *Spiroclypeus* in the Indo-Pacific area can be included in one species, namely *S. margaritatus* (Schlumberger) (1902). This species has a comparatively short stratigraphic range in Tertiary *e*—extending from the top of the *Heterostegina borneensis* zone to, or slightly into, the base of the *Miogypsinoides dehaartii* zone (Cole, 1957b, p. 747).

In median section there is no difference between any of the supposed species of *Spiroclypeus* except in the size of the embryonic chambers. Specimens previously assigned to *S. tidoenganensis* (pl. 3, fig. 11) usually have large embryonic chambers, but actually these chambers are not any larger than those in specimens previously assigned to *S. pleurocentralis* (pl. 3, fig. 13) or to *S. orbitoideus* (Tan, 1937, pl. 3, fig. 4), or those in topotypes of *S. margaritatus* (Yabe and Hanzawa, 1925, p. 630).

Transverse sections of *Spiroclypeus* show differences, particularly in the thickness of the roofs and floors of the lateral chambers and the strength of the pillars. The specimens (pl. 2, figs. 1-6) from a depth of 1,029 feet in the Reef hole have lateral chambers with thick roofs and floors. These specimens resemble others formerly assigned to *S. tidoenganensis* (Tan, 1937, pl. 4, fig. 4), or to *S. margaritatus* (Yabe and Hanzawa, 1925, pl. 3, fig. 7).

Specimens (pl. 2, fig. 15) from a depth of 1,075 feet and others (pl. 2, fig. 8) from a depth of 1,087 feet, in the Reef hole resemble specimens previously assigned to *S. higginsii* (Cole, 1957b, pl. 239, fig. 11). Other specimens (pl. 2, figs. 12, 16) from depths of 1,075 feet and 1,091 feet are identical with specimens from Bikini hole 2B, which previously were identified as *S. yabei* (Cole, 1954, pl. 208, figs. 25, 26). A specimen (pl. 2, fig. 18) from Eniwetok hole E-1, previously identified as *S. yabei*, is illustrated for comparison.

The greatest contrast in transverse sections is that between the specimens recovered at 1,029 feet and those recovered at greater depths in the Reef hole. The specimens at 1,029 feet were embedded in a tuff, whereas those at the other depths came from a fine calcareous sand. Two distinct ecological environments are represented in these samples, and these conditions are reflected in the development of the tests, particularly as viewed in transverse section.

Specimens that have lateral chambers with thick roofs and floors of the kind previously assigned to *Spiroclypeus higginsii* and *S. tidoenganensis* commonly were recovered from compact limestones of the reef kind. However, specimens assigned to *S. orbitoideus* which have lateral chambers with thin roofs and floors, occur in this kind of sediment but not as abundantly as the specimens that have lateral chambers with thick roofs and floors. Specimens from this ecological situation commonly have larger embryonic chambers than do specimens recovered from calcareous, foraminiferal sands.

Therefore, the suggestion is made that the size difference in the embryonic chambers and the development of the lateral chambers and pillars is a response of the individual to the ecological situation in which the specimen developed. If this assumption is correct, all the so-called Indo-Pacific Miocene species of *Spiroclypeus* are ecological variants of one species, *S. margaritatus* (Schlumberger).

#### Family MIOGYPSINIDAE

Genus MIOGYPSINOIDES Yabe and Hanzawa, 1928

#### *Miogypsinoides dehaartii* (van der Vlerk)

Plate 1, figures 1-20

1924. *Miogypsina dehaartii* van der Vlerk, *Eclogae Geol. Helvetiae*, v. 18, p. 429-432, text figs. 1-3.
1928. *Miogypsina* (*Miogypsinoides*) *dehaartii* van der Vlerk var. *formosensis* Yabe and Hanzawa, *Tokyo Imp. Acad. Proc.*, v. 4, no. 9, p. 534, text figs. 1a-b.
1936. *Miogypsinoides complanata* forma *bantamensis*. Tan. *De Ingenieur in Nederland-Indië*. 4. *Mijnbouw en Geologie*, v. 3, no. 3, p. 48-50, pl. 1, fig. 13.
1940. *Miogypsinoides complanata* (Schlumberger) var. *mauretania* Brönnimann, *Schweizer. Palaeont. Abh. Mem.*, v. 63, p. 77-80, pl. 7, figures 7-14; pl. 8, fig. 18; pl. 9, figs. 1, 2; pl. 11, figs. 9-17.
1940. *Miogypsinoides dehaartii* (van der Vlerk) var. *pustulosa* Hanzawa, Jubilee publication in commemoration of Professor H. Yabe, M.I.A., sixtieth birthday, v. 2, p. 780, 782, pl. 40, figs. 9-29; pl. 42, fig. 13.
1940. *Miogypsinoides bantamensis* Tan. Hanzawa, idem, p. 782, 783, pl. 39, figs. 15-19; pl. 41, figs. 24-26.
1940. *Miogypsinoides lateralis* Hanzawa, idem, p. 783, pl. 39, figs. 10-14.
1957. *Miogypsinoides bantamensis* Tan. Cole, U.S. Geol. Survey Prof. Paper 280-I, p. 338, 339, pl. 110, figs. 8-18; pl. 111, figs. 1-4.
1957. *Miogypsinoides dehaartii* (van der Vlerk). Cole, idem, p. 339, 340, pl. 111, figs. 5-16 (additional references).

In the zone between 590 and 960 feet in the Reef hole, many cores contain abundant specimens of *Miogypsinoides*. These specimens can be separated broadly into two groups on the characteristics of the embryonic apparatuses. Certain specimens (pl. 1, figs. 3, 4) have



embryonic apparatuses similar to that of *M. dehaartii* (van der Vlerk) (van der Vlerk, 1924, text fig. 2). In this kind the second embryonic chamber is adjacent to the apex of the test. Other specimens (pl. 1, figs. 18, 19) have embryonic apparatuses similar to that of *M. bantamensis* Tan (Tan, 1936, pl. 1, fig. 13), in which the embryonic chambers are separated from the apex of the test by the periembrionic chambers.

This separation into two groups (or species) may be entirely artificial, and in actuality only one species may be represented in these populations. Hanzawa (1962, p. 153, 154, 156, 157) proposed a classification for miogypsinoids which, if applied to the specimens from the Reef hole, would result in the recognition of four species at the minimum. These would be *Miogypsinoides dehaartii* (van der Vlerk) (pl. 1, fig. 4), *M. bantamensis* Tan (pl. 1, fig. 18), *M. lateralis* Hanzawa (pl. 1, fig. 12), and *M. mauretana* Brönnimann (pl. 1, fig. 17).

The classification devised by Hanzawa is based on the assumption that the arrangement and orientation of the embryonic and periembrionic chambers is constant in a given species. Thus, in a single population several species of *Miogypsinoides* may occur, each of which forms a group of individuals which differ from other groups of individuals by a minor shift in the arrangement and orientation of the embryonic and periembrionic chambers.

Cole (1957a, p. 339) objected to such an inflexible classification. He wrote: "Although the number of coils and the number of periembrionic chambers are significant, it does not appear that the position of the periembrionic chambers, with regard to the apical part of the test, has any special significance." This concept was enlarged in a review of American species of miogypsinids (Cole, 1967, p. 102, 103), in which certain Indo-Pacific species of *Miogypsinoides* were used to demonstrate that the development of the embryonic apparatus is variable.

The difference in approach to the classification of species of *Miogypsinoides* is shown by the analysis of four specimens from locality B391, Saipan Island (Cole, 1957a, pl. 110, figs. 12, 15; pl. 111, figs. 2, 3), all of which were assigned by Cole to *M. bantamensis* Tan. Hanzawa (1962, p. 157) reclassified these four specimens into three species as follows: *M. bantamensis* Tan (Cole, 1957a, pl. 110, fig. 12; pl. 111, fig. 2); *M. lateralis* Hanzawa (Cole, 1957a, pl. 110, fig. 15); and *M. formosensis* (Yabe and Hanzawa) (Cole, 1957a, pl. 111, fig. 3).

Hanzawa (1940, p. 783) described *Miogypsinoides lateralis* from the Kita-daitō-jima test hole at a depth of 302.31–394.92 meters, where it occurred with other specimens which he assigned to *M. bantamensis* Tan, a species described from East Borneo. Hanzawa (1940,

p. 783) wrote concerning *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 the juvenarium."

*Miogypsinoides formosensis* was described by Yabe and Hanzawa (1928, p. 535) from Taiwan (Formosa). Cole (1957a, pl. 111, figs. 10, 11) illustrated two specimens from the type locality of *M. formosensis*, one of which (Cole, 1957a, pl. 111, fig. 10) is entirely comparable to *M. bantamensis*, and the other (Cole, 1957a, pl. 111, fig. 11) is similar to *M. lateralis*.

On Saipan Island, Hanzawa (1957, tables 2, 3) reported that the following species of *Miogypsinoides* are associated with *Miogypsinoides dehaartii* (van der Vlerk) at one or more localities: *M. bantamensis*, *M. borodinensis*, *M. lateralis*, and *M. mauretana*. Although Hanzawa (1957, p. 92) recognized *M. formosensis* on Saipan Island, it was recorded as occurring with *M. borodinensis*, *M. complanata*, and *M. lateralis*, but not with *M. dehaartii*.

From this analysis of the association of species of *Miogypsinoides* from various geographic areas, seven of the 10 supposedly valid species recognized by Hanzawa (1965, p. 253) may occur together at the same stratigraphic horizon. If all the illustrations which have been published of *M. formosensis*, *M. borodinensis*, *M. bantamensis*, *M. mauretana*, *M. lateralis*, and *M. dehaartii* are studied, these species will be found to constitute a continuous series.

All the specimens are virtually the same. Differences between individual specimens or groups of specimens are those of degree, not of kind. Moreover, if a sufficient number of specimens are sectioned, all the supposed species can be found in any given population.

The suggested consolidation of these specimens into one species based upon analysis of internal structures of associated specimens seems, moreover, to be reasonable if the probable reproduction is considered. Although the species of *Miogypsinoides* are extinct, the assumption may be made that their life cycle was similar to that of Foraminifera still living. Therefore, in sexual reproduction it is doubtful if the gametes from one microspheric individual would repel those from another. If the gametes from individuals fuse, regardless of the relative minor differences between two reproducing individuals, only one biologic species, in contradistinction to several "form" species, would be present in such populations.

Cole (1966, p. 241) wrote concerning the probable reproduction of certain camerinids: "In my opinion this population (pl. 20, fig. 12) represents one in which cross-fertilization would occur as I can not conceive



of gametes from specimens so similar to each other repelling one another. If this occurred, only one species is present as the comparative series (pl. 20, fig. 12) indicates."

The populations of *Miogypsinoides* in the Reef hole consist of a single species, *M. dehaartii*. *M. formosensis*, *M. bantamensis*, *M. mauretana*, and *M. lateralis* are synonyms of *M. dehaartii*.

In specimens (for example, pl. 1, fig. 4) which are identical with the types of *Miogypsinoides dehaartii*, the second embryonic chamber is separated from the apical margin of the test only by the marginal fringe (Cole, 1964, p. 144), and the coil of periembrionic chambers is short. Specimens (for example, pl. 1, fig. 5) in which the embryonic chambers are oriented so the second embryonic chamber is directed toward one side of the test have a longer coil of periembrionic chambers, but the second embryonic chamber is still separated from the margin of the test only by the marginal fringe. This represents "*M. lateralis*."

In "*Miogypsinoides mauretana*" (pl. 1, fig. 13), "*M. bantamensis*" (pl. 1, fig. 18), and "*M. formosensis*" (Cole, 1957a, pl. 111, fig. 3), the coil of periembrionic chambers is long and completely surrounds the embryonic chambers.

The shape, size, and general arrangement of the embryonic apparatuses are the same in all these specimens. The only marked differences are the orientation of the embryonic chambers with regard to the long axis of the test and the number of periembrionic chambers which develop. Any separation of specimens so constituted must be entirely artificial, as a gradation series occurs in every population from which a sufficient number of specimens have been studied.

The illustrations (pl. 1, figs. 3, 6, 9, 11, 14-16, 19, 20) show a continuous series, from specimens (pl. 1, fig. 3) in which the second embryonic chamber is situated at the apex of the test to those (pl. 1, fig. 17) in which the second embryonic chamber has been revolved nearly 180° so that it is directed toward the distal margin of the test.

This same development of embryonic apparatuses within a single species occurs also in *Miogypsina*. Cole (1964, p. 144) wrote:

certain individuals \* \* \* rapidly develop a longer coil of periembrionic chambers as most of the protoplasmic mass is utilized for the construction of these chambers. Other individuals, however, have only a part of the protoplasmic mass available for the construction of periembrionic chambers as the other part is extruded as the filaments from which the marginal fringe develops.

The basic pattern of the embryonic apparatus is determined by the distribution of the protoplasm as well as the position of the stolons. Certain specimens of a species may develop a long coil of periembrionic chambers \* \* \* whereas other specimens of this species may construct a short coil of periembrionic

chambers. Specimens \* \* \* which rapidly develop the long coil of periembrionic chambers have these chambers between the embryonic chambers and the margin of the test. Specimens \* \* \* in which the periembrionic coil is short have the second embryonic chamber in contact with the marginal fringe which is highly developed because of the numerous filaments of protoplasm.

The interval between 590 and 960 feet in the Reef hole is assigned to the *Miogypsinoides dehaartii* zone and correlates with the Tagpochau limestone (Tertiary *e*) of Saipan (Cole, 1957a, p. 324), with the interval between 209.26 meters and 394.98 meters in the Kitadaitō-jima test hole (Hanzawa, 1940, p. 762), with the interval between 1,387 and 1,597 feet in Bikini hole 2B (Cole, 1954, p. 572), and with the interval between 1,190 and 1,452 feet in Eniwetok hole E-1 (Cole, 1957b, p. 746, 747). The *Miogypsinoides dehaarti* zone is 370 feet thick in the Reef hole, 609 feet thick in the Kita-daitō-jima test hole, 210 feet thick in Bikini hole 2B, and 262 feet thick in Eniwetok hole E-1.

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<i>complanata, Miogypsinoides</i>	11	<i>polymorpha</i>	3	<i>bintoetensis</i>	9
<i>bantamensis, Miogypsinoides</i>	10	<i>theclidaeformis</i>	3	<i>globulus</i>	8
<i>mauretanicus, Miogypsinoides</i>	10	( <i>Miogypsinoides</i> ) <i>dehaartii</i>	10	<i>higginsii</i>	8, 9, 10
<i>curdica, Borelis melo</i>	6, 7	<i>Miogypsinella borodinensis</i>	3	<i>leupoldi</i>	8, 9
Current directions	3	<i>Miogypsinidae</i>	3, 10	<i>margaritatus</i>	2, 3, 10; pls. 2, 3
<i>Cycloclypeus communis</i>	3	<i>Miogypsinoides</i>	2, 3, 4	<i>orbitoideus</i>	8, 9, 10
sp.	3	<i>bantamensis</i>	3, 10, 11, 12	<i>pleurocentralis</i>	8, 9, 10
<i>dehaartii, Miogypsina</i>	10	<i>borodinensis</i>	11	<i>tidoenganensis</i>	8, 9, 10
<i>Miogypsina (Miogypsinoides)</i>	10	<i>complanata</i>	11	<i>vermicularia</i>	8
<i>Miogypsinoides</i>	2, 3, 4, 10; pl. 1	<i>bantamensis</i>	10	<i>wolfgangi</i>	8, 9
<i>pustulosa, Miogypsinoides</i>	2, 3, 10	<i>mauretanicus</i>	10	<i>yabei</i>	8, 9, 10
zone, <i>Miogypsinoides</i>	5, 10	dehaartii	2, 3, 4, 10; pl. 1	<i>striata, Austrotrillina</i>	2, 4; pls. 4, 5
<i>depressa, Heterostegina</i>	2, 3, 8	<i>pustulosa</i>	2, 3, 10	<i>suborbicularis, Heterostegina</i>	1, 2, 3, 4, 8; pl. 3
East Borneo, Naintoepo beds	8, 9	zone	5, 10	<i>sumatrensis, Lepidocyclus (Eulepidina)</i>	3
Eniwetok Atoll	2	<i>formosensis</i>	11, 12	Sverdrup, H. U., Johnson, M. W., and Fleming, R. H., quoted	4
Eniwetok drill hole, Foraminifera	3	<i>lateralis</i>	3, 10, 11, 12	Tagpochau limestone, Saipan	5, 6, 12
( <i>Eulepidina</i> ) <i>sumatrensis, Lepidocyclus</i>	3	<i>mauretanicus</i>	11, 12	Tan, S. H., quoted	8
( <i>Fasciolites</i> ) <i>pygmaea, Borelis</i>	5	<i>ubaghsi</i>	3	<i>theclidaeformis, Miogypsina</i>	3
Fleming, R. H., Sverdrup, H. U., and Johnson, M. W., quoted	4	( <i>Miogypsinoides</i> ) <i>dehaartii, Miogypsina</i>	10	<i>tidoenganensis, Spiroclypeus</i>	8, 9, 10
<i>Flosculinella</i>	7	Naintoepo beds of Tidoengsche Landen, East Borneo	8, 9	<i>tournoueri, Nephrolepidina</i>	3
<i>globulosa</i>	2, 7; pl. 4	<i>Nautilus melo</i>	5	<i>ubaghsi, Miogypsinoides</i>	3
( <i>Flosculinella</i> ) <i>globulosa, Alveolinella</i>	7	<i>Neoalveolina</i>	6	<i>venosa, Camerina</i>	8
<i>formosensis, Miogypsinoides</i>	11, 12	<i>pulchra</i>	6, 7	<i>vermicularia, Spiroclypeus</i>	8
<i>gaimardi, Operculina</i>	3	<i>pygmaea</i>	6	<i>vertebralis, Marginopora</i>	1, 2, 4, 5; pls. 3, 4
<i>globulosa, Alveolinella (Flosculinella)</i>	7	<i>schlumbergeri</i>	5, 6	<i>wolfgangi, Spiroclypeus</i>	8, 9
<i>Flosculinella</i>	2, 7; pl. 4	<i>Nephrolepidina plicomargo</i>	3	<i>yabei, Spiroclypeus</i>	8, 9, 10
<i>globulus, Spiroclypeus</i>	8	<i>tournoueri</i>	3		



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**PLATES 1-5**

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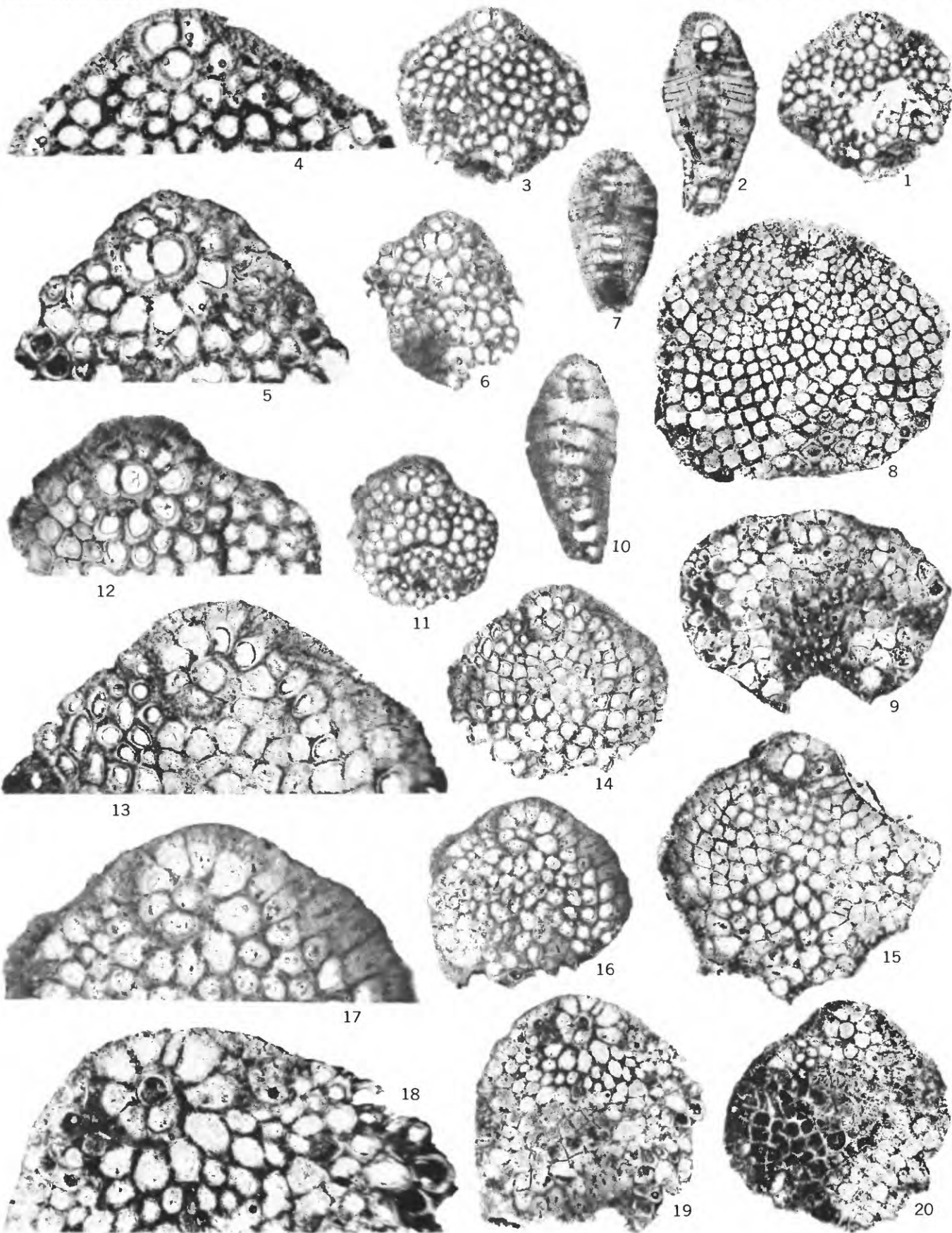
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## PLATE 1

[All figures  $\times 20$ , except 4, 5, 12, 13, 17, 18, which are  $\times 40$ ]

FIGURES 1-20. *Miogypsinooides dehaartii* (van der Vlerk) (p. C10).

- All specimens from Reef hole and are from cores except fig. 10 which is from a cutting sample: 1-4, 7, 11, 12, at 595-600 ft; 5, 6, 13, 14, 16-19, at 926-927 ft; 8, 9, 15, 20, at 901-906 ft; 10, at 956 ft.
- 1, 13, 14, 16, 17. Equatorial sections of megalospheric specimens with "*M. mauretanic*" kind of embryonic apparatus. Fig. 13 is an enlargement of apical part of fig. 14. Fig. 17 is an enlargement of apical part of fig. 16. USNM 642909, 642918, and 642920.
- 2, 7, 10. Vertical sections of megalospheric specimens. USNM 642910, 642913, and 642916.
- 3, 4, 15. Equatorial sections of megalospheric specimens with typical *M. dehaartii* kind of embryonic apparatus. Fig. 4 is an enlargement of apical part of fig. 3. USNM 642911 and 642919.
- 5, 6, 9, 11, 12, 20. Equatorial sections of megalospheric specimens with "*M. lateralis*" kind of embryonic apparatus. Fig. 5 is an enlargement of apical part of fig. 6. Fig. 12 is an enlargement of the apical part of fig. 11. USNM 642912, 642915, 642917, and 642922.
8. Equatorial section of a microspheric specimen. (Compare with Cole, 1957a, pl. 110, fig. 18.) USNM 642914.
- 18, 19. Equatorial sections of a megalospheric specimen with "*M. bantamensis*" kind of embryonic apparatus. Fig. 18 is an enlargement of fig. 19. USNM 642921.



MIOCENE MIOGYPSINOIDES



## PLATE 2

[All figures  $\times 20$ , except 14, 19,  $\times 40$  and 17,  $\times 13$ ]

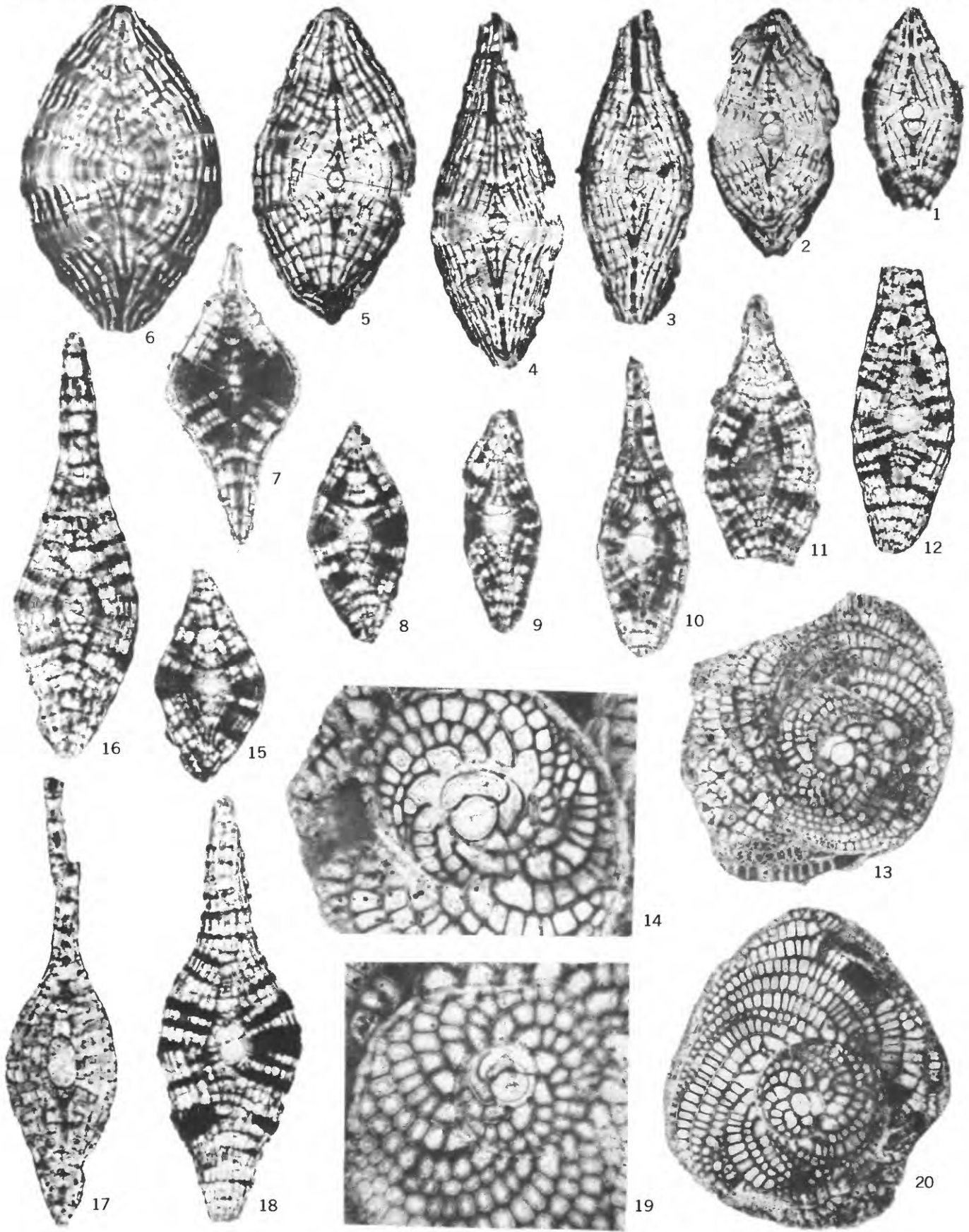
FIGURES 1-20. *Spiroclypeus margaritatus* (Schlumberger) (p. C8).

Figs. 1-16, 19, 20, from Reef hole core, Midway: 1-6, 19, at 1,029 ft; 7, 8, at 1,087 ft; 9-12, 14, 15, 20, at 1,075 ft; 13, at 1,081 ft; 16, at 1,091 ft. Fig. 17 from Schlumberger (1902, pl. 7, fig. 4). Fig. 18 from a cutting sample, Eniwetok hole E-1 at 1,629-1,658 ft.

1-12, 15-18. Transverse sections of megalospheric specimens. Fig. 17 is type illustration of *S. margaritatus*. Fig. 18 is specimen from Eniwetok hole E-1 previously identified as "*S. yabei*," introduced for comparison with the Reef hole specimens. Figs. 1-12, 15, 16, 18, USNM 642923-642934 and 642937-642939.

13, 20. Median sections of megalospheric specimens. USNM 642935 and 642941.

14, 19. Parts of median sections of megalospheric specimens to illustrate the embryonic, operculine, and heterostegine chambers. USNM 642936 and 642940.



MIOCENE SPIROCLYPEUS

### PLATE 3

FIGURES 1-5, 18. *Heterostegina suborbicularis* d'Orbigny (p. C8).

Figs. 1, 2, and 18 from Reef hole core at 385.5 ft. Figs. 3-5 from Sand Island hole core at 412 ft. USNM 642942-642946 and 642958.

1, 3. Transverse sections,  $\times 20$ .

2, 4, 5, 18. Median sections; 2, 4, 5,  $\times 20$ , 18,  $\times 40$ .

6, 15, 17. *Marginopora vertebralis* Quoy and Gaimard (p. C5).

From Sand Island hole core at 137 ft. USNM 642947 and 642957.

6. Upper part of transverse section shown in fig. 15,  $\times 40$ .

15. Transverse section,  $\times 20$ .

17. Part of median section,  $\times 40$ .

7, 8, 16. *Sorites orbiculus* (Forskål) (p. C5).

From Reef hole core at 103.5 ft.  $\times 40$ . USNM 642948, 642949, and 642956.

7, 16. Median sections. Fig. 7 in reflected light to illustrate embryonic chambers and the initial coiled chambers.

8. Transverse section.

9-14, 19. *Spiroclypeus margaritatus* (Schlumberger) (p. C8).

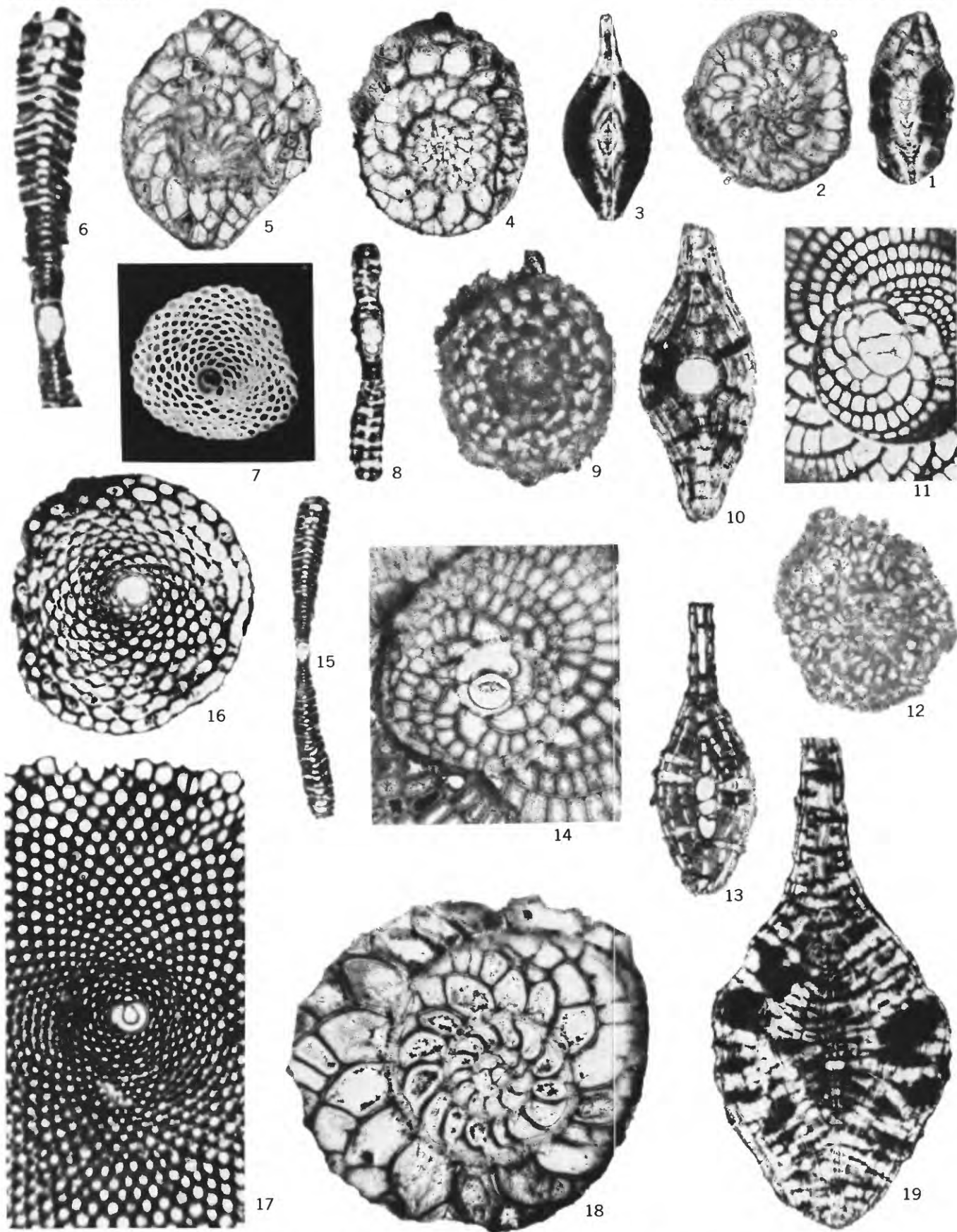
Figs. 9, 12, 14, and 19 from Reef hole core: 9, 14, at 1,029 ft; 12, at 1,075 ft; 19, at 1,087 ft. Specimens shown in figs. 10, 11, and 13, courtesy of Dr. I. M. van der Vlerk; 10, 11, from P. Padang, Balikpapan, Borneo; 13, from Kahajan, Borneo.  $\times 20$ . USNM 642950-642955 and 642959.

9, 12. Sections parallel to but above the median plane.

10, 13. Transverse sections of specimens from Borneo identified by Dr. I. M. van der Vlerk (written commun.), introduced for comparison. Fig. 10 originally identified as "*S. tidoenganensis*," fig. 13 originally identified as "*S. pleurocentralis*."

11. Part of a median section of a specimen from Borneo identified by Dr. I. M. van der Vlerk as "*S. tidoenganensis*."

19. Transverse section of a microspheric specimen.

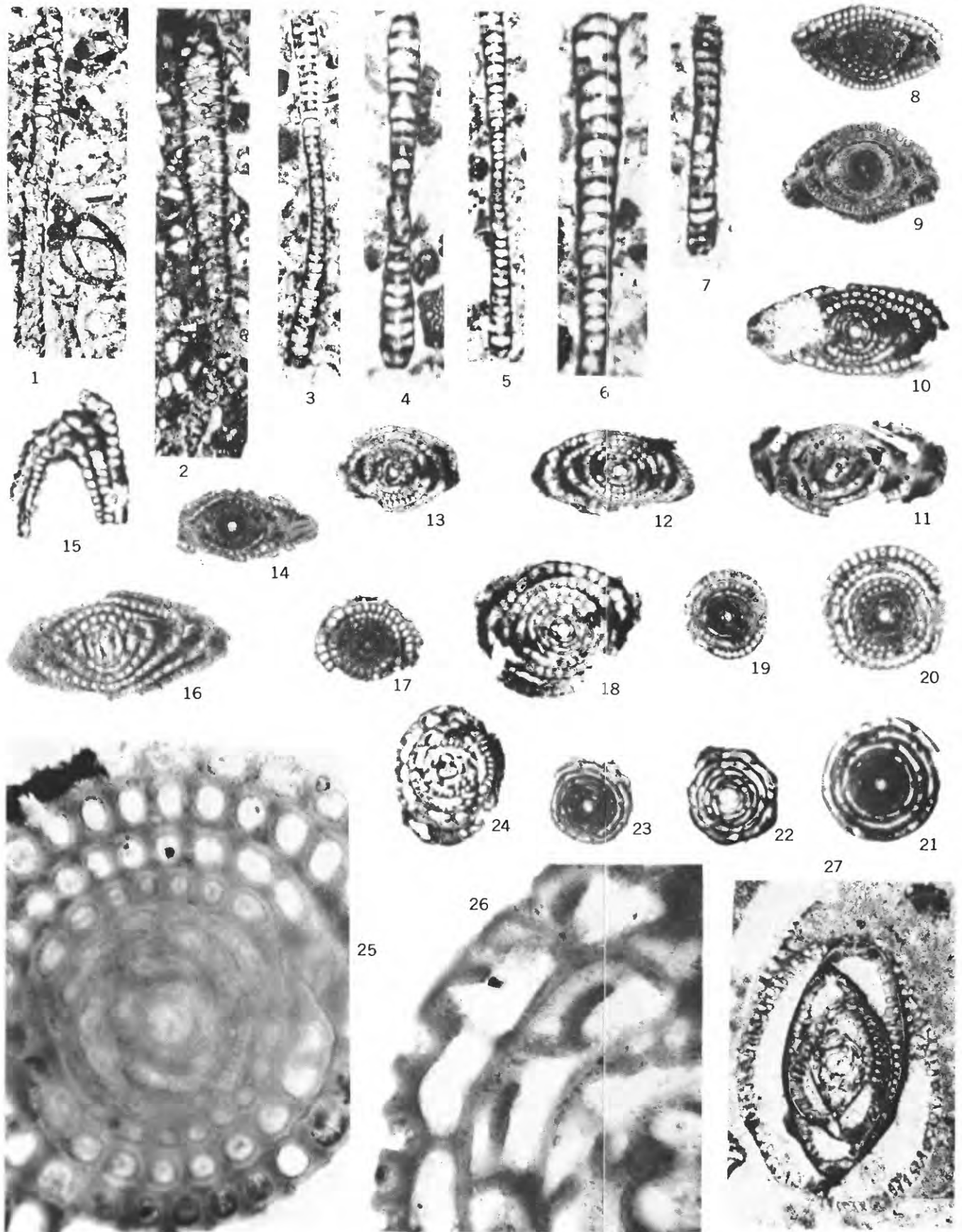


MIOCENE *SPIROCLYPEUS* AND POST-MIOCENE *HETEROSTEGINA*,  
*MARGINOPORA*, AND *SORITES*

PLATE 4

- FIGURES 1, 2. *Marginopora vertebralis* Quoy and Gaimard (p. C5).  
Transverse sections,  $\times 20$ . Note *Austrotrillina striata* and calcareous algae on the right side of fig. 1. Reef hole core at 906–911 ft. USNM 650988, 650989.
- 3–7. *Sorites orbiculus* (Forskål) (p. C5).  
Transverse sections, 2, 3, 5,  $\times 20$ ; 4, 6, 7,  $\times 40$ . Fig. 6 is upper part of specimen illustrated as fig. 5, enlarged. Reef hole core at 906–911 ft. USNM 650990–650993.
- 8–23, 25. *Borelis melo* (Fichtel and Moll) (p. C5).  
Figures 8–18, 22, and 25 from Reef hole core: 8, 14, 17, 25, at 73 ft; 9, at 88 ft; 11, 12, at 1,042 ft; 16, at 1,117 ft; 10, 15, 22, at 1,126.3 ft. Figs. 19–21 and 23 from Sand Island hole core: 19, 23, at 140 ft; 20, 21, at 137 ft. USNM 650994–651009.  
8–20. Axial sections,  $\times 40$ . These sections show change from globular to fusiform specimens. The central part of figs. 10, 14, and 17–19 shown in enlargement: 17, on this plate, fig. 25; 10, 14, 18, 19, on plate 5, figs. 6, 3, 8, 7.  
21–23. Transverse sections,  $\times 40$ . The central part of figs. 22 and 23 shown in enlargement on plate 5, figs. 2 and 1.  
25. Same specimen as this plate, figure 17,  $\times 210$ .
- 24, 26. *Flosculinella globulosa* L. Rutten (p. C7).  
From Reef hole core at 1,043 ft. USNM 651010.  
24. Transverse section,  $\times 40$ , not centered.  
26. Upper left quadrant of specimen shown in fig. 24.
27. *Austrotrillina striata* Todd and Post (p. C4).  
Axial section,  $\times 40$ . From a random thin section, Reef hole core at 926–927 ft. USNM 650011.





MIOCENE *MARGINOPORA*, *SORITES*, *BORELIS*, *FLOSCULINELLA*, AND *AUSTROTRILLINA*  
AND POST-MIOCENE *BORELIS*

PLATE 5

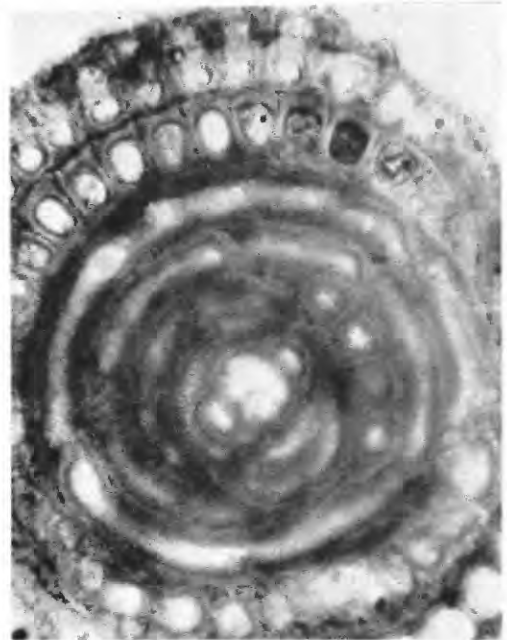
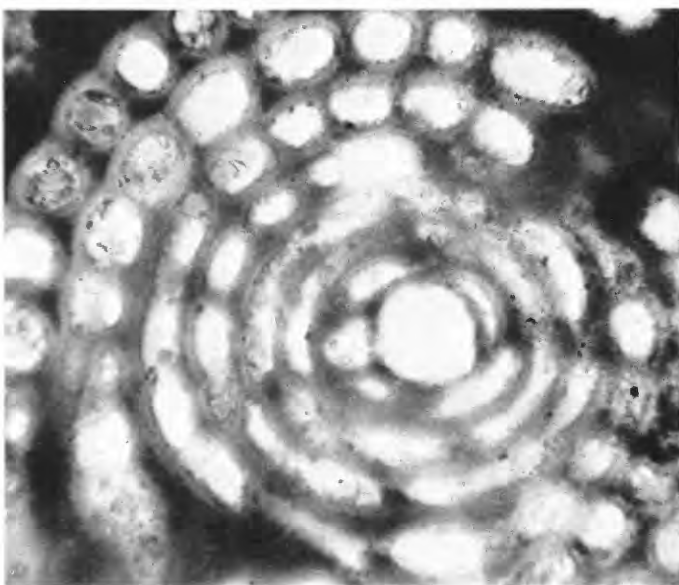
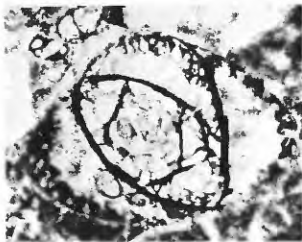
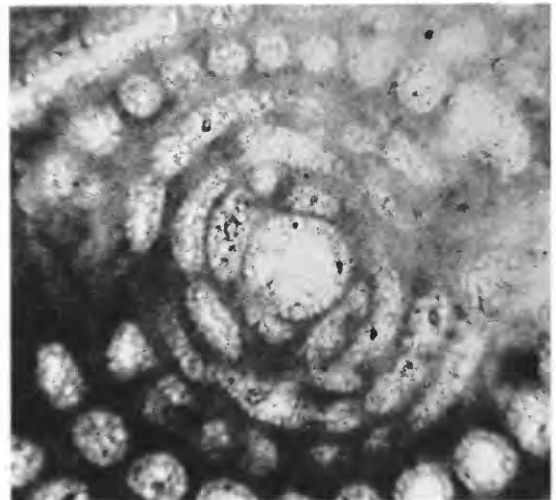
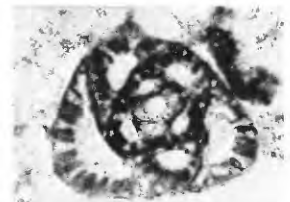
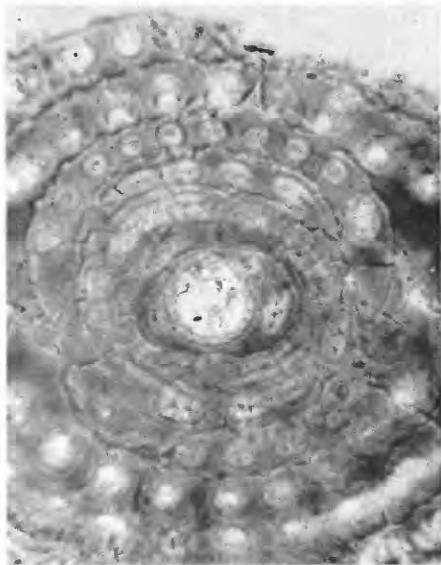
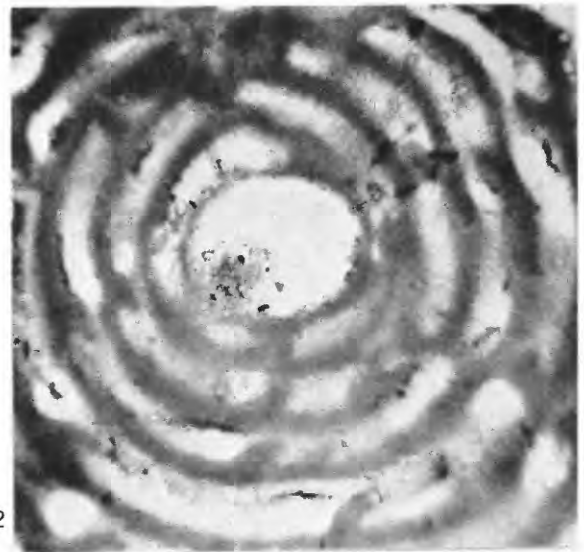
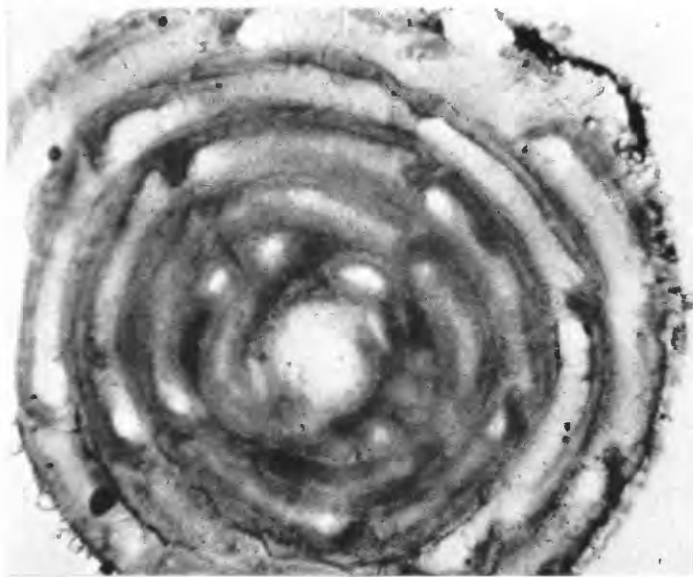
FIGURES 1-3, 6-8. *Borelis melo* (Fichtel and Moll) (p. C5).

1, 2. Transverse sections,  $\times 210$ . The same specimens are illustrated,  $\times 40$ , on plate 4, figs. 23 and 22.

3, 6-8. Axial sections,  $\times 210$ . The same specimens are illustrated,  $\times 40$ , on plate 4, figs. 14, 10, 19, and 18.

4, 5. *Austrotrillina striata* Todd and Post (p. C4).

Transverse sections,  $\times 40$ . From a random thin section, Reef hole core at 906-911 ft. USNM 651012, 651013.



MIOCENE *BORELIS* AND *AUSTROTRILLINA* AND POST-MIOCENE *BORELIS*