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MIDDLE EOCENE FORAMINIFERA FROM PEÑON SEEP, MATANZAS PROVINCE, CUBA

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ABSTRACT—Nineteen species of Foraminifera, including six new species and a new genus, *Penoperculoides*, are described from a six inch layer located at Rancho Peñon, Matanzas Province, Cuba. This fauna which is dominated by discocyclinids is considered to be the approximate equivalent in age of the *Lepidocyclina antillea-Pseudophragmina perpusilla* zone of the Gulf Coast of the United States.

INTRODUCTION

THE occurrence of abundant larger Foraminifera at the asphalt seep and quarry on Rancho Peñon, located 7 kilometers south of Martí (Hato Nuevo) and 850 meters northwest of the little settlement of Peñon, Matanzas Province, Cuba has been known for some years. The late Mrs. Dorothy K. Palmer (1934, p. 259) reported the occurrence at this locality of *Gunteria floridana* Cushman and Ponton in association with abundant other Foraminifera, including *Dictyoconus* and *Discocyclina*. Cushman and Bermudez (1937, pp. 7–9, and 1937a, pp. 107, 108) described certain smaller Foraminifera from this locality, and Cole and Bermudez (1944, pp. 333, 340) discussed specimens of *Fabiania cubensis* (Cushman and Bermudez) which were collected at Peñon Seep.

* Donald W. Gravell died unexpectedly of a heart attack October 14, 1951 as the final manuscript was being typed. Therefore, he could not give his approval to this manuscript, but the senior author believes that he has expressed the ideas held by Mr. Gravell as all points in dispute had been reconciled by an extensive correspondence during the preparation of this article.

The locality at Peñon Seep is placed in the Loma Candela formation (Bermudez, 1950) and is correlated by Bermudez with the Guayabal formation of Mexico and the combined Tallahassee and Lake City limestones of Florida.

In 1940 D. W. Gravell (then employed by the Atlantic Refining Company) became interested in the fauna of Peñon Seep after he examined collections from this locality (A. R. C. No. 5442) made by H. L. Geis. As this material was impregnated by heavy asphalt which interfered somewhat with the examination and study of the specimens, D. W. Gravell and J. B. Klecker in 1941 revisited and recollected at the locality. This selected material yielded a well-preserved fauna which is the basis of this study.

The collection originally made by Gravell and Klecker was supplemented by additional material obtained by Gravell and Emelio Aleman in 1951. Both of these collections came from the lowest 6 inches of strata exposed in an abandoned pit, 8 feet deep, made to obtain road material.

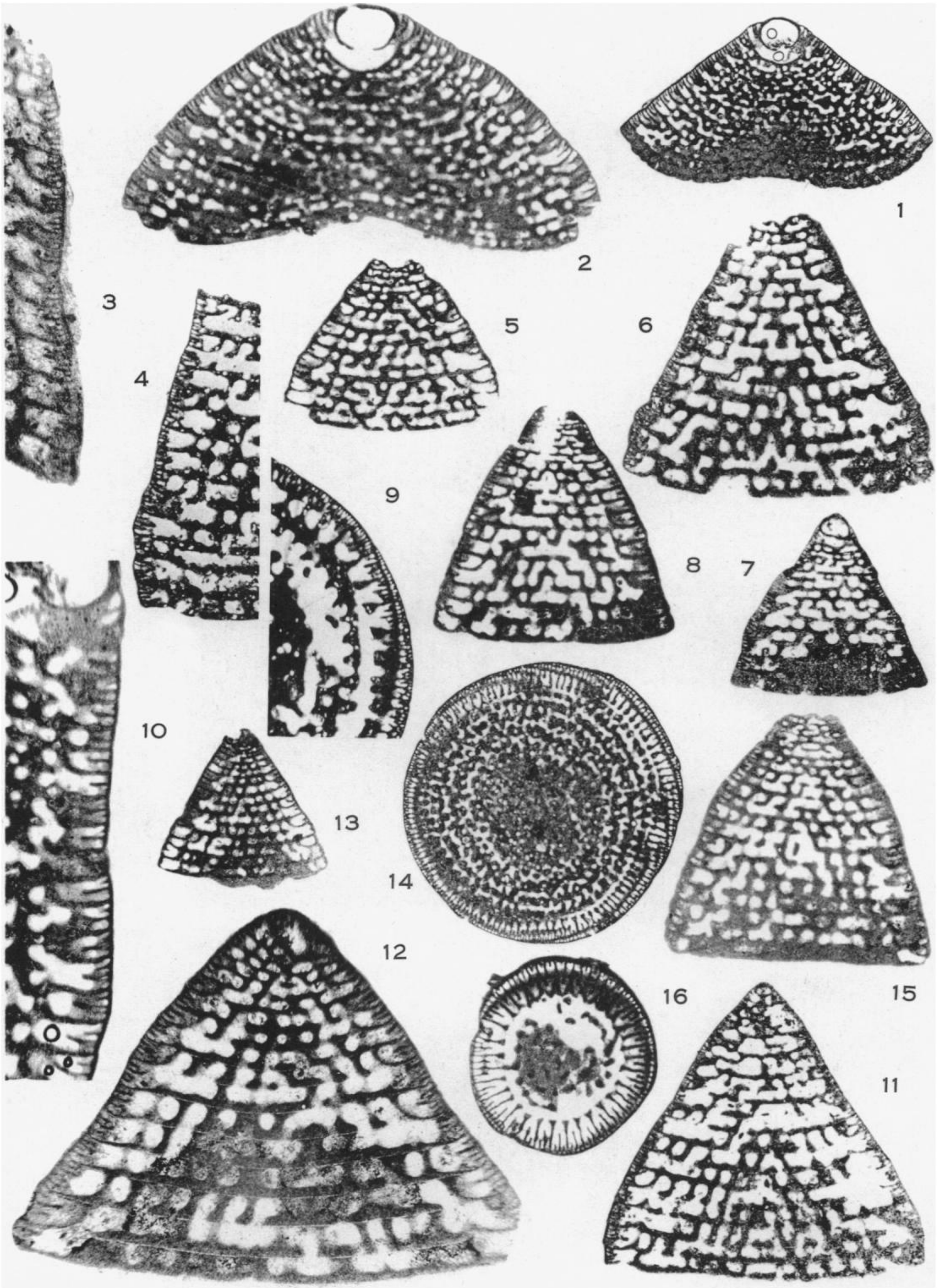
During 1943 Gravell and Enrique Comacho made a number of thin sections of specimens from this fauna, drew up preliminary

EXPLANATION OF PLATE 90

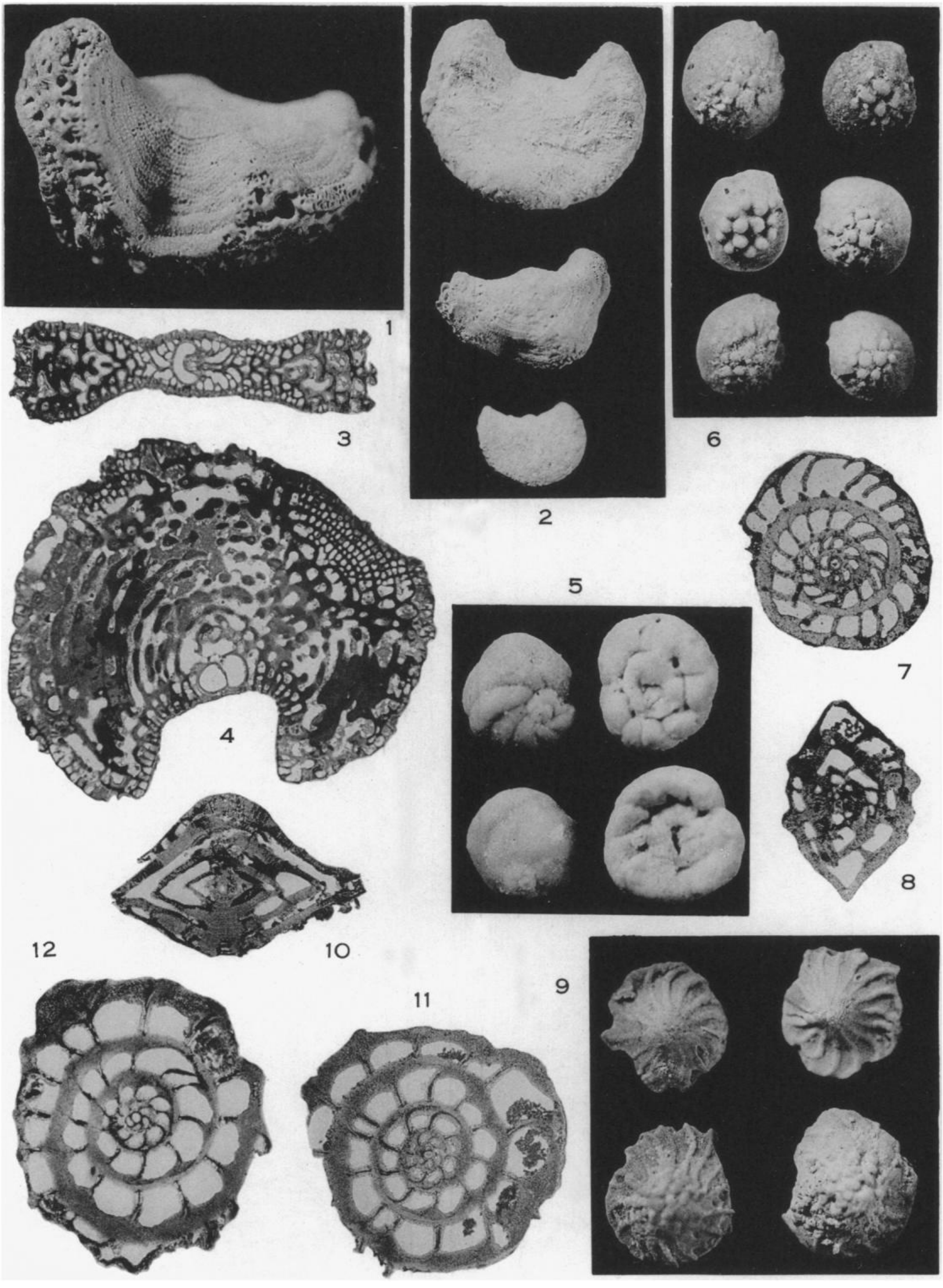
All the specimens used as illustrations are from the Peñon Seep locality except as otherwise designated in the explanation of plates. The entire cost of the printed plates has been contributed equally by the Gulf Oil Corporation and the William F. E. Gurley Fund for Paleontological Research at Cornell University.

FIGS. *1–4, 6, 7, 9–12, 14, 16*—*Dictyoconus americanus* (Cushman). *1–4, 6, 7, 10–12*, axial sections; *1*, ×12.5; *2, 4, 6, 7, 9, 11*, ×20; *3, 10, 12*, ×40; *9, 14, 16*, transverse sections, ×20; *3, 12*, specimens from the Senn collection, collected from the promontory separating Anse de Lezards and Anse des Cayes on the north coast of St. Bartholomew, French West Indies (p. 711)

5, 8, 13, 15—*Dictyoconus cookei* (Moberg). Axial sections, ×20. (p. 711)



Cole and Gravell, Cuban Eocene Foraminifera



Cole and Gravell, Cuban Eocene Foraminifera

descriptions of the species present and identified a number of species. In 1944 Gravell was transferred to Venezuela, and at that time he forwarded all the material to Dr. T. Wayland Vaughan at the U. S. National Museum. Unfortunately, Vaughan was unable to work on the Peñon material, and eventually he requested Cole to undertake his portion of the work.

Our deepest appreciation is expressed to Mr. R. C. Harris of the Atlantic Refining Company for the permission to publish on this material.

The specimens used in this study are deposited temporarily in the Cole collection at Cornell University but eventually will become the permanent property of the U. S. National Museum.

GEOLOGIC RELATIONSHIPS

Peñon Seep is located in an area of low topographic relief. As the area is deeply covered with residual soil, natural exposures are infrequent and poor.

During 1943 a number of core holes were drilled in the vicinity of Peñon Seep by the Bureau of Economic Warfare under the supervision of the late Dr. R. E. Dickerson. Gravell had the opportunity of examining certain of the cores from these test holes.

These samples demonstrated that the middle Eocene of this area is a lithologic and faunal unit virtually identical with the material on which this article is based. The thickness of this unit varies from a few feet to about 40 feet. The strata appear to be rather massive, and the dip although not readily measurable appears to be low and to the north.

CORRELATION

Although this article is based primarily upon those Foraminifera which must be studied by thin section, certain of the outstanding smaller Foraminifera were identified. These will be included in the discussion of the probable correlation. The previously named species recognized at Peñon Seep, their type localities and occurrences elsewhere follow:

Previously named species	Type locality	Other occurrences
Amphistegina lopeztrigoi Palmer	Cuba	Florida, Mexico
Asterocyclina habanensis Cole and Bermudez	Cuba	
monticellensis Cole and Ponton	Florida	
Dictyoconus americanus (Cushman)	St. Bartholomew	Cuba, Florida
cookei (Moberg)	Florida	Cuba
Discocyclina (Discocyclina) marginata (Cushman)	St. Bartholomew	Cuba, Barbados
Discorinopsis gunteri Cole	Florida	
Eoconuloides wellsi Cole and Bermudez	Cuba	
Fabiania floridana Cushman and Bermudez	Cuba	Florida, St. Bartholomew
Gunteria floridana Cushman and Ponton	Florida	Cuba
Helicostegina gyralis Barker and Grimsdale	Mexico	Cuba, Florida
Pseudophragmina (Proporocyclina)		
cushmani (Vaughan)	Mexico	Cuba
psila (Woodring)	California	
Spirolina coryensis Cole	Florida	
Textularia coryensis Cole	Florida	
Valvulina martii Cushman and Bermudez	Cuba	Florida

EXPLANATION OF PLATE 91

FIGS. *1–4*—*Gunteria floridana* Cushman & Ponton. *1*, external view, ×10, to illustrate the marginal pores and the chamberlets; *2*, external views, ×5, of 3 specimens to show size and general form; *3*, transverse section, ×20; *4*, median section, ×20. (p. 712)

5—*Discorinopsis gunteri* Cole. External views of 4 specimens, those on the right show the ventral surface, ×20. (p. 714)

6–8—*Amphistegina lopeztrigoi* D. K. Palmer, *6*, external views, ×10, of 6 specimens; *7*, median section, ×20; *8*, transverse section, ×20. (p. 714)

9–12—*Penoperculoides cubensis* Cole & Gravell, n. sp. *9*, external views, ×10, of 4 specimens; upper left specimen holotype, Cole collection No. 410; *10*, transverse section, ×20; *11, 12*, median sections, ×20. (p. 714)

The most distinctive species in this list is *Gunteria floridana* which was described from the Suwannee Petroleum Corporation's Sholtz well No. 1 located in Levy County, Florida. Cole (1942) reports that the base of the Ocala limestone (upper Eocene) occurs at about 140 feet in this well. In the middle Eocene he recognizes the following zones: 1. *Dictyoconus cookei* zone at 145 feet; 2. *Fabularia vaughani* zone at 310 feet; 3. *Dictyoconus americanus* zone at 840 feet; 4. *Gunteria floridana* zone at 1100 feet; and 5. *Amphistegina lopeztrigoi* zone at 1340 feet. Of the species used to demark these five zones in Florida, four occur together at Peñon Seep.

Applin and Applin (1944) attempt to divide the subsurface Eocene of Florida into formations according to the following divisions:

and *Fabiania cubensis* (Cushman and Bermudez).

In Florida Cole (1944) defined in the St. Mary's Oil Corporation, Hilliard Turpentine Company well No. 1 the subsurface continuation of the Lisbon formation to include the *Dictyoconus cookei*, the *D. americanus*, the *L.* (*Polylepidina*) *antillea* and the *Amphistegina lopeztrigoi* zones. This interval in the well extends from 860 to 1350 feet.

In this same interval Applin and Applin (1944, p. 1745) recognize the Avon Park limestone, the non-fossiliferous equivalent of the Tallahassee limestone and the Lake City limestone. It would appear that the 6 inch bed at Peñon Seep contains many of the key fossils by which three or four formations in Florida are recognized.

The fauna at Peñon Seep is approximately the equivalent of the *Pseudophragmina perpusilla-Lepidocyclina antillea* zone of Texas and Louisiana as defined by Gravell and Hanna (1938), that is, it occurs near the base of the Cook Mountain formation of the Claiborne group.

Age	Formation	Key fossils*
Late middle Eocene	Avon Park limestone	*Dictyoconus cookei* (Moberg)
		Discorinopsis gunteri Cole
		Spirolina coryensis Cole
		Textularia coryensis Cole
		Valvulina martii Cushman and Bermudez
	Tallahassee limestone	non-fossiliferous
Early middle Eocene	Lake City limestone	*Amphistegina lopeztrigoi* D. K. Palmer
		Asterocyclina monticellensis Cole and Ponton
		Dictyoconus americanus (Cushman)
		Fabiania cubensis (Cushman and Bermudez)
		Gunteria floridana Cushman and Ponton
Lower Eocene	Oldsmar limestone	*Helicostegina gyralis* Barker and Grimsdale

* Selected from lists given by Applin and Jordan (1945) to match the species present at Peñon Seep.

Of the 16 previously named species considered at Peñon Seep, 11 occur in Florida, and according to Applin and Jordan range from lower Eocene to late middle Eocene.

Pseudophragmina (*Proporocyclina*) *cushmani* (Vaughan) occurs in the Guayabal beds of Mexico (Muir, 1936, p. 114) at an horizon virtually the same as that of *P.* (*P.*) *perpusilla*. Gravell and Hanna (1938) place the *P.* (*P.*) *perpusilla* zone of Louisiana and Texas in the Cook Mountain formation of the Claiborne. In this area *P.* (*P.*) *perpusilla* occurs with *Lepidocyclina* (*Polylepidina*) *antillea* Cushman.

At St. Bartholomew *D.* (*D.*) *marginata* occurs with *L.* (*Polylepidina*) *antillea* Cushman, *Dictyoconus americanus* (Cushman)

However, it should be noted that Gravell considers this fauna to be slightly older than the *P. perpusilla-L. antillea* zone as he believes it developed before the appearance of *Lepidocyclina* (*Polylepidina*) and *Operculinoides* in this area. Cole, on the other hand, believes this fauna to be contemporaneous with the *P. perpusilla-L. antillea* fauna, and that these species do not occur in this particular area because of ecological conditions.

Although the conditions would seem

favorable at Peñon Seep for the existence of *Lepidocyclina* and *Operculinoides*, it should be noted that *L.* (*Polylepidina*) *antillea* has a very irregular geographic distribution in Florida. It occurs much more frequently in sediments which tend to be sandy than it does in limey sediments. Some such control may have operated in Cuba.

COMPARISON WITH OTHER CUBAN FAUNAS

There is some similarity in the fauna of Peñon Seep with one described by Cole and Bermudez (1947) from the cut at Finca "La Coronela" on the road from Habana to Rancho Boyeros, Habana Province (Bermudez station 1266). The following species are common to both localities:

Amphistegina lopeztrigoi D. K. Palmer
Asterocyclina habanensis Cole and Bermudez
Dictyoconus americanus (Cushman)
cookei (Moberg)
Discocyclina (*Discocyclina*) *marginata* (Cushman)
Eoconuloides wellsi Cole and Bermudez
Pseudophragmina (*Proporocyclina*) *cushmani* (Vaughan)

Cole and Bermudez (1947, p. 193) wrote concerning the fauna of station B-1266: "The presence of *Dictyoconus* of the *americanus* type and of *P.* (*Proporocyclina*) *cushmani* causes us to place the fauna of station 1266 in the middle Eocene . . ." Later Bermudez (1950, p. 230) assigns this fauna (station B-1266) to the Lucero member of the Capdevila formation. The Capdevila formation is placed by Bermudez at the base of the lower Eocene.

The present writers agree with the opinion expressed by Cole and Bermudez in 1947 that the fauna from station B-1266 is middle Eocene. It should be pointed out, however, that the fauna from station B-1266 contains much reworked material from the Upper Cretaceous, and probably from the Paleocene and lower Eocene as well.

At the present time we consider the locality at Finca "La Coronela" (station B-1266) represents middle Eocene, stratigraphically lower than the Peñon Seep fauna. The type locality of the Loma Candela formation (Bermudez station 261) is stratigraphically slightly higher than the Peñon Seep locality.

DESCRIPTION OF SPECIES

Family VALVULINIDAE

Genus DICTYOCONUS Blanckenhorn, 1900

DICTYOCONUS AMERICANUS (Cushman)

Plate 90, figures 1–4, 6, 7, 9–12, 14, 16

Conulites americana CUSHMAN, 1919, Carnegie Inst. Washington, Publ. 291, p. 43, text fig. 3.
Dictyoconus americanus (Cushman). COLE, 1942, Florida Geol. Survey Bull. 20, pp. 21–24, pl. 3, figs. 12, 13; pl. 6, figs. 1–9; pl. 7, figs. 1–5; pl. 16, figs. 14, 15 (references and synonymy); 1944, idem, Bull. 26, pp. 36, 37, pl. 4, figs. 1–6; pl. 8, figs. 12, 13; pl. 18, fig. 11; 1945, idem, Bull. 28, p. 97, pl. 12, fig. 3.

Cole (1942, pp. 21–24) studied specimens of *Dictyoconus* from deep wells in Florida and combined several species under the name *D. americanus*. These species were: *D. codon* Woodring, *D. puilboreauensis* Woodring and *D. gunteri* Moberg. At that time Cole published a transverse section of *D. americanus* from St. Bartholomew. This island is the type locality of *Conulites americana*. Since that time a large collection from St. Bartholomew made by the late Dr. Alfred Senn was sent to Cole for study by Dr. T. Wayland Vaughan. It is, therefore, possible to illustrate at this time axial sections of specimens from St. Bartholomew (pl. 90, figs. 3, 12).

The axial sections of the St. Bartholomew specimens have three or four short lamellae between the peripheral platforms. Although a single specimen normally has marginal chamberlets with both three or four short lamellae, there is generally a predominance of one number or the other in an individual specimen. Vaughan (1928, p. 281) and Cole (1944, p. 37) have noted this condition previously.

DICTYOCONUS COOKEI (Moberg)

Plate 90, figures 5, 8, 13, 15

Coskinolina cookei MOBERG, 1928, Florida Geol. Survey 19th Ann. Rept., pp. 166–168, pl. 3, figs. 1–5, 7, 8 (not fig. 6).
Dictyoconus cookei (Moberg). COLE, 1941, Florida Geol. Survey Bull. 19, pp. 26, 27, pl. 3, fig. 11–13; pl. 5, figs. 6–10, 12, 13; pl. 6, figs. 1–8; pl. 18, fig. 12; 1942, idem. Bull. 20, pp. 24, 25, pl. 3, fig. 10; pl. 4, fig. 8; 1945, idem, Bull. 28, pp. 26, 97, pl. 2, figs. 1, 2; pl. 12, figs. 2, 6, 8.

The axial sections of this species show the marginal chamberlets with a single, horizontal plate. The Cuban specimens are en-

tirely comparable to those found in deep wells in Florida.

Family CYMBALOPORIDAE

Genus FABIANIA A. Silvestri, 1926

FABIANIA CUBENSIS

(Cushman & Bermudez)

Pseudorbitolina cubensis CUSHMAN & BERMUDEZ, 1936, Contrib. Cushman Lab. Foram. Res., vol. 12, p. 59, pl. 10, figs. 27–30.

Eodictyoconus cubensis COLE & BERMUDEZ, 1944, Bull. Amer. Paleont., vol. 28, no. 113, pp. 336–340, pl. 1, fig. 1; pl. 2, figs. 1–12; pl. 3, fig. 1–5 (references).

Entirely typical specimens occur, but not in the abundance of most of the other species.

Genus GUNTERIA Cushman & Ponton, 1933

GUNTERIA FLORIDANA Cushman & Ponton

Plate 91, figures 1–4

Gunteria floridana CUSHMAN & PONTON, 1933, Contrib. Cushman Lab. Foram. Res., vol. 9, pp. 25–30, pl. 3, figs. 1–3; —— D. K. PALMER, 1934, Soc. Cubana Hist. Nat. Mem., vol. 8, pp. 257–259, pl. 15, figs. 5, 7, 9; pl, 16, figs. 1, 2, 4, 5, 8; —— L. M. DAVIES, 1939, Roy. Soc. Edinburgh Trans., vol. 59, p. 780, pl. 1, figs. 2, 5, 8, 10, 11; —— COLE, 1942, Florida Geol. Survey Bull. 20, pp. 28, 29, pl. 16, figs. 1–4.

This genus was assigned originally to the family *Valvulinidae* by Cushman and Ponton. Later, Davies (1939, p. 780) proved that the wall is perforate, hyaline and the internal organization is different from that of *Dictyoconus*. Cole (1942, p. 28) suggested placing this genus in the family Buliminidae. The thin sections used in this study demonstrate, however, that the wall structure of *Gunteria* is very similar to that shown by *Cymbalopora irregularis* Keijer (= *C. cushmani* Cole and Bermudez) and *Fabiania cubensis* (Cushman and Bermudez). The genus *Gunteria* is, therefore, transferred to the family Cymbaloporidae.

Distribution.—This species was described from the Suwannee Petroleum Corporation's Sholtz well No. 1, Levy County, Florida where it occurs at depths of 1055 to 1100 feet in middle Eocene strata. It has been reported from other deep wells in Florida. In Cuba this species occurs at

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EXPLANATION OF PLATE 92

FIGS. *1–10*—*Eoconuloides wellsi* Cole & Bermudez. *1–6*, axial sections, ×20, except *5*, ×40; *7–10*, transverse sections, ×20. (p. 713)

11–21—*Helicostegina gyralis* Barker & Grimsdale. *11–14*, axial sections, ×20; *15–19*, transverse sections, ×20; *20*, external views, ×5, of 2 microspheric specimens; *21*, external views, ×10, of 3 megalospheric specimens. (p. 713)

EXPLANATION OF PLATE 93

FIGS. *1–9*—*Discocyclina* (*Discocyclina*) *marginata* (Cushman). Vertical sections to illustrate the difference in external shape and internal features between individuals, *1*, *2*, *4–9*, ×20; *3*, ×12.5; *2*, a specimen from the Senn collection, collected on the northeast ridge of the small rocky island of Pain de Sucre, west of Gustavia, St. Bartholomew, French West Indies; *3*, *4*, specimens from Angelita Seep, about 4 kms. S 60° W of Peñon Seep. (p. 714)

EXPLANATION OF PLATE 94

FIGS. *1–8*—*Discocyclina* (*Discocyclina*) *marginata* (Cushman). *1–3*, vertical sections, *1*, ×12.5; *2*, *3*, ×20; *4*, equatorial section, ×20; *5–8*, portions of equatorial sections to demonstrate the position of the annular stolon, ×210; all the photographs are oriented so that the distal side of the radial chamber wall is at the top; *6*, *8*, portions of the same specimen illustrated as fig. *4*; *1*, *2*, *4*, *6*, *8*, from specimens from the Boston Manganese Mine, Santiago (Oriente) Province, Cuba, presented to W. S. Cole by Dr. Pedro J. Bermudez; *3*, specimen from Angelita Seep, about 4 kms. S 60° W of Peñon Seep. (p. 714)

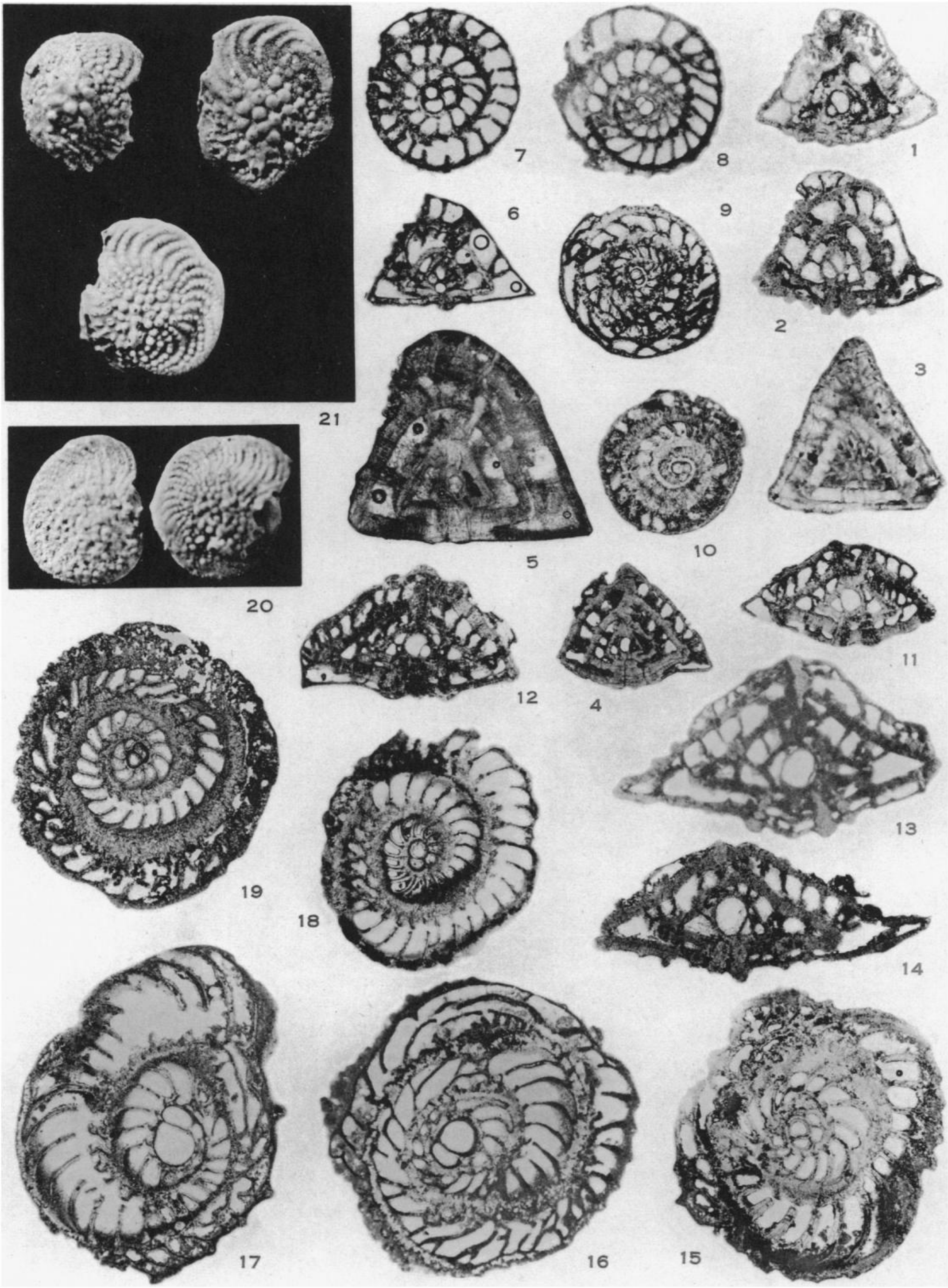
EXPLANATION OF PLATE 95

FIGS. *1–3*, *5*—*Asterocyclina habanensis* Cole & Bermudez. Equatorial sections, ×20, to illustrate differences in size and number of rays. (p. 716)

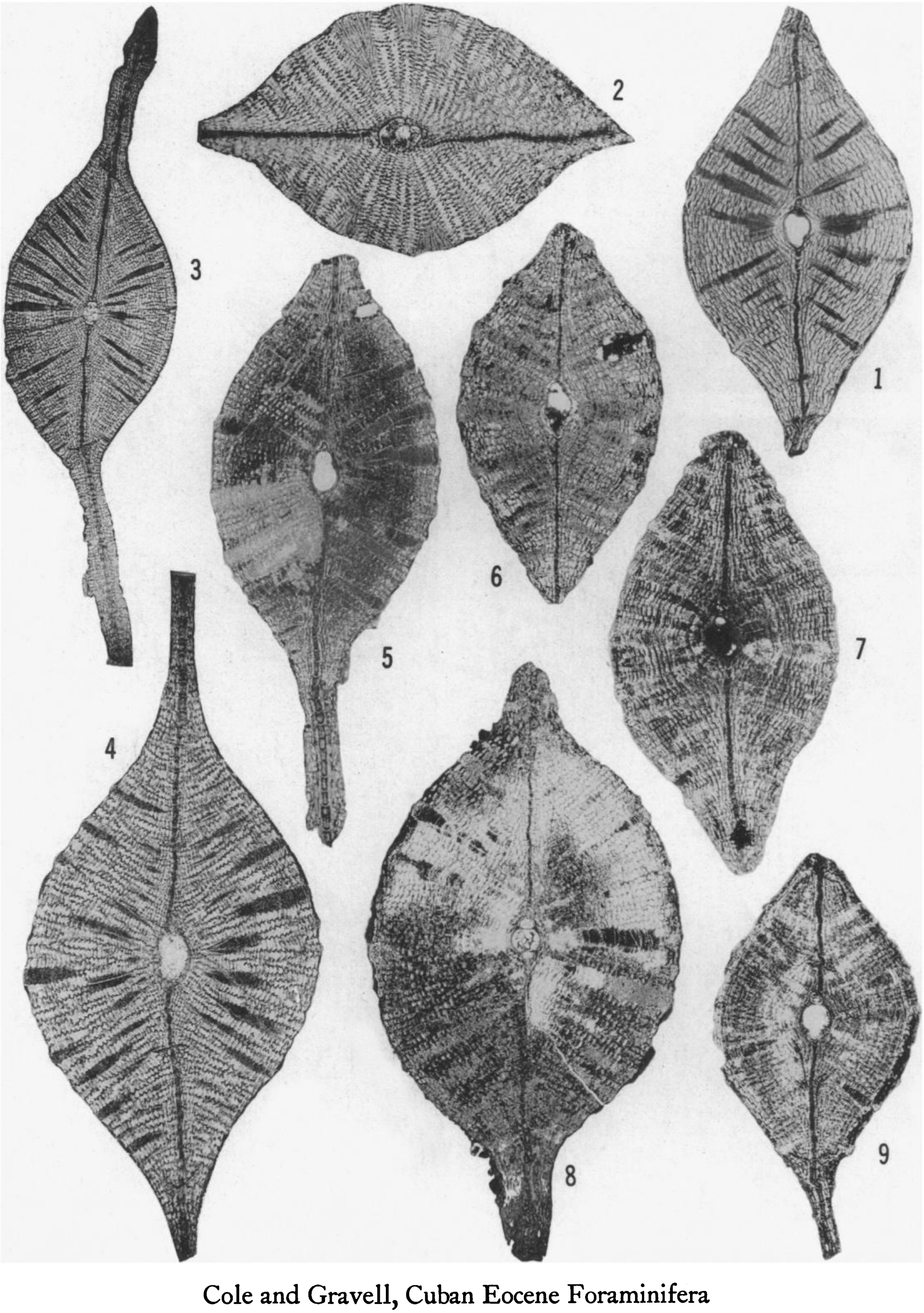
4—*Asterocyclina monticellensis* Cole & Ponton. Equatorial section, ×20. (p. 718)

6—*Pseudophragmina* (*Proporocyclina*) *compacta* Cole & Gravell, n. sp. Portion of an equatorial section, ×20, to illustrate multiple embryonic chambers. (p. 720)

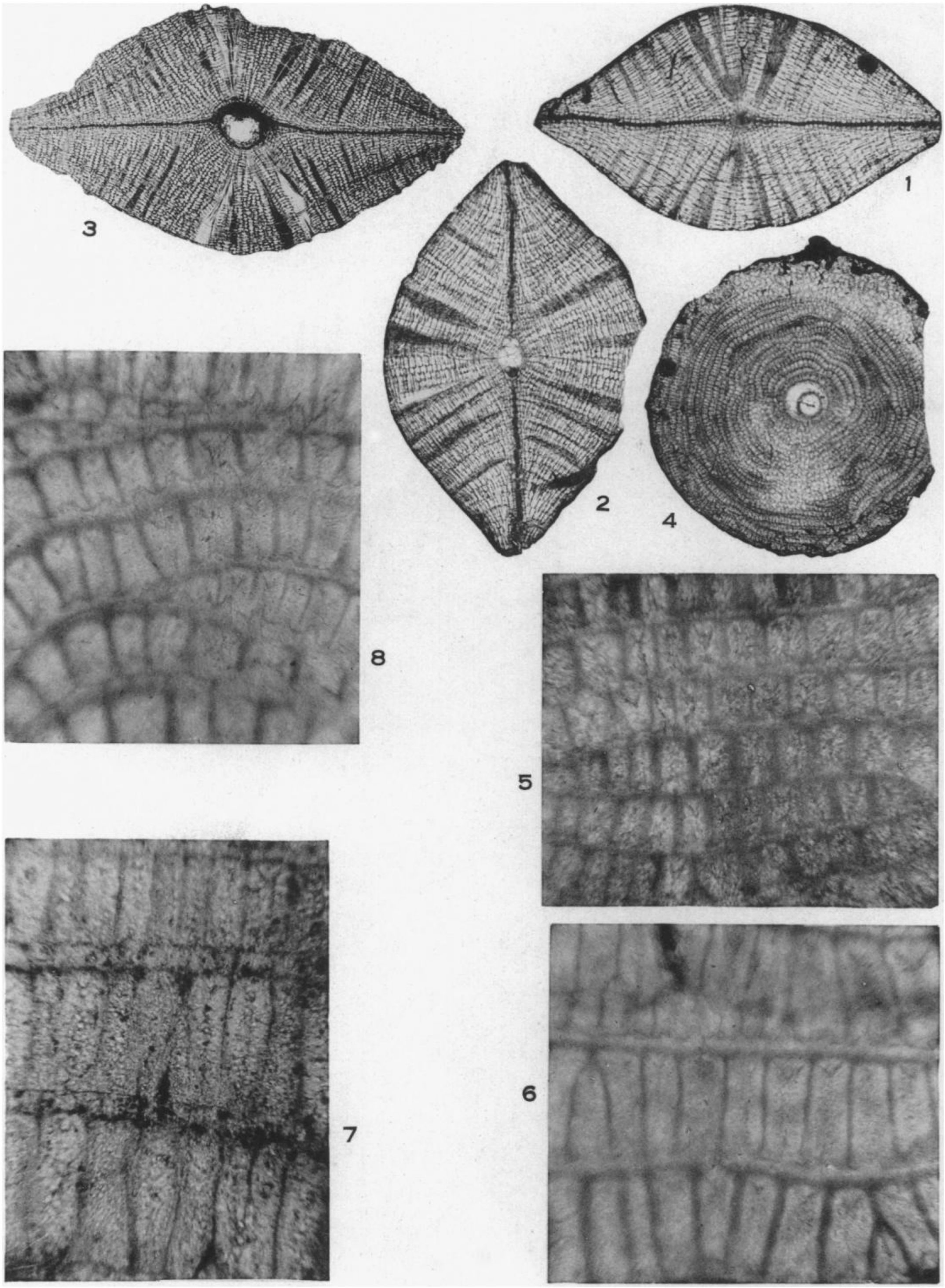
7, *8*—*Discocyclina* (*Discocyclina*) *marginata* (Cushman). Equatorial sections, ×20. (p. 714)



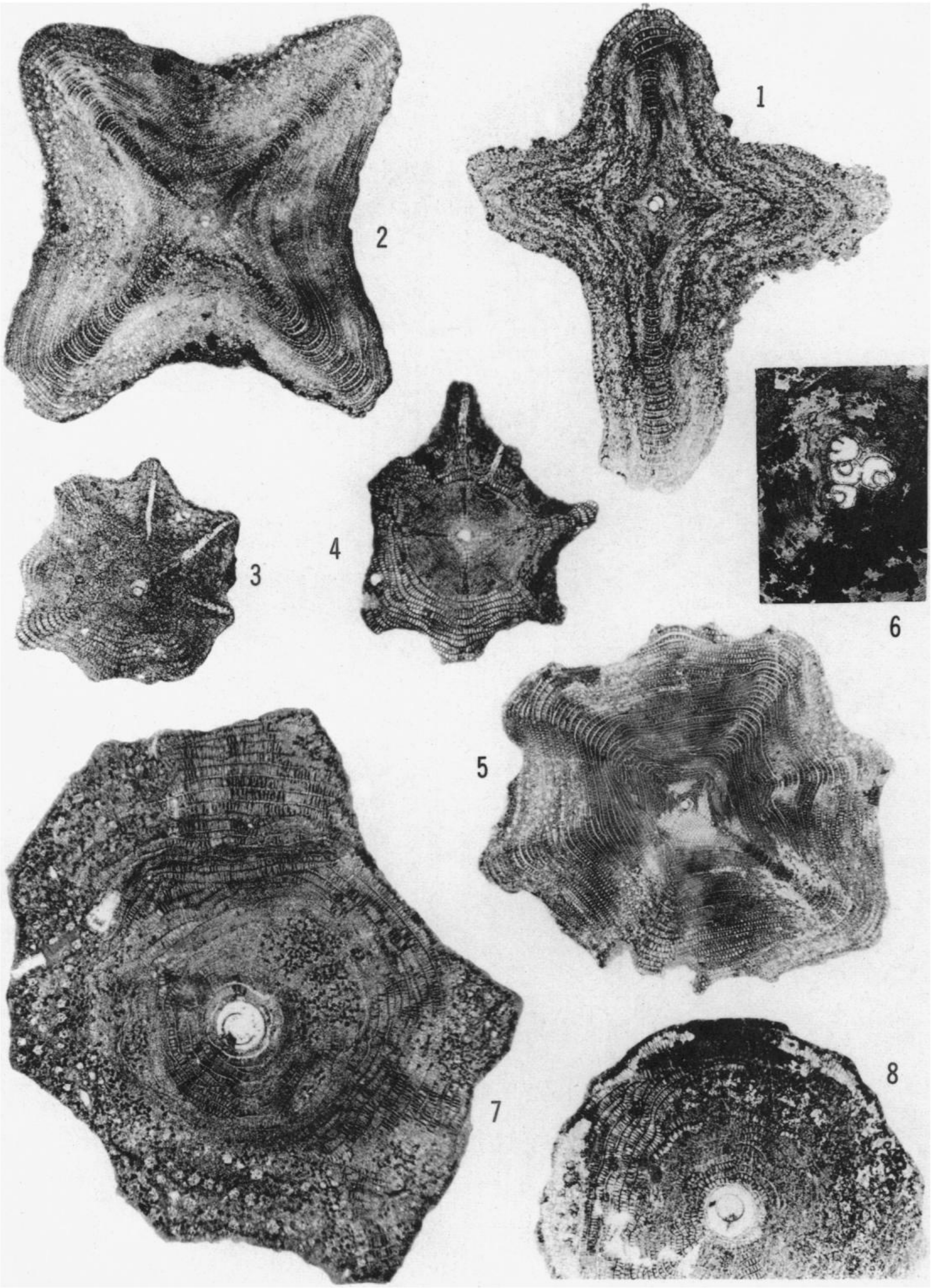
Cole and Gravell, Cuban Eocene Foraminifera



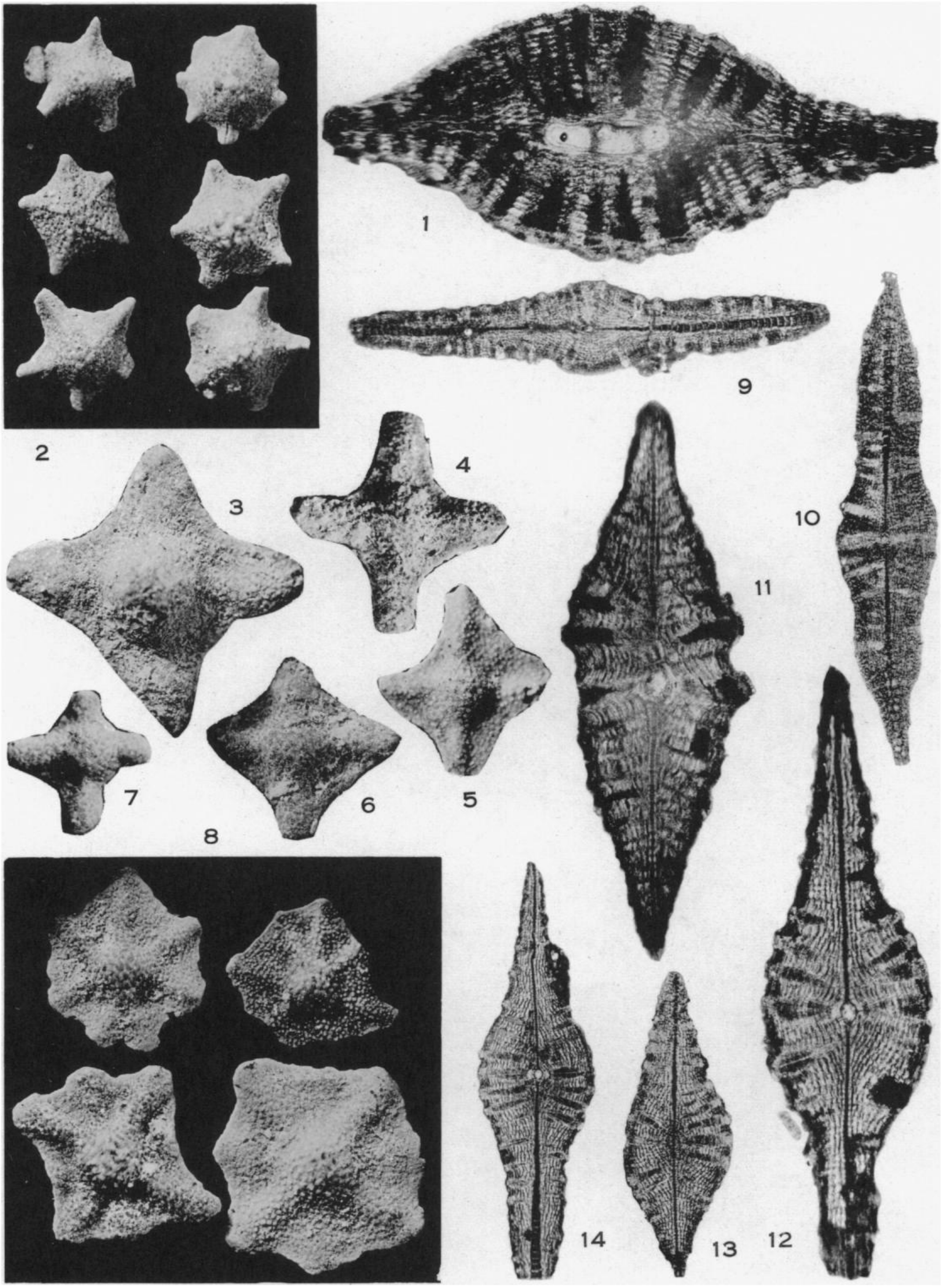
Cole and Gravell, Cuban Eocene Foraminifera



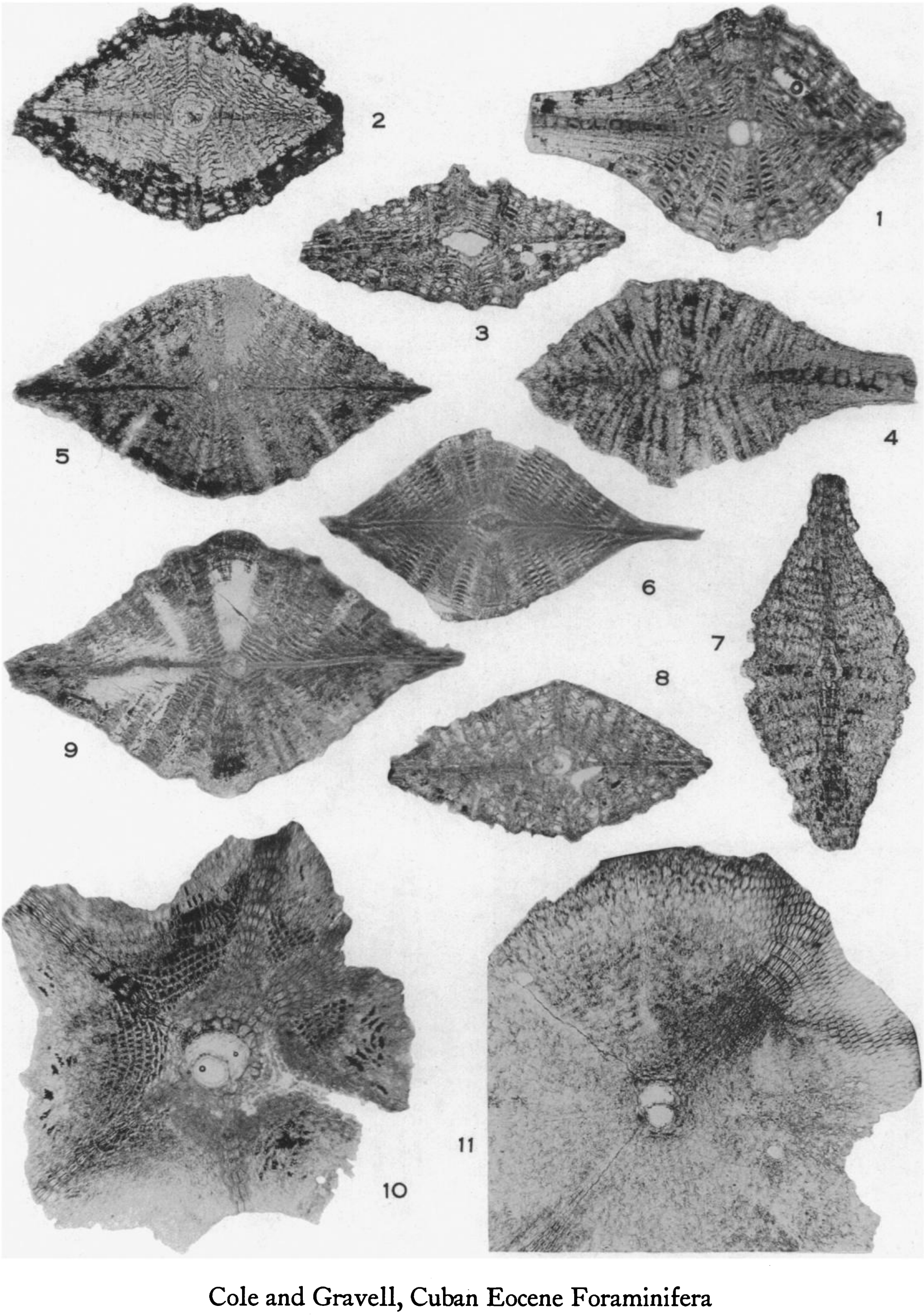
Cole and Gravell, Cuban Eocene Foraminifera



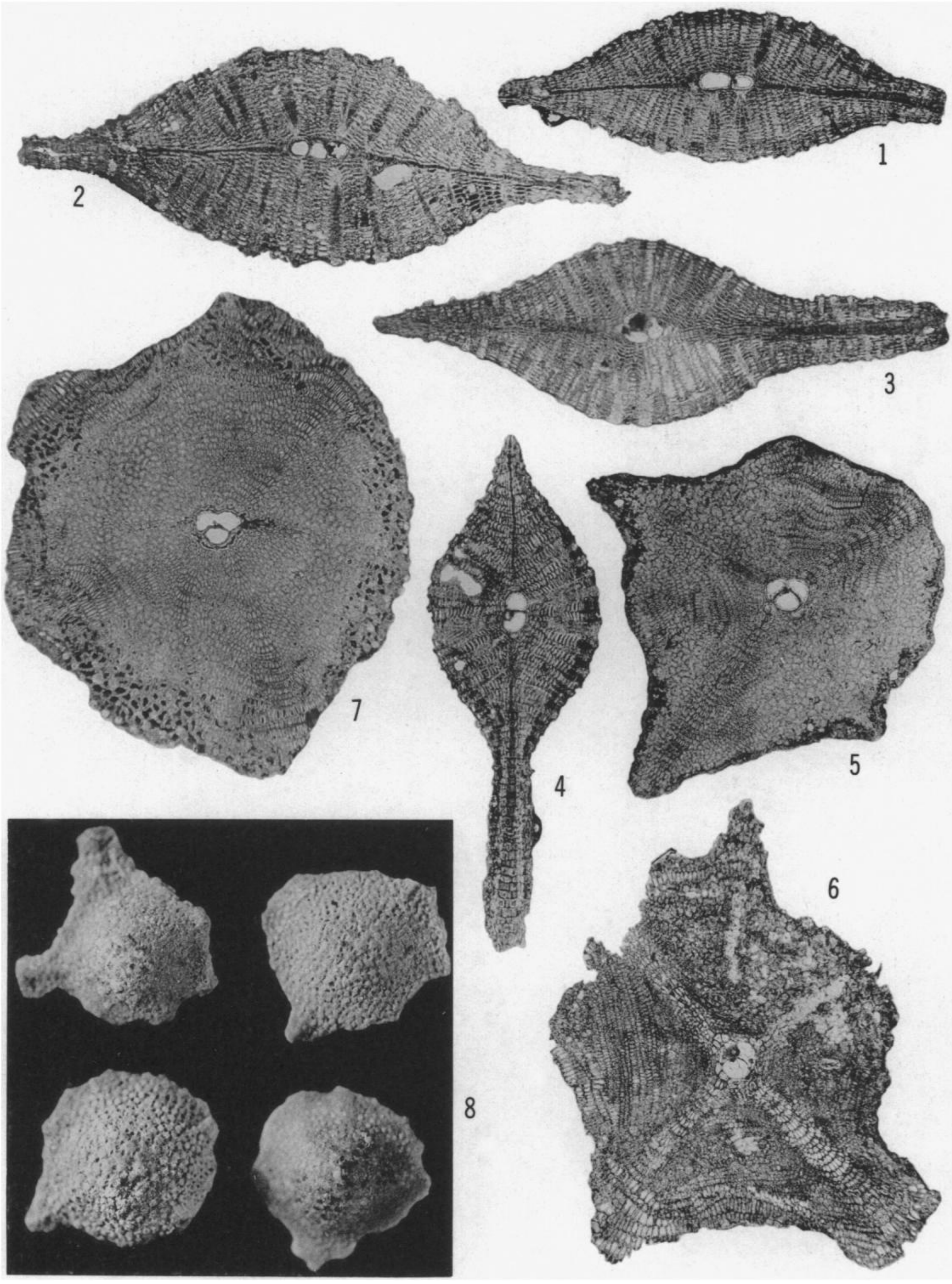
Cole and Gravell, Cuban Eocene Foraminifera



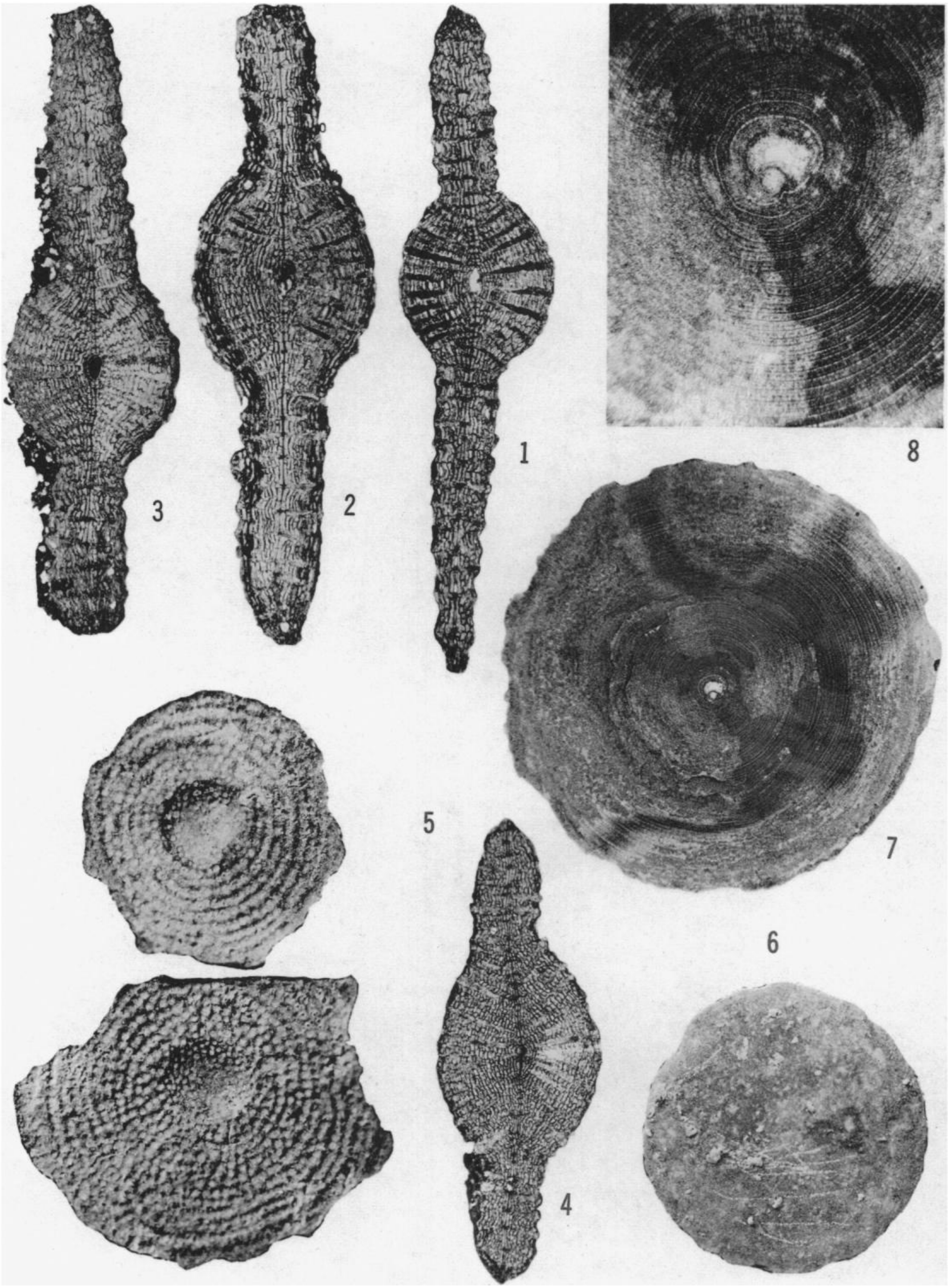
Cole and Gravell, Cuban Eocene Foraminifera



Cole and Gravell, Cuban Eocene Foraminifera



Cole and Gravell, Cuban Eocene Foraminifera



Cole and Gravell, Cuban Eocene Foraminifera

Bermudez station 337A, 4.5 kilometers west of Guanajay on the road to Mariel, Pinar del Rio Province, the locality under discussion and the immediate vicinity. It is a very distinctive species.

Family AMPHISTEGINIDAE
Genus HELICOSTEGINA Barker & Grimsdale, 1936
HELIOCOSTEGINA GYRALIS Barker & Grimsdale
Plate 92, figures 11–21

Helicostegina gyralis BARKER & GRIMSDALE, 1936, Jour. Paleontology, vol. 4, pp. 236, 237, pl. 30, figs. 3–5; pl. 32, figs. 4, 5; pl. 34, figs. 2–6; pl. 37, figs. 6; —— COLE, 1942, Florida Geol. Survey Bull. 20, p. 34, pl. 15, figs. 4–6; pl. 16, fig. 10.

There is a serious question whether this species can be separated from *H. dimorpha* Barker and Grimsdale (1936, p. 235). These authors (p. 237) state: "*Helicostegina gyralis* is the more primitive of the two species here referred to that genus. It differs from *H. dimorpha* in the possession of a greater number of whorls in the spire, and in the absence of a flange."

At first, in the very abundant material from Peñon Seep two species of *Helicostegina* were recognized. But, on detailed study these appear to form a continuous series. The number of whorls and the degree of development of the flange appear to be individual rather than specific features.

The development of the peripheral subsidiary chamberlets varies from individual to individual. Moreover, the direction in which the thin section passes through the individual governs the number and manner in which the subsidiary chamberlets will appear in the completed thin section.

Genus EOCONULOIDES Cole & Bermudez, 1944
EOCONULOIDES WELLSI Cole & Bermudez
Plate 92, figures 1–10

Eoconuloides wellsi COLE & BERMUDEZ, 1944, Bull. Amer. Paleont., vol. 28, no. 113, pp. 341, 342, pl. 1, figs. 4–10.

Individuals vary from high conical (pl. 92, fig. 3) to low conical (pl. 92, fig. 6) in cross-sectional form. The flat base of many individuals has a central group of papillae which appear internally as short pillars (pl. 92, fig. 2). However, other individuals which appear to be in all other respects similar to the papillate forms do not possess the external papillae or the internal pillars. Reexamination of the type specimens which are not nearly as well preserved as those from Peñon Seep demonstrates that this variation occurs in these specimens also.

EXPLANATION OF PLATE 96

FIG. *1*—*Asterocyclina penonensis* Cole & Gravell, n. sp. Vertical section, ×40, of a specimen which externally resembled *A. monticellensis.* (p. 718)
2—*Asterocyclina monticellensis* Cole & Ponton. External views, ×10, of 6 specimens. (p. 718)
3–14—*Asterocyclina habanensis* Cole & Bermudez. *2–8*, external views, ×10, to illustrate specimens with 4 rays and lacking interray webbing through 8-rayed specimens with completely developed interray areas; *9–14*, vertical sections, *9, 10, 13, 14,* ×20; *11, 12,* ×40. (p. 716)

EXPLANATION OF PLATE 97

FIGS. *1–11*—*Asterocyclina monticellensis* Cole & Ponton. *1–9*, vertical sections, ×40, to show differences in internal structure between individuals; *10, 11*, equatorial sections, ×40. (p. 718)

EXPLANATION OF PLATE 98

FIGS. *1–8*—*Asterocyclina penonensis* Cole & Gravell, n. sp. *1–4*, vertical sections, ×20; *5–7*, equatorial sections, ×20; *8*, external views, ×10, of 4 specimens; upper right specimen, holotype, Cole collection No. 407. (p. 718)

EXPLANATION OF PLATE 99

FIGS. *1–5*—*Pseudophragmina* (*Proporocyclina*) *cushmani* (Vaughan). *1–4*, vertical sections, ×20; *5*, external views of 2 specimens, ×10. (p. 722)
6–8—*Pseudophragmina* (*Proporocyclina*) *compacta* Cole & Gravell, n. sp. *6*, external view, ×10 of holotype, Cole collection No. 409; *7*, equatorial section, ×20; *8*, embryonic and equatorial chambers, ×40, of the same specimen. (p. 720)

Genus AMPHISTEGINA d'Orbigny, 1826
AMPHISTEGINA LOPEZTRIGOI Palmer
Plate 91, figures 6–8

Amphistegina lopeztrigoi PALMER, 1934, Mem. Soc. Cubana Hist. Nat., vol. 8, no. 4, p. 255, pl. 15, figs. 6, 8. —— BARKER & GRIMSDALE, 1936, Jour. Paleontology, vol. 10, p. 233, pl. 30, figs. 1, 2; pl. 32, figs. 1–3; pl. 34, fig. 1; pl. 38, fig. 3; —— COLE, 1942, Florida Geol. Survey Bull. 20, pp. 33, 34, pl. 15, figs. 2, 3; pl. 16, fig. 11; 1944, idem, Bull. 26, p. 55, pl. 1, fig. 17; pl. 8, fig. 16; pl. 9, figs. 10–13.
Amphistegina senni CUSHMAN in Vaughan, 1945, Geol. Soc. America, Mem. 9, p. 49, pl. 19, figs. 1–4.

We have abundant topotype material of this species from Palmer Sta. 687. These specimens range in size from 1.0 mm. to 2.8 mm. Barker and Grimsdale (1936, p. 236) give the diameter of Mexican specimens as 1.0 to 1.5 mm. Cole (1942, p. 33) states the largest Floridian specimens have a diameter of 1.8 mm.

Cushman separates *A. senni* from *A. lopeztrigoi* by its smaller size, fewer chambers and fewer but more prominent bosses in the umbonal region. However, it would be impossible to distinguish between the smaller topotype specimens of *A. lopeztrigoi* and the larger (diameter up to 1.10 mm.) specimens of *A. senni*. It is logical, therefore, to combine these species.

Genus PENOPERCULOIDES
Cole and Gravell, new genus

Genotype.—Penoperculoides cubensis Cole and Gravell, new species.

Test slightly asymmetrical, trochoid in the early stages, adult nearly planispiral, involute; wall calcareous, laminated, and finely tubulated; aperture, an arched slit at the base of the last formed chamber so arranged that it extends more on one side of the median line than the other.

Penoperculoides differs from *Operculinoides* in being slightly asymmetrical and having a much thicker revolving wall. *Penoperculoides* differs from *Crespinella* in having thinner walls and an aperture without a hood. *Penoperculoides* is intermediate in most of its features between *Amphistegina* and *Operculinoides*.

PENOPERCULOIDES CUBENSIS Cole & Gravell, n. sp.
Plate 91, figures 9–12

Test with prominent umbos bordered by a thin flange, slightly asymmetric in cross section. On one side there is a single, large boss in the umbonal region, but on the opposite side there is a group of about 14 raised papillae. The flange on both sides is crossed by raised, distinct sutures which radiate from the umbonal areas. These raised sutures are straight and radial until the periphery is approached at which point they recurve. The sutures on the side of the single boss are not beaded, but on the papillate side the sutures may be beaded near the umbonal area. Diameter, about 2.2 mm.; thickness, about 1.2 mm.

The embryonic chambers are bilocular, the initial chamber is subcircular with an internal diameter of about 55 μ, the second chamber is reniform with diameters of about 40 by 65 μ.

The test is composed of $4\frac{1}{2}$ whorls with 6 chambers in the first whorl, 9 chambers in the second, 10 chambers in the third and 13 chambers in the fourth whorl.

The aperture is an arched slit at the base of the last formed chamber so arranged that it extends more on the unbeaded side of the test than on the other.

Family ROTALIIDAE
Genus DISCORINOPSIS Cole
DISCORINOPSIS GUNTERI Cole
Plate 91, figure 5

Discorinopsis gunteri COLE, 1941, Florida Geol. Survey Bull. 19, pp. 36, 37, pl. 1, figs. 7–9.

Entirely typical specimens occur abundantly at Peñon Seep.

Family DISCOCYCLINIDAE
Genus DISCOCYCLINA Gümbel, 1870
Subgenus DISCOCYCLINA Gümbel, 1870
DISCOCYCLINA (DISCOCYCLINA) MARGINATA (Cushman)
Plate 93, figures 1–9; plate 94, figures 1–8; plate 95, figures 7, 8

Orthophragmina marginata CUSHMAN, 1919, Carnegie Inst. Washington, Publ. 291, p. 56, pl. 1, fig. 2; pl. 2, fig. 4.
Orthophragmina crassa CUSHMAN, 1919, idem, p. 53, pl. 9, figs. 4, 5; pl. 10, figs. 2, 4.
Discocyclina californica SCHENCK, 1929, Trans. San Diego Soc. Nat. Hist., vol. 5, no. 14, pp.

224–227, pl. 27, figs. 3, 4, 6; pl. 28, figs. 2–6; pl. 29; pl. 30, figs. 2, 3; text figs. 8, 9, 10.
Discocyclina (Discocyclina) harrisoni VAUGHAN, 1945, Geol. Soc. America Mem. 9, pp. 35–37, pl. 11.
Discocyclina (Discocyclina) crassa VAUGHAN, 1945, idem, pp. 71, 72, pl. 23, figs. 5–7; pl. 24, figs. 1, 2.
Pseudophragmina (Proporocyclina) marginata VAUGHAN, 1945, pp. 96, 97, pl. 40, figs. 1, 2.
Discocyclina (Discocyclina) mestieri COLE & BERMUDEZ (part), 1947, Bull. Amer. Paleont., vol. 31, no. 125, pp. 202, 203, pl. 4, fig. 7; pl. 7, fig. 4 (not pl. 3, fig. 3; pl. 4, figs. 6, 8, 9, 10 which are *D. mestieri* Vaughan).

D. marginata was inadequately described by Cushman from the Eocene of St. Bartholomew. Vaughan (1945) later illustrated an unoriented vertical section and a portion of an oblique equatorial section of a specimen from the type locality of the species which shows some of the equatorial chambers. At this time he incorrectly assigned this species to *Pseudophragmina (Proporocyclina)*.

At the same time that Cushman described *D. (D.) marginata*, he proposed another new species, *O. crassa*, from the Eocene of Cuba. Recently, Vaughan (1945) assigned this species to *Discocyclina (Discocylina)*. In the same paper Vaughan described a new species, *Discocyclina (Discocyclina) harrisoni*, from the middle Eocene of Barbados.

All three species show an inflated central portion with numerous lateral chambers and rather heavy pillars. Two of them, *D. (D.) marginata* and *D. (D.) harrisoni* have the inflated central portion surrounded by a wide, thin rim, but the illustrations of *D. (D.) crassa* do not show this rim. However, its presence might be suspected by an examination of the margin of the test.

Although the embryonic chambers of *D. (D.) marginata* were unknown, those of *D. (D.) crassa* and *D. (D.) harrisoni* are illustrated adequately by Vaughan, and are virtually identical in the two species.

Thus the literature contains at least three species from different islands, very similar in many respects, but separated so far from each other that two are placed in one genus and one in another.

Gravell in the preliminary study of the specimens from Peñon Seep correctly identified one type with *D. (D.) marginata*. However, certain doubts existed. Therefore, Cole restudied *D. (D.) crassa*, *D. (D.) harrisoni* and *D. (D.) marginata*. The collection of the late Dr. Alfred Senn from St. Bartholomew contained numerous specimens which could be assigned at once to *D. (D.) marginata*.

It became clear as the study progressed that Vaughan (1945) had placed *D. (D.) crassa* and *D. (D.) harrisoni* in the correct genus, but he incorrectly assigned *D. (D.) marginata* to the genus *Pseudophragmina*. Vaughan (1945, pl. 40, fig. 1) had an oblique equatorial section of *D. (D.) marginata* which shows only the peripheral equatorial chambers. The radial chamber walls of these chambers are more or less in alignment, wavy and thin. These are certainly features of *Pseudophragmina*. Moreover, Vaughan believed he saw the annular stolon located on the distal side of the radial chamber walls.

However, examination of equatorial sections of specimens in this collection assigned to *D. (D.) marginata* shows that the equatorial chambers near the center of the test are of the type possessed by *Discocyclina* s.s. with the annular stolon in the proximal situation (figs. 5, 8, pl. 94). Toward the periphery, however, these chambers become similar in many respects to those of *Pseudophragmina* (fig. 7, pl. 94), but the annular stolon maintains its proximal situation.

D. (D.) crassa and *D. (D.) harrisoni* show this same change in the plan of the equatorial chambers from the center of the test toward the periphery, and more nearly oriented equatorial sections in the Senn collection from St. Bartholomew of specimens identified as *D. (D.) marginata* conform to the pattern developed in the Cuban and Barbados specimens. Therefore, it is easy to understand why Vaughan assigned the type specimens of *D. (D.) marginata* to the genus *Pseudophragmina*.

Schenck (1929) described a species from California, *Discocyclina californica*, which is identical with the West Indian specimens assigned by us to *D. (D.) marginata*, a conclusion which Woodring and Daviess (1944, p. 366) have stated would be drawn if the Californian and Cuban species were critically compared.

Certain of the specimens described by Cole and Bermudez (1947) as *D. (D.) mes-*

tieri Vaughan are not correctly identified. These specimens are *D.* (*D.*) *marginata*, but other specimens are correctly assigned to *D.* (*D.*) *mestieri* Vaughan.

Genus Asterocyclina Gümbel, 1870
Asterocyclina habanensis
Cole & Bermudez
Plate 95, figures 1–3, 5; plate 96, figures 3–14

Discocyclina (*Asterocyclina*) *habanensis* Cole & Bermudez, 1947, Bull. Amer. Paleont., vol. 31, no. 125, pp. 204, 205, pl. 18, figs. 1–6.

Test of medium size, stellate with a pronounced, sharply defined, central umbo from which the rays radiate. Many specimens have only four distinct rays, but other specimens have in addition interray areas which connect the principal rays. These specimens may or may not have secondary rays. If secondary rays are developed, they vary in number from one to four. The umbo and the rays are covered with strong, slightly raised papillae with diameters of about 100 μ. The interray areas have slightly smaller papillae with diameters of 40 to 60 μ.

The embryonic chambers consist of a circular to subcircular initial chamber which is partially embraced by a reniform second chamber. There appear to be four periembryonic chambers, two of which lie on each side of the initial chamber, and two of which occur on each side of the second chamber. These chambers have arcuate distal walls.

Measurements of equatorial sections follow:

Equatorial sections of *Asterocyclina habanensis* Cole & Bermudez

Specimen	1	2	3	4	5	6
Diameter	3.2 mm.	4.2+ mm.	4.4+ mm.	3.5 mm.	3.8 mm.	3.5+ mm.
Embryonic chambers:						
Diameter of initial chamber	40 μ	60 μ	60 μ	60 μ	40 μ	40 μ
Diameters of second chamber	20×60 μ	40×80 μ	40×100 μ	40×100 μ	35×60 μ	40×60 μ
Distance across both chambers	60 μ	100 μ	110 μ	100 μ	80 μ	80 μ
Equatorial chambers near periphery						
Interray areas:						
Tangential diameter	20 μ	20 μ	20 μ	—	20 μ	20 μ
Radial diameter	20 μ	30–40 μ	30 μ	—	20 μ	20 μ
Rays:						
Tangential diameter	20 μ	20–30 μ	20–30 μ	20 μ	20 μ	20 μ
Radial diameter	40 μ	60–80 μ	40–60 μ	40–60 μ	20–50 μ	20–40 μ
Number of rays shown	6	4	4	4	4	4

Explanation of Plate 100

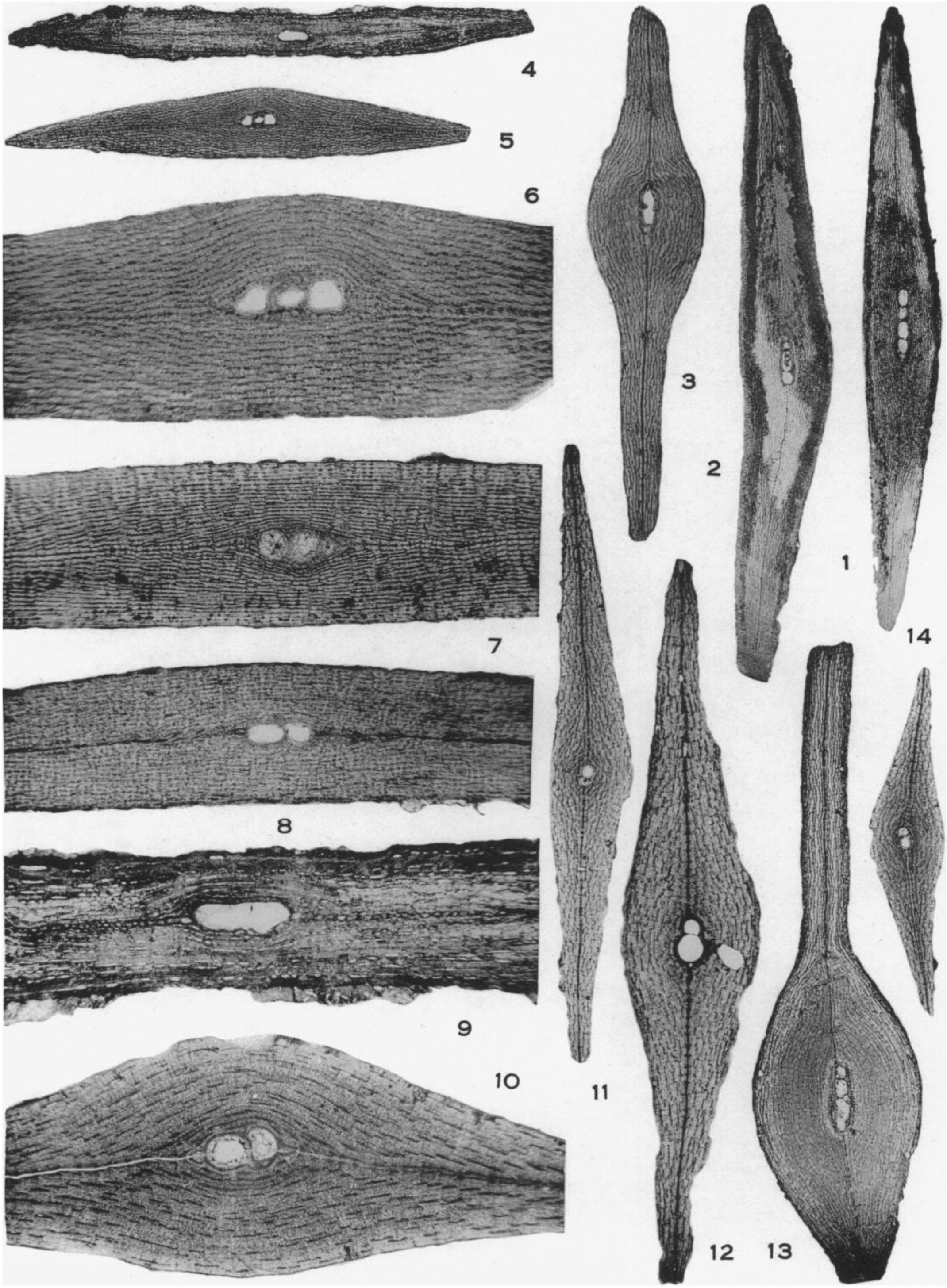
Figs. *1, 2, 5, 6, 13*—*Pseudophragmina* (*Proporocyclina*) *compacta* Cole & Gravell, n. sp. Vertical sections, *1, 2, 13*, ×12.5; *5*, ×20; *6*, an enlarged portion, ×40, of the specimen illustrated as fig. *5*. (p. 720)

4, 9—*Pseudophragmina* (*Proporocyclina*) *advena* (Cushman). Vertical sections, *4*, ×12.5; *9*, an enlarged portion, ×40, of the same specimen; topotype specimen from the Cane River, Natchitoches, Louisiana, introduced for comparison with *P.* (*P.*) *compacta*. (p. 721)

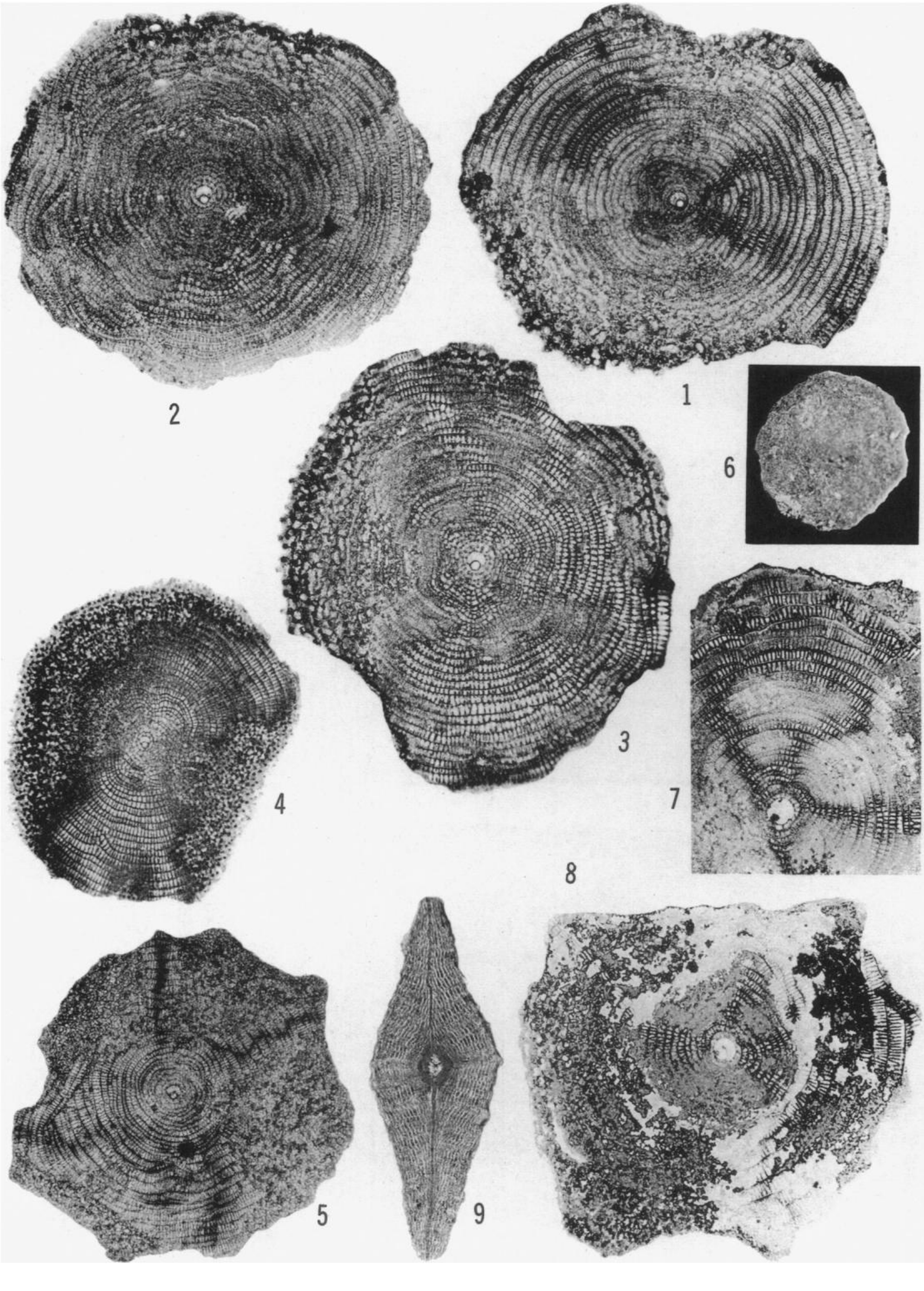
7—*Pseudophragmina* (*Proporocyclina*) *perkinsi* (Vaughan). Portion of a vertical section, ×40, of a specimen from D. K. Palmer sta. 1479, between km. 73.9 and km. 74.6 on the railroad between Nuevitas and Pastelillo, Camaguey Province, Cuba, introduced for comparison with *P.* (*P.*) *compacta*. (p. 721)

8—*Pseudophragmina* (*Proporocyclina*) *cloptoni* (Vaughan). Portion of a vertical section, ×40, of a topotype specimen from Arroyo Guadalupe, 50 miles northwest of La Paz, Lower California, introduced for comparison with *P.* (*P.*) *compacta*. (p. 721)

3, 10–12, 14—*Pseudophragmina* (*Proporocyclina*) *teres* Cole and Gravell, n. sp. Vertical sections, *3, 11, 12, 14*, ×12.5; *10*, an enlarged portion, ×40, of the specimen illustrated as fig. *14*. (p. 725)



Cole and Gravell, Cuban Eocene Foraminifera



Cole and Gravell, Cuban Eocene Foraminifera

The equatorial chambers near the center of the test are small, square with diameters of about 15 μ. These chambers are arranged in a quadrate manner so that the position of the four principal rays is defined in the center of the equatorial section although these rays do not appear on the surface of the test until the edge of the umbonal area is reached. Secondary rays appear in equatorial sections at some distance from the central area.

Measurements of vertical sections follow:

Vertical sections of *Asterocyclina habanensis* Cole & Bermudez

Specimen	1	2	3	4	5	6
Diameter	2.2 mm.	3.+ mm.	2.2 mm.	3.4 mm.	3.4 mm.	3.5 mm.
Thickness	0.64 mm.	0.86 mm.	0.8 mm.	0.7 mm.	0.7 mm.	0.76 mm.
Diameter of umbo	0.9 mm.	0.9 mm.	1.0 mm.	0.7 mm.	0.8 mm.	0.9 mm.
Embryonic chambers:						
Length	40 μ	60 μ	—*	80 μ	40 μ	60 μ
Height	35 μ	50 μ	—	40 μ	25 μ	50 μ
Equatorial layer:						
Height at center	18 μ	10 μ	10 μ	20 μ	10 μ	15 μ
Height at periphery	20 μ	20 μ	20 μ	60 μ	40 μ	50 μ
Lateral chambers:						
Number	15	22	16	15	15	15
Length	60–80 μ	40–60 μ	60–80 μ	60 μ	60–100 μ	60 μ
Height	5 μ	5–8 μ	5 μ	5 μ	5 μ	5 μ
Thickness of roofs and floors	5–10 μ	8–20 μ	10 μ	10 μ	10 μ	10 μ
Surface diameter of pillars	60–80 μ	60–80 μ	80–100 μ	60 μ	60–100 μ	80–120 μ

* Not centered.

The lateral chambers have low, appressed, slit-like cavities between heavy roofs and floors. Between the pillars the lateral chambers are arranged in rather regular tiers, but elsewhere there is considerable overlapping from one tier to the next adjacent one.

Heavy pronounced pillars occur in the central umbonate area and scattered smaller pillars are found in the peripheral zone.

Discussion.—There are some minor differences between the type specimens of this species and the specimens in the collection under discussion. The type specimen has stronger, more elevated and fewer papillae on the umbo than do the specimens from Peñon Seep. Moreover, the type specimen does not have papillae on the interray areas. The vertical sections of the specimens from the type locality have fewer lateral chambers and less frequent but heavier pillars than do the specimens from Peñon Seep. However, the shape, arrangement and distribution of the external and internal features in the specimens from the two localities are such that one would hesitate to create two distinct species.

A vertical section of a topotype specimen of *A. aster* Woodring (fig. 9, pl. 101) is illustrated for comparison with the Cuban species of *Asterocyclina*. The roofs and floors of the lateral chambers of *A. aster* are much thinner than those of *A. habanensis*.

EXPLANATION OF PLATE 101

FIGS. *1–3*—*Pseudophragmina* (*Proporocyclina*) *convexicamerata* Cole & Gravell, n. sp. Equatorial sections, ×20. (p. 721)

4, 5—*Pseudophragmina* (*Proporocyclina*) *psila* (Woodring). Equatorial sections, ×20. (p. 725)

6–8—*Pseudophragmina* (*Proporocyclina*) *teres* Cole & Gravell, n. sp. *6*, external view, ×5, of the holotype, Cole collection No. 408; *7, 8*, equatorial sections, ×20. (p. 725)

9—*Asterocyclina aster* Woodring. Vertical section, ×20, of a topotype specimen from Cal. Inst. Tech. Loc. 595, south slope of western Santa Ynez Range, Santa Barbara County, California, west side of Canada de los Sauces 1.2 miles above coast. (p. 717)

Asterocyclina monticellensis Cole & Ponton

Plate 95, figure 4; plate 96, figure 2; plate 97, figures 1–11

Discocyclina (*Asterocyclina*) *monticellensis* Cole & Ponton, 1934, Amer. Midland Nat., vol. 15, pp. 141, 142, pl. 2, figs. 6–11; —— Cole, 1944, Florida Geol. Survey Bull. 26, pp. 76–79, pl. 1, fig. 8; pl. 2, fig. 11; pl. 8, fig. 23; pl. 13, fig. 5; pl. 23, figs. 1–12; Cole, 1945, idem, Bull. 28, pp. 122, 123, pl. 21, figs. 1–13.

Tests small, stellate, central portion inflated, rays peripherally developed, projecting as short, pointed arms, five to eight in number, from their junction with the central area which shows no reflection of the rays. There is an apical crown of larger papillae with diameters of about 140 μ beyond which there are smaller papillae with diameters of about 60 μ. The arms and a narrow peripheral zone appears to be without papillae.

The embryonic chambers are bilocular with a spherical initial chamber with an internal diameter of about 60 μ and a reniform second chamber with internal diameters of about 40 by 100 μ.

The stellate pattern of the test is shown by the arrangement of the equatorial chambers. Chambers in the interray area have radial diameters of about 30 μ and tangential diameters of about 20 μ. Chambers in the center of the rays have radial diameters of about 40 μ and tangential diameters of about 20 μ.

Measurements of vertical sections follow:

The lateral chambers are aligned in regular tiers and have a rectangular shape. The chamber cavity is low, open, distinct. The floors and roofs are either straight or very slightly convex toward the periphery.

Large, strong pillars occur normally over the embryonic chambers with smaller pillars scattered in the areas beyond the zone of the large pillars.

Discussion.—There is certain individual variation between specimens assigned to this species. Certain specimens (pl. 97, fig. 3) are compressed whereas others are inflated (pl. 97, fig. 5). Specimens from Florida show the same features, however. The specimen from Peñon Seep (pl. 97, fig. 8) should be compared with the vertical section (pl. 2, fig. 9) illustrated by Cole and Ponton (1934) and the Cuban specimen (pl. 97, fig. 1) should be compared with the Floridian specimen (pl. 23, fig. 1) illustrated by Cole (1944).

Asterocyclina penonensis Cole and Gravell, n. sp.

Plate 96, figure 1; plate 98, figures 1–8

Test medium size, strongly inflated with a narrow rim on which five or six short arms are developed. The arms are entirely confined to the rim and do not appear on the umbonate portion of the test. The inflated central portion is thickly and regularly studded with small, slightly raised papillae which continue outward on the arms. The rim has a few scattered papillae.

Vertical sections of *Asterocyclina monticellensis* Cole & Ponton

Specimen	1	2	3
Diameter	1.7 mm.	1.4+ mm.	1.4+ mm.
Thickness	0.98 mm.	0.9 mm.	0.72 mm.
Embryonic chambers:			
Length	60 μ	120 μ	60 μ
Height	40 μ	75 μ	60 μ
Equatorial layer:			
Height at center	15 μ	20 μ	15 μ
Height at periphery	40 μ	40 μ	20 μ
Lateral chambers:			
Number	16	15	15
Length	60–80 μ	60–80 μ	50 μ
Height	20 μ	15 μ	10 μ
Thickness of floors and roofs	15 μ	20 μ	10 μ
Surface diameter of pillars	80–200 μ	60–100 μ	100–180 μ

The embryonic chambers are either nephrolepidine or eulepidine in type. There is considerable variation in total size of these chambers from specimen to specimen. The embryonic chambers are surrounded by a complete ring of rather large, more or less square periembryonic chambers.

Measurements of equatorial sections follow:

Moderate size pillars are scattered irregularly throughout the umbonate area. Small pillars occur in the rim.

Comparisons.—Externally, this species resembles *Asterocyclina franksi* Vaughan (1945, p. 43) from the middle Eocene of Barbados. Unfortunately, *A. franksi* is known only by its external appearance and a few of the characteristics of the equatorial

Equatorial sections of *Asterocyclina penonensis* Cole & Gravell, n. sp.

Specimen	1	2	3	4	5
Diameter	2.9 mm.	3.2 mm.	3.2 mm.	3.2+ mm.	3.2 mm.
Embryonic chambers:					
Diameters of initial chamber	80×180 μ	80×160 μ	120×180 μ	140×180 μ	260×280 μ
Diameters of second chamber	140×300 μ	120×320 μ	120×260 μ	120×240 μ	60×560 μ
Distance across both chambers	240 μ	220 μ	260 μ	280 μ	340 μ
Thickness of outer wall	10 μ	10 μ	10 μ	8 μ	5 μ
Equatorial chambers:					
Near center					
Tangential diameter	20 μ	20 μ	20 μ	20 μ	20 μ
Radial diameter	20 μ	25 μ	25 μ	20 μ	40 μ
Near periphery (interray)					
Tangential diameter	20 μ	20 μ	25 μ	25 μ	20 μ
Radial diameter	40 μ	40 μ	50 μ	100 μ	50–60 μ
Near periphery (ray)					
Tangential diameter	30 μ	20–30 μ	20–30 μ	20–30 μ	20 μ
Radial diameter	60 μ	40–80 μ	55–60 μ	40–80 μ	50–60 μ

Measurements of vertical sections follow:

Vertical sections of *Asterocyclina penonensis* Cole & Gravell, n. sp.

Specimen	1	2	3	4	5
Diameter	4.3 mm.	4.1 mm.	3.2 mm.	4.1 mm.	3.7 mm.
Thickness	1.56 mm.	1.4 mm.	1.1 mm.	1.16 mm.	1.26 mm.
Diameter of umbo	2.8 mm.	2.0 mm.	2.0 mm.	2.4 mm.	1.8 mm.
Width of rim	0.8 mm.	1.3 mm.	0.5 mm.	1.0 mm.	1.5 mm.
Thickness of rim	0.2 mm.	0.5 mm.	0.2 mm.	0.2 mm.	0.32 mm.
Embryonic chambers:					
Length	400 μ	280 μ	340 μ	300 μ	260 μ
Height	120 μ	220 μ	120 μ	160 μ	160 μ
Equatorial layer:					
Height at center	35 μ	20 μ	20 μ	20 μ	20 μ
Height at periphery	60 μ	100 μ	70 μ	40 μ	160 μ
Lateral chambers:					
Number	20	19	16	17	18
Length	80 μ	60–100 μ	80–100 μ	50–80 μ	60–80 μ
Height	20 μ	18 μ	15 μ	15 μ	10 μ
Thickness of floors and roofs	20 μ	10–15 μ	20 μ	15 μ	15 μ
Surface diameter of pillars	80–120 μ	100 μ	80–100 μ	60–120 μ	120 μ

The lateral chambers are arranged in regular tiers. The chamber cavities are open, rectangular in shape with rather heavy roofs and floors.

chambers. As the classification of these forms depend largely on the internal features, it would not be safe to assign the Peñon Seep specimens to this species.

Genus PSEUDOPHRAGMINA H. Douvillé, 1923
Subgenus PROPOROCYCLINA Vaughan and Cole, 1940
PSEUDOPHRAGMINA (PROPOROCYCLINA) COMPACTA Cole & Gravell, n. sp.
Plate 95, figure 6; plate 99, figures 6–8; plate 100, figures 1, 2, 5, 6, 13

Test compressed, lenticular, sloping regularly from the center to the periphery Surface smooth, unornamented.

chambers in a specimen with a set of four follow:

Diameter of initial chamber	Diameter of second chamber	Distance across both chambers
120×120μ	150×300μ	280μ
170×160μ	180×380μ	360μ
150×160μ	120×340μ	290μ
120×120μ	180×320μ	310μ

Measurements of equatorial sections with only one set of embryonic chambers follow:

Equatorial sections of *Pseudophragmina* (*Proporocyclina*) *compacta* Cole & Gravell, n. sp.

Specimen	1	2	3
Diameter	5.0 mm.	5.4 mm.	3.6 mm.
Embryonic chambers:			
Diameters of initial chamber	80×90 μ	120×130 μ	60×65 μ
Diameters of second chamber	120×220 μ	110×340 μ	90×155 μ
Distance across both chambers	210 μ	240 μ	160 μ
Equatorial chambers:			
Radial diameter	30 μ	40 μ	20 μ
Tangential diameter	20 μ	20 μ	20 u

The initial embryonic chamber is circular to subcircular in shape as viewed in equatorial section. The second embryonic chamber is reniform and strongly embraces the initial chamber. The outer wall of the embryonic chambers is thin. There is a

The annuli are narrow. The annular walls are distinct, but the radial walls are imperfectly developed. These radial walls are incomplete, irregular and wavy, but aligned. The annular stolon is located on the distal side. Measurements of vertical sections follow:

Vertical sections of *Pseudophragmina* (*Proporocyclina*) *compacta* Cole & Gravell, n. sp.

Specimen	1	2	3	4
Diameter	7.7 mm.	5.4 mm.	7.8 mm.	7.0 mm.
Thickness	1.08 mm.	0.8 mm.	1.0 mm.	0.92 mm.
Embryonic chambers:				
Length	460 μ	380 μ	360 μ	760 μ*
Height	100 μ	100 μ	90 μ	120 μ
Equatorial layer:				
Height at center	7 μ	6 μ	8 μ	5 μ
Height at periphery	40 μ	20 μ	20 μ	20 μ
Lateral chambers:				
Number	20	14	19	16
Length	40–60 μ	40–80 μ	40–130 μ	50–120 μ
Height	5 μ	5 μ	5 μ	5 μ
Thickness of roofs and floors	20–30 μ	20 μ	20 μ	10–20 μ

* Double embryonic chambers.

complete ring of periembryonic chambers.

In many specimens there is more than one set of embryonic chambers, the number of which may be two, three or four. Measurements of the individual embryonic

The lateral chambers are not arranged in definite tiers. The chamber cavities are very low, appressed, slit-like between heavy floors and roofs.

Pillars are not present.

Comparisons.—This new species has an equatorial section which resembles that of *P.* (*P.*) *advena* (Cushman). However, the vertical sections are not at all similar to those of *P.* (*P.*) *advena* (figs. 4, 9, pl. 100) as the lateral chamber cavities are lower and more appressed, the floors and roofs are thinner and there are more lateral chambers to a tier.

In vertical section this species does have a resemblance to *P.* (*P.*) *cloptoni* (fig. 8, pl. 100) and *P.* (*P.*) *perkinsi* (fig. 7, pl. 100). The general structure is, however, much coarser than either of the named species, and in consequence there are fewer lateral chambers to a tier.

The embryonic chambers of this new species are frequently multiple (fig. 6, pl. 95), a feature which Vaughan (1929, pl. 5, figs. 4, 5) found in *P.* (*P.*) *cloptoni.* However, vertical sections are sufficiently distinct to allow separation of specimens from Peñon Seep from those described from Mexico.

PSEUDOPHRAGMINA (PROPOROCYCLINA) CONVEXICAMERATA Cole & Gravell, n. sp.
Plate 101, figures 1–3; plate 102, figures 12–19

Test small, evenly lenticular. Surface ornamented by small, raised papillae arranged in concentric circles. The papillae have surface diameters of about 60 μ and are separated from each other by a distance of 40 to 60 μ. The papillae are equally well developed over the entire surface of the test.

The embryonic chambers are small and nephrolepidine in type. There is a complete ring of periembryonic chambers surrounding the embryonic chambers.

Measurements of equatorial sections follow:

Equatorial sections of *Pseudophragmina* (*Proporocyclina*) *convexicamerata* Cole & Gravell, n. sp.

Specimen	1	2	3	4
Diameter	3.1 mm.	3.2 mm.	3.2 mm.	3.1 mm.
Embryonic chambers:				
Internal diameter of initial chamber	60 μ	50 μ	60 μ	50 μ
Internal diameters of second chamber	100×140 μ	80×120 μ	100×130 μ	80×90 μ
Distance across both chambers	120 μ	120 μ	120 μ	100 μ
Thickness of outer wall	4 μ	5 μ	5 μ	4 μ
Equatorial chambers:				
Radial diameter				
Near center	20 μ	25 μ	20 μ	20 μ
At periphery	60 μ	80 μ	80 μ	80 μ
Tangential diameter				
Near center	20 μ	20 μ	20 μ	20 μ
At periphery	40 μ	40 μ	40 μ	40 μ

The radial chamber walls are complete, in alignment and very slightly wavy. The annular stolon is in a distal situation.

Measurements of vertical sections made from a series of specimens of this interesting new species are given in the table below:

Vertical sections of *Pseudophragmina* (*Proporocyclina*) *convexicamerata* Cole & Gravell, n. sp.

Specimen	1	2	3	4
Diameter	2.8+ mm.	3.+ mm.	2.7+ mm.	2.24+ mm.
Thickness	1.0 mm.	1.0 mm.	0.86 mm.	0.7 mm.
Embryonic chambers:				
Internal length	120 μ	—	70 μ	40 μ
Internal height	30 μ	—	35 μ	30 μ
Equatorial layer:				
Internal height at center	20 μ	15 μ	10 μ	10 μ
Internal height at periphery	20 μ	20 μ	20 μ	15 μ
Lateral chambers:				
Number on each side of equatorial layer	14	15	12	9
Length	100–120 μ	60–100 μ	40–160 μ	60–100 μ
Height	20 μ	10–20 μ	20 μ	20 μ
Thickness of floors and roofs	20 μ	15–30 μ	20 μ	20 μ
Surface diameter of pillars	40–80 μ	40–80 μ	60 μ	60 μ

The lateral chambers are arranged more or less in tiers, but there is considerable overlapping from one tier to the next adjacent one. The chamber cavities are low with the floors and roofs about equal in thickness to the height of the chamber cavities. Most specimens have the floors and roofs of the lateral chambers convex toward the periphery so that the lateral chambers are arcuate in shape. This condition is especially noticeable in the lateral chambers adjacent to the equatorial layer. Small, slender pillars are irregularly distributed through the vertical sections.

Comparisons.—This new species externally and in equatorial section resembles *P.* (*P.*) *perpusilla* (Vaughan) (1929, p. 9) from the Guayabal formation (Cole, 1927) of Mexico. Therefore, a new vertical section of *P.* (*P.*) *perpusilla* was prepared and is illustrated as figure 11, plate 102. *P.* (*P.*) *perpusilla* is a thinner form with relatively few lateral chambers on each side of the embryonic apparatus.

PSEUDOPHRAGMINA (PROPOROCYCLINA) CUSHMANI (Vaughan)
Plate 99, figures 1–5

Discocyclina cushmani VAUGHAN, 1929, Proc. U. S. Nat. Museum, vol. 76, art. 3, pp. 11–13, pl. 3, figs. 1–4.

Pseudophragmina (*Proporocyclina*) *cushmani* VAUGHAN, 1945, Geol. Soc. America Mem. 9, pp. 94, 95, pl. 38, figs. 1–3*a*; —— COLE & BERMUDEZ, 1947, Bull. Amer. Paleont., vol. 31, no. 125, pp. 18, 19, pl. 6, figs. 1–4; pl.7 fig. 9.

In the description of a fauna from a road-cut at Finca "La Coronela" on the road from Habana to Rancho Boyeros, Habana Province, Cole and Bermudez (1947) report this species among others. This Cuban occurrence was the first to be recorded for this species outside of its type area in the Mecapala Hills southwest of Tantoyuca, State of Vera Cruz, Mexico.

The equatorial sections of this species are not distinctive, but the vertical sections are. There is a small, sharp umbo at the center which is surrounded by a wide, thin, flat rim.

The original description and illustration of the external features of this species is excellent. Subsequently, Vaughan published photomicrographs of additional thin sections which show the internal structures in a most adequate manner. The specimens in the present collection agree at all points with the type specimens from Mexico.

Measurements made from thin sections of typical specimens in the present collection follow:

Vertical sections of *Pseudophragmina* (*Proporocyclina*) *cushmani* (Vaughan)

Specimen	1	2	3
Diameter	5.48 mm.	5.2 mm.	5.2 mm.
Diameter of umbo	1.1 mm.	1.6 mm.	1.2 mm.
Width of flange	2.1 mm.	1.8 mm.	1.9 mm.
Thickness of umbo	1.1 mm.	1.3 mm.	1.2 mm.
Thickness of flange near umbo	0.46 mm.	0.6 mm.	0.6 mm.
Thickness of flange near periphery	0.3 mm.	0.5 mm.	0.4 mm.
Embryonic chambers:			
Length	200 μ	180 μ	160 μ
Height	60 μ	80 μ	90 μ
Equatorial layer:			
Height at center	5 μ	4 μ	3 μ
Height at periphery	20 μ	20 μ	17 μ
Lateral chambers on each side of equatorial layer:			
In umbo	14	16	16
In flange near umbo	6	9	7
In flange near periphery	1	3	2
Lateral chambers:			
Length (umbonal, peripheral)	120 μ	100–120 μ	90 μ
Height (umbonal, peripheral)	20 μ	15 μ	5–15 μ
Thickness of roofs and floors	20 μ	20 μ	20 μ
Surface diameter of pillars	40–60 μ	40 μ	40–70 μ

Discussion.—There is little doubt that the vertical section of "*Orthophragmina*" = *Asterocyclina antillea* published by Cushman (1919, pl. 2, fig. 3, lower left corner) as one of the type illustrations of this species represents *P.* (*P.*) *cushmani.*

PSEUDOPHRAGMINA (PROPOROCYCLINA) PENONENSIS Cole & Gravell, n. sp.
Plate 103, figures 2–9

Test slightly selliform, composed of three distinct portions, a depressed central area, a broadly rounded elevated portion and a wide, thin rim. Scattered, and rather inconspicuous papillae occur in the central area, but large, closely spaced, prominent papillae occur on the elevated ring-shaped area which surrounds the central depression. The outer rim has a few, widely scattered small papillae.

The embryonic chambers are large, thin-walled, with the second chamber enclosing the initial chamber except along the common boundary of the chambers. A ring of periembryonic chambers completely surrounds the embryonic chambers except for a short distance near the middle of the common boundary between the initial and the second chamber where periembryonic chambers do not occur.

Measurements of equatorial sections follow:

The lateral chambers near the equatorial plane have slit-like cavities between very thick roofs and floors. Near the periphery the lateral chambers have more open cavities and the floors and roofs are not so thick. The lateral chambers are not arranged in regular tiers.

The ring-like elevated portion of the test has more layers of lateral chambers than does the depressed central portion. Moreover, the lateral chambers in the elevated portion have slightly thicker roofs and floors than do those in the central area.

Heavy pillars are concentrated in the elevated portion of the test. Scattered pillars occur in both the depressed, central portion and in the marginal rim.

Comparisons.—In cross-sectional form this species resembles *Orthophragmina umbilicata* Deprat (1905, p. 497, pl. 16, figs. 2–11) from the Eocene of New Caledonia. Fortunately, Deprat gives an excellent illustration of the equatorial chambers of this species. They prove that *O. umbilicata* should be placed in the genus *Discocyclina.*

Cole (1942, p. 46) identified certain specimens from the lower middle Eocene of Florida from Florida Oil Discovery Company's Cedar Keys well No. 2 with *Pseudophragmina* (*Proporocyclina*) *zaragosensis* (Vaughan) from the Eocene of Mexico. Later, Cole (1944, p. 81) created a new species *P.* (*P.*) *cedarkeysensis* for these specimens. In this same publication, but from the St. Mary's River Oil Corporation, Hilliard Turpentine Company well No. 1, Cole (p. 84) described another new species under the name *P.* (*P.*) *hannai.*

Equatorial sections of *Pseudophragmina* (*Proporocyclina*) *penonensis* Cole & Gravell, n. sp.

Specimen	1	2
Diameter	5.0 mm.	6.5 mm.
Embryonic chambers:		
Internal diameters of initial chamber	240×280 μ	220×240 μ
Internal diameters of second chamber	400×600 μ	500×540 μ
Distance across both chambers	460 μ	500 μ
Thickness of outer wall	15 μ	10 μ
Equatorial chambers:		
Near center		
Radial diameter	60 μ	40 μ
Tangential diameter	40 μ	40 μ
Near periphery		
Radial diameter	50 μ	80 μ
Tangential diameter	40 μ	20 μ

The radial chamber walls are rather well-developed, slightly wavy and in alignment. The annular stolon is located on the distal side.

Measurements of vertical sections are shown at the top of the next page.

Vertical sections of *Pseudophragmina* (*Proporocyclina*) *penonensis* Cole & Gravell, n. sp.

Specimen	1	2	3	4
Total diameter		5.6+ mm.	9.2 mm.	8.+ mm.
Umbonal diameter	3.8 mm.	3.9 mm.	4.4 mm.	5.0 mm.
Width of flange	missing	1.0+ mm.	2.8 mm.	1.6+ mm.
Thickness at central depression	0.84 mm.	0.94 mm.	1.04 mm.	1.08 mm.
Thickness of elevated portion surrounding depressed center	0.92 mm.	1.1 mm.	1.4 mm.	1.6 mm.
Embryonic chambers:				
Internal length	440 μ	520 μ	540 μ	500 μ
Internal height	160 μ	200 μ	200 μ	220 μ
Thickness of outer wall	20 μ	20 μ	20 μ	20 μ
Equatorial layer:				
Internal height at center	3 μ	5 μ	6 μ	6 μ
Internal height at periphery	6 μ	10 μ	25 μ	20 μ
Lateral chambers:				
Number on each side of equatorial layer				
At center	12	12	13	14
In the elevated portion	14	15	17	23
Internal length	60–100 μ	60–100 μ	80–100 μ	80–140 μ
Internal height	20 μ	15 μ	10 μ	20 μ
Thickness of roofs and floors	20 μ	20 μ	20 μ	20 μ
Pillars:				
Surface diameter	100 μ	100–120 μ	100 μ	120 μ

The Floridian specimens have been restudied, and it is apparent the entire series represents only one species, here designated *P.* (*P.*) *cedarkeysensis* with *P.* (*P.*) *hannai* a synonym.

Certain of the Floridian specimens, particularly those formerly known as *P.* (*P.*) *hannai* possess a slightly depressed central area and have a bordering rim. A vertical section of one of these is illustrated as figure 1, plate 103.

Some of the Cuban specimens have a barely depressed central area. This form is illustrated by the vertical section figure 2, plate 103. Therefore, one extreme of the Cuban form is very similar in external shape to that of certain of the Floridian specimens.

If external shape only were considered, it would be entirely reasonable to assign the Floridian and Cuban specimens to the same species. Internally, however, there appear to be differences by which the two types can be separated even with specimens of the same external shape.

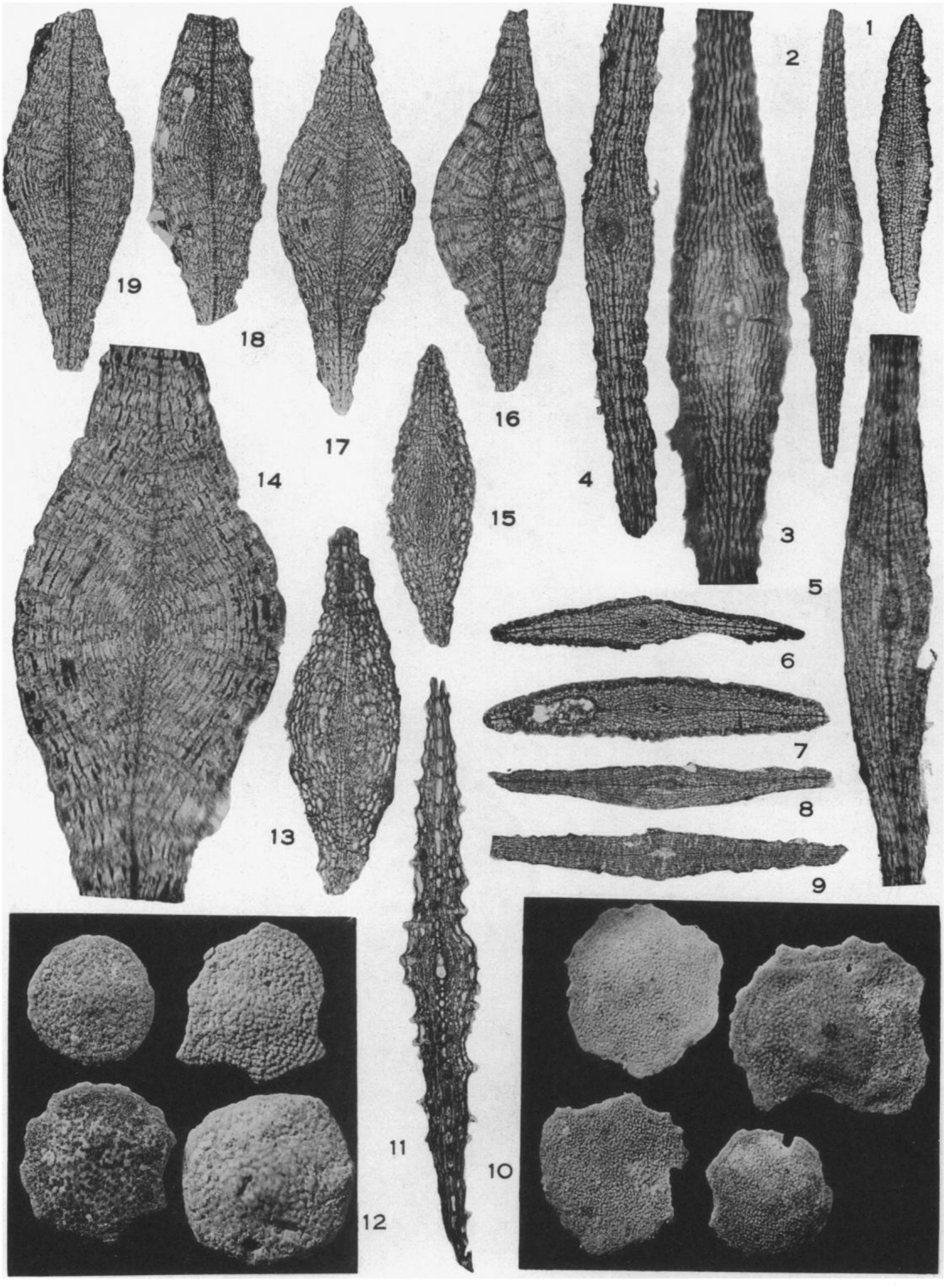
In equatorial section the embryonic chambers of *P.* (*P.*) *penonensis* are twice as large as those of *P.* (*P.*) *cedarkeysensis*, and the radial walls of the equatorial chambers of *P.* (*P.*) *penonensis* are much better developed than those of *P.* (*P.*) *cedarkeysensis*. In vertical section the lateral chambers are arranged more regularly and have thinner floors and roofs in *P.* (*P.*) *penonensis* than in *P.* (*P.*) *cedarkeysensis*. However, there are many aspects of the vertical sections which appear very similar, if not identical.

EXPLANATION OF PLATE 102

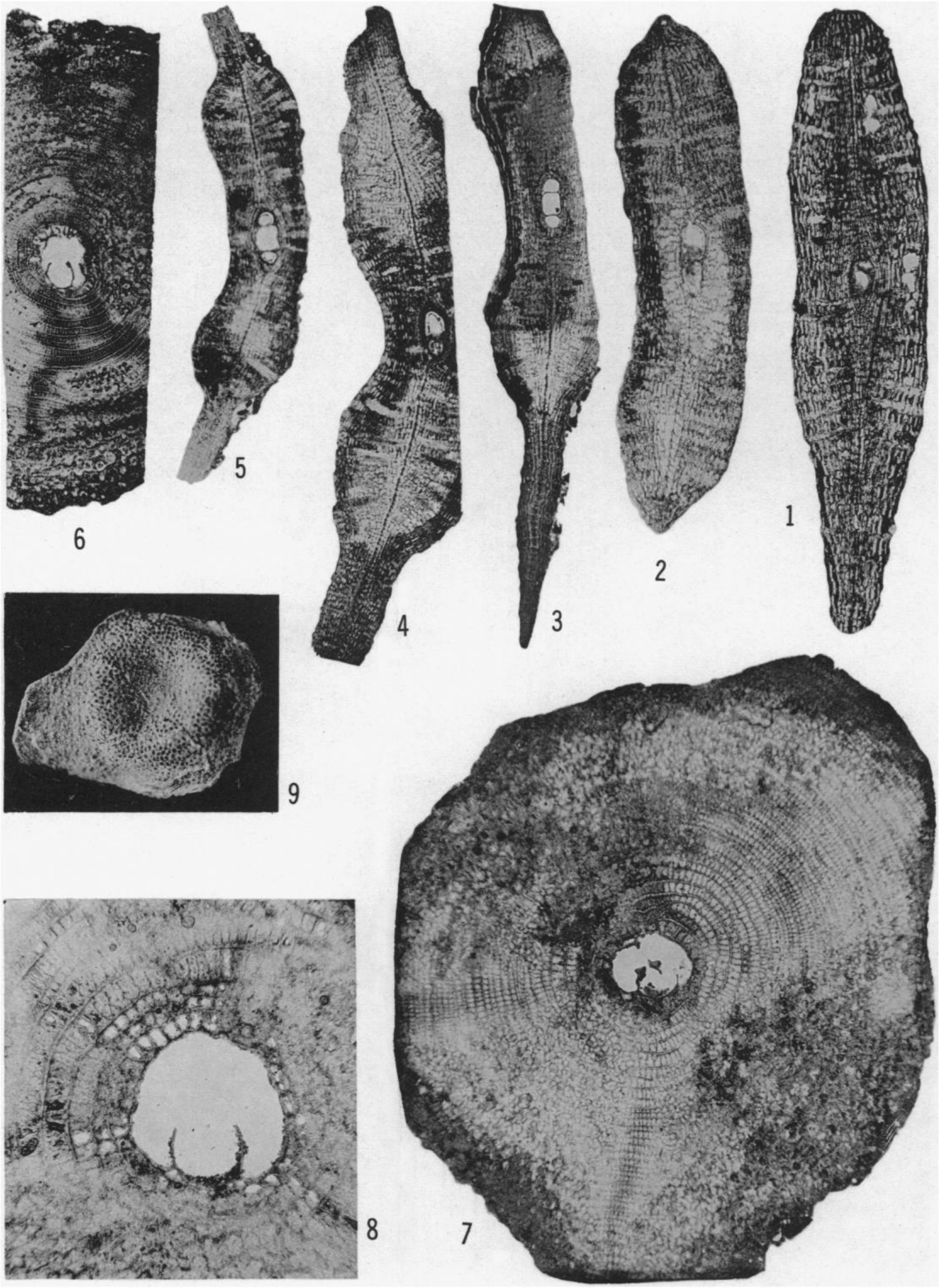
FIGS. *1–10*—*Pseudophragmina* (*Proporocyclina*) *psila* (Woodring). *1–9*, vertical sections, *1*, *2*, *6–9*, ×20; *3–5*, ×40; *4*, *5*, *8*, *9*, topotype specimens from Cal. Inst. Tech. Loc. 595, south slope of western Santa Ynez Range, Santa Barbara County, California, west side of Canada de los Sauces 1.2 miles above coast, introduced for comparison with the Cuban specimens; *10*, external views, ×10, of 4 specimens. (p. 725)

11—*Pseudophragmina* (*Proporocyclina*) *perpusilla* (Vaughan). Vertical section, ×40, from a speeimen from the type locality of the Guayabal formation, introduced for comparison. (p. 722)

12–19—*Pseudophragmina* (*Proporocyclina*) *convexicamerata* Cole & Gravell, n. sp. *12*, external views, ×10, of 4 specimens; upper left specimen, holotype, Cole collection No. 411; *13–19*, vertical sections, ×20, except *14*, ×40. (p. 721)



Cole and Gravell, Cuban Eocene Foraminifera



Cole and Gravell, Cuban Eocene Foraminifera

The vertical sections of this new species also resemble those of *Discocylina* (*Discocyclina*) *grimsdalei* Vaughan and Cole, known from Trinidad and Barbados. However, *D.* (*D.*) *grimsdalei* is correctly assigned generically and, therefore, is distinct from the specimens under discussion.

PSEUDOPHRAGMINA (PROPOROCYCLINA) PSILA (Woodring)
Plate 101, figures 4, 5; plate 102, figures 1–10

Discocyclina psila WOODRING, 1930, Trans. San Diego Soc. Nat. Hist., vol. 6, pp. 148–151, pl. 14, figs. 2, 4–6; pl. 15, fig. 17; — VAUGHAN, 1936, Jour. Paleontology, vol. 10, pp. 255, 256, pl. 42, figs. 7, 8.
Pseudophragmina (*Proporocyclina*) *psila* VAUGHAN, 1945, Geol. Soc. America, Mem. 9, pp. 65, 104, 106, 115.

Test small, compressed, thin, evenly lenticular without an umbo. Surface ornamentation consists of closely-spaced, slightly raised, papillae evenly distributed over the entire surface.

The embryonic chambers are small and nephrolepidine in type. These chambers are completely surrounded by a ring of periembryonic chambers with about ten chambers in the ring.

Measurements of equatorial sections follow:

The radial chamber walls are well developed, in alignment and slightly wavy. The annular stolon is on the distal side of the radial chamber walls.

Measurements of vertical sections are shown at top of next page.

The cavities of the lateral chambers are slit-like between thick roofs and floors. The lateral chambers are not in regular tiers. Small, slender pillars are irregularly scattered throughout the entire length of the vertical sections.

Discussion.—Through the courtesy of Drs. Wendell P. Woodring and Charles Merriam, a generous supply of topotype specimens were made available for study. Two vertical sections and enlarged portions of two others, made from the topotype specimens, are illustrated for comparison with the specimens from Peñon Seep. It is impossible to separate the California specimens from those found in Cuba.

PSEUDOPHRAGMINA (PROPOROCYCLINA) TERES Cole & Gravell, n. sp.
Plate 100, figures 3, 10–12, 14; plate 101, figures 6–8

Test either inflated lenticular or with a distinct umbo bordered by a wide gently sloping rim. Surface smooth, unornamented, but with irregular light areas scattered over

Equatorial sections of *Pseudophragmina* (*Proporocyclina*) *psila* (Woodring)

Specimen	1	2	3
Diameter	1.9 mm.	2.4 mm.	2.8 mm.
Embryonic chambers:			
Diameters of initial chamber	40 μ	35 μ	40 μ
Diameters of second chamber	30×60 μ	35×65 μ	40×100 μ
Distance across both chambers	70 μ	70 μ	80 μ
Equatorial chambers:			
Near center			
Radial diameter	20 μ	25 μ	25 μ
Tangential diameter	20 μ	20 μ	20 μ
Near periphery			
Radial diameter	70 μ	60 μ	50 μ
Tangential diameter	20 μ	20 μ	20 μ

EXPLANATION OF PLATE 103

FIG. *1*—*Pseudophragmina* (*Proporocyclina*) *cedarkeysensis* Cole. Vertical section, ×20, of a specimen, from a depth of 1745–1752 feet from the St. Mary's River Oil Corporation, Hilliard Turpentine Company well No. 1, located in Nassau County, Florida, introduced for comparison with *P.* (*P.*) *penonensis*. (p. 723)

2–9—*Pseudophragmina* (*Proporocyclina*) *penonensis* Cole and Gravell, n. sp. *2–5*, vertical sections, *2*, ×20; *3*, ×12.5; *4*, ×20; *5*, ×12.5; *6–8*, equatorial sections, *6*, ×12.5; *7*, ×20; *8*, ×40; *9*, external view, ×5, of the holotype, Cole collection No. 406. (p. 723)

Vertical sections of *Pseudophragmina* (*Proporocyclina*) *psila* (Woodring)

Specimen	1	2	3	4
Diameter	2.14 mm.	2.4 mm.	2.6 mm.	3.3 mm.
Thickness	0.42 mm.	0.4 mm.	0.5 mm.	0.46 mm.
Embryonic chambers:				
Length	30 μ	40 μ	—	40 μ
Height	25 μ	25 μ	—	40 μ
Equatorial layer:				
Height at center	10 μ	10 μ	10 μ	10 μ
Height at periphery	14 μ	14 μ	14 μ	10 μ
Lateral chambers				
Number	6	6	9	8
Length	60 μ	40 μ	40–60 μ	40–80 μ
Height	10 μ	15 μ	10 μ	10 μ
Thickness of floors and roofs	20 μ	20 μ	20 μ	20 μ
Surface diameter of pillars	20 μ		30 μ	40 μ

a darker background. These light areas undoubtedly represent the position of the lateral chambers.

The initial chamber is circular with an internal diameter of about 130 μ. The second chamber is reniform with internal tial diameter of these chambers is 30 to 40 μ. The radial chamber walls are complete, distinct, slightly wavy and aligned. The annular stolon is located on the distal side of the radial chamber walls.

Measurements of vertical sections follow:

Vertical sections of *Pseudophragmina* (*Proporocyclina*) *teres* Cole & Gravell, n. sp.

Specimen	1	2	3	4	5
Diameter	4.0 mm.	5.68 mm.	6.+ mm.	7.0 mm.	5.2 mm.
Thickness	0.9 mm.	0.92 mm.	1.4 mm.	1.0 mm.	1.0 mm.
Shape	inflated lenticular	sharp umbo flat rim	sharp umbo flat rim	inflated lenticular	inflated lenticular
Embryonic chambers:					
Length	250 μ	480 μ	400 μ	240 μ	300 μ
Height	120 μ	100 μ	160 μ	120 μ	180 μ
Equatorial layer:					
Height at center	5 μ	—	7 μ	7 μ	7 μ
Height at periphery	10 μ	—	15 μ	10 μ	9 μ
Lateral chambers:					
Number	12	12	14	15	12
Length	40–120 μ	20–240 μ	40–220 μ	40–200 μ	40–160 μ
Height	5 μ	5 μ	7 μ	5 μ	7 μ
Thickness of floors and roofs	20–40 μ	20–40 μ	20–60 μ	20–60 μ	20–40 μ

diameters of about 110 by 260 μ. The distance across both chambers is about 240 μ. The outer wall is thin with a thickness of about 5 μ. The embryonic chambers are surrounded by a complete ring of periembryonic chambers.

The equatorial chambers gradually increase in radial diameter as the periphery of the test is approached. Peripheral equatorial chambers have a radial diameter as much as 160 μ, although the average radial diameter is about 100 μ. The tangen-

The lateral chambers are not arranged in regular tiers. Their distribution is very irregular so that it is difficult to decide on the actual number of layers of lateral chambers. The number given in the table is the best approximation that can be made. The chamber cavities are low, appressed between very thick roofs and floors.

Pillars are not present.

Comparisons.—Three species of *Pseudophragmina* (*Proporocyclina*) have vertical sections with low, appressed cavities of the

lateral chambers, thick floors and roofs between the cavities, and overlap of the chamber cavities from one tier to the next adjacent one. These are *P.* (*P.*) *advena* (Cushman) from the Cane River formation of the Claiborne group, *P.* (*P.*) *perkinsi* (Vaughan) from the upper Eocene of Jamaica and *P.* (*P.*) *cloptoni* (Vaughan) from the middle Eocene of Lower California. Portions of enlarged vertical sections of these three species are shown as figures 4, 7, 8, 9, plate 100.

The illustrations show clearly the differences between these species and the specimens from Peñon Seep.

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