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THE GENUS GLOBOTRUNCANA IN NORTHEASTERN COLOMBIA

By

Rolando Gandolfi

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THE GENUS GLOBOTRUNCANA IN NORTHEASTERN COLOMBIA

Rolando Gandolfi*

ABSTRACT

This paper deals with the occurrence, distribution, and development of the genus *Globotruncana* in northeastern Colombia.

Thirty-eight species and subspecies of the genus *Globotruncana* are described and assigned to the subgenus *Globotruncana*. Three species and twenty subspecies of them are new. Twenty-two species and subspecies of forms reminiscent of *Globigerina* with partially or not developed keels are described as closely related to *Globotruncana* along many phylogenetic lines. Three species and eleven subspecies of them are new. These forms are included under *Rugoglobigerina* Bronnimann, 1952, which is used, however, in a broad sense with a slightly modified definition and considered as a subgenus of *Globotruncana*, like *Ticinella*, *Thalmanninella*, and *Rotalipora*.

INTRODUCTION

This paper deals with the genus *Globotruncana* in northeastern Colombia, its occurrence, and stratigraphic distribution. The study is of particular interest, primarily since the genus *Globotruncana* is becoming more and more important due to its wide geographic distribution and its rapid tempo of evolution; secondly, there is a fair opportunity to check, by help of widely distributed pelagic genera, the local stratigraphy of Colombia, the Upper Cretaceous age of which is based on benthonic forms (Cushman and Hedberg, 1941).

Regarding the genus *Globotruncana*, there is no previous record of its occurrence in Colombia, with the exception of *Glt. fornicata* Plummer mentioned by Cushman and Hedberg, 1941.

In Europe the genus was thoroughly investigated during recent years with the aim of obtaining finer stratigraphic subdivisions and recognizing, as far as possible, the morphologic and genetic relationship between the steadily increasing number of new species. Brotzen, 1942, and Sigal, 1948, named respectively the genera *Rotalipora* and *Thalmanninella*. These were considered by Reichel, 1949, as subgenera of *Globotruncana* along with the new subgenus *Ticinella* which he erected. The importance of *Globotruncana*, *s.l.* as a time marker and its interest as paleontologic evidence for evolution has been recognized over the world.

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In America the most notable advance in the study of distribution and development of *Globotruncana* is seen in the recent paper issued by Bolli, 1951, based on the *Globotruncana* fauna of Trinidad.

Thirty-eight species and subspecies of the genus *Globotruncana,* twenty-three of which are new, are described in the paper and assigned to the subgenus *Globotruncana.* Twenty-two species and subspecies of forms reminiscent of *Globigerina,* with partially or no developed keels, have also been described as closely related to *Globotruncana* along many phylogenetic lines. Of these, three species and eleven subspecies are new. These forms are included under *Rugoglobigerina* Bronnimann, 1952, which, however, is used in a broad sense with a slightly modified definition and considered as a subgenus of *Globotruncana,* as are *Thalmanninella, Ticinella,* and *Rotalipora.* No complete systematic study of the abundant "*Globigerina*" population has been carried out, since it was thought to be beyond the scope of the paper. Therefore, the possibility exists that other similar forms may still be present in our material.

These 38 forms were first arranged in groups based on certain morphological similarities. Each of them is believed to represent a unit with a common genetic development.

The groups were in turn subdivided into branches, whenever branches were recognized or postulated. Each of the branches has, or is believed to have, generally the value of a direct line. Obviously, the scientific value of such subdivisions will be, for each case, carefully discussed and their paleontologic evidence verified.

No attempt is made here to place a systematic value on the group or its branches; these divisions only represent forms which appear to be related based on the study to date.

The classification and delimitation of species and subspecies in the present material is felt to be more artificial than usual since frequently one form grades into another without any apparent sharp break in the morphologic line. Consequently, nomenclatural units were created only when a sufficient number of specimens with common characteristics allowed fixing, even if artificially, some limits of variability between the single species and/or subspecies.

The study has been carried out within the limits of detail allowed by the routine work of practical paleontology. A systematic study of the apertures was, therefore, not attempted, although it would have been advisable in many cases. Nevertheless, the fair preservation of the material and the possibility of occasionally cleaning the umbilical cavity in some specimens provided for a fair amount of information. The holotypes of the new species and new subspecies described herein have been deposited in the Paleontological Research Institution of Ithaca, New York; topotypes at the Museo Geológico of Bogotá. Specimens of species not described as new in the text are deposited with the collection of the Micropaleontological Laboratory of the International Petroleum (Colombia), Limited.

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GEOGRAPHIC AND STRATIGRAPHIC OCCURRENCES

The material was derived entirely from the northeastern part of Colombia, where marine Upper Cretaceous sediments are well developed in open sea facies: the Ranchería and César Valleys.

INDEX MAP OF NORTHEASTERN COLOMBIA
SHOWING LOCATION OF SECTIONS AND WELLS
FIG. I

Fig. 1. Index map of northeastern Colombia, showing location of sections and wells.

Three surface sections and two wells have supplied the greatest quantity of the material. The sections are:

1. Manaure Section: César Valley, Rio Manaure, 100 km. east-southeast of the town of La Paz: 60 m. of thin-bedded brown shale weathering gray (Manaure shale, occurrence of *Marginulina jonesi*).

2. Molino Section: César Valley, Rio Molino, 200 km. northeast of the town of Villanueva; 70 m. of Manaure shale underlying 500 m. of soft green silty shale (Colon formation: *Pullenia cretacea* and *Siphogenerinoides bramlettei* zones).

3. Km. 92 Section: Ranchería Valley, Fonseca—Rio Hacha road, 400 km. northeast of the town of Fonseca; a few meters of calcareous, siliceous shale (Manaure ?) underlying 175 m. of Colon formation.

The wells are:

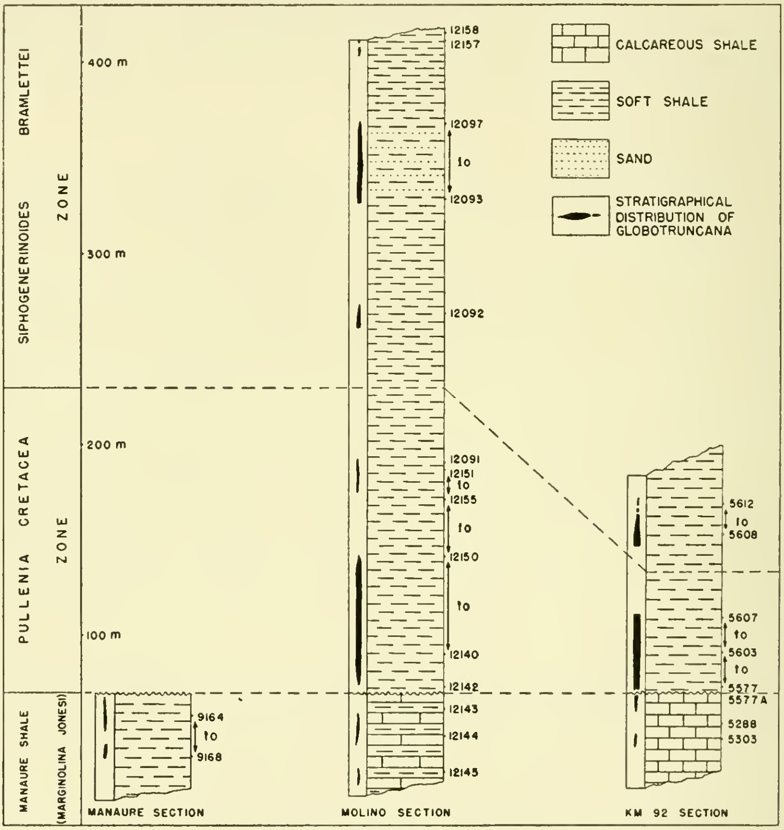
1. Papayal #1, 300 km. north-northeast Fonseca.
2. Cerrejon #1, 200 km. east of Papayal #1.

The best and most fossiliferous material was obtained from the Km. 92 section (Colon shale) and Papayal #1 (Colon shale). In general, the occurrence of *Globotruncana* is more frequent to the north, and locally (wells Cerrejon #1 and Papayal #1) from east to west in accordance with the facies change toward more open sea conditions. This is especially true of, and is limited to, the lower Colon shale (*Pullenia cretacea* zone), where the frequence of *Globotruncana* follows and marks the ingression of the sea from the north. In the upper Colon shale, the population of *Globotruncana* decreases rapidly and disappears completely, corresponding to the progressive development of more brackish conditions at the end of the Cretaceous.

In the Manaure shale, the *Globotruncana* population is scarce and poorly preserved. In the underlying beds a uniform *Globigerina*-*Guembelina*-Radiolaria assemblage is usually all that is present in Colombia.

The study is confined, therefore, to the lower part of the Colon formation (*Pullenia cretacea* zone) and only a few observations were possible for the upper portion (*Siphogenerinoides bramlettei* zone) for the underlying Manaure shale.

The stratigraphic results are consequently considered as indicative. Regarding the local stratigraphic subdivision, it is to be noted that respectively the Manaure shale, the *Pullenia cretacea* zone, the *Siphogenerinoides bramlettei* zone are considered Coniacian, Campanian, and Maestrichtian in age (Santonian has not been



COLUMNAR SECTIONS
WITH STRATIGRAPHICAL DISTRIBUTION OF GLOBOTRUNCANA
FIG.2

Fig. 2. Columnar sections with stratigraphic distribution of *Globotruncana.*

recognized locally). Stratigraphic boundaries cannot be definitely correlated, however, with European time divisions; and overlaps probably exist, as will be brought out when discussing the distribution of *Globotruncana*.

DESCRIPTION OF SPECIES

Genus **GLOBOTRUNCANA** Cushman, 1927

Type species.—By original designation, *Pulvinulina arca* Cushman, 1926, Cont. Cushman Lab Foram. Res., vol. 2, p. 23, pl. 3, fig. 1. Mendez shale, Upper Cretaceous, Mexico.

The following species and subspecies are described in the paper:

	Plate	Figure
Globotruncana lapparenti longilocula, n.subsp.	1	1
Globotruncana mayaroensis Bolli	1	2
Globotruncana tricarinata colombiana, n.subsp.	1	3-4
Globotruncana tricarinata desioi, n.subsp. pp. 27, 103		
Globotruncana ventricosa ventricosa (White)	1	5
Globotruncana marginata austinensis, n.subsp.	1	6
(Rugoglobigerina) beldingi beldingi, n.sp., n.subsp.	1	8
(Rugoglobigerina) beldingi subbeldingi, n.subsp.	1	7
Globotruncana bulloides bulloides (Vogler)	1	9
Globotruncana bulloides globigerinoides (Brotzen)	1	10
(Rugoglobigerina) hexacamerata hexacamerata (Bronnimann)	1	12
(Rugoglobigerina) hexacamerata subhexacamerata, n. subsp.	1	11
Globotruncana bulloides naussi, n. sp., n. subsp.	1	13
Globotruncana mariai, n.n. pp. 33, 106		
(Rugoglobigerina) loetterli subloetterli, n. subsp.	1	14
Globotruncana fornicata fornicata (Plummer)	2	2
Globotruncana fornicata manaurensis, n. subsp.	2	1
Globotruncana fornicata plummerae, n. subsp.	2	3-4
Globotruncana fornicata ackermanni, n. subsp.	2	5-7
(Rugoglobigerina) circumnodifer circumnodifer (Finlay)	2	9

	Plate	Figure
(Rugoglobigerina) circumnodifer subcircumnodifer, n. subsp.	2	8
Globotruncana fornicata cesarensis, n. subsp.	2	10
(Rugoglobigerina) macrocephala macrocephala (Bronnimann)	2	12
(Rugoglobigerina) macrocephala submacrocephala n. subsp.	2	11
Globotruncana caliciformis caliciformis (de Lapparent)	3	1
Globotruncana caliciformis trinidadensis, n. subsp.	3	2
Globotruncana caliciformis sarmientoi, n. subsp.	3	3
Globotruncana intermedia difformis, n. subsp.	3	4-5
(Rugoglobigerina) ornata ornata (Bronnimann)	3	7
(Rugoglobigerina) ornata subornata, n. subsp.	3	6
Globotruncana intermedia intermedia	3	8
(Rugoglobigerina) glaessneri glassneri, n. sp., n. subsp.	3	11
(Rugoglobigerina) glaessneri subglaessneri, n. sp., n. subsp.	3	10
Globotruncana citae Bolli	3	12
(Rugoglobigerina) petaloidea petaloidea, n. sp., n. subsp.	3	14
(Rugoglobigerina) petaloidea subpetaloidea, n. sp., n. subsp.	3	13
Globotruncana contusa contusa (Cushman)	4	3
Globotruncana contusa scutilla, n. subsp.	4	1
Globotruncana contusa patelliformis, n. subsp.	4	2
Globotruncana thalmanni thalmanni, n.sp., n.subsp.	4	4-5
Globotruncana thalmanni flexuosa (van der Sluis)	4	6
Globotruncana aff. cretacea Cushman	4	7
Globotruncana bollii, n. sp.	5	1
Globotruncana arca arca Cushman	5	2-4
Globotruncana arca caribica, n. subsp.	5	5
Globotruncana stuarti stuarti (de Lapparent)	5	6
Globotruncana stuarti parva, n. subsp.	5	7
Globotruncana stuarti conica (White)	5	8
Globotruncana rosetta rosetta (Carsey)	6	1
Globotruncana rosetta insignis, n.subsp.	6	2
Globotruncana rosetta pettersi, n. subsp.	6	3-4
Globotruncana gansseri gansseri Bolli	6	5-6-8

	Plate	Figure
Globotruncana gansseri subgansseri, n. subsp.	6	7
(Rugoglobigerina) rotundata rotundata (Bronnimann)	7	2
(Rugoglobigerina) rotundata subrotundata, n. subsp.	7	1
Globotruncana wiedenmayeri wiedenmayeri, n. sp. n. subsp.	7	4
Globotruncana wiedenmayeri magdalenaensis, n.sp., n. subsp.	7	3
(Rugoglobigerina) rugosa rugosa (Plummer)	7	6
(Rugoglobigerina) rugosa subrugosa, n. subsp.	7	5
(Rugoglobigerina) pennyi pennyi (Bronnimann)	7	8
(Rugoglobigerina) pennyi subpennyi, n. subsp.	7	7

All species listed above are described as belonging to the genus *Globotruncana* with the exception of the forms which are genetically related to *Globotruncana* but morphologically reminiscent of *Globigerina*. These last forms were included under *Rugoglobigerina* Bronnimann, 1952, under the following description, which is slightly modified from the original description of Bronnimann:

> Subgenus *Rugoglobigerina* Bronnimann, 1952. Type by original designation: *Rugoglobigerina rugosa rugosa* (Plummer 1926). Test *Globigerina*-like, almost planispiral to trochoidal. Chambers of *Globigerina* type, rounded peripherally, truncated toward the umbilicus. Umbilical cavity generally large with umbilical apertures, protected by liplike projections. Test smooth, with partially developed keels or rough with rich ornamentation, rugosities of various types, irregularly distributed or arranged in rows radiating from a central point of the surface towards the aperture (meridian pattern). The chambers may be occasionally provided with hantkeninoid points, especially in the first stages of the last whorl.

This subgenus fits into the *Globotruncana* genus according to the definition which was given by Reichel, 1949, (p. 600), as *Thalmanninella*, *Ticinella*, *Rotalipora*, and *Globotruncana*, *s. str.*

In the description of the following species, several morphological terms are used. A few of them perhaps need some kind of explanation:

"Bourrelet sutural" (from French authors): Raised sutures; continuous (pl. 1, fig. 1b) or beaded (pl. 1, fig. 2b).

"Bourrelet umbilical" (from French authors): Sutural thickening limited to the area around the umbilicus (pl. 6, fig. 2b).

Lapparenti type of ventral sutures: Sigmoidal and plunging back into the umbilicus (pl. 1, fig. 1b).

Rosetta type of ventral sutures: Raised, curved, and generally attached to suture of previous chambers (pl. 6, fig. 1b).

Peripheral band: The portion of the test which is embraced by the keels of double-keeled forms (pl. 1, fig. 1c).

Umbilical lips: Slightly arched (pl. 1, fig. 1b), strongly arched with central projections (pl. 5, fig. 6b), nearly straight (pl. 4, fig. 4b, 6b).

Ventral side and dorsal side: In agreement with Reichel, 1949 (p. 602, footnote 7) respectively umbilical and spiral side.

GLOBOTRUNCANA LINNEI GROUP

Description.—Flat or slightly convex forms, double-keeled, two being equally developed, peripheral band at right angle to the coiling plane, and symmetrical in the middle of the chamber; chambers generally flat with occasional protruding or inflated ventral side, elongated or short; thick, continuously raised or finely beaded sutures, marginal elevations partially disappearing when the sutures are radial and depressed in the umbilical side.

The group, as will be discussed later, is in a broad sense intended to include primitive double-keeled species with short chambers and radial sutures (*Glt. imbricata* Mornod, *Glt. inflata* Bolli, *Glt. indica* Jacob and Sastry, *Glt. canaliculata* Reuss); *Glt. lapparenti* forms with elongated chambers and curved sutures on the umbilical side; later evolved species with chambers becoming secondarily short and sutures radial in the same umbilical side (*Glt. canaliculata* Cushman, *Glt. mayaroensis*) and finally forms with protruding, truncated umbilical side (*Glt. tricarinata, Glt. colombiana*, n. sp., *Glt. ventricosa*). Three main branches are here considered:

Lapparenti branch: Flat double-keeled forms.

Tricarinata branch: Flat dorsal side, protruding truncated umbilical side.

Ventricosa branch: Flat dorsal side, protruding umbilical side, chambers inflated on this side.

Apertural system.—All *Glt. linnei* types, regardless of belonging to the *linnei, tricarinata,* and *ventricosa* branches, are characterized by an umbilical cavity with the apertures of the chambers protected by liplike borders which are thin but developed as a continuous thin plate in the more primitive forms (Mornod, 1949, p. 581, fig. 2c, 3c), more strongly developed and split into single arched lips in the last chambers (Reichel, 1949, pl. 16, fig. 9) in *Glt. lapparenti.* With more evolved species as *Glt. colombiana* (fair observations were possible in the Colombian material, Pl. 1, fig. 3, 4), *Glt. ventricosa* (Pl. 1, fig. 5), the cover plates keep their arched shape, but they reduce again to fine lips which tend to blend together as a continuous thin plate all around the umbilicus.

The observations on *Glt. mayaroensis* were poor, but apparently apertural cover plates still exist.

LAPPARENTI BRANCH

Globotruncana lapparenti longilocula, n. subsp.

Pl. 1, fig. 1, Text figs. 3,4 (8a-b)

Description.—Flat or only slightly convex on both sides, peripheral band wide and perpendicular to the coiling plane, double-keeled; chambers short, slightly over-lapping each other in the early stages, becoming later in the adult stage (four-five in the last whorl) long, arched and strongly overlapping (*fornicata* type); sutures continuously raised, sigmoidal on the ventral side, running and plunging back into the umbilicus (*lapparenti* type). Test smooth, dextrally coiling in all counted specimens, umbilical apertures with slightly arched, moderately developed cover plates.

Dimensions of holotype.—Width, 0.40 x 0.36 mm.; thickness, 0.12 mm.

Holotype.—No. 20826, Paleontological Research Institution.

Occurrence.—Rare in the Manaure shale, Manaure and Km. 92 sections. Holotype (Pl. 1, fig. 1a-c) from the Manaure shale, Manaure section, S. 9168.

Remarks.—It is the usual flat double-keeled form of the *lapparenti* type. The chambers, however, are more elongated and arched, the sutures more finely raised than in *Glt. lapparenti lapparenti.*

As can be seen in text figures 3 and 4, the tests of the Breggia material (south Switzerland) have chambers (five-six) in the last whorl which, however, overlap less on each other and increase less rapidly in size as added. In text figure 4 *Glt. lapparenti* Cita appears to be similar with chambers somewhat elongated. The few specimens of the present material show more pronounced elongated chambers. *Glt. tricarinata colombiana* seems to bear an analogous relationship to *Glt. tricarinata tricarinata.*

Glt. canaliculata Cushman (not Reuss) of the Annona chalk is a different, more evolved species, showing more oblique sutures on the dorsal side, which are clearly beaded and, on the ventral side, simply curved without any sigmoidal development; the test, especially in the early chambers, is abundantly spinose.

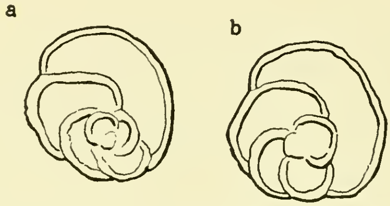


Fig. 3. *Globotruncana lapparenti longilocula,* n. subsp., 60 X, showing the rapid increase in size of the chambers. S. 9168. Manaure shale (*Marginulina jonesi*).

Globotruncana mayaroensis Bolli Pl. 1, fig. 2a-c, Text fig. 4(10a-b)

Globotruncana mayaroensis Bolli, 1951, p. 198, pl. 35, figs. 10-12.

Description.—Besides the double-keeled peripheral band, typical characteristics are, according to Bolli, the oblique arrangement of the chambers with respect to each other and the radial sutures on the umbilical side.

A close examination of our material, as well as of topotype material of Trinidad, shows further that the keels are not parallel or converging in the direction of the coiling, as generally occurs in Upper Cretaceous species, but are diverging, sometimes strongly and in such a way that the last chambers have a considerably wider peripheral band than the early ones. On the umbilical side the sutures are generally radial, but isolated specimens show the last chambers with curved, finely beaded sutures. The lines of beads are, in part, fringing the chambers and, in part, disappearing in the sutural depressions, while the sutures of the early chambers remain radial and depressed.

Occurrence.—Colon shale, Km. 92 section and Papayal well, appearing somewhat in the middle of the *Pullenia cretacea* zone. Rare.

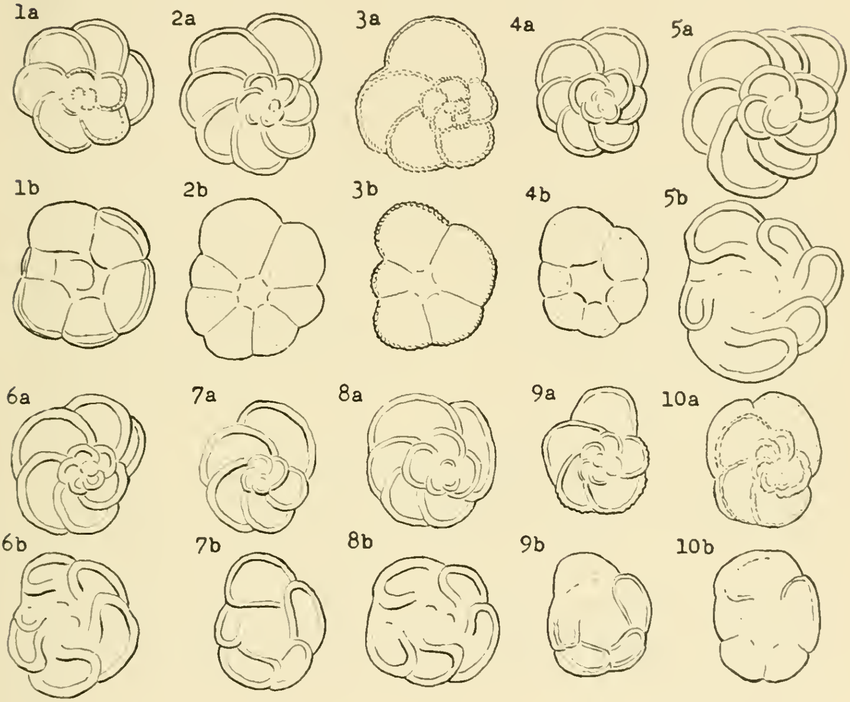


Fig. 4. Comparative view of *Globotruncana* of the *linnei* group. 1a-b. *Glt. imbricata* Mornod, 1949 (Text fig. 5/1,2), Cenomanian, Prealpes Suisses. 2a-b. *Glt. canaliculata* (Reuss, 1854, pl. 26, fig. 4), Cenomanian?-Coniacian, Austria. 3a-b. *Glt. indica* Jacob and Sastry, 1950 (fig. 2), Cenomanian, India. 4a-b. *Glt. linnei* (d'Orbigny, 1839, pl. 5, fig. 10-12), age ? Cuba. 5a-b. *Glt. linnei* Gandolfi, 1942 (Text fig. 16, 2a-c), equivalent to *Glt. lapparenti coronata* Bolli, Turonian, south Switzerland. 6a-b. *Glt. linnei* Gandolfi, 1942 (pl. 3, fig. 3) = *Glt. lapparenti lapparenti* Bolli, Turonian, south Switzerland. 7a-b. *Glt. lapparenti lapparenti* Cita, 1948 (pl. 4, fig. 2), Turonian-Maestrichtian, Tignale, north Italy. 8a-b. *Glt. lapparenti longilocula,* n.subsp., Manaure shale (*Marginulina jonesi*), Colombia, S. A. 9a-b. *Glt. canaliculata* Cushman, 1946 (not Reuss), pl. 61, fig. 17a-c, Annona chalk, Texas. 10a-b. *Glt. mayaroensis* Bolli, Colon shale, *Pullenia cretacea* zone, Colombia, S. A.

Remarks.—No intermediate forms were found with *Glt. intermedia intermedia* as Bolli points out. From fig. 3, *Glt. mayaroensis* occupies a singular position among all *Globotruncana* of the *linnei* group, being quite different from all *Glt. canaliculata, Glt. linnei,* and *Glt. lapparenti* forms. A certain similarity is shown only with *Glt. canaliculata* Cushman of the Annona chalk because of the arrangement and shape of chambers and the straight, oblique sutures.

The position of *Glt. mayaroensis* is, therefore, still uncertain. A genetic as well as a morphologic relationship with *Glt. intermedia* is still possible as Bolli suggests and may be postulated by a slight dorsal convexity, which is occasionally shown in some specimens and by the slightly elongated chambers. It was, however, placed in the *linnei* group because of the wide, double-keeled peripheral band, which is perpendicular to the plane of coiling; the generally flat form with equally flat chambers, which are considered as common characters of the *linnei* group, and because of the similarity to *Glt. canaliculata* Cushman.

TRICARINATA BRANCH

Globotruncana tricarinata colombiana, n. subsp.

Pl. 1, fig. 3a-c, 4a-c, Text figs. 5(1a-c), 5(2a-c), 6(4a-b)

Description.—The form is flat dorsally with protruding umbilical side, sidewall making a large angle with the roof of the chambers, as in *Glt. tricarinata tricarinata* (Quereau, 1893) and *Glt. stuarti.* The peripheral band is wide, perpendicular to the plane of coiling, with two well-developed, parallel keels. The chambers are generally arched, considerably overlapping, and rapidly increasing in size as added. The sutures are curved, generally thick, and continuously raised; on the ventral side the sutural elevations are running sigmoidal around the umbilicus (*lapparenti* type) thickening considerably around the same umbilicus ("bourrelet umbilical," Mornod, 1949) which appears in side view or axial section as a third well-developed keel. The umbilicus is large and open.

In some specimens (Pl. 1, fig. 4, Text fig. 5 (1a-c) the early chambers of the last coil are slightly inflated, gradually becoming flat in the more adult stage; the keels are finely beaded becoming increasingly raised in the adult stage; the test is spinose; on the umbilical side, the sutures are radial and depressed, the chambers slightly inflated. The forms are quite similar to *Glt. ventricosa* (White), as described in detail by Mornod, 1949. The only remaining distinctive characteristic: the strongly developed umbilical thickening. *Glt. ventricosa* of Mornod (*op. cit.* fig. 85/3a-c) may belong to this type of transitional form, but due to the strong umbilical thickening should still belong to the *Glt. tricarinata* type.

Dimensions of holotype.—Width 0.44 x 0.32 mm.; thickness, 0.16 mm.

Holotype.—No. 20827, Paleontological Research Institution.

Occurrence.—Manaure shale; frequent at the bottom of Colon shale (*Pullenia cretacea* zone). Holotype (Pl. 1, fig. 3a-c) from the Colon shale, *Pullenia cretacea* zone, Molino section, S. 12141.

Remarks.—The form shows a side view which is identical to *Glt. tricarinata* (Quereau 1893, pl. 5, fig. 3). As is known, this form is named only from thin section. Later the authors made pictures of *Glt. tricarinata* which show all the same typical axial sections, but the number, shape, and arrangement of chambers (fig. 6) differ considerably. Therefore, the problem arises which of those forms, including ours, is to be identified with the original of Quereau. Since, however, it is here believed that many forms of "*tricarinata* type" are perhaps present in the original material, and since there is no possibility for the writer to check it, the forms figured by Cushman,

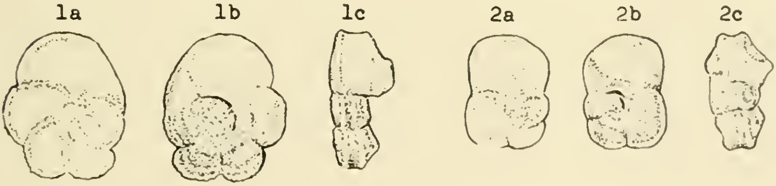


Fig. 5. 1a-c. *Glt. tricarinata colombiana* showing radial, depressed umbilical sutures in the early chambers of the last volution and slightly inflated roof of chambers. S. 5591. Colon shale, *Pullenia cretacea* zone, 2a-c. *Glt. tricarinata colombiana ?;* notice extreme development of last chambers. S. 5606. Colon shale, *Pullenia cretacea* zone. 60 X.

1936 (pl. 61, fig. 18a-c) are considered as holotype of *Glt. tricarinata tricarinata* in spite of some apparently evolved characteristics.

It is of particular phylogenetic interest to describe in detail a single specimen which was found high and isolated in the section and is shown in fig. 4 (2a-c). The side view shows the identical profile which is common to all *tricarinata* forms with the third keel well developed. Peculiar, however, is the extreme development of the last chamber, the spinose test, the radially depressed umbilical sutures in the early stages and the slight inflation of the chambers. In accordance with our procedure of not creating any new nomenclatural units without having a sufficient number of specimens, this specimen has been considered as a *Glt. tricarinata colombiana* and was consequently not named. It is believed, however, that it may represent a stage of a well-defined line of evolution and, accordingly, a new species or subspecies for the following reasons:

1. It cannot be interpreted as an immature form of *Glt. colombiana* because of the extremely peculiar development of the last chambers.
2. It was found isolated and high in the section where no *Glt. colombiana* was found.

A similar tendency toward such forms with few chambers in the last whorl is shown in other groups (cf. *Glt. cesarensis*, Pl. 2, fig. 10a-c).

VENTRICOSA BRANCH

Globotruncana ventricosa ventricosa (White) Pl. 1, fig. 5a-c

Glt. ventricosa White, Cushman 1946, p. 150, pl. 62, fig. 3a-c; Mornod, 1949, p. 590, fig. 121a-c; Cita 1948, p. 20, pl. 4, fig. 9.

Description.—The early chambers tend to become short with radial sutures (general genetic development). The sutures are finely beaded. Four or five chambers are present in the last whorl with a more pronounced increase in size as in the references. In some specimens the first chambers of the last whorl show a slight inflation on the dorsal side (cf. *Glt. tricarinata colombiana*, Pl. 1, fig. 4a-c, Text fig. 5 (1a-c).

Higher in the section (*Glt. gansseri* zone) the keels are slightly converging so that in the last chambers they are almost joined.

Occurrence.—Colon shale. Rare.

Remarks.—By comparing the figures of Cushman (Cushman, 1936, pl. 62, fig. 3a-c), Cita (Cita, 1948, pl. 4, fig. 9a-c) and Mornod (Mornod, 1949, text fig. 12 1a-c), there are practically no appreciable differences. However, it can be seen that the specimen shown by Cita is slightly flatter than the other one; the specimen of Mornod has a more pronounced petaloid periphery. Our Colombian material, however, has increasingly larger chambers.

Bolli suggests for this species a genetic derivation from *Glt. tricarinata* which appears probable to the writer (see description of *Glt. tricarinata colombiana*). It is noteworthy that the American records of the species do not agree, having different stratigraphic ranges in Texas, Mexico, and Trinidad.

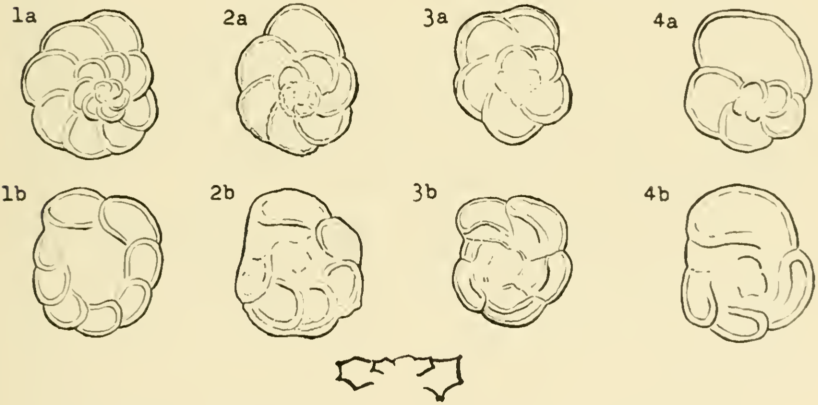


Fig. 6. Comparative view of *Globotruncana* of the *tricarinata* branch. 1a-b. *Glt. tricarinata* Cita, 1948 (pl. 4, fig. 4) Turonian-Maestrichtian, Tignale Nord Italy 2a-b. *Glt. tricarinata* Cushman, 1936 (pl. 61, fig. 18), St. Johann, Bavaria, Germany. 3a-b. *Glt. tricarinata* Mornod, 1949 (fig. 12/2a-c) which is probably a *Glt. ventricosa ventricosa* (White), Santonian, Préalpes, Suisses. 4a-b. *Glt. tricarinata colombiana*, Colon shale, *Pullenia cretacea* zone, Colombia, S. A.

COMMENTS ON THE PHYLOGENETIC DEVELOPMENT OF THE LINNEI GROUP

Although the Colombian material is poor in *linnei* forms and consequently is not favorable for phylogenetic investigation, some general considerations will be tentatively discussed.

From the bibliographic references, it appears that all flat, double-keeled forms have been called *Glt. linnei* in Europe and *Glt. canaliculata* in America. The writer believes that there are many different species of flat two-keeled forms within what has been called *Glt. linnei* in Europe and *Glt. canaliculata* in America. The reason for this is that in many cases only thin sections were available (Renz, 1936).

Brotzen (1936) recognized that the forms described by De Lapparent as *linnei* were not identical to *Glt. linnei* (d'Orb). Accordingly, the flat forms with elongated sigmoidal raised sutures on the umbilical side were later separated (*Glt. lapparenti* Brotzen) from other forms which show depressed, radial sutures (*Glt. linnei, Glt. canaliculata*). Figure 4 shows a comparative view of some of the main flat, double-keeled forms.

Flat forms with a sharp three-keeled profile were called *Glt. tricarinata* from *Glt. tricarinata* (Quereau) which is known only from thin sections. *Glt. tricarinata* was often included in *Glt. canaliculata* (Cushman, 1936) or considered as a subspecies of *Glt. lapparenti* by other authors (Vogler, Cita, Bolli). Figure 6 shows a comparative view of "*tricarinata*" forms.

Flat double-keeled forms with chambers more or less inflated on the ventral side were called *Glt. ventricosa* (White). This species was first described as a "variety" of *Glt. canaliculata* and later as a separate species closely related to *Glt. tricarinata* (Mornod, 1949, Bolli, 1951).

From the above short review it appears that *linnei* (*lapparenti*), *tricarinata*, and *ventricosa* tests are considered genetically related. The writer does not object to this view. The respective morphological relationship was pointed out also in the species descriptions and appears unquestionable. The only problem is to define when the splitting of the three main phylogenetic developments occurred. From our material it appears that the *ventricosa* branch diverged from the *tricarinata* branch last (Santonian?), since forms which can be interpreted as transitional ones between *ventricosa* and *tricarinata* are still to be observed in Campanian (Pl. 1, fig. 4a-c, Text fig. 5/1a-c). Link forms between *tricarinata* and *linnei* branches have not been found to date but, as far as can be judged from stratigraphic records, a divergence between these branches should have been not later than Turonian.

Lapparenti branch.—Following the view of Brotzen (1936) in respect to *lapparenti* and *linnei* forms, later authors (Bolli, Vogler) developed the opinion that two groups of double-keeled, flat *Globotruncana* may exist with a different, independent genetic development. Contrary to this view, all flat double-keeled forms herein studied have been considered as belonging to a single evolutionary system. In fact, from fig. 4 it appears that:

Primitive double-keeled *Globotruncana* of Cenomanian and Turonian time (Text fig. 4(1a-b), 4(2a-b), 4(3a-b), respectively *Glt. imbricata*, *Glt. canaliculata?*, *Glt. indica* (as well as *Glt. stephani?* Gandolfi, 1942, *Glt.* aff. *renzi* Reichel, 1949, which are not considered in the figure) have more or less beaded dorsal sutures, a regularly convex dorsal side, narrow umbilicus, radial depressed sutures on the umbilical side.

Glt. canaliculata is known and described from the Gosaumergel (Austria) which ranges from uppermost Cenomanian to Coniacian. The exact stratigraphical position of the specimen illustrated is unfortunately not given but, from the figure, this species shows quite primitive characteristics, such as to place it close to *Glt. indica*. (This species has only chambers which rapidly increase in size).

Later forms have long continuously raised sigmoidal sutures on the umbilical side (*lapparenti* type) like *Glt. linnei* Gandolfi, 1942, of southern Switzerland (=*Glt. lapparenti* Brotzen) and of Turonian age, or *Glt. lapparenti* Cita, 1948, of north Italy and ranging, according to the author, from Turonian to Maestrichtian.

The above mentioned form illustrated by Cita, 1948, is slightly different from the species illustrated by Gandolfi, 1942, in that it has more elongated chambers which increase rapidly in size, more or less like our Colombian forms do (unfortunately the exact position of the specimen illustrated by Cita is not known).

Later forms generally show more finely beaded, straight, and oblique sutures on the dorsal side, spinose test, and large umbilicus like *Glt. canaliculata* Cushman, Annona chalk (Campanian), or *Glt. mayaroensis* Bolli of Trinidad (late Campanian?-Maestrichtian).

Among these forms *Glt. coronata* Bolli [fig. 4 (5a-b)] and *Glt.*

linnei d'Orb. have also been illustrated [fig. 4 (4a-b)]. *Glt. coronata*[1], however, diverges from the average *lapparenti* type (five-six chambers) by developing an exceptionally greater number of chambers (seven and even eight) in the last whorl. *Glt. linnei* (d'Orb.) is still a form of uncertain morphological characters, due to the insufficient original figure and description and even more uncertain stratigraphical position (beach sand of Cuba). It is here interpreted as a primitive form closely related to *Glt. canaliculata* and *Glt. indica* (the umbilicus is considerably larger) due to the apparent morphological similarity.

The stratigraphic sequence above appears valid even though it cannot be checked in detail. Therefore, it seems probable that:

Young primitive double-keeled *Globotruncana* with umbilical radial depressed sutures (*stephani-canaliculata* types) have developed into *Globotruncana* with raised sigmoidal sutures (*lapparenti* types).

The *lapparenti* type has evolved into forms with more and more elongated chambers (Coniacian) of *fornicata* type and later still (Santonian-Campanian) into forms with shorter chambers, petaloid periphery, beaded sutures and radial depressed sutures on the umbilical side (*Glt. canaliculata* Cushman, *Glt. mayaroensis*).

To support this opinion it may be seen that:

The phylogenetic tendency from primitive forms with radial umbilical sutures to *lapparenti* types is evident by comparing primitive and *lapparenti* forms. The general derivation of the *Glt. lapparenti* type from a *stephani* form was also proved by Reichel's (1949) study on the apertural system.

The phylogenetic trend toward forms with more rapidly increasing chambers is to be observed in the *tricarinata* branch (*Glt. tricarinata colombiana*) and is also suggested by *Glt. lapparenti longilocula* in the *lapparenti* branch.

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[1] *Glt. lapparenti coronata* (Bolli) was considered synonymous with *Glt. linnei* var. *angusticarinata* Gandolfi, 1942 by Sigal, 1948 (p. 14). The forms are, however, similar but not identical since *Glt. linnei* "var." *angusticarinata* is a *lapparenti* form (*Glt. lapparenti angusticarinata*) with pronounced dorsal and ventral convexity. *Glt. lapparenti coronata* is present in the Breggia material (Gandolfi, 1942); in fact, fig. 46 shows typical *Glt. lapparenti lapparenti* (1a-c), *Glt. lapparenti coronata* (2a-c), and *Glt. lapparenti angusticarinata* (3a-c) together.

The phylogenetic trend toward new forms with shorter chambers, radial umbilical sutures and spinose tests appears from the detailed studies of the *ventricosa* branch, in the *bulloides*, *fornicata*, and *thalmanni* groups, as a general morphological trend. There is no reason to assume that the *linnei* branch should have behaved differently from the other branches or groups.

Tricarinata branch.—In fig. 6, different types of *Glt. tricarinata* are compared since they were illustrated by different authors.

Taking as an average type the specimen of Cushman (Senonian ?)[2] which has a normal number of chambers (five-six) in the last whorl, there are tests with an exceptionally large number of chambers (seven-eight) in the last whorl—*Glt. tricarinata* Cita, 1948—[3]identical to *Glt. tricarinata*, Noth, 1951 (pl. 8, fig. 18a-c), and tests with fewer chambers in the last whorl which are more elongated and increase more rapidly in size (*Glt. tricarinata colombiana*). Large and petaloid chambers (fig. 5 (1a-c), 5(2a-c) with radial, depressed, umbilical sutures are suggested to have developed in uppermost Cretaceous time. Therefore, though the stratigraphic sequence cannot be entirely checked, the main evolutionary trend appears to be that primitive *tricarinata* forms with short chambers (Turonian) developed into tests with more elongated chambers during Coniacian time (*Glt. tricarinata colombiana*) and these again into forms with shorter chambers and depressed radial sutures in Santonian-Campanian time. High chambered tests diverge from this main evolutionary line in an analogous way as *Glt. lapparenti coronata* does within the *lapparenti* branch.

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[2] The specimen figured shows, however, some apparently more evolved characters, like chambers increasing in size as added, sutures slightly oblique and, which is perhaps of phylogenetic interest, early chambers being quite elongated and arched (*fornicata* type). This, together with the age of the fossil (Senonian) indicates that the type figured may differ from a theoretically postulated main type (chamber arrangement like *Glt. lapparenti*) as *Glt. lapparenti lapparenti* Cita, 1948 or *Glt. lapparenti longilocula* differ from the typical and earlier *Glt. lapparenti lapparenti*.

[3] Pending a more detailed study on *tricarinata* types, the form of Cita with such a large number of chambers should be considered at least as a subspecies of *Glt. tricarinata tricarinata* and newly named *Glt. tricarinata desioi*. The new subspecies name is proposed after Prof. A. Desio, Head of the Geological Institute of the Milan University, who sponsored the paleontological investigation of Cita. Ref.: *Globotruncana lapparenti tricarinata* Cita (not Quereau) 1948, p. 15, pl. 4, fig. 4.

Another special phylogenetic line seems to be represented by forms with an extremely reduced number of chambers in the last whorl as suggested by the specimen in text fig. 5(2a-c).

Ventricosa branch.—In regard to the evolution of this branch there is little evidence, since our specimens are almost identical with the species illustrated by Cushman and Mornod. However, some of the slight differences which were noticed in the various figures of *Glt. ventricosa* take on some meaning from the point of view of evolution. The petaloid contour of *Glt. ventricosa* Mornod is quite similar to that of *Glt. aegyptiaca* Nakkady. Since the keels in our material have been observed to converge into a single one (late Campanian-Maestrichtian), a development toward forms with a more lobate periphery and less chambers in the last coil (*Glt. aegyptiaca* Nakkady and its "variety" *duwi*) is suggested inasmuch as similar developments occur in other groups and seem to follow this general plan (cf. *Glt. fornicata cesarensis*).

Concluding remarks.—From a close comparison of our material with the available references, it appears that the *linnei* and *tricarinata* branches evolved in a similar way. The *lapparenti* branch appears to develop from primitive *stephani-canaliculata* forms with radial umbilical sutures to *lapparenti* types with raised sigmoidal sutures. These latter develop more elongated chambers which later change to large petaloid chambers leading eventually to *mayaroensis* forms which have radical depressed umbilical sutures due to secondary genetic process. The *tricarinata* branch, which appears later, develops from an average *lapparenti* form to ones with more elongated chambers and to forms with larger chambers, lobate periphery and radial umbilical sutures. The *ventricosa* forms, which appear last, develop only from tests with raised umbilical sutures to lobate forms with radial, depressed, umbilical sutures. Lateral development toward tests with many chambers in the last whorl apparently takes place in both the *tricarinata* and *lapparenti* branches. Trends toward forms with extremely few chambers in the last whorl are probably present in the *tricarinata* (text fig. 5 (2a-c) and *ventricosa* branches (*Glt. aegyptiaca* Nakkady var. *duwi* Nakkady?).

GLOBOTRUNCANA BULLOIDES GROUP

Description.—Flat "*linnei* types," double keel becoming faint and gradually disappearing, chambers inflated, developing toward a complete *Rugoglobigerina* test.

It is divided into three branches:

marginata branch; *bulloides* branch; *naussi* branch

Apertural system.—The observations are poor because of the hard, siliceous material filling the umbilical cavity. However, the apertural system belongs to the *lapparenti* type with wide umbilical cavity and reduced arched lips covering the apertures. In the *Rugoglobigerina* forms the lips tend to reduce to a thin continuous plate around the umbilicus. In some forms the aperture of the last chamber appears to extend slightly toward the periphery.

MARGINATA BRANCH

Globotruncana marginata austinensis, n. subsp. Pl. 1, fig. 6

Globotruncana marginata (Reuss) Thalmann, Cushman, 1936, p. 150, pl. 62, fig. 2a-c.

Description.—Flat form or slightly convex on both sides, double-keeled. Keels close to each other, chambers (five in the last whorl) inflated on both sides, slightly overlapping and rapidly increasing as added. Due to the increasing inflation of the chambers, the dorsal side of the test is depressed in the central part. The sutures are continuously raised in the last chambers, being finely beaded in the early ones. On the ventral side the sutures are generally slightly curved and raised in the adult stages, radial and depressed in the early stages, with the sutural elevations disappearing in the umbilical sutural depressions (only an umbilical thickening remains). The test is rougher and somewhat spinose in the early stage, dextrally coiling.

Dimensions of holotype.—Width 0.38 x 0.32 mm.; thickness, 0.16 mm.

Holotype.—No. 20828, Paleontological Research Institution.

Occurrence.—Manaure shale and Colon shale (*Pullenia cretacea* zone) more frequent at the bottom of this formation. Holotype from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5604.

Remarks.—The form is closely related to *Glt. marginata* (Reuss) of the Plänemergel (Cushman, 1946, pl. 62, fig. 1a-c) which has been considered by the author as identical to the Austin species. However, a comparision of both figures shows a difference in the shape and growth of the chambers, whereas in regard to other morphological characteristics the two are apparently identical. The difference cannot be interpreted as deriving from an eventual sexual dimorphism since both specimens illustrated by Cushman are apparently megalospheric forms. The variability of the species cannot be inferred because all our specimens are more or less related to the species of the Austin chalk, and none can be compared to the European species.

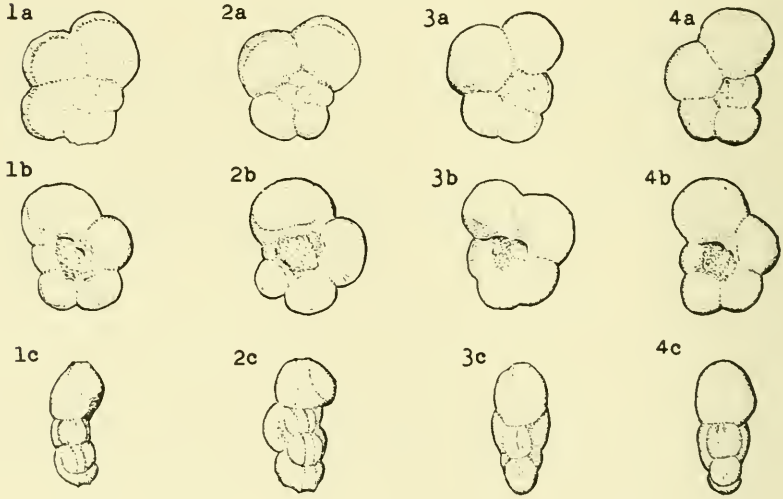


Fig. 7. Evolutive line *Globotruncana marginata austinensis*, n.subsp., (*Rugoglobigerina*) *beldingi beldingi*, n.sp., n.subsp. All specimens from the same level. S. 5587, 60 ×. Colon shale, *Pullenia cretacea* zone. 1a-c. *Glt. marginata austinensis*, n.subsp.; notice small size of the specimen, which is faintly but completely keeled. 2a-c. Same as above; however, showing chambers more inflated. 3a-c. (*Rugoglobigerina*) *beldingi subbeldingi*, n.sp., n.subsp., partially keeled in the early chambers of the last volution. 4a-c. (*Rugoglobigerina*) *beldingi beldingi*, n.sp., n.subsp., showing only faint rugosity at place where keels disappear.

Genus **RUGOGLOBIGERINA** Bronnimann, 1952

Type species by original designation, *Rugoglobigerina rugosa rugosa* (Plummer), 1926. Navarro clay, Walker Creek, Cameron, Milam Co., Texas.

Globotruncana (Rugoglobigerina) beldingi beldingi, n.sp., n. subsp.

Pl. 1, fig. 8, Text fig. 7, (4a-c)

Description.—Test nearly planispiral becoming somewhat involute on the dorsal side, since the last coil is slightly overlapping the early ones, chambers (five-six in the last whorl) inflated, slightly depressed and slightly overlapping each other in the early stages, increasing in height as added; with central depression as the previous *Globotruncana* species. A thin lip can be observed extending into the umbilicus and covering the apertures of the last chambers. The test is smooth, somewhat rough in the early stages, dextrally coiling; tubercles, papillae are more frequent along the margin of the shell, where especially in the early chambers they appear in two approximately parallel lines. The last chamber is often subangular with a smooth triangular terminal face.

Dimensions of holotype.—Width, 0.31 x 0.26 mm.; thickness, 0.15 mm.

Holotype.—No. 20830, Paleontological Research Institution.

Occurrence.—Colon shale, (*Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone). Holotype (Pl. 1, fig. 8) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5587.

Remarks.—*Globigerina compressa* Plummer of the Midway formation has some umbilical lips but the chambers are more flattened and the umbilicus is narrower. *Globigerina voluta* (White) differs because of its lobate periphery with outstanding four petaloid chambers, its smaller umbilicus and aperture which, according to the figure of White, is a lineate opening in the middle of the terminal face of the last chamber, whereas in our species it opens into the umbilicus and is covered by a thin lip. *Globigerinella messinae messinae* Bronnimann shows a more pronounced four-chambered periphery and a marginal aperture provided with a liplike projection extending into the umbilicus. This feature, as well as the similarity of the test, suggests that *Globigerinella messinae messinae* may derive from *Rugoglobigerina beldingi beldingi.*

The species was named after H. F. Belding of International Petroleum (Colombia), Limited, who collected part of the material studied in this paper.

Globotruncana (Rugoglobigerina) beldingi subbeldingi, n.sp., n. subsp.
Pl. 1, fig. 7, Text fig. 7(3a-c)

Description.—General shape similar to Glt. *marginata austinensis;* size, however, smaller; a double keel faint and present, in a continuous manner only in the early stages; chambers less and less overlapping toward the adult stage, growing more inflated, central depression, therefore, more pronounced. The sutures on the ventral side are radial, only a slight thickening toward the umbilicus occasionally testifies the disappearance of the umbilical raised sutures. On the dorsal side the sutures are raised and finely beaded only in the early stages. The terminal face of the last chambers maintains its triangular shape, being subangular along the once present sutural elevations. The test is smooth, somewhat rougher in the early stages, dextrally coiling.

Dimensions of holotype.—Width 0.32 x 0.28 mm.; thickness, 0.16 mm.

Holotype.—No. 20829, Paleontological Research Institution.

Occurrence.—Colon shale, *Pullenia cretacea* zone (more frequent in the uppermost part). Holotype (Pl. 1, fig. 7) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5587.

BULLOIDES BRANCH

Globotruncana bulloides bulloides (Vogler) Pl. 1, fig. 9

Rosalina linnei type 3 de Lapparent, 1918, p. 4, fig. 14, p. 5, fig. 2a.
Globotruncana lapparenti bulloides Bolli, 1944, p. 231, pl. 9, fig. 12.

Description.—Chambers inflated showing good variability in this regard; peripheral band large, the two keels are evident and thick (*lapparenti* type). The last chambers are occasionally flat. On the ventral side the early chambers tend as usual to become shorter with radial, depressed sutures, but the last chambers remain elongated with *lapparenti*-like running marginal elevations.

Occurrence.—Manaure shale, bottom of Colon shale. Rare.

Remarks.—This form was known originally in thin sections (aforementioned types of the *Lapparenti*) and was considered later by Vogler as a subspecies of *Glt. lapparenti* (Brotzen). Bolli, 1951, put it in synonymy with *Glt. marginata* (Reuss).

Regarding its close relationship with *Glt. lapparenti* the writer does not object to the above. The morphological characteristics are identical if we except the inflation of the chambers; however, it seems justifiable to raise it to the rank of a species, since it has apparently quite an independent development from *Glt. lapparenti*, leading toward specific *Rugoglobigerina* forms.

On the other hand the *Glt. marginata* tests, which have been illustrated by Cushman, 1946 (pl. 62, fig. 1a-c, 2a-c), are quite different such as to exclude any synonymy but having a narrower double-keeled peripheral band (this character is maintained in all transitional stages of this form toward *Rugoglobigerina* forms) and finely beaded keels.

Globotruncana bulloides globigerinoides (Brotzen) Pl. 1, fig. 10

Globotruncana globigerinoides Brotzen, 1936, pl. 12, fig. 3a-c, pl. 13, fig. 3.

Description.—Round *Globigerina*-like chambers, two faint, but generally evident, developed keels, parallel in the same direction of coiling, wide peripheral band.

Dimensions.—Width 0.38 x 0.32 mm.; thickness, 0.16 mm.

Occurrence.—Manaure shale, frequent in the lower Colon shale.

Remarks.—*Rosalinella globigerinoides* Marie, 1941, Mus. Nat. Hist., mém., t. 12, fasc. 1, p. 239, is morphologically close but apparently not identical with *Glt. globigerinoides* Brotzen.

From the figure and original description (Marie, p. 239, pl. 36, fig. 338a-c), it may be seen that the form is more convex dorsally, chambers and keels are obliquely arranged with respect to the plane of coiling, and the keels are diverging. *Rosalinella globigerinoides* Marie 1941, should be considered, therefore, as an independent species separated from *Glt. globigerinoides* Brotzen, 1936, and the name invalid. *Glt. mariai** is proposed as a new name.

(Rugoglobigerina) hexacamerata hexacamerata (Bronnimann) Pl. 1, fig. 12

Rugoglobigerina reicheli hexacamerata Bronnimann, 1952, p. 23, pl. 2, fig. 10-12

Occurrence.—Colon shale (*Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone).

**Type locality*: well drilled by the Service des Ponts et Chaussées à Montereau, Seine-et-Marne, bassin de Paris, Upper Cretaceous, Campanian, craie a *Belemnitella mucronata*.

Remarks.— This form has the general shape of *Glt. bulloides globigerinoides,* if we except the smaller size, the rough test, and the absence of keels. Morphologically it is closely related to *Rugoglobigerina loetterli loetterli,* but it differs in the more regular increase of chambers. From *Rugoglobigerina circumnodifer circumnodifer,* it differs because it has fewer chambers in the last whorl which are less closely spaced. As in most of these *Rugoglobigerina* forms, the full ornamentation appears in the completely evolved *Rugoglobigerina* tests(without keels) and in the uppermost *Pullenia cretacea* zone.

Globotruncana (Rugoglobigerina) hexacamerata subhexacamerata, n. subsp. Pl. 1, fig. 11

Description.—Flat to slightly convex on the dorsal side, double-keeled in the early stages, keels finely beaded often not in a continuous way, chambers (five-six in the last whorl) round, inflated, slightly overlapping especially in the early stages, truncated toward the umbilicus; sutures in the early stages curved, raised, finely beaded, becoming later radial and depressed; on the ventral side they are radial and depressed. The apertures are covered by thin plates. The lip projection of the last chamber appears sometimes as extending slightly from the umbilicus to the periphery. Test rough in the early stages, dextrally coiling.

Dimensions of holotype.—Width 0.26 x 0.22 mm.; thickness, 0.13 mm.

Holotype.—No. 20831, Paleontological Research Institution.

Occurrence.—Colon shale, *Pullenia cretacea* zone. Holotype (Pl. 1, fig. 11a-c) from the Colon shale, *Pullenia cretacea* zone, Well Papayal No. 1, 210-215′.

Remarks.—As seen in *Rugoglobigerina beldingi subbeldingi,* the size is generally small, the *Rugoglobigerina* appearance evident. The wide peripheral band is maintained until the keels disappear.

NAUSSI BRANCH

Globotruncana bulloides naussi, n. subsp. Pl. 1, fig. 13a-c

Description.—Flat double-keeled form, tending to become loosely coiled; wide peripheral band, lobate periphery, chambers (six-seven in the last whorl) inflated on both sides, becoming considerably higher in the last coil and more loosely spaced, whereas in the younger stages they are normally overlapping. The increase in size is irregular in the last coil so that the last chambers are generally smaller or more flattened than the previous ones; senile chambers are frequent. Thin continuously raised sutures, finely beaded in the early stages, occur on the dorsal side. On the ventral side the sutures are radial and depressed, the thickening toward the umbilicus generally weak. Occasionally, one or two of the last chambers show a weak curved sutural elevation. The test is smooth, rougher in the early chambers. The apertural system, as far as could be seen in the last chambers, apparently belongs to the *lapparenti* type with thin, slightly arched lip projections.

Dimensions of holotype.—Width 0.38 x 0.34 mm.; thickness, 0.15 mm.

Holotype.—No. 20832, Paleontological Research Institution.

Occurrence.—Rare in the Colon shale, middle of *Pullenia cretacea* zone. Holotype (Pl. 1, fig. 13a-c) from the Colon shale, *Pullenia cretacea* zone, Well Papayal No. 1, 210-215′.

Remarks.—This species is close to *Glt. bulloides bulloides* (Vogler) and *Glt. bulloides globigerinoides* (Brotzen). The last coil, the petaloid chambers, and the irregular increase in size of the last chambers are quite distinctive, keeping on throughout the following mutations toward a *Rugoglobigerina* form.

This subspecies was named after A. W. Nauss, who discovered and named *Rugoglobigerina loetterli loetterli.*

Globotruncana (Rugoglobigerina) loetterli loetterli (Nauss)
Pl. 1, fig. 15a-c

Globigerina loetterli Nauss, 1947, p. 336, pl. 49, fig. 11.

Description.—The main distinctive characters of *Glt. bulloides naussi* are to be observed unvaried in this species such as the last loose coil and smaller, generally more flattened, last chambers. The apertures in the adult stages are covered by reduced, slightly arched lips, with an apparent slight extension in the last chamber toward the periphery. The test is especially rough along the margin of the shell.

Dimensions.—Width 0.28 x 0.26 mm.; thickness, 0.14 mm.

Occurrence.—Present in the Colon shale, more frequent in the uppermost *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone.

Globotruncana (Rugoglobigerina) loetterli subloetterli, n.sp.
Pl. 1, fig. 14a-c

Description.—It is similar to *Glt. bulloides naussi.* It differs, as usual in all these forms transitional to *Rugoglobigerina,* by its more rounded and inflated chambers of *Globigerina* type, and by its keels which are weak and disappear in the last chambers. The test is rough especially in the early chambers, dextrally coiling.

Dimensions of holotype.—Width 0.36 x 0.34 mm.; thickness, 0.16 mm.

Holotype.—No. 20833, Paleontological Research Institution.

Occurrence.—Colon shale, *Pullenia cretacea* zone. Holotype from the Colon shale, *Pullenia cretacea* zone, Well Papayal No. 1, 210-215′.

Remarks.—Transitional stages present to *Glt. bulloides naussi* and *Rugogl. loetterli loetterli.*

COMMENTS ON THE PHYLOGENETIC DEVELOPMENT OF THE BULLOIDES GROUP

The comparatively rich material for this group of forms has made it possible to follow the phylogenetic development of the single *Globotruncana* species much more closely than for the previously described group.

Linnei-like forms are here considered as belonging to the group, which have, however, inflated and more or less *Globigerina*-like chambers. *Glt. bulloides* has been recognized by many authors as closely related to *Glt. lapparenti. Glt. marginata* (Reuss) was often put in synonymy with *Glt. globigerinoides* Brotzen and/or with *Glt. ventricosa* White.

Glt. bulloides naussi is a new species closely related to *Glt. bulloides* and *Glt. globigerinoides.* From their description, it is obvious these forms should be kept separated, since they have distinct morphological characteristics. They represent independent evolutionary stages toward *Rugoglobigerina.*

The group is assumed to form a kind of evolutionary system developing parallel and somewhat independently from the *linnei* one with probably repeated derivations from *linnei* forms, since a close morphological relationship to the *linnei* group is observed through their development.

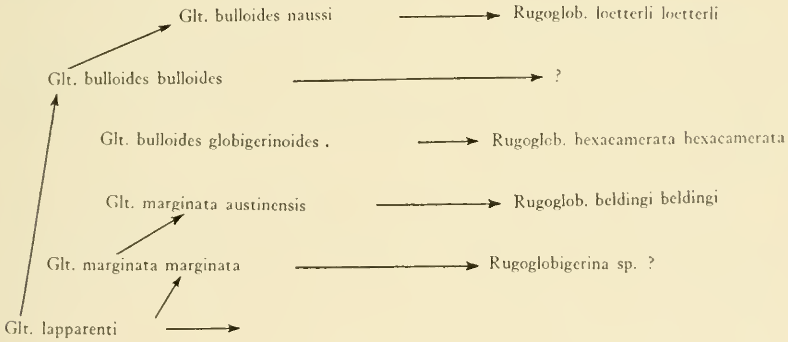
Different branches have been separated as was done for the *linnei* group:

Marginata branch.—Flat forms, peripheral band double-keeled, narrow. There is no apparent possibility of interpreting these forms as intermediate stages between *Glt. bulloides bulloides*, *Glt. bulloides globigerinoides*, and *Glt. bulloides naussi.* The narrow double keel was seen to persist in the transitional stages to *Rugoglobigerina,* as a fixed conservative characteristic, quite typical of the branch, the same as the wide peripheral band for the *bulloides* and *naussi* branches.

Bulloides branch.—Flat forms, wide peripheral band, regular development of chambers.

Naussi branch.—Wide peripheral band as the previous one, more irregular development of chambers.

Schematic, in the light of our observations, the phylogenetic development of these forms is figured as follows:



Remarks on the Globotruncana-Rugoglobigerina mutations.—The most striking fact in all these phylogenetic developments is undoubtedly the explosive mutation of different *Globotruncana* into *Rugoglobigerina.* There is apparently no doubt in the observation. The phyla are represented with complete evidence of transitional stages; in some of them particular morphological characters persist through the comparatively rapid evolution in a conservative way, so that in most of the cases no doubt can remain as to the derivation of a specific *Rugoglobigerina* form from a corresponding *Globotruncana.*

Regarding the sense of development (which can easily become a basis for discussion) the paleontological evidence appears convincing. The evolution of these *Globotruncana* forms occurred mostly in Campanian (or early in Santonian) since they are abundant in lower Colon shale (*Pullenia cretacea* zone) together with derived *Rugoglobigerina* forms.

Upward they disappear completely at the appearance of *Glt. gansseri gansseri* so that later only typical *Rugoglobigerina* spread out.

Noteworthy is the gradual increase of ornamentation going hand in hand with the disappearance of keels. Generally the ornamentation of most of these *Rugoglobigerina* forms appears as a secondary morphological development which finds its maximum in the full spread of these forms in Maestrichtian, since some tests which were found down-section in the *Pullenia cretacea* zone show only a slightly rough or even smooth test. Equally, the growing of hantkeninoid spines (*Plummerita* Brönnimann, 1952) does not mean a different genetical derivation of these richly ornamented forms but enters into the general morphological change which on the other end can also be observed in *Globotruncana, s. str.* (*Globotruncana calcarata, Globotruncana gansseri, Globotruncana wiedenmayeri, Globotruncana rugosa*).

The *bulloides* group is, within the limits of our study, the one which has a more evident and more prominent development toward *Rugoglobigerina*. It is not the only one since a similar development will be observed in other groups.

GLOBOTRUNCANA FORNICATA GROUP

Description.—Convex dorsal side, sometimes strongly so, two keels close together and usually parallel to each other, but sometimes diverging along the direction of coiling; the second keel is weak, frequently shifted inside toward the umbilicus in more evolved species; chambers elongated, curved, arched, strongly overlapping each other; in some species longitudinally inflated, irregularly and obliquely arranged to the plane of coiling.

In some branches (*fornicata* branch, *cesarensis* branch, *contusa* branch) the last chambers become large and petaloid, somewhat undulated, depressed in the middle and toward the inner side of the coil. In the species with inflated chambers, the inflation is growing around and outside this median inner-marginal depression, causing a squeezed appearance from the inside. This is quite a peculiar morphological characteristic which to date has been observed by the writer only in *Globotruncana* of the *fornicata* group (aforementioned branches). It is apparently persistent and well defined, the same as the narrow, double keel in the *marginata* branch, the wide double keel in the *bulloides* and *naussi* branches. It continues through the several evolutionary stages such as may be observed sometimes in the derived *Rugoglobigerina* forms. This character disappears in the *caliciformis* and *intermedia-difformis* branches and appears again in the more evolved forms of the *contusa* branch.

This group shows the most complex variability. The long arched chambers and the more convex dorsal side, however, are common to all types included in the group.

The group was subdivided into the following branches:

Fornicata branch: Chambers elongated and flat, becoming petaloid (last ones).

Plummerae branch: Chambers becoming inflated with pronounced median innermarginal depression.

Cesarensis branch: Three-four chambers in the last whorl (extremely rapid increase of size as added).

Caliciformis branch: Strongly convex dorsal side, petaloid periphery, second keel disappearing.

Difformis-intermedia-citae branches: Extremely petaloid periphery, margin becoming single-keeled or rounded (both keels disappearing).

Contusa branch: Extreme conical forms, extreme elongated chambers, peripheral band almost horizontal, second keel weakening and disappearing.

Apertural system: The *Globotruncana* of this group have generally a wide open umbilical cavity with straight or slightly arched apertural lips (*i.e., Glt. fornicata brotzeni, Glt. fornicata fornicata, Glt. intermedia ackermanni, Glt. fornicata cesarensis*, primitive *Glt. caliciformis caliciformis*). Extreme arched lips are developed in some of the more evolved species like *Glt. caliciformis sarmientoi* and *Glt.*

contusa contusa. These show an apertural system more or less of the *rosetta-stuarti* type (Reichel, 1949, p. 613, pl. 16, fig. 10).

Little observation was possible of *Glt. intermedia difformis*, *Glt. intermedia intermedia*, *Rugogl. petaloidea*, *s.l.*, and *Glt. citae*. Nevertheless, it appears that a thin plate fringes the umbilicus and extends sometimes slightly (*Glt. citae*) from the umbilicus toward the periphery.

FORNICATA BRANCH

Globotruncana fornicata fornicata (Plummer) Pl. 2, fig. 2a-c

Globotruncana fornicata Plummer, 1931, p. 198, pl. 13, fig. 4-6; Sandidge, 1932, p. 285, pl. 44, fig. 12-13; Cushman and Hedberg, 1941, p. 99, pl. 23, fig. 18; Cushman, 1946, p. 149, pl. 61, fig. 19.

Description.—Test convex on the dorsal side, double-keeled, the second keel shifted to the inner of the shell, tending to weaken and disappear in the adult stages, peripheral band narrow, oblique to the plane of coiling (sometimes it is strongly so) becoming almost horizontal (cf. *Glt. contusa contusa*). The chambers are long, arched, elongated, becoming large, flat, petaloid, and undulated especially in the adult stages. The sutural elevations are often beaded especially in the early stages. The umbilical cavity is narrower than in the previous form; arched lips cover the apertures. The test in the early stages is rough.

The specimens investigated are dextrally coiling.

Dimensions.—Width 0.41 x 0.38 mm.; thickness, 0.22 mm. (primitive); width 0.48 x 0.40 mm.; thickness, 0.28 (evolved).

Occurrence.—Fairly frequent in the Manaure shale and bottom of the Colon shale (bottom of *Pullenia cretacea* zone), rarer upward in section.

Remarks.—This is the form which most often has been identified and figured by authors as *Glt. fornicata* Plummer.

It must be noted, however, that higher in section (upper *Pullenia cretacea* zone) the test shows a more pronounced dorsal convexity, a slight inflation of the chambers which extends into the early stages of the last coil with a more pronounced sutural depression toward the inner coil (cf. the description of Plummer, 1931, and figure of Cushman and Hedberg, 1941).

In the Manaure shale, transitional forms are present toward *Glt. fornicata manaurensis*. Some tests with dorsal convexity, slightly inflated chambers, show completely mixed characters between *fornicata, caliciformis,* and *intermedia* tests. *Glt. convexa* Sandidge, which according to Cita should be a *Glt. fornicata,* is probably to be related to these forms.

Globotruncana fornicata manaurensis, n. subsp.

Pl. 2, fig. 1a-c, Text fig. 9(1a-c), 9(2a-c)

Globotruncana fornicata Cita, 1948, p. 11, pl. 3, fig. 8.

Description.—Test convex on the dorsal side, double-keeled, subcircular with a narrow peripheral band; the second keel only slightly shifted toward the umbilicus; chambers becoming long, arched, elongated in the adult stage, sutural elevations thinner than in *Glt. lapparenti lapparenti,* but continuously raised on the umbilical side, running with sigmoidal development, but bending sharply back and tending to attach themselves to the previous ones. The last ones sometimes still plunge within the umbilical cavity. The test is generally smooth; the umbilical cavity is large with thin, long, nearly straight apertural lips. The specimens investigated are dextrally coiling.

Dimensions of holotype.—Width 0.41 x 0.38 mm.; thickness 0.22 mm.

Holotype.—No. 20834, Paleontological Research Institution.

Occurrence.—Apparently confined to the Manaure shale (*Marginulina jonesi*). Holotype (pl. 2, fig. la-c) from the Manaure shale, Manaure section, S. 9168.

Remarks.— Of phylogenetic interest is the "*lapparenti*" appearance of this primitive *fornicata* type. Though the material is not abundant, all intermediate stages are present and connect this form with *Glt. lapparenti longilocula* on one side and with Glt. *fornicata fornicata* on the other side.

Some tests show a more pronounced dorsal convexity with either extremely elongated chambers such as to be transitional toward *Glt. contusa scutilla* or with larger final chambers and more lobated contour such as to be connected with *Glt. caliciformis-intermedia* tests.

The name is derived from the name of the Manaure shale, César Valley.

In the Manaure shale and in the lower Colon formation all degrees of intermediate stages were found connecting this form with *Glt. fornicata plummerae.*

PLUMMERAE BRANCH

Globotruncana fornicata plummerae,* n.subsp. Pl. 2, fig. 3a-c, 4a-c

? *Globotruncana fornicata* Cushman and Deaderick, 1944, p. 340, pl. 153, fig. 28.

Description.—Flat or slightly convex on the dorsal side, two keels equally developed, somewhat diverging, peripheral band only slightly oblique to the plane of coiling; four-five chambers in the last whorl long and arched as the previous species but longitudinally inflated with well-developed, median inner marginal depression in the last chambers. On the ventral side, the chambers are usually flat with long curved raised sutures, but the early ones are occasionally inflated, short with the marginal elevations disappearing in the radial sutural depressions. The test is dextrally coiling.

Dimensions of holotype.—Width 0.38 x 0.28 mm.; thickness, 0.22 mm.

Holotype.—No. 20835, Paleontological Research Institution.

The form is related to *Glt. fornicata fornicata* Plummer, from which it differs by the pronounced inflation of the chambers in the same way as *Glt. bulloides bulloides* differs from *Glt. lapparenti lapparenti.*

Occurrence.—Rare in the Manaure shale, where large forms with more flattened chambers are prevailing (transition to *Glt. fornicata plummerae*); frequent and typical at the bottom of the Colon shale. Holotype (Pl. 2, fig. 3a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5578.

Remarks.—This species is named after the late Helen Jeanne Plummer, who discovered and named *Glt. fornicata fornicata.*

Globotruncana fornicata ackermanni, n. subsp. Pl. 2, fig. 5a-c, 6a-c, 7a-c

Description.—Similar to the previous one with more outstanding convexity on the dorsal side, chambers short, strongly inflated especially on the ventral side, the last one occasionally more elongated and arched with well-developed median inner depression. Sutures on the ventral side radial, depressed, being somewhat raised only around the umbilical margin. Only the last chamber may still

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* Editor's note: Correction of spelling of subspecific name of *plummeri* to *plummerae* was made after Plates 8 and 10 were engraved. The corrections should be made on the plates accordingly.

show a more or less continuous raised suture. The test is rougher than in *Glt. fornicata fornicata* and *Glt. fornicata plummerae* with spinose tubercles on the surface of the early chambers. Frequent tests are sinistrally coiled.

Dimensions of holotype.—Width 0.36 x 0.30 mm.; thickness, 0.29 mm.

Holotype.—No. 20836, Paleontological Research Institution.

Occurrence.—Colon shale, more typical and frequent upward in the section. Holotype (Pl. 2, fig. 5a-c) from the Colon shale, *Siphogenerinoides bramlettei* zone, Km. 92 section, S. 5608.

Remarks.—Morphologically this form is similar to *Glt. marginata austinensis;* however, the elongated, arched chambers (especially the last ones), the median inner marginal depression, the dorsal convexity are distinctive for the species.

Rare tests appear in the uppermost *Pullenia cretacea* zone and *Siphogenerinoides bramlettei* zone (Pl. 2, fig. 6a-c, 7a-c) with chambers and keels oblique to the plane of coiling but diverging along the direction of coiling. In one specimen a dichotomic keel was observed.

Rosalinella globigerinoides Marie (see p. 33) shows a similar oblique arrangement of chambers and keels but differs in the less elongated last chambers which are symmetrically inflated on both sides and less increasing in size. An oblique arrangement of the chambers, diverging keels are shown also by *Glt. mayaroensis*, and *Glt. intermedia intermedia*. A dichotomic keel was up to the present known only to *Glt. imbricata* Mornod, 1948, (Turonian).

The species was named after E. D. Ackerman, Exploration Manager of International Petroleum (Colombia), Limited.

Globotruncana (Rugoglobigerina) circumnodifer circumnodifer (Finlay)
Pl. 2, fig. 9a-c

Globigerina circumnodifer Finlay, 1940, p. 469, pl. 65, figs. 150-158.

Description.—More lobate periphery than in *Rugogl. circumnodifer subcircumnodifer* chambers; subangular, rapidly becoming loosely spaced, sutures almost radial in the adult stages, test somewhat smooth, but in the early stages rougher with tubercles, as in these *Rugoglobigerina* forms, especially along the margin of the early chambers. The terminal face of the last chamber is broadly triangular with a more or less pronounced edge at the position when the ventral keel was formerly present in the subgenus *Globotruncana.*

Dimensions.—Width 0.28 x 0.26 mm.; thickness 0.18 mm.

Holotype.—No. 20838, Paleontological Research Institution.

Occurrence.—Colon shale (*Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone).

Remarks.—The form is morphologically related to *Rugogl. hexacamerata hexacamerata,* differs because of fewer, more elongate chambers in the last whorl, its more asymmetric umbilical inflation of the chambers. It differs from *Rugogl. rugosa rugosa* Plummer because of its smaller size, smaller test and less outstanding umbilical convexity of the chambers.

Globotruncana (Rugoglobigerina) circumnodifer subcircumnodifer, n. subsp.

Pl. 2, fig. 8a-c

Description.—The form is similar to *Glt. fornicata ackermanni,* but the *Rugoglobigerina* habitus is more developed. The test is slightly convex, the chambers are inflated, subangular with the inflation more pronounced in the umbilical side, so that the faintly beaded double keel (narrow peripheral band) is not exactly in the middle of the chamber, but shifted more toward the dorsal side. The chambers, four-five in the last whorl, are slightly more elongated; the sutures become radial in the last chambers; the test is rough especially in the early stages and the umbilicus is narrower. The test is dextrally coiling.

Dimensions of holotype.—Width 0.38 x 0.32 mm.; thickness, 0.22 mm.

Holotype.—No. 20837, Paleontological Research Institution.

Occurrence.—Colon shale (*Pullenia cretacea* zone). Holotype (Pl. 2, fig. 8a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 Section, S. 5579.

Remarks.—Morphologically it is closely related to *Rugogl. hexacamerata subhexacamerata,* but the irregular growth of the chambers (more inflated toward the umbilical side), their narrower shape, the fewer chambers in the last whorl, the position and arrangement of the keels are distinctive characteristics. From *Rugogl. rugosa subrugosa,* it differs by having a smoother test (lack of rugose ridges) and less pronounced umbilical inflation of the chambers.

CESARENSIS BRANCH

Globotruncana fornicata cesarensis, n. subsp. Pl. 2, fig. 10a-c

Description.—Form flat or slightly convex dorsally, the chambers (three-four in the last whorl) are considerably inflated on both sides, more strongly so on the umbilical one. It is similar to *Glt. fornicata plummerae*, with chambers, however, more rapidly increasing in size, the last one usually considerably elongated and occupying half of the test. It shows a narrow, well-defined double keel, and a peripheral band which is nearly perpendicular to the plane of coiling. On the ventral side the sutures are radial and depressed; the last chamber is provided with more or less evident and *Globotruncana*-like terminal face; the test is rough especially in the early chambers and dextrally coiling.

Dimensions of holotype.—Width 0.35 x 0.24 mm.; thickness, 0.17 mm.

Holotype.—No. 20838, Paleontological Research Institution.

Occurrence.—Rare in the Colon shale, *Pullenia cretacea* zone. Holotype (Pl. 2, fig. 10a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5587.

Remarks.—This form apparently represents a final stage of evolution with respect to the reduction of the number of chambers in the last whorl (cf. *Glt. tricarinata colombiana*). The arched, elongated last chamber with median inner marginal depression remains a distinctive character.

Globotruncana (Rugoglobigerina) macrocephala macrocephala Bronnimann Pl. 2, fig. 12a-c

Rugoglobigerina macrocephala macrocephala Bronnimann, 1952, p. 25, pl. 2, figs. 1-3.

Description.—As in the following *Globotruncana* form, the chambers are rapidly increasing in size so that three, occasionally four, chambers form the last whorl. The inflation is more conspicuous and more rapidly developing toward the adult stages so that the inner spire is more depressed than in the previously described *Globotuncana* species. The subglobular chambers are still slightly arched and slightly overlapping each other. The last chamber maintains its subangular *Globotruncana*-like shape with triangular terminal face.

Dimensions.—Width 0.18 x 0.24 mm.; thickness, 0.17 mm.

Occurrence.—Colon shale. *Pullenia cretacea* zone. *Siphogenerinoides bramlettei* zone. Fully ornamented tests are more frequent in the uppermost part of the *Pullenia cretacea* zone.

Globotruncana (Rugoglobigerina) macrocephala submacrocephala, n. subsp. Pl. 2, fig. 11a-c

Description.—Similar to *Glt. fornicata cesarensis,* but the test is rougher, the chambers are more uniformly rounded, and a faintly beaded double keel is present only in the early chambers, tending to weaken and completely disappear. The test is dextrally coiling.

Dimensions of holotype.—Width 0.31 x 0.23 mm.; thickness, 0.16 mm.

Holotype.—No. 20839, Paleontological Research Institution.

Occurrence.—Colon shale, *Pullenia cretacea* zone. Holotype (Pl. 2, fig. 11a-c) from the Colon shale, *Pullenia cretacea* zone, Well Papayal No. 1, 210-215′.

CALICIFORMIS BRANCH

Globotruncana caliciformis caliciformis (de Lapparent) Pl. 3, fig. 1a-c

Glt. caliciformis Cita, 1948, p. 7, pl. 3, fig. 7a-c, text fig. 7/3a-c, 4a-c; Bolli, 1951, p. 194, pl. 34, fig. 4-6.

Description.—The test is fairly convex on the dorsal side, the chambers are long, arched, and overlapping each other (*fornicata* type) with the exception of the last two or three chambers which are short and petaloid.

On the dorsal side the sutures are beaded in the early stages and become continuously raised later. On the ventral side completely and continuously raised sutures run along the chambers. The umbilical cavity is large; thin, slightly arched lips with apparently an irregularly cut margin cover the apertures.

Occurrence.—Typical forms with petaloid periphery start to become abundant in the Colon shale, upper *Pullenia cretacea* zone.

Rare early specimens with a less developed petaloid periphery, more arched chambers, transitional to *Glt. fornicata plummerae* were found down section in the Manaure shale.

Remarks.—The form was first described from isolated specimens by Cita, 1948, who referred it to the species of De Lapparent (*Rosalina linnei* mut. *caliciformis* de Lapparent, 1918, p. 8, fig. 2i; pl. 1, fig. 2), which in turn was known only from thin section. Many species of such conical appearance are already known, and it can be easily foreseen that others may be discovered. Therefore, the reference may be correct (the stratigraphic range apparently corresponds), but this cannot be entirely proved without cutting thin sections from isolated tests and comparing with the holotype of De Lapparent. For this reason the form of Cita is here considered as holotype.

Globotruncana caliciformis trinidadensis, n. subsp. Pl. 3, fig. 2a-c

Globotruncana caliciformis Bolli, 1951, p. 194 (part).

Description.—Fairly convex dorsally; lobate periphery, chambers of the last whorl petaloid as *Glt. caliciformis sarmientoi.* The chambers, however, are more elongated and flattened on the ventral side, where the sutures are radial with sutural elevations generally absent, at least in the early stages. The umbilical cavity is smaller than in *Glt. caliciformis caliciformis* but larger than in typical *Glt. caliciformis sarmientoi.* The form is single-keeled in the adult stages, double-keeled in the early stages. The test is considerably rougher, especially in the umbilical side of the early chambers. The apertural system takes a completely intermediate position as in general do all the morphological characteristics between *Glt. caliciformis* and *Glt. caliciformis sarmientoi.* The test is dextrally coiling.

Dimensions of holotype.—Width 0.44 x 0.37 mm.; thickness, 0.15 mm.

Holotype.—No. 20840, Paleontological Research Institution.

Occurrence.—Limited to a short range immediately underlying the first appearance of typical *Glt. caliciformis sarmientoi.* Holotype (Pl. 3, fig. 2a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5606.

Remarks.— Bolli described such *caliciformis* forms with the keel disappearing in the adult stage in his Trinidad paper. In fact, this form is to be considered transitional between *Glt. caliciformis caliciformis* and *Glt. caliciformis sarmientoi.*

Globotruncana caliciformis sarmientoi, n. subsp. Pl. 3, fig. 3a-c

Description.—Dorsal convexity more outstanding than in the previous species, chambers on the last whorl (four-five) fairly petaloid, flat on the dorsal side, slightly inflated on the ventral side. The sutures on the dorsal side are continuously but irregularly raised in the adult stages, somewhat beaded in the early stages.

Ventrally the umbilicus is considerably narrow (as respect to *Glt. caliciformis caliciformis*), with well-developed arched lips of *rosetta* type; the sutures are deeply depressed, radial with sutural elevations completely absent or reduced to a slight thickening around the umbilicus. The form is single-keeled and the chambers are fringed by a kind of large umbilical peripheral limbation like many *Globorotalia* or *Epistomina* are.

The lip of the last chamber is slightly crenate and extending somewhat toward the periphery. The test is dextrally coiling.

Dimensions of holotype.—Width 0.46 x 0.39 mm.; thickness, 0.18 mm.

Holotype.—No. 20841, Paleontological Research Institution.

Occurrence.—Colon shale, starting at the top of the *Pullenia cretacea* zone. Holotype (Pl. 3, fig. 3a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5606.

Remarks.—This species is morphologically related to *Globorotalia pshadae* Keller (Keller, 1946, p. 99, pl. 2, fig. 4-6). As well as can be judged from the poor figure, this form is a *Globotruncana,* perhaps belonging to the *caliciformis* branch but does not appear to be identical to our species, showing a completely flat umbilical side and a narrower umbilicus.

At any rate *Glt. caliciformis sarmientoi* and *Glt. pshadae* show that new conical lobate, single-keeled *Globotruncana* appear in Campanian-Maestrichtian time which are similar to *rosetta* forms but have a completely different genetical derivation.

This species was named after R. Sarmiento, geologist of International Petroleum (Colombia), Limited.

DIFFORMIS-INTERMEDIA-CITAE BRANCHES

Globotruncana intermedia intermedia (Bolli) Pl. 3, fig. 8a-c

Globotruncana intermedia (Bolli), 1951, p. 197, pl. 35, figs. 7-9

Description.—The material is scarce and generally badly preserved. However, a comparison with topotype material of Trinidad allowed a complete identification of this species and some interesting observations. The form is generally convex on the dorsal side with curved, inflated, slightly overlapping chambers (four-five in the last whorl). The periphery is lobate as in *Glt. caliciformis caliciformis,* and a narrow peripheral band is present along with two finely beaded keels, diverging along the direction of coiling. Chambers and keels are irregularly and obliquely arranged as to the plane of coiling but not so strongly as in *Glt. intermedia difformis.* The sutures are radial and depressed on the umbilical side.

Occurrence.—Upper Colon shale (upper *Pullenia cretacea* zone); rare.

Remarks.—A fine umbilical lip was observed, as in the previous species, fringing the last chamber. A few badly preserved tests were found in the Manaure shale, with raised curved umbilical sutures and morphological characteristics, which are intermediate between *Glt. caliciformis caliciformis, Glt. intermedia difformis,* and *Glt. fornicata manaurensis. Glt. convexa* Sandidge, which was interpreted as a *Glt. fornicata* by Cita, may refer to these forms.

Globotruncana intermedia difformis, n.sp. Pl. 3, figs. 4a-c, 5a-c

Description.—Test more convex on the dorsal side, chambers elongated, arched, tending to become petaloid and strongly oblique to the plane of coiling in the adult stage. They are rapidly inflated but irregularly increased so that the second chamber is considerably developed, often bigger than the last one. The sutural elevations are round and thick, being absent on the ventral side. A large, blunt, thick peripheral keel is present which splits somewhat into equally rounded blunt keels in the early stages. The test is rough and the umbilicus narrow. The presence of an umbilical lip could be observed through the hard matrix filling the umbilical cavity (fig. 5-b).

Dimensions of holotype.—Width 0.44 x 0.35 mm.; thickness, 0.25 mm.

Holotype.—No. 20842, Paleontological Research Institution.

Occurrence.—Rare in the Manaure shale. Holotype (Pl. 3, fig. 4a-c) from the Manaure shale, Manaure section, S. 9167B.

Remarks.—The form is closely related to *Glt. intermedia intermedia* Bolli which differs because of its more regular arrangement of chambers and its finely beaded, not so strongly diverging keels.

(Rugoglobigerina) ornata ornata (Bronnimann) Pl. 3, fig. 7a-c

Rugoglobigerina macrocephala ornata Bronnimann, 1952, p. 27, pl. 2, figs. 4-6.

Occurrence.—Colon shale, *Pullenia cretacea* zone. Rare.

Remarks.—The scarce material does not allow a complete check of its phylogenetic development. However, the typical protruding second chamber, the disappearance of keels while the rugosity is increasing, seem to confirm the postulated bioseries *Glt. intermedia difformis-Rugoglobigerina ornata ornata*. For this reason the form of Bronnimann was raised to the rank of species and separated from *Rugoglobigerina macrocephala macrocephala* which appears to have a completely distinct genetical derivation.

Globotruncana (Rugoglobigerina) ornata subornata, n. subsp.
Pl. 3, fig. 6a-c

Description.—Low trochoidal test with depressed inner whorl, four chambers in the last whorl rapidly and irregularly increasing in size so that the second one is frequently larger than the last one. The chambers are truncated toward the umbilicus; the sutures are curved in the early stages of the last volution, becoming straight later in completed adult development. Two finely beaded keels are distinctly visible and limit a narrow peripheral band in the early stages, though often being masked by well-developed rugosities. The test is dextrally coiling.

Dimensions of holotype.—Width 0.40 x 0.31 mm.; thickness, 0.28 mm.

Holotype.—No. 20843, Paleontological Research Institution.

Occurrence.—Colon shale, *Pullenia cretacea* zone. Rare. Holotype (Pl. 3, fig. 6a-c) from the Colon shale, *Pullenia cretacea* zone, Well Papayal No. 1, 210-215′.

(Rugoglobigerina) glaessneri glaessneri, n.sp., n. subsp. Pl. 3, fig. 10a-c

Description.—Test convex on the dorsal side, four to five subglobular and laterally protruding chambers with a broadly triangular periphery, loosely arranged with deep radial sutures on both sides, umbilicus smaller than *Rugoglobigerina glaessneri subglaessneri* (umbilical aperture or apertures with fine lips ?). The test is dextrally coiling, similar to that of *Rugogl. glaessneri subglaessneri* but without keels.

Dimensions of holotype.—Width 0.27 x 0.24 mm.; thickness, 0.17 mm.

Holotype.—No. 20845, Paleontological Research Institution.

Occurrence.—Colon shale, uppermost *Pullenia cretacea* zone, and *Siphogenerinoides bramlettei* zone. Rare. Holotype (Pl. 3, fig. 10a-c) from the Colon shale, *Pullenia cretacea* zone, Well Papayal No. 1, 110-115′.

This species was named after M. F. Glaessner for his contribution to the knowledge of the *Globotruncana* of the Caucasus.

(Rugoglobigerina) glaessneri subglaessneri, n. subsp. Pl. 3, fig. 9a-c

Description.—Four to five chambers in the last coil, high, protruding, loosely arranged, broadly pointed and polygonal; periphery fairly petaloid; a finely beaded diverging double keel is discontinuously present. On the umbilical side the sutures are radial and depressed. The last chamber has a triangular terminal face, subangular along the once present marginal elevation. A slight thickening is generally present around the umbilical cavity. The test is rather smooth, being rougher in the early stages. The umbilical cavity is smaller than in *Glt. intermedia intermedia*. As far as the matrix filling the cavity allowed observation, a fine umbilical lip is present, at least in the last chamber, extending somewhat toward the periphery. The test is dextrally coiling.

Dimensions of holotype.—Width 0.28 x 0.26 mm.; thickness, 0.18 mm.

Holotype.—No. 20844, Paleontological Research Institution.

Occurrence.—*Pullenia cretacea* zone. Rare. Holotype (Pl. 3, fig. 9a-c) from the Colon shale, *Pullenia cretacea* zone, Well Papayal No. 1, 210-215′.

Remarks.—The general morphological appearance of this form resembles *Rotalipora benacensis* Cita which is, however, single-keeled and has sutural apertures.

Although observation on the aperture cannot be considered as conclusive, the general appearance of the test seems to be close to *Glt. intermedia intermedia* such as to suggest an intermediate genetic position toward *Rugoglobigerina glaessneri glaessneri.*

Globotruncana citae Bolli Pl. 3, fig. 11a-c

Globotruncana citae Bolli, 1951, p. 197, pl. 35, fig. 4a-c.

Description.—The pronounced petaloid periphery is the main diagnostic characteristic. Topotype material from Trinidad allowed a close comparison. The early chambers are more globular, the last ones more flattened. The development of the keel is variable, but here only the forms which have a well-developed keel all around the test are included. Specimens with extremely developed petaloid periphery are present, their test being smoother than in the topotype.

A thin umbilical lip fringes the apertures of the chambers and extends somewhat toward the periphery.

Occurrence.—Rare in the Colon shale. *Pullenia cretacea* zone.

Remarks.—According to Bolli there are transitional stages toward *Glt. intermedia intermedia.*

Globotruncana (Rugoglobigerina) petaloidea petaloidea, n.sp.

Pl. 3, fig. 13a-c

Description.—Pronounced petaloid periphery as in *Glt. citae* and *Rugogl. petaloidea subpetaloidea,* chambers subglobular, sutural elevations completely disappearing or marked sometimes by more frequent tubercles, especially along the margin of the early chambers. The terminal face is as usual more or less triangular with a faint edge toward the umbilical face. The test is dextrally coiling.

Dimensions of holotype.—Width 0.29 x 0.27 mm.; thickness, 0.18 mm.

Holotype.—No. 20847, Paleontological Research Institution.

Occurrence.—Rarely present and only in the higher Colon shale (uppermost *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone). Holotype (Pl. 3, fig. 13a-c) from the Colon shale, *Pullenia cretacea* zone, Well Papayal No. 1, 70-75′.

Remarks.—A fine umbilical lip appears to fringe the last chamber and extends somewhat toward the periphery.

Globotruncana (Rugoglobigerina) petaloides subpetaloidea, n.sp.,

Pl. 3, fig. 12a-c

Description.—Test slightly convex; five chambers in the last whorl, which are short, high, and protruding with only a partially developed marginal keel. The chambers are less flattened in *Globotruncana citae,* the periphery is generally lobate in a more outstanding way. The test is dextrally coiling.

Dimensions of holotype.—Width 0.31 x 0.26 mm.; thickness, 0.18 mm.

Holotype.—No. 20846, Paleontological Research Institution.

Occurrence.—Colon shale, more frequent up section. Holotype (Pl. 3, fig. 12a-c) from the Colon shale. *Pullenia cretacea* zone, Km. 92 section, S. 5584.

Remarks.—Figure 8 illustrates an isolated specimen of *Rugogl. petaloidea subpetaloidea.* The test of the early chambers is rougher and provided with hantkeninoid spines. A comparison of this form with the figures of *Plummerita* given by Bronnimann, especially *Plummerita hantkeninoides inflata* (Bronnimann, 1952, pl. 3, figs. 7-9) which appears more primitive, is suggestive of a genetical derivation of *Plummerita* from such forms.

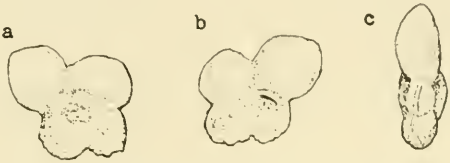


Fig. 8. ***Rugoglobigerina petaloidea subpetaloidea,*** n.sp., n.subsp.; showing faint keel and hantkeninoid spines in the early chambers of the last volution. S. 5595. Colon shale, *Pullenia cretacea* zone. 60 ×.

CONTUSA BRANCH

Globotruncana contusa contusa (Cushman) Pl. 4, fig. 3a-c

Globotruncana arca var. *contusa* Cushman 1946, pp. 150-151, pl. 62, fig. 6a-b.

Description.—Chambers of the last coil with a sharply cut polygonal periphery conspicuously undulated, the second keel sometimes completely disappearing. The chambers are occasionally slightly inflated, especially in the early stages. The umbilical lips are more arched and developed than in the previous species (*rosetta* type).

Dimensions.—Width 0.64 x 0.53 mm.; thickness 0.41 mm.

Figured specimen.—No. 20850, Paleontological Research Institution.

Occurrence.—Upper Colon shale (upper *Pullenia cretacea* and *Siphogenerinoides bramlettei* zones); more frequent in shallower environment.

Remarks.—As was noted by Cita, 1948 (p. 8), and Bolli, 1951 (p. 196), *Glt. conica* var. *plicata* White should be identical with this species. All transitional stages connect this form with *Glt. contusa patelliformis. Glt. contusa contusa* becomes more and more frequent higher in the section as compared with *Glt. contusa patelliformis.*

Cita, 1948, suggested that this form should be separated from *Glt. arca,* being somewhat closer to *Glt. caliciformis.* Bolli, 1951, recognized its close relationship to *Glt. fornicata. Glt. fornicata fornicata* and *Glt. caliciformis caliciformis* are undoubtedly genetically closely related species. Besides the transitional stages which connect this line of forms to primitive *fornicata* types, the reader will notice by comparing figs. 1, 2, and 3 of Plate 3, how the ontogenetic development of the chambers confirms this assumption. Except for the last irregularly lobate chambers, the early ones both of *Glt. contusa patelliformis* and *Glt. contusa contusa* are identical in all morphological details with those of *Glt. contusa scutilla.* Even the test in the early stage is regularly convex on the dorsal side as it is in this primitive form. On the other hand, the long arched chambers of *Glt. contusa scutilla* and the general appearance of the test are close to *Glt. fornicata manaurensis.*

Globotruncana contusa scutilla, n. subsp. Pl. 4, fig. 1a-c

Description.—Fairly and regularly convex on the dorsal side, flat on the ventral side, double-keeled, the peripheral band almost horizontal and lying in the same plane as the umbilical surface; periphery subcircular and slightly lobate, chambers narrow, long, arched, even the last ones. Sutural elevations generally thick, sometimes thinner but always continuous and fringing the chambers on the dorsal as well as the ventral side. Umbilical cavity large with slightly arched lips as in *Glt. fornicata manaurensis.* The test is dextrally coiling.

Dimensions of holotype.—Width 0.38 x 0.36 mm.; thickness, 0.23 mm.

Holotype.—No. 20848, Paleontological Research Institution.

Occurrence.—Manaure shale and bottom of the Colon shale (bottom of *Pullenia cretacea* zone). Holotype (fig. 4, 1a-c) from the Manaure shale, Manaure section, S. 9168.

Remarks.—Transitional stages are present toward *Glt. contusa patelliformis*, n.subsp. and toward *fornicata* forms.

Globotruncana contusa patelliformis, n. subsp. Pl. 4, fig. 2a-c
Globotruncana contusa Bolli, 1951, p. 196, pl. 34, figs. 7-9

Description.—Form more convex on the dorsal side than *Glt. contusa scutilla,* the convexity being more pronounced in the last stages; last chambers higher, petaloid and often undulated; sutural elevations thinner and frequently split in the dorsal side into lines of beads. The form is double-keeled, becoming often single-keeled in the more adult stages. The umbilical cavity is large, the umbilical lips are thin and slightly more arched than in the previous forms. The test is dextrally coiling.

Dimensions of holotype.—Width 0.48 x 0.42 mm.; thickness, 0.35 mm.

Holotype.—No. 20849, Paleontological Research Institution.

Occurrence.—Colon shale, *Pullenia cretacea, Siphogenerinoides bramlettei* zones, more frequent in shallower environment. Holotype (Pl. 4, fig. 2a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5579.

Remarks.—The form is evidently closely related to *Glt. contusa contusa. Glt. contusa* was originally described by Cushman as a "variety" of *Glt. arca* from the Papagallos shale, but no figure was given. Later Cushman, 1946 (p. 50, pl. 62, fig. 6), presented a drawing of it, but the form differs from the present one in having a more prominent pyramidal shape.

COMMENTS ON THE PHYLOGENETIC DEVELOPMENT OF THE FORNICATA GROUP

The close morphologic and genetic relationship between *fornicata, caliciformis,* and *contusa* forms have already been suggested by some authors (Cita, 1948, Bolli, 1951), as noticed in the detailed description of the single species. This is not only entirely confirmed by this study, but it can be noted that *caliciformis, fornicata, contusa* had, to date, a generic meaning indicating evolutionary lines or, at any rate, groups of closely related forms. This is also true of *Glt. linnei, Glt. bulloides,* and *Glt. tricarinata,* as noted previously. A close relationship between *intermedia-citae* forms and the other forms of the group can here only be suggested by rare, poorly preserved, primitive forms which appear, however, transitional toward *caliciformis* and *fornicata* types. New groups of forms have been found and inserted in the group, like the *cesarensis* branch.

Some developments toward *Rugoglobigerina* forms were also found which occur in a similar way to those observed and described in the *bulloides* group and with the same stratigraphic distribution. This has, however, some important significance since it proves that the *Rugoglobigerina* originate in repeated mutations of *Globotruncana, s. str.,* perhaps not occurring contemporaneously (influence of full marine ecologic conditions?).

Origin of the group.—A few specimens which were classified as *Glt. fornicata manaurensis* show some primitive characteristics which are closely reminiscent of *Glt. lapparenti longilocula.*

This supports strongly the opinion that the *fornicata* group may have its ancestor in a *lapparenti* species (*Glt. lapparenti longilocula* or closely related form).

Fornicata branch.—*Glt. fornicata* ranges high in the section, but unfortunately becomes rare upward so that it was not possible to check its morphological evolution closely as was done for other forms. Nevertheless, some morphological changes could be noted which appear to be of statigraphical interest. Upsection:

The test becomes more convex.

The chambers become more lobate, loose, petaloid, and more or less undulate in the more adult stages, somewhat inflated toward the inner margin of the spire especially in the early stages.

The apertural lips start to be more arched and better developed.

The margin becomes single-keeled in the adult stage.

The sutural elevations change to thinner, beaded ones, especially in the early stages.

Plummerae branch.—The evolutionary trend of *Glt. fornicata fornicata* to *Glt. fornicata ackermanni* through *Glt. fornicata plummerae* is documented by a full set of intermediate stages. Genetically related *Rugoglobigerina* forms are apparently *Rugoglobigerina circumnodifer subcircumnodifer* and *Rugoglobigerina circumnodifer circumnodifer.*

Cesarensis branch.—*Glt. fornicata cesarensis* is interpreted as representing a lateral trend toward forms with fewer chambers in the last whorl in consequence of the extremely rapid development of the chambers as added. A similar evolution was accordingly suspected in the *tricarinata* and *ventricosa* branches. The phylum *Glt. fornicata cesarensis-Rugogl. macrocephala macrocephala* is fairly well documented by a complete set of transitional stages as well as by the typical few chambered tests.

Well-documented transitional stages also show the close genetic relationship between *fornicata, plummerae,* and *cesarensis* forms.

Caliciformis branch.—This represents a well-defined trend toward convex tests, fairly well-developed petaloid chambers, finely beaded sutures, narrower umbilicus, radial depressed sutures on the umbilical side and a more complicated, *rosetta*-like, apertural system (Pl. 3, figs. 1-3).

It derives from *fornicata-intermedia* tests (fig. 7/1-4).

Difformis-intermedia-citae branches.—Only a few specimens were recognized of *Glt. intermedia difformis.* It appears to be closely related to *Glt. intermedia intermedia* (convex test, inflated petaloid chambers) and to *Glt. caliciformis caliciformis* (convex test, flat, petaloid chambers).

The rounded margin suggests a lateral trend toward a *Rugoglobigerina* test, *i.e.*, toward *Rugoglobigerina ornata ornata,* which

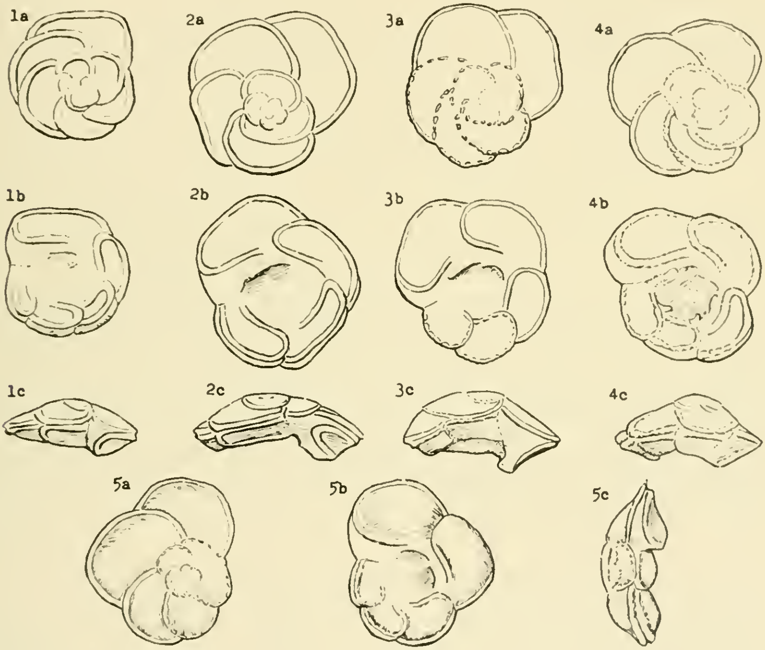
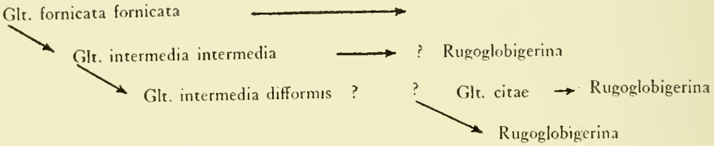


Fig. 9. Drawings 1-4 show morphological line *Glt. fornicata manaurensis,* n.subsp. *Glt. caliciformis caliciformis* (de Lapparent). All figures 45 ×. 1a-c. *Glt. fornicata manaurensis,* n.subsp. (from Pl. 2, fig. 1). 2a-c. *Glt. fornicata,* n.subsp. S. 9164. Manaure shale (*Marginulina jonesi*); showing intermediate characters. 3 a-c. *Glt. caliciformis caliciformis* (de Lapparent). S. 9164. Manaure shale. (*Marginulina jonesi*); showing beaded sutures in early chambers, but still subcircular periphery. 4a-c. *Glt. caliciformis caliciformis* (de Lapparent), from Pl. 3, fig. 1; showing well-developed petaloid chambers. Notice nearly straight apertural lips in primitive forms which become arched in more evolved types. 5a-c. *Glt. intermedia intermedia* (Bolli). S. 5881. Bottom of Colon shale (*Pullenia cretacea* zone) showing raised umbilical sutures and intermediate characteristics with *Glt. fornicata brotzeni* and *Glt. caliciformis caliciformis.*

shows a typical well-developed second last chamber. *Glt. intermedia intermedia* is also rare, so that its relationship to the other forms of the group could not be completely analyzed, but the specimen of fig. 9(5a-c) shows characteristics which are quite similar to those of primitive *caliciformis* and *fornicata* tests.

The phylum *Glt. intermedia-Glt. citae* leads to extreme petaloid single-keeled species with transitional forms which have been also recorded by Bolli. However, both forms appear to split separately toward *Rugoglobigerina* tests.

The phylogenetic development of the branch appears to the writer as follows:



Contusa branch.—The evolutionary trend represented by this branch is remarkably similar and parallel to that of *Glt. fornicata fornicata* with, however, an extreme development of certain particular characteristics like the dorsal convexity, the irregular periphery, the undulated, and long polygonal chambers. Of some interest is that here the apertural system becomes, in the more evolved species, more complicated.

GLOBOTRUNCANA THALMANNI GROUP

Description.—Forms generally biconvex or flat dorsally with a strongly protruding convex, or conical, underside, generally single-keeled. A narrow double keel is sometimes present in the early stages (*cretacea* branch) or all around the shell (*arca* branch, second keel shifted inside). The side wall of the chambers tends to make a large angle with the roof as in *tricarinata* tests. The chambers, typically polygonal or petaloid in the adult stage are long, arched in the more primitive species, and keep their elongated shape in the early stages of the more evolved ones; the sutures are continuously raised in the more primitive forms, becoming sharp and thin or finely beaded in the more evolved species.

This group includes different branches:

Cretacea branch.—Biconvex, with elongated, *fornicata*-like chambers, a double keel sometimes present in the early stages, test trochoidal in the early stages and becoming later flattened.

This is apparently the more primitive branch and can be considered as a link between the *fornicata* and the *thalmanni* groups.

Arca branch.—Biconvex, double-keeled, the second one shifted toward the umbilicus, periphery subcircular to slightly lobate, chambers petaloid, sutures on the dorsal side gently curved.

Stuarti branch.—Generally biconvex or conical, single-keeled, sutures straight, tending to bend sharply at the periphery, chambers more or less polygonal, elongated and imbricated on the ventral side with fine sutural elevations which tend to become attached to the previous ones at the margin of the umbilicus.

Rosetta branch.—Flat or slightly convex side, single-keeled, sutures curved, raised or finely beaded, chambers normally increasing in size, becoming fairly petaloid; ventral side more or less protruding, with sutures tending to be attached to the previous ones.

Wiedenmayeri-gansseri branches.—Flat on the dorsal side, strongly convex and protruding on the ventral one, test particularly rough with ornamentation, chambers slightly inflated dorsally, strongly so on the ventral side; single or double-keeled with a narrow peripheral band, which is asymmetrically placed being closer to the roof of the chambers because of the strong umbilical convexity.

The *arca, stuarti,* and *rosetta* branches are closely related, showing an evident link in *Glt. bollii.* The morphological similarity is becoming less evident higher in the section (Colon shale), following their progressively diverging evolution.

The *wiedenmayeri-gansseri* branches are closely related to the *rosetta* branch and may represent, as will be seen later, complex trends of evolution. As far as could be understood, single-keeled forms appear to lead to spinose tests, with radial umbilical sutures and a narrow umbilicus as well as to *Rugoglobigerina;* on the other hand, double-keeled forms seem to lead toward only *Rugoglobigerina.*

Apertural system.—A wide umbilical cavity is to be observed with nearly straight, simple lips in the more primitive forms, as in the primitive *fornicata* tests. In more evolved species and within the simple species hand in hand with their evolution, the apertural system becomes more and more complicated showing strongly developed arched lips. The lips grow and tend to open opposite to the sense of coiling in the more evolved and well-developed *rosetta* and *stuarti* tests. The *cretacea* branch is apparently forming a complicated apertural system with great expansion of lamellar plates (Reichel, *op. cit.*, p. 615). The apertural lips are still well developed in *Glt. rosetta pettersi* and *Glt. wiedenmayeri wiedenmayeri*. They become thinner and reduced in *Glt. gansseri gansseri* and *Rugoglobigerina*, maintaining, however, their tendency to open somewhat opposite to the direction of coiling.

CRETACEA BRANCH

Globotruncana thalmanni thalmanni, n.sp. Pl. 4, figs. 4a-c

Description.—Biconvex, more strongly so on the ventral side, periphery subcircular, one keel in the adult stage, two keels close together in the early chambers. The spiral coils trochoidal in the early stages, becoming flattened in the adult ones. The chambers are elongated, arched, and curved (*fornicata* type), becoming rapidly more convex and protruding on the umbilical side in the adult stages. The sutural elevations are generally thick and continuous (*lapparenti* type), oblique and tending to bend sharply and typically when attaching to the previous coil. On the ventral side they are curved, well marked, tending to attach themselves to the previous ones around the umbilicus. The test is rough and somewhat spinose in the early stages; the umbilical cavity is large with thin, slightly arched or nearly straight lips. The lips are dextrally coiling.

Specimens with one keel—the second being reduced to an indistinct rough line in the early chambers—and with less elongated and arched chambers mark transitional stages toward *Glt. flexuosa* van der Sluis.

Dimensions of holotype.—Width 0.45 x 0.38 mm.; thickness, 0.18 mm.

Holotype.—No. 20851, Paleontological Research Institution.

Occurrence.—Rare in the Manaure shale. Holotype (Pl. 4, fig. 4 a-c) from the Manaure shale, Manaure section, S. 9167.

Remarks.—The most striking characteristics of this species are the long arched chambers of *fornicata* type and the overlapping manner of the chambers on the umbilical side which is of *rosetta-stuarti* type. Morphologically the species is related to *Glt. fornicata brotzeni* on one side and on the other one to *Glt. thalmanni flexuosa* (van der Sluis). It differs from the first species especially because of its more protruding umbilical side, and from the other because of the more elongated and typically shaped chambers. Noteworthy is that the manner of growth of the spire in the early stages (more convex dorsal side, chambers more flattened on the ventral one) is identical to that of *Glt. fornicata brotzeni* (the early part of the test of a *Glt. thalmanni thalmanni* is a complete *Glt. fornicata manaurensis*).

This species was named after H. Thalmann for his general contribution on micropaleontological studies.

Globotruncana thalmanni flexuosa (van der Sluis) Pl. 4, fig. 6a-c

Globotruncana flexuosa van der Sluis, 1950, p. 21, pl. 1, figs. 7a-c, 8a-c.

Description.—As in *Glt. thalmanni thalmanni,* the second keel is occasionally present as an indistinct rugose ridge fringing the early chambers of the last whorl, being often somewhat masked by tubercles, which render particularly rough the test of the early chambers. The undulation of the chambers is fairly evident and increasing in the adult stages. The umbilical cavity is large, the lips are thin, slightly arched or nearly straight.

Occurrence.—Manaure shale.

Remarks.—The chambers increase more rapidly in size, as appears in the reference. The scarce material does not permit one to ascertain what stratigraphic meaning this discrepancy may have (the holotype of this species is recorded in the Maestrichtian of the island of Ceram, Indonesia).

The form differs from *Glt. thalmanni thalmanni* in its larger size, its more elongated periphery, its larger more petaloid and evidently undulated chambers, its oblique nearly straight sutures. On the other hand the species is closely related to *Glt. cretacea* Cushman which has fewer, more lobate and petaloid chambers in the last whorl, sutures more conspicuously beaded and raised, test more spinose.

Globotruncana aff. **cretacea** Cushman Pl. 4, fig. 7a-c

Description.—Nearly flat on the dorsal side, strongly convex on the ventral side, a double keel present in the early chambers, the second one becoming weak and disappearing in the adult stage. Four to five chambers in the last whorl, short, slightly lobate; sutures conspicuously raised and spinose, oblique, becoming straight (*stuarti* type). On the ventral side the sutural elevations are of *rosetta* type, being curved and tending to be attached to the previous suture around the umbilicus. The umbilicus is comparatively narrower than in the previously described species and is provided with well-developed arched lips (*rosetta* type).

Dimensions.—Width 0.38 x 0.35 mm.; thickness, 0.25 mm.

Figured specimen.—No. 20852, Paleontological Research Institution.

Occurrence.—Rare in the Colon shale (uppermost *Pullenia cretacea* zone).

Remarks.—The form differs from *Glt. cretacea* by its outstanding ventral convexity and its more circular periphery. However, in the quoted reference, it is stated that on the ventral side, "the sides in the later chambers are often becoming more than 45°," which means that the convexity occasionally becomes more noticeable than appears in the illustration.

ARCA BRANCH

Globotruncana bollii, n.sp. Pl. 5, fig. 1a-c

Globotruncana arca Cushman, 1946, pl. 62, fig. 5a-c; Cushman, 1932, pl. 51, fig. 13a-c.

Description.—Slightly convex on the dorsal side, more strongly so on the umbilical one with a narrow double keel fringing the early chambers, the second one often reduced to an indistinct rugose line, becoming single-keeled in the adult stages. The test coils in a more pronounced way in the early stages with long, arched chambers (cf. *Glt. thalmanni thalmanni,* n.ssp.) which becomes larger and petaloid in later stages. The sutural elevations are thick and rugose in the early stages, later becoming thin, well defined and smooth, with a somewhat straight, oblique development (*stuarti* type). On the umbilical side the sutural elevations are present, well defined and curved as in all *arca* and *rosetta* tests. The umbilical cavity is large with thin, nearly straight or slightly arched lips. The test is dextrally coiling.

Dimensions of holotype.—Width 0.51 x 0.48 mm.; thickness, 0.22 mm.

Holotype.—No. 20853, Paleontological Research Institution.

Occurrence.—Frequent in the lowermost portion of the Colon shale (lowest *Pullenia cretacea* zone). Holotype (Pl. 5, fig. 1a-c) from the Colon shale, *Pullenia cretacea* zone, Molino section, S. 12161.

Remarks.—This species was interpreted from Cushman's figures as a *Glt. rosetta* by Cita, 1948, and as *Glt. stuarti* by Bolli, 1951. Actually, this species shows intermediate (undifferentiated) characteristics between *Glt. rosetta, Glt. stuarti,* and *Glt. arca.* The present material is poor. However, a sample of the Pecan Gap, which was available to the writer through the courtesy of Mr. F. B. Ellis, shows a complete set of transitional passages from *Glt. bollii, Glt. arca arca,* and *stuarti-rosetta* forms.

A point of phylogenetic interest is that, in the early stages, the test becomes more trochoidal with elongated chambers, similar to a complete test of *Glt. thalmanni thalmanni.*

Bolli, 1945, described and named *Glt. leupoldi* only from thin sections, a species which apparently shows an internal double keel later becoming a single one. The thin sections were found later by Reichel, 1949, (p. 614) to be identical with thin sections of *Glt. arca.* It is probable, therefore, that *Glt. leupoldi* may include both forms, *Glt. bollii* and *Glt. arca arca*, inasmuch as it ranges through the Campanian and Maestrichtian. *Glt. leupoldi* is, at any rate, more convex on the dorsal side (*Glt. arca arca*) than the present one.

This species was named after H. Bolli, paleontologist of Trinidad Leaseholds, Ltd., for his contribution to the knowledge of *Globotruncana.*

Globotruncana arca arca (Cushman) Pl. 5, figs. 2a-c, 3a-c, 4a-c

Pulvinulina arca Cushman, 1926, p. 23, pl. 3, fig. 1a-c.
Globotruncana arca Cushman, 1946, p. 15, pl. 62, fig. 4a-c.

Description.—Typical forms are convex on both sides with a rather large, fairly oblique peripheral band, two well-developed keels which sometimes tend to converge in the direction of coiling, and six-seven quite petaloid chambers in the last whorl. The sutural elevations are generally continuously curved and well developed in the ventral side, sometimes beaded on the early portion of the dorsal side. The umbilical cavity is large. In more evolved forms the lips become more arched and overlap each other (*rosetta* type). Primitive forms (Pl. 5, fig. 2a-c) show straight and oblique *stuarti*-like sutures on the dorsal side and a narrower double keel (transition to *Glt. bollii*).

Occurrence.—Colon shale, more frequent upward in section.

Globotruncana arca caribica, n. subsp. Pl. 5, fig. 5a-c

Description.—Similar to *Glt. arca* but has fewer chambers (4-5) in the last whorl, increasing more rapidly in size with more finely beaded sutures. The test is dextrally coiling.

Dimensions of holotype.—Width 0.38 x 0.36 mm.; thickness, 0.25 mm.

Holotype.—No. 20854, Paleontological Research Institution.

Occurrence.—Colon shale, upper *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone. Holotype (Pl. 5, fig. 5) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5592.

Remarks.—The form is rare, but it appears more frequently higher in the section, probably representing a more evolved test and an evolutionary tendency toward forms with fewer chambers in the last whorl (cf. *Glt. fornicata cesarensis, Glt. tricarinata colombiana*, and *Glt. ventricosa*).

Morphologically it may be related to *Glt. fornicata fornicata* (evolved forms) because of the somewhat elongate chambers. The regular test without undulating chambers, the more convex and sharply angled sideview, the more protruding umbilical slide are distinctive characteristics.

STUARTI BRANCH

Globotruncana stuarti stuarti (de Lapparent) Pl. 5, figs. 6a-c

Rosalina stuarti de Lapparent, 1918, p. 11, fig. 4, 5a-c.
Globotruncana stuarti Cita, 1948, p. 18, pl. 4, fig. 7a-c.
Globotruncana conica Bolli, 1951?, pl. 34, figs. 13-15.

Description.—Biconvex with protruding umbilical side and typical sutures forming a sharp bend at the peripheral edge. The chambers increase slightly in size (six-seven in the last whorl). The apertural system is provided with strongly developed and arched lips (Reichel, 1949, p. 614).

Dimensions.—Width 1.18 x 1.20 mm.; thickness, 0.47 mm.

Occurrence.—Colon shale, *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone.

Remarks.—The only American record of this species (Bolli, 1951, pl. 34, fig. 12) shows a smaller specimen with only four-five chambers in the last whorl (*Glt. stuarti parva*), whereas the holotype from the afore-quoted De Lapparent reference has six-seven chambers in the last whorl.

Globotruncana stuarti parva, n. subsp. Pl. 5, fig. 7a-c

Globotruncana stuarti Bolli, 1951, p. 196, pl. 34, figs. 10-12.

Description.—Test considerably smaller than the previous one, chambers more rapidly increasing in size and becoming larger than in *Glt. stuarti stuarti* (five in the last whorl). The sutures are, in the previous form, less sharply bent or more gently curved (*rosetta* type) in the last stages.

Dimensions of holotype.—Width 0.72 x 0.70 mm.; thickness, 0.37 mm.

Holotype.—No. 20855, Paleontological Research Institution.

Occurrence.—Colon shale, more frequent in upper part of section. Holotype (Pl. 5, fig. 7) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5597.

Remarks.—The observation of the umbilical cavity was poor, but nevertheless the lips are apparently less arched and developed than in the typical form. It is not possible from our material to judge which of the two forms may be more primitive. At any rate this subspecies appears to represent a special phylogenetic tendency of the species toward forms with fewer chambers in the last whorl, as seen in *Glt. tricarinata colombiana* and *Glt. fornicata cesarensis*.

Globotruncana stuarti conica (White) Pl. 5, fig. 8a-c

Globotruncana conica White, 1928, p. 285, pl. 38, figs. 7a-c; Cushman and Renz, 1947, p. 50, pl. 12, fig. 12; Cita, 1948?, pp. 149-150, pl. 3, fig. 5a-c.

Description.—Typical for the species are: the strong dorsal convexity of the test, the flat, sometimes concave, umbilical side, the long narrow chambers (seven-eight in the last whorl) which become rectangular in consequence of the sharply bending sutures. Round arched lips are present in the umbilical side, opening in a pronounced way opposite to the direction of coiling. The last chambers may become petaloid and the sutures gently curved (*rosetta* type).

Occurrence.—Colon shale, upper *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone.

Remarks.—The close relationship of these three *stuarti* forms is documented by a full set of transitional stages. Sharply cut rectangular chambers are here typical, sometimes becoming later more gently curved as noted. Curved sutures and petaloid chambers are on the contrary shown in the original figure of White, as well as in *Globotruncana conica* Cita, *Glt.* aff. *conica* Reichel, 1949 (p. 614, fig. 7b) has also *rosetta* type chambers and a lobate periphery but has a more convex umbilical side. *Glt. conica* Cushman and Renz (afore-quoted reference) is somewhat intermediate, having only the last chambers petaloid. There is, therefore, the possibility that the conical character, as well as the exceptionally high number of chambers, may develop independently (common morphological trend) in different branches such as the *rosetta* and *stuarti* branches (cf. also *Glt. caliciformis sarmientoi*) giving way to similar but genetically different forms.

ROSETTA BRANCH

Globotruncana rosetta rosetta (Carsey) Pl. 6, fig. 1a-c

Globigerina rosetta Carsey, 1926, p. 44, pl. 5, fig. 3a-b; Plummer 1926, p. 36, pl. 2, fig. 9a-c.

Globotruncana rosetta Glaessner, 1936, pl. 1, fig. 12.

Description.—Typical forms show a lobate periphery with petaloid chambers, curved sutures (a slight sharp bending toward the periphery is occasionally observed), protruding convexity on the ventral side, while the dorsal one is flat or only slightly convex. There are five or six chambers in the last coil. The apertural system has strongly arched lips.

Occurrence.—Colon shale.

Remarks.—The form described by Cita, 1948 (p. 16, pl. 4, fig. 5a-c) has more *stuarti*-like chambers in the last whorl (six-eight). Perhaps the specimen illustrated can be identified with *Glt. bollii* which includes the more primitive type with undifferentiated morphological characteristics.

The specimen on text figure 10 shows a slightly different morphological character compared with the average *rosetta* type. The periphery is fairly lobate, the umbilical side of the chambers is slightly inflated, the sutures are here radial and depressed, the sutural elevations disappearing in the sutural depressions. The test is also apparently rougher than in typical forms. The form is closely related to *Glt. seranensis* van der Sluis, 1950, which differs only in a more developed spinose test and short inflated chambers on the umbilical side with radial, depressed sutures without any "bourrelet sutural" even around the umbilicus.

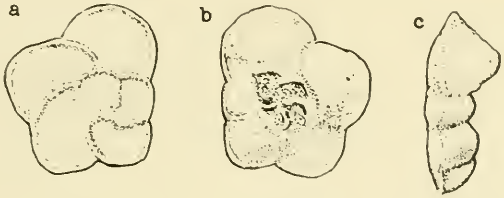


Fig. 10. *Glt. rosetta rosetta* (Carsey) showing depressed umbilical sutures with "bourrelet sutural" partially disappearing. S. 5602. Colon shale, upper *Pullenia cretacea* zone. 60 ×.

Globotruncana rosetta insignis n. subsp. Pl. 6, fig. 2a-c

Description.—Usually seven-eight fairly lobate (especially the last one) chambers which become shorter in the adult stages. They are strongly protruding and slightly inflated on the ventral side, where the sutural elevations disappear here and there in the sutural depressions, however, with the "bourrelet umbilical" generally present. The sutures are more conspicuously beaded than in *Glt. rosetta.* Fairly arched lips are present in the umbilical cavity.

Dimensions of holotype.—Width 0.99 mm.; thickness 0.33 mm.

Holotype.—No. 20856, Paleontological Research Institution.

Occurrence.—Rare in the Colon shale (upper *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone ?). Holotype (Pl. 6, fig. 2a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5603.

Remarks.—*Glt.* aff. *conica* Reichel, 1949 (p. 614, fig. 7b) is closely related, but differs by its more outstanding dorsal convexity and slightly conical umbilical side with fairly evident sutural elevations.

Rotalia elevata Brotzen also shows a strongly protruding umbilical side, as well as many chambers in the last whorl (six-nine); the specimen illustrated has, however, only six chambers, its chambers are inflated on the ventral side with radial, depressed sutures, without any trace of raised sutures. Probably this form is a more evolved *rosetta* type somewhat related to *Glt. seranensis.*

Globotruncana rosetta pettersi, n. subsp. Pl. 6, figs. 3a-c, 4a-c, Text fig. 11a

Description.—Test subcircular, flat dorsally, strongly convex on the ventral side, single-keeled; the chambers increase slightly in size, are curved and overlapping, as in *Glt. rosetta rosetta.* They are strongly convex ventrally, flat and even concave dorsally. The sutural elevations are thin, well defined and sharply raised. The ventral convexity of the chambers can be so strong as to give in typical specimens a truncoconical profile (side wall nearly at right angles with the roof of the chambers).

The chambers overlap in the ventral side, with thin marginal elevations along the sutures which extend back to the previous ones. The umbilical cavity is open; the apertures are covered by well-developed arched lips (*rosetta* type), cf. fig. 11a.

Dimensions of holotype.—Width 0.89 x 0.86 mm.; thickness, 0.44 mm.

Types.—No. 20857, holotype; No. 20858, paratype, Paleontological Research Institution.

Occurrence.—Lower Colon shale, lower *Pullenia cretacea* zone, disappearing when the first *Glt. gansseri gansseri* starts. Holotype (Pl. 6, fig. 3a-c) from the Colon shale, *Pullenia cretacea* zone, Km. section, S. 5589.

There are tendencies both toward *Glt. rosetta rosetta* (more flattened forms) on one side and *Glt. gansseri gansseri* on the other one (Pl. 6, figs. 4, 5, 6).

Remarks.—It was named after Viktor Petters, Head of the Paleontological Laboratory of the International Petroleum (Colombia), Limited.

GANSSERI-WIEDENMAYERI BRANCHES

Globotruncana gansseri gansseri (Bolli) Pl. 6, fig. 8a-c, Text fig. 11b

Globotruncana gansseri Bolli, 1951, p. 196, pl. 35, fig. 1-3.

Description.—The chambers are slightly inflated on the dorsal side and strongly so on the ventral side, sometimes irregularly arranged with the plane of coiling. Small senile chambers frequently are seen lying somewhat lower toward the umbilical side. The test is definitely rough with occasional horizontal and transverse rugose ridges in the early chambers. This feature is more pronounced in *Rugoglobigerina rugosa rugosa* (Plummer).

The apertures open deep in the umbilical cavity and are covered by arched cover-plates, similar to but less developed than in *Glt. rosetta pettersi* (text fig. 11b).

Occurrence.—Colon shale, uppermost *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone.

Remarks.—A comparison with topotype material from Trinidad shows that our specimens are identical but generally bigger. Four to five chambers in the last whorl are common, but specimens with six chambers are present. Transitional stages with *Glt. rosetta pettersi* are present, thus making it difficult to distinguish the last stages of *Glt. rosetta pettersi* from the early ones of *Glt. gansseri gansseri.*

In some tests of *Glt. gansseri gansseri* (Pl. 6, fig. 8a-c) in which the keel marks the entire circumference, the inflation of the early

Fig. 11. Comparative view of cleaned umbilical sides of: a. *Glt. rosetta pettersi,* n.subsp. S. 5587. Colon shale, *Pullenia cretacea* zone. b. *Glt. gansseri gansseri* (Bolli). S. 5607. Colon shale, *Pullenia cretacea* zone. c. *Rugogl. rugosa rugosa* (Plummer). S. 5607. Colon shale, *Pullenia cretacea* zone. All drawings 60 ×.

chambers extends to the last coil and the chambers become narrower so that the test is reminiscent of *Rugoglobigerina rotundata rotundata,* except for the last more flattened chambers.

Glt. helvetica Bolli is morphologically similar, being different, however, because of its sharp, well-defined keel, its more outstanding inner whorl, and its slightly concave dorsal side.

Globotruncana gansseri subgansseri*, n. subsp. Pl. 6, fig. 7a-c

Description.—Test flat dorsally and considerably inflated ventrally, six-seven chambers in the last volution, one finely beaded keel. The chambers increase more rapidly in size as in *Glt. gansseri gansseri* and are more inflated even dorsally; the test is rougher. The inner volutions are not visible because of the fairly developed rugosity.

Dimensions of holotype.—Width 0.58 x 0.54 mm.; thickness, 0.38 mm.

Holotype.—No. 20859, Paleontological Research Institution.

Occurrence.—Uppermost *Siphogenerinoides cretacea* zone. Fairly rare. Holotype (Pl. 6, fig. 7a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5605.

Remarks.—It differs from the *Glt. gansseri gansseri* because of the greater number of chambers in the last whorl, the smaller size, the less evident keel, the more inflated chambers.

Globotruncana (Rugoglobigerina) rotundata rotundata (Bronnimann)
Pl. 7, fig. 2

Rugoglobigerina rugosa rotundata Bronnimann, 1952, p. 34, pl. 4, figs. 7-9, Text figs. 15-16.

Occurrence.—Rare in the uppermost *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone.

Globotruncana (Rugoglobigerina) rotundata subrotundata, n. subsp.
Pl. 7, fig. 1a-c

Description.—Large, subspherical test, with inflated umbilical side and inflated chambers which become more and more elongated in the axial direction. The surface is rough, particularly in the early chambers, but a distinct keel fringes the early chambers of the last volution in a discontinuous way. The umbilical cavity appears to be larger than in the original figure of *Rugoglobigerina rugosa rotundata* (Bronnimann) and is provided with umbilical lips.

*Editor's note: On plate 8 this subspecies is listed as *Glt. gansseri hexacamerata.* The correction to *Glt. gansseri subgansseri* on the plate should be made accordingly.

Dimensions of holotype.—Width 0.88 x 0.85 mm.; thickness, 0.56 mm.

Holotype.—No. 20860, Paleontological Research Institution.

Occurrence.—Colon shale, *Pullenia cretacea* zone. Rare. Holotype (Pl. 7, fig. 1) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5597.

Remarks.—Plate 6, fig. 8, suggests that *Glt. gansseri gansseri* undergoes a process of "globigerinization" like other *Globotruncana* forms. The fact that the few tests of *Glt. gansseri gansseri* show a tendency toward a more trochoidal coiling and toward more elongated end-chambers supports the opinion that *Rugoglobigerina rotundata rotundata* is an offshoot of *Glt. gansseri gansseri* and appears genetically separated from *Rugoglobigerina rugosa rugosa.*

Globotruncana wiedenmayeri wiedenmayeri, n.sp. Pl. 7, fig. 4a-c

Description.—Test flat on the dorsal side with slightly inflated chambers (generally six in the last whorl) convex on the ventral side with chambers strongly inflated and round, two finely raised keels close to the dorsal side and to each other, chambers short, petaloid; sutures, deep depressed, and radial on the ventral side with sutural elevations occasionally present in the last chambers. Test rough with spines, papillae, rugose ridges on the ventral side, developed arched lips (*rosetta* type) covering the umbilical apertures.

Dimensions of holotype.—Width 0.78 x 0.89 mm.; thickness, 0.32 mm.

Holotype.—No. 20861, Paleontological Research Institution.

Occurrence.—Colon shale, lower *Pullenia cretacea* zone. Holotype (Pl. 7, fig. 4a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5577.

Remarks.—In general the form is similar to *Glt. gansseri gansseri* Bolli with the same rough test and ornamentation of early chambers. The only marked difference is the double keel and generally greater number of chambers in the last whorl.

The species was named after the late Dr. C. Wiedenmayer, Chief Geologist of Societá Petrolifera Italiana (Standard Oil Company of New Jersey).

Globotruncana wiedenmayeri magdalenaensis, n.sp., n. subsp.

Pl. 7, fig. 3a-c

Description.—Flat dorsally; strongly convex and inflated on the ventral side like the previous form; double-keeled in the early stages of the last volution, it later becomes single-keeled or somewhat subangular. The chambers are four-five in the last whorl, exceptionally six; the test is rough as is common in these forms with ridges and various types of rugosity especially in the early chambers.

Dimensions of holotype.—Width 0.55 x 0.53 mm.; thickness, 0.30 mm.

Holotype.—No. 20862, Paleontological Research Institution.

Occurrence.—Rare in the lower Colon shale. Holotype (Pl. 7, fig. 3) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5577.

Remarks.—The form is similar to *Glt. wiedenmayeri wiedenmayeri;* it differs in that the double keel is fringing only in the early part of the shell and has generally fewer chambers in the last whorl. The test is smoother.

Globotruncana (Rugoglobigerina) rugosa rugosa (Plummer)

Pl. 7, fig. 6a-c, Text fig. 11c

Globigerina rugosa Plummer, 1926, p. 38, pl. 2, fig. 10.

Rugoglobigerina rugosa rugosa (Plummer), Bronnimann, 1952, p. 28, Text figs. 11, 12, 13.

Description.—Small irregularly arranged senile chambers frequently appear. Transversal and horizontal rugose ridges are generally well developed. The test is rough. The umbilical cavity is small as compared with that of *Glt. rosetta pettersi* and *Glt. gansseri,* and the umbilical apertures are deep with thin, reduced cover plates, still opening opposite to the direction of coiling. The last aperture seems to extend slightly toward the periphery.

Occurrence.—Colon shale, uppermost *Pullenia cretacea* zone, *Siphogenerinoides bramlettei* zone. Abundant.

Globotruncana (Rugoglobigerina) rugosa subrugosa, n. subsp.

Pl. 7, fig. 5a-c

Description.—Test low trochoidal; six chambers rapidly increasing in size, subglobular at the peripheral side and truncated at the umbilical side. Last chamber generally inclining toward the umbilicus. In the early stages of the last volution two keels fringe the shell, but they are somewhat masked by the other well-marked rugose ridges and rugosity in general. Because of this, the keels are not always apparent.

Dimensions of holotype.—Width 0.53 x 0.51 mm.; thickness, 0.31 mm.

Holotype.—No. 20863, Paleontological Research Institution.

Occurrence.—Lower Colon shale. Rare. Holotype (Pl. 7, fig. 5a-c) from the Colon shale, *Pullenia cretacea* zone, Km. section, S. 5579.

Remarks.—It is identical to *Rugoglobigerina rugosa rugosa* with the only well-marked difference being the presence of a discontinuous beaded double keel. The rugosity is apparently increasing higher stratigraphically.

Globotruncana (Rugoglobigerina) pennyi pennyi (Bronnimann)
Pl. 7, fig. 8a-c

Rugoglobigerina rugosa pennyi Bronnimann, 1952, p. 34, pl. 4, figs. 1-3, Text fig. 16.

Occurrence.—Colon shale. Rare.

Remarks.—The similarity with *Rugoglobigerina hexacamerata hexacamerata* is noteworthy. It differs in size (larger)—intermediate to *Rugogl. rugosa rugosa* as Bronnimann points out—the rougher ornamentation, the chambers becoming more inflated and protruding on the umbilical side, the large umbilicus.

Globotruncana (Rugoglobigerina) pennyi subpennyi, n. subsp.
Pl. 7, fig. 7a-c

Description.—The test is slightly smaller than in Glt. *wiedenmayeri wiedenmayeri;* six or seven chambers are present in the last volution which increase slightly in size but less than in *Rugogl. rugosa rugosa.* A discontinuous beaded double keel fringes the shell and becomes somewhat masked by rugosity in the early stages of the last volution. The umbilical cavity is quite large; no apertural lips could be observed through the hard matrix.

Dimensions of holotype.—Width 0.80 x 0.78 mm.; thickness, 0.48 mm.

Holotype.—No. 20864, Paleontological Research Institution.

Occurrence.—Colon shale. Extremely rare. Holotype (Pl. 7, fig. 7a-c) from the Colon shale, *Pullenia cretacea* zone, Km. 92 section, S. 5580.

COMMENTS ON THE PHYLOGENETIC DEVELOPMENT OF THE THALMANNI GROUP

There is no doubt that the *rosetta* and *stuarti* branches are closely related. This affinity is strikingly shown in the manner of growth. The general morphological characteristics (especially on the umbilical side), and the apertural system, suggest that *stuarti* forms are *rosetta* tests with a more convex dorsal side and sharply curved sutures. On the other hand *rosetta* tests occasionally show a tendency toward a sudden sharp curve in the sutures when approaching the periphery.

The *arca* branch is also close to the *rosetta* and *stuarti* branches. Cushman, 1946, was justified in placing *Glt. arca* and *Glt. stuarti* together, insofar as a full set of intermediate stages are present, so that a sharp separation of these species in the early stages of the development is difficult. *Glt. bollii,* n.sp. represents the early natural link between the three branches.

On the other hand, the *cretacea* branch occupies a peculiar, somewhat more isolated, position within the group, because no evident transition form was found between this and the other branches of the group.

However, an ontogenetic investigation in the *arca, rosetta,* and *stuarti* types show, especially in the more primitive, still undifferentiated forms (*Glt. bollii*) that the early chambers have a different, more arched, and elongated shape than the later ones. The sutures are also more broadly and continuously raised in the early stages, starting radially and bending sharply, as in *Glt. thalmanni thalmanni.* This morphological feature is particularly evident in *Glt. bollii,* the early stage of which practically corresponds to a complete test of *Glt. thalmanni thalmanni.* In more evolved species or specimens this ontogenetic development is more or less masked by the sequence of the new appearing characteristics. Moreover, in *Glt. bollii,* all other morphological details such as the profile of the test, the typical trochoidal growth of the early chambers becoming later more flattened, and the apertural system confirm a close genetical relationship between the *cretacea* branch and the more evolved *rosetta, stuarti,* and *arca* branches. On the other hand in *Glt. thalmanni thalmanni* the long, elongated chambers of *fornicata* type, the early more pronounced dorsal convexity (cf. *Glt. fornicata manaurensis*) suggest an early derivation of this species from a primitive *fornicata* type or at least that both *thalmanni* and *fornicata* tests may have had a common origin (*lapparenti* form).

In accordance with the above considerations, the *cretacea* branch occupies somehow a midposition between the *fornicata* group and the other branches of the same *thalmanni* group.

At any rate, any relationship of the *rosetta-stuarti* forms to the *tricarinata* branch appears to be excluded, in spite of a certain morphological affinity (large angle between sidewall and roof), as well as, to the *sigali* forms (cf. *Glt. sigali* Reichel).

Cretacea branch.—It represents a well-defined phylogenetic development toward biconvex forms with first elongated, later shorter petaloid chambers. The second lower keel tends to disappear as in other branches of the group without, however, giving way to a completely single-keeled form. Noteworthy also is that the sutural elevations tend to split in lines of beads; the test becomes spinose and the apertural system more complicated in more evolved forms (these are general tendencies which will be discussed later). The more pronounced early trochoidal way of coiling (which gives a typical side view) is common to all forms of the group, although it becomes fainter and fainter in more evolved species (cf. *Glt. cretacea* Cushman 1938, p. 67, pl. 11, fig. 6).

Arca branch.—The morphological development is also toward biconvex forms with an oblique double-keeled peripheral band, the second keel shifting more and more toward the umbilicus in more evolved species. A tendency toward fewer chambered forms in the last whorl is also to be observed (*Glt. arca caribica*) as in *Glt. tricarinata colombiana* and *Glt. tricarinata cesarensis.* It is to be noted that the sutural elevations become beaded, the test spinose, the apertural system more complicated hand in hand with the evolution of these forms.

Stuarti branch.—Different phylogenetic trends are to be observed, *i.e.,* toward forms with comparatively few chambers in the last whorl (*Glt. stuarti parva*) and toward conical forms (*Glt. stuarti conica*).

Rosetta branch.—Forms with fewer chambers in the last whorl (*Glt. rosetta pettersi*) or more chambers (*Glt. rosetta insignis*) can also be distinguished from a normal average type.

Extremely high tests are also to be noted (*Glt. rosetta pettersi*).

Gansseri-wiedenmayeri branches.—*Glt. rosetta pettersi* appears to evolve in a complicated way toward single and double-keeled tests with inflated sides (*Glt. gansseri gansseri* and *Glt. wiedenmayeri wiedenmayeri*). *Rugoglobigerina* tests originate also from the above development.

The paleontological evidence of these developments shall be closely examined herewith:

At the bottom of the Colon shale, together with normal *rosetta* types and *Glt. rosetta pettersi*, specimens appear which are similar to *Glt. gansseri gansseri* as to general form, growth and arrangement of chambers and rough test. However, they have a well-marked double keel which is sometimes present only in the early chambers and becomes a single one, often somewhat rounded in the adult stage.

The aforementioned *Glt. rosetta pettersi* later develops more inflated chambers on the umbilical side which becomes less and less overlapping with more spinose test.

Intermediate, partially keeled, and weakly ornamented *Rugoglobigerina* appear in the *Pullenia cretacea* zone (*Rugoglobigerina rugosa subrugosa*, *Rugoglobigerina pennyi subpennyi*) together with other rare *Rugoglobigerina* forms without any keel and with rather smooth test.

Typical *Glt. gansseri gansseri* begin to appear after the disappearance of previously described forms, together with keeled and unkeeled *Rugoglobigerina rotundata* tests.

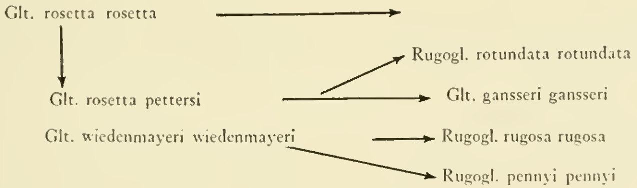
In addition to the similarity of the general morphological appearance, a close relationship between *Rugoglobigerina rugosa, s.l.* (including *Rugoglobigerina rotundata rotundata*), *Globotruncana gansseri*, and *Glt. wiedenmayeri* is proved by the following morphological details:

Small senile chambers are frequent in these forms and are typically inclined toward the umbilical side.

The test is equally rough with the same kind of ornamentation which is more clearly developed in *Rugoglobigerina* types.

The same type of apertures is to be observed in these forms. The lips progressively reduce from *Glt. rosetta pettersi* and *Glt. wiedenmayeri wiedenmayeri* to *Glt. gansseri gansseri* and *Rugoglobigerina rugosa rugosa,* as in fig. 11. Typical *Globotruncana gansseri gansseri* specimens show occasionally (Pl. 6, fig. 8a-c) obviously inflated, more elongated, *Globigerina*-like chambers in the early portions of the last coil, though having a completely keeled periphery (transition to *Rugoglobigerina rotundata rotundata*).

Therefore, if the evolutionary pattern cannot be considered as completely understood, a double parallel development from a *rosetta* test (*Glt. rosetta pettersi*) toward *Glt. gansseri gansseri-Rugoglobigerina* on one side, and *Glt. wiedenmayeri wiedenmayeri-Rugoglobigerina* on the other, appears to the writer for the moment as the more logical explanation, according to the following scheme:



The somewhat rounded chambers of *Glt. gansseri subgansseri* suggest additional development toward *Rugoglobigerina,* or even toward *Globorotalia*-like tests.

COMMENTS—GENETICAL DEVELOPMENT OF GLOBOTRUNCANA

LINES OF INVESTIGATION

It was already observed that the material which is the object of the present study is unfortunately confined, with respect to its richest and best preserved fossiliferous content, to a comparatively limited section of the Colon shale, *Pullenia cretacea* zone, which is considered Campanian in age. Nevertheless, in spite of the limited section, the variability of the genus was greater than could be expected.

In order to avoid any unjustified splitting of the genus, due attention was paid to the securing of sufficient numbers of specimens before differentiating any new nomenclatural unit. The eventuality of a dimorphism also was considered before separating species and subspecies, although no special study of the initial chamber was made.

It appeared, however, that A and B forms occurred indifferently in species and subspecies which have been recorded and named. They have also for the most part a different stratigraphic range (note that, to the writer's knowledge, no marked sexual dimorphism has been encountered to date in the *Globotruncana* genus).

When a new species and/or subspecies were named, all efforts were made to understand its relative position within the genus.

Though it is realized that in several cases this reciprocal relationship could only be postulated, these efforts were considered, in this particular case, as absolutely necessary. In fact, few genera are able to offer, when studied in detail, such evidence of a complicated evolutionary pattern as does the genus *Globotruncana*. And science is, first of all, in need of understanding and order so that the study would not have been complete if there had been only a description of the observation made without also recording the application of imagination.

Accordingly, during the course of the investigation, after the main trends and tendencies of evolution were outlined, it was possible to apply some of these principles to most of the branches of the genus. Some transitional forms could be postulated before they were actually found. This was the case for many of the globigeriniformis *Globotruncana* which were expected to be found after some of the complicated pattern of evolution toward *Glt. gansseri gansseri* and *Rugoglobigerina rugosa rugosa* had been casually observed. This was the case also for a part of the *fornicata* forms, as well as for the primitive *rosetta-stuarti-arca* forms and for the *cretacea* branch.

Particular care was taken not to adopt just any theory, but to use each as it might best serve the purpose, being always ready to modify and change it according to new observations.

For instance in the particular case of the *stuarti-rosetta* forms, the first lines of thought lead to investigate a possible transition form between the *rosetta-stuarti* and the *tricarinata* or *sigali* tests suggested by a certain morphological similarity (large angle between side wall and roof). Later, after *Glt. thalmanni thalmanni* was found, the study on the ontogenetic development of the early chambers of all the *rosetta-stuarti* forms suggested a more probable phylogenetic derivation from an undifferentiated *lapparenti-fornicata* form excluding the afore postulated bioseries.

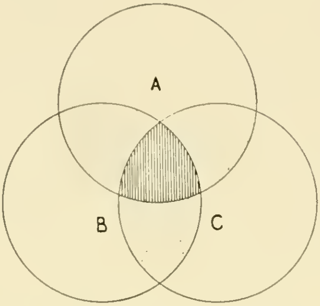


Fig. 12. Theoretic case of a dichotomic evolution. Species A is evolving toward species B and C. Dashed area indicates zone of mixed characteristics between A, B, and C; dark dotted areas, mixed zones between A, B, and A, C; light dotted area, mixed zone between B and C (no evolution between B and C).

As already mentioned, particular difficulty was encountered in establishing the limits of subspecies or species, since in many cases they were found grading into one another without any apparent morphological break. This difficulty is, of course, well known to all paleontologists who so often during their routine work observe that there is no biological concept of species when geological time is taken into consideration, but merely more or less artificial nomenclatural units. This becomes even more a problem when an organism evolves rapidly as happens with the genus *Globotruncana*.

Thus theoretically there are two possibilities: (a) a form evolved in one direction, (b) a form evolved in two directions.

a. When a genotype evolved along a well-defined trend, it is always possible to draw a sharp line of separation even if artificially between two or more species. These species have a certain number of common characteristics which do not change, together with other characteristics which, on the contrary, change continuously, but along a certain well-defined evolutionary trend (cf. fig. 12 and consider the development trends A-B, A-C as independent ones). Between A-B and/or A-C, the ideal case would be to find its geometrical solution, *i.e.*, the chord common to the two circles.

However, since the dark dotted areas represent the area of occurrence of specimens with mixed characteristics between A-B and A-C, as a matter of diagnostic procedure the logical solution of the problem would be to give a new name (species and subspecies) to all the specimens falling in the areas considered (this was the procedure adopted in most of our transitional cases).

b. Species A (fig. 12) evolved along two diverging lines of evolution toward B and C, which may represent hypothetical final stages of this process.

When the trends A-B and A-C are considered independently, it may be seen that it is always possible (a) to draw a sharp dividing line and to differentiate new species and/or subspecies as transitional ones (dark dotted areas).

However, if the respective A-B and A-C trends are considered as they are postulated as belonging to a whole complex system, another dotted area may be observed (light dotted) which include specimens with mixed characters between B and C. It is here theoretically impossible to separate B and C, and it would be biologically wrong to name a new species or subspecies for this mixed area, since this would include similar phenotypes with, however, completely different genotypes (cf. first *rosetta-stuarti* type, where the characteristic of the sharp gentle bending of the sutures is not differentiated). Quite different and more complicated is the case of the dashed area. Here fall specimens which have intermediate characters between the three forms. Theoretically, it is an impossibility to separate the specimens, and for the same reason previously postulated it would be biologically wrong to name new species or subspecies in such cases.

However, in all these cases in which it is a theoretical impossibility to separate two or more species, a prevailing characteristic may intervene and help make a decision, which will still be an arbitrary one since not all characteristics develop with the same speed in the same way and not all of them are considered as equally important; or else the form with mixed genotypes also may appear to be restricted within a certain limited stratigraphic range. In these cases, a new nomenclatural unit can be named, which is biologically wrong as expressed before (identical phenotypes with different genotypes) but paleontologically and stratigraphically useful (*Glt. bollii*). It must not be forgotten that the form is not in any case a biological species.

Plate 10 shows a tentative evolutionary chart of the genus *Globotruncana* and related genera which summarizes the writer's thinking on the subject, not only from personal experience but as it appears to him after reviewing the work of other authors, especially Reichel, Brotzen, Sigal, Mornod, Bolli, Cita. The writer has attempted here, as throughout the rest of the study, to keep facts sharply separate from theory and to discuss briefly the evidence on which each opinion is based.

ORIGIN AND EARLY DEVELOPMENT OF THE GENUS

1. The genus *Globotruncana* first appeared in uppermost Albian—lower Cenomanian time with a primitive *Anomalina-Pseudovalvulineria*-like form: *Thalmanninella ticinensis* (Gandolfi, 1942).

2. The genus *Globotruncana* developed quite rapidly from *Thalmanninella* through *Ticinella* into *Rotalipora* subgen. (early Cenomanian). The first studies of the writer, and excellent detail studies of Reichel, 1949, were made to prove this. The *Thalmanninella, Ticinella,* and *Rotalipora* line is well established and confirmed by the aforementioned detail studies on the apertural system.

3. Early in the Cenomanian, and apparently in the uppermost Albian, doubtful *Globotruncana* occur which appear transitional toward *Globigerina*-like forms (*Glt. stephani* Gandolfi, and *Globorotalia? marginoaculeata* Loeblich and Tappan).

From the above, it appears that the genus *Globotruncana* probably originated in a *Pseudovalvulineria* type (*Pseudovalvulineria lorneyana,*) cf. Gandolfi, 1942, Reichel, 1949, although more detail structural studies are needed to confirm it. To date, there is no evidence to support the possibility that the *Globotruncana* may have a plurigenetic origin, *i.e.*, that they may derive at least from different types of *Pseudovalvulineria,* and that mutations may have occurred repeatedly during Albian.

The subgenus *Globotruncana* developed in turn through *Glt. stephani* directly from *Thalmanninella* (*Thalmanninella ticinensis* or perhaps another still undiscovered *Thalmanninella* type). An earlier development of *Glt. stephani* from another *Pseudovalvulineria* type (Reichel, 1949, p. 615) enters in the realm of possibility, but to admit it would be the same as to accept a plurigenetic origin of *Globotruncana* and consequently consider *Rotalipora* and *Globotruncana* as completely separated genera with different derivation. A comparison between the apertures of *Thalmanninella ticinensis* and primitive *Globotruncana* (*Glt. stephani* Reichel, 1949, pl. 16, figs. 1-6) does not show any fundamental differences but a striking similarity. In *Th. ticinensis* only the first chamber has an umbilical lip which does not extend over the apertures; in *Glt. stephani* the umbilical lips extend clearly over the apertures of the last chambers only. The early chambers (*Glt. turbinata* Mornod, 1949, fig. 11) open apparently into the umbilicus without covering lips like in *Thalmanninella*.

It seems, therefore, that during the early stages of development the genus *Globotruncana* split into a two way evolution as regards the apertural system with:

Migration of the apertures from the umbilical cavity toward the sutural depressions (*Rotalipora*).

Maintaining of the apertures in the same umbilical cavity but progressive extension all over them of the umbilical lip which covers the interiomarginal-umbilical aperture of the last chamber of the more primitive forms (cf. *Globotruncana, s. str., Tc. roberti,* and *Glt. stephani*). This two way evolution seems to the writer more appropriate inasmuch as all mutations appear to occur explosively and multiple, *i.e.,* with more than one line of evolution.

Accordingly, it seems highly probable that the first mutations from *Globotruncana* toward *Globigerina*-like forms started early with the first developments of *Globotruncana*. It also seems that no development occurred, as it is generally agreed by many, from *Globigerina* to *Globotruncana*.

In this connection besides the arguments which Reichel, 1949 presented for postulating what he called a "globigerinization des Globotruncana" (*op. cit.* p. 615), it can be noted:

During his study of the Cenomanian of Switzerland, the writer found all through the Cenomanian a population of partially keeled *Globotruncana* forms (*Glt. stephani*) without being able to reach a stratigraphic separation of these *Globotruncana* forms (Gandolfi, 1942, p. 137-143).

Transitional *Globigerina-Globotruncana* forms are reported by Loeblich and Tappan in uppermost Albian (*Globorotalia ? marginoaculeata-Globigerina ? multispira*).

Globotruncana-Globigerina forms have been recorded by many authors all through the Cretaceous.

Several obvious *Globotruncana-Rugoglobigerina* lines are reported in this study from the uppermost Cretaceous (Campanian).

ROTALIPORA SUBGENUS

4. *Rotalipora evoluta* Sigal (=*Glt. apenninica* α Gandolfi) and *Rotalipora apenninica* (Gandolfi) are primitive *Rotalipora* forms, derived from *Thalmanninella ticinensis* (period of rapid evolution) as from 2.

5. *Rotalipora reicheli* Mornod (= *Glt. appenninica* α Gandolfi) on one side and *Rtp. montsalvensis*, *Rtp. benacensis*, *Rtp. turonica* and *Rtp. cushmani* on the other, are more evolved species (later period of rapid evolution).

Rotalipora reicheli represents probably a lateral development with a phylogenetic tendency toward extremely high tests and fairly well-developed petaloid periphery. On the other hand *Rtp. montsalvensis* and *Rtp. benacensis* have a somewhat more primitive appearance (chambers less inflated, less petaloid periphery) than the other two. They can be considered as intermediate forms between early *Rotalipora* and the later *Rtp. turonica* and *Rtp. cushmani* (see also Reichel, 1949, p. 604).

The *Rotalipora* subgenus probably disappeared in late Turonian, or evolved to *Cymbaloporetta* as Brotzen believes, or even toward tests reminiscent of *Globigerina*.

Mornod reported (Mornod, 1949, p. 586) the occurrence of two specimens of *Rtp. montsalvensis* in Senonian together with *Glt. ventricosa ventricosa*. This discovery warrants further investigation because, according to present information, the genus *Rotalipora* seems to be confined to Cenomanian and Turonian.

Rotalipora-like forms were found by the writer during the present study (*Glt. citae, Rugogl. petaloidea subpetaloidea*) in late Campanian. They are single or double-keeled with some evidence of *Globotruncana*-like umbilical apertures.

In late Cenomanian-early Turonian the *Rotalipora* subgenus showed its biggest development with particular morphological characteristics suggesting senility or that the subgenus at this point was ready to split into new mutations or to become extinct.

GLOBOTRUNCANA SUBGENUS

6. The *Globotruncana* subgenus was derived from *Glt. stephani*, which is to date the most primitive and earliest appearing form with a rudimentary system of *Globotruncana*-like aperture. This is proved by the structural details of the apertural system. A thickening and splitting of the single keel is already shown by *Glt. stephani* (Mornod, 1949, p. 588; Reichel, 1949, p. 615).

Accordingly, *Glt. stephani*, species with primitive and undifferentiated characters, gives way to *Glt. turbinata* Reichel, *Glt. imbricata* Mornod and probably, to *Rugoglobigerina* tests (period of rapid evolution).

Glt. turbinata and *Glt. imbricata* appear to represent lateral developments since they have already some specialized characters (extremely high conical test of the first one, dichotomic keel of the second one).

At the end of Cenomanian *Glt. stephani* gave way to the *lapparenti* branch (main branch), to the *helvetica-sigali* branches, and perhaps to new *Rugoglobigerina* phyla (new period of rapid evolution). *Glt.* aff. *renzi* Reichel is the evident intermediate form between the primitive *Glt. stephani* and the *lapparenti* forms. There is no doubt of its close relationship to *Glt. stephani*. *Glt. renzi* Gandolfi(not Thalmann) appears to the writer and Reichel as a more evolved species. Its narrow inner double keel, its tendency to an inflated umbilical side suggest, in the light of the new observations, an intermediate position between the *lapparenti* branch and the *sigali* branch. In this connection the inflated umbilical side of *Glt. helvetica* and the thick somewhat double keel of the early chambers of *Glt. sigali* (Reichel, 1949, fig. 6) are remarkable characteristics of phylogenetic interest.

Another splitting seems to follow later (Turonian) with the appearance of *Glt. tricarinata tricarinata, Glt. bulloides bulloides, Glt. lapparenti coronata.*

These forms gave way to main evolutionary branches which developed and diverged from the *lapparenti* branch. They were called: *tricarinata* branch and *bulloides* group. The *coronata* branch does not appear to evolve to any appreciable extent (slight lateral variation).

The *fornicata* group is believed to have diverged later from a more evolved *lapparenti* form.

The evolution within the main phyla *lapparenti, tricarinata, bulloides* occurs in a similar way with respect to certain characteristics. Evolved forms show a more rapid increase of the chambers which become more elongate (upper Turonian-Coniacian) and later, higher and petaloid with fewer chambers in the last whorl, sutural "bourrelets" becoming first thin and continuously raised, then finely beaded; sutures on the umbilical side becoming radial. This seems to be, as will be seen later, a general evolutionary process of all *Globotruncana.*

9. A period of evolutionary activity followed later in Coniacian (late Coniacian, Santonian ?) with the appearance of *thalmanni, intermedia,* and *caliciformis* forms. Accordingly, the Upper Turonian (and lower Coniacian ?) are apparently periods of evolutionary quiescence.

10. Another period of rapid evolution followed in early Campanian (Senonian) with the differentiation of other side branches and the appearance of new forms: *Glt. bollii, Glt. arca arca, Glt. stuarti stuarti, Glt. rosetta rosetta, Glt. ventricosa ventricosa.*

It appears thereafter that:

All these forms represent independent, separated phylogenetic tendencies which derive from more primitive main branches and diverge along their own lines.

The Campanian is a period of continuous repeated developments in all branches which subdivide in an increasingly more complicated way. Particular and extreme morphological trends toward three-chambered forms in the last coil are to be observed in many branches (*Glt. fornicata cesarensis, Glt. tricarinata colombiana, Glt. ventricosa ventricosa*).

The already mentioned morphological trends toward higher, petaloid chambers, radial depressed sutures on the umbilical side, beaded sutures developed completely (cf. *Glt. fornicata plummerae, Glt. fornicata ackermanni, Glt. fornicata fornicata*) and can be observed even in the *contusa* forms.

Aside from, but parallel to, the general phylogenetic trends of the genus, special tendencies become evident in the single branches of which we recall the main types:

> Flat forms with flat dorsal side, petaloid chambers: *rosetta* tests. One keeled biconvex forms with polygonal chambers: *stuarti* tests. Two keeled biconvex forms (second keel shifting): *arca* tests. Two keeled slightly convex, arched, and inflated chambers: *fornicata* tests. Strongly convex with long and arched chambers: *contusa* tests.

11. In the early Campanian an increased tendency toward the development of *Globotruncana* forms with inflated chambers (*Glt. bulloides bulloides, Glt. bulloides naussi, Glt. bulloides globigerinoides, Glt. marginata austinensis, Glt. fornicata plummerae, Glt. fornicata cesarensis*) which lead to *Rugoglobigerina* forms is observed also. This tendency is more or less represented in all main branches.

12. With the late Campanian, probably early Maestrichtian (uppermost *Pullenia cretacea* zone), there is another splitting of new forms: *Glt. gansseri gansseri, Glt. caliciformis sarmientoi, Glt. fornicata ackermanni, Glt. stuarti conica.*

The tendency toward conical forms which started early in late Coniacian (primitive *contusa* and *caliciformis-intermedia* forms), continued during Campanian time with the evolved *contusa* tests and had its best development at the end of this period with the more or less contemporaneous appearance of conical species in different groups (*Glt. stuarti conica, Glt. caliciformis sarmientoi*).

In the late Maestrichtian there is to date no complete set of records, but by analogy it can be deducted from the development of the previously described morphological trends that further evolutive activity may characterize this period toward *Rugoglobigerina* (*Trinitella, Plummerita forms*) and toward forms with radial sutures, narrow *Globorotalia*-like umbilicus, spinose test, beaded keels (cf. *Glt. rosetta rosetta* of fig. 10, Glt. *aegyptiaca* with its "variety" *duwi*, *Glt. rugosa*, *Glt. seranensis*).

THE "GLOBIGERINIZATION" OF GLOBOTRUNCANA

It appears evident from the present observation that the process of "globigerinization" of *Globotruncana* which occurs in Campanian (Santonian ?) developed repeatedly from different *Globotruncana* forms which are completely separated genetically. This process led to *Rugoglobigerina* tests, *i.e.*, to forms with a *Globigerina* form but a *Globotruncana*-like umbilicus. The ornamentation is probably a secondary genetic process which is observed also in the late appearing *Globotruncana* and does not infer a particular genetic derivation (hantkeninoid spines of *Plummerita*).

In other words, this last morphological evolution seems to occur independently and separately from the true process of "globigerinization," which in turn appears to be strongly related to environmental conditions (full pelagic life). If the ecologic condition may have acted in a selective way or have entirely influenced the evolutive process, this obviously cannot be deduced from the evidence we have at hand.

In the light of these considerations, it appears fairly possible that other processes of "globigerinization" may have occurred since the early Cretaceous time so that, for instance, most forms reminiscent of *Globigerina*, including the new ones introduced by Bronnimann, cf. *Globigerina gautierensis*, somewhat reminiscent of *Rotalipora evoluta* in the arrangement of the chambers, *Globigerina cretacea* as illustrated by Bronnimann, 1952, *Globigerinella messinae* with its subspecies *subcarinata*, may develop from *Globotruncana*, *Rotalipora*, or possibly *Thalmanninella*, *Ticinella* forms. In this connection *Globigerinella escheri clavata* suggests some relationship also with the *Hasterigerinoides* forms as described by Bronnimann. *Trinitella scotti* is somewhat morphologically reminiscent of *Glt. rugosa* van der Sluis.

If all these forms can be included under the subgenus *Rugoglobigerina*, as was done in this paper, or can justify an additional splitting into new different subgenera, further embryological studies on the transitional forms will show this. These transitional forms appear to have generally a limited range.

Regarding the process of "globigerinization" itself there appears to follow certain general rules:

a. When a *Globotruncana* form mutated into a corresponding *Rugoglobigerina* the morphological characteristics changed in different ways, some early, others later.

b. The shape of the chambers changed first, becoming inflated, later short, subglobular and finally *Globigerina*-like.

c. The sutures on the ventral side became radial, depressed, the keel started to disappear, the test became rougher (other ornamentation started to appear) the umbilicus became narrower, and the apertural system reduced.

d. The keels disappeared and the lips covering the aperture tended to reduce and to blend into a continuous thin plate (cf. primitive *Globotruncana, i.e., Glt. stephani, Glt. turbinata*). It is remarkable in this regard that the "globigerinization" of the test is almost completed, but the keels disappear completely later, being more and more masked by the increasing rugosity of the test. The apertural system changed even later, therefore, almost complete *Globigerina*-like forms still showed keels and multiple umbilical apertures with lips.

e. The terminal face of the last chambers still kept its triangular shape, as it was determined once by the two diverging and bending keels in fully developed *Rugoglobigerina* tests.

f. The loss of the keels and the reduction of the umbilical lips followed somewhat an inverse process as can be observed in the early *Globotruncana*. In fact, in the early *Globotruncana* the keel began in the early chambers, extending regularly without any apparent interruption so that the early chambers were already and completely keeled whereas the last ones were still globular or only slightly flattened. On the other hand, during the "globigerinization" of *Globotruncana,* the adult chambers lost first, the keel, or keels, but the process was not regular. Traces of finely beaded keels remained here and there, whereas the sharp margin became more or less rounded. In a similar way a flood first invaded all low areas and advanced gradually toward higher ones. But when it retreated, scattered isolated spots of flooded areas remained here and there.

At this point a logical suspicion arises as to whether the "Globigerinidae" really form a natural homogeneous system. Such suspicion is justified in the light of the fact that as more and more frequent records of deep structural differences within the Globigerinidae (Bronnimann, 1952) appear, the greater is the need of differentiating new genera. This is further emphasized by the general difference between most of the Cretaceous *Globigerina*-like forms and the Tertiary ones. The *Globigerina* form appears to be nothing but a form of adaptation or preadaptation to the pelagic life which develops in species of quite different genetical relationship, as a phenomenon of convergence (a *Globigerina* may differ from another as Cetacea differs from fish or a *Plesiosaurus* from an *Archaeopteryx*).

GENERAL RULES ON THE DEVELOPMENT OF GLOBOTRUNCANA

On reviewing the general development of *Globotruncana* (pl. 10), two striking facts may be observed:

a. The prevailing of certain morphological characteristics during certain geological periods in most of the forms of the genus.

b. The presence of certain general morphological trends, which leads to analogous phylogenetic developments in widely related branches.

Both facts are related to and dependent upon each other.

In upper Albian-early Cenomanian, the early *Globotruncana* subgenera (*Ticinella, Thalmanninella, Globotruncana*) are characterized by a narrow umbilicus, round, inflated chambers with radial and depressed umbilical sutures. They tend to become single-keeled; the keel is beaded; papillae and tubercles cover the early portion of these primitive tests.

The late Cenomanian is characterized by a conspicuous development of *Rotalipora* which are all single-keeled and provided with sutural apertures (other one-keeled forms of the subgenus *Globotruncana* will develop later from *Globotruncana* tests with a different morphology and through a different genetic process). At the time when the *Rotalipora* show more rapidly evolved characteristics like the development of the "bourrelet sutural" on the umbilical side, lobate periphery, the subgenus *Globotruncana* maintain primitive characteristics (*Anomalina*-like test, radial and depressed umbilical sutures, ornamentation, and primitive type of apertures).

In late Cenomanian-early Turonian, the *Rotalipora* show some evidence of a complete maturity, like the irregular arrangement of the chambers, the strongly lobate periphery, the abnormally high tests, and the secondarily inflated chambers.

In early Turonian the subgenus *Globotruncana* starts to develop the umbilical "bourrelet sutural" in single-keeled and two-keeled forms.

In late Turonian and Cenomanian, forms prevail with elongated chambers (fewer chambers in the last whorl). This characteristic becomes more pronounced in late Coniacian.

In the Santonian ?, Campanian forms appear again with characteristics similar to the primitive ones like short chambers, sutures becoming finely beaded or sharply raised on the dorsal side, radial and depressed on the umbilical side, test spinose and rougher.

Abnormal forms (extremely high or conical with petaloid periphery and/or well-developed ornamentation, frequence of senile chambers) spread at the top of Campanian (evidence of senility ?).

From this short review it appears that all forms, regardless to which group they belong, show in a certain period certain common morphological characteristics which finally become typical and diagnostic for this period. This indicates that certain evolutionary factors are active more or less in all species and all groups. These factors develop common morphological trends. They are sometimes weak, such as may be observed in a limited number of species, but sometimes behave as "strong ones," being observed to guide all forms of the genus and build up certain characteristics, which in some species may reach their full development and be typical for a species, a branch or a group, whereas in other ones may remain only rudimentary. For instance:

The single-keeled morphological development spread all through the primitive *Rotalipora* and *Globotruncana* not, however, reaching its full development in *Glt. stephani*.

The formation of continuously raised umbilical sutures starts early with the more evolved *Thalmanninella*, spreads later in the subgenera *Rotalipora* and *Globotruncana*, but in many *Rotalipora* it remains rudimentary showing up only in the early stages.

The attitude toward double-keeled tests starts in the late Cenomanian and Turonian *Globotruncana*, remaining rudimentary in *Glt.* aff. *renzi*.

The inflation of the chambers, as well as the petaloid periphery, is more or less developed in all later appearing *Rotalipora.*

The inflation of the chambers is widespread in all groups. In some species like *Glt. marginata, s.l., Glt. bulloides, s.l., Glt. fornicata ackermanni,* it becomes a typical characteristic; in others it remains only rudimentary (*Glt. tricarinata colombiana, Glt. fornicata plummerae, Glt. contusa contusa*).

The elongated chambers become a prominent characteristic in the *fornicata, thalmanni,* and *contusa* tests but can be more or less observed in many other species (*Glt. lapparenti longilocula, Glt. tricarinata colombiana, Glt. marginata austinensis*).

The tendency toward radial, depressed umbilical sutures, short, petaloid chambers is well developed in *Glt. mayaroensis, Glt. citae, Glt. intermedia, s.l., Glt. rugosa, Glt. seranensis,* but appears also in the more evolved *rosetta, fornicata, arca* tests and even in the last adult chambers of *Glt. fornicata fornicata*, and *Glt. contusa contusa.*

The tendency toward sharply bending sutures (polygonal chambers) which is quite typical for the *stuarti* forms is, to a lesser degree, also observed in *rosetta, arca* tests as well as in *Glt. canaliculata* Cushman of the Pecan Gap Marl, *Glt. mayaroensis.*

The tendency toward a diverging, sometimes dichotomic, keel which appears early in *Glt. imbricata,* is also developed in various later appearing species like *Glt. fornicata ackermanni, Glt. mayaroensis, Glt. intermedia, s.l., Glt. globigerinoides* Pierre Marie (not Brotzen)=*Glt. mariai,* n.n., p. 33.

The tendency toward conical forms finds its best development in the late Campanian and early Maestrichtian, spreading into forms which are genetically independent like *Glt. stuarti conica, Glt. caliciformis sarmientoi.*

The tendency toward few and extremely well-developed chambers in the last volution is fairly evident in the *fornicata* group (*Glt. fornicata cesarensis*), but some evidence suggests that it is present also in other groups (cf. *Glt. rosetta pettersi* in the *rosetta* branch, *Glt. stuarti parva* in the *stuarti* branch, *Glt. arca caribica* in the *arca branch*). On the other hand, phylogenetic trends toward forms with many chambers in the last whorl are observed in the *tricarinata* branch (*Glt. tricarinata* Cita, 1948), in the *rosetta* branch (*Glt.

rosetta insignis), in the *linnei* group (*Glt. lapparenti coronata*).

Another striking fact of the evolution of *Globotruncana* is that some morphological characteristics start early in some forms and reappear later, and through a secondary genetic process, in new species without any apparent reason (cf. remarks on apertural system of *rosetta* type as compared with primitive *Ticinella, Thalmanninella,* Reichel, 1949, p. 614).

The inflation of the chambers, spinose test, radial umbilical sutures, and narrow umbilicus appear primarily as primitive characteristics in the early *Globotruncana.* They reappear later in more evolved species together with senile characteristics.

The phylogenetic trend toward single-keeled forms develops early in Cenomanian with the *Rotalipora* subgenus; it appears again through a different secondary genetic process in Cenomanian and Turonian *Globotruncana* and later, as a dominating characteristic in all Campanian-Maestrichtian forms.

The tendency toward extremely petaloid chambers, which is somewhat typical in evolved *Rotalipora,* is repeated by special evolved *Globotruncana* species (*Glt. citae, Glt. intermedia, s.l.*).

Phylogenetic trends toward forms with *stuarti*-like sutures or with strong umbilical convexity and inflations develop early with respect to *Glt. sigali* and *Glt. helvetica* and reappear with *rosetta, stuarti,* and *gansseri* forms.

The apertural system develops in some tests toward complicated types (evolved *rosetta, arca,* and *contusa* tests); in others, it reverses again following an inverse process as compared to the primitive forms.

Shows of senility.—In many cases when describing abnormally high or conical tests, extremely lobate outline, certain irregular arrangement of chambers, and finally the occurrence of senile chambers, these were proposed as evidence of senility.

In fact, the aforementioned morphological characters, and in general anything which differentiates strongly from a normal average type, were observed to appear whenever a species, a branch, or group showed an optimum of development. The species, branch, or group later becomes extinct or develops into new mutations. This is quite evident in all evolved *Rotalipora* of late Cenomanian and Turonian, and again in all *Globotruncana* of late Campanian and Maestrichtian.

ECOLOGY AND RACES

It is generally agreed that *Globotruncana* are pelagic with similar ecological conditions to *Globorotalia* and *Globigerina.* However, the fact that some species of the *contusa* branch (especially the more evolved ones like *Glt. contusa patelliformis* and *Glt. contusa contusa*) have been found to be particularly abundant in sediments deposited in shallower water where the frequence of the other forms strongly decreases, suggests that not all *Globotruncana* species are pelagic. In fact, it is possible that all extremely high or conical forms of the subgenus *Globotruncana,* as well as of the genus *Rotalipora* (*Rotalipora reicheli*), may be entirely benthonic.

On the other hand, forms with round *Globigerina*-like chambers probably represent the extreme pelagic adaptation of forms which in origin were undifferentiated with respect to their environment (*Pseudovalvulineria, Ticinella*).

World-wide detailed studies would be necessary to determine if some forms which are to date known as species and subspecies may have a geographic significance (race) in the sense of Thalmann.

In our particular case, the forms which showed a more rapid and marked development of chambers, such as *Glt. tricarinata colombiana, Glt. marginata austinensis,* have been interpreted as more evolved ones as compared with forms which show chambers more normally increasing in size. This fact has the appearance of a general evolutionary trend in the later appearing *Globotruncana.* On the other hand, chambers more rapidly increasing in size apparently represent a primitive characteristic in primitive forms (*Rtp. evoluta, Glt. indica*) compared to normal tests (*Rtp. apenninica, Glt. canaliculata*). It cannot be denied, however, that this may also be related to a certain extent to the geographical distribution, with possible ecological and geographic differentiation.

GENERAL CONCLUSIONS

In reviewing the complex evolutionary pattern of *Globotruncana,* some general observations may be made on evolution.

Evolution does not occur in a continuous and uninterrupted way but develops repeatedly in an explosive manner. In other words, short periods of rapid evolution follow longer periods of relative quiet, in a similar way that short periods of orogenetic paroxysms follow long periods of quiet. The periods of evolutionary quiescence cannot be explained by the presence of stratigraphic gaps and consequently by lack of records, since some of them were observed in continuous and normal sections.

Evolution follows in an abrupt manner with respect to geologic time, but the mutations follow gradually so as to pass through all intermediate stages. If a morphologic gap exists, it is only due to lack of paleontological records.

When a genotype is ripe for evolution, it does not develop a single offshoot but generally two or more new mutations.

All forms are sometimes completely replaced by new ones, *i.e.*, they apparently become extinct after generating the new forms. In other cases, they keep on living along with their offshoots.

When a new morphologic characteristic is ripe for its development it often appears not only in one species but in widely related species so that different genotypes apparently include the new gene. This, however, may develop completely in one species and remain more or less rudimentary in others.

The phylogenetic law is true if taken and accepted in a general way. The ancestoral stages are repeated in the ontogenetic development of the new species, but sometimes many steps of the phylogenetic development are reduced or completely by passed. (In *Glt. contusa scutilla* and some *Glt. contusa patelliformis,* the *fornicata* stage is well recognizable after the nepionic stage, also in *Glt. bollii* the *thalmanni* stage is still evident. These ancestral characteristics disappear, however, in the later appearing and more evolved *contusa rosetta, stuarti,* and *arca* tests.)

Certain phylogenetic developments occur without any apparent reasons (the formation of the keel, two keels, the number and shape of chambers, the building of ornamentation). Other developments are apparently related to the environment (adaptation ?, preadaptation ?), like the globular chambers and *Globigerina* form of highly pelagic types, or the strong conical shape, the flattened and horizontal peripheral band of probably benthonic types.

Some morphological trends reappear without any apparent reason and give way to similar forms through different genetic processes.

Whenever a living organism reaches its maximum development, it is generally close to its death or ripe for mutations. Particular morphologic characteristics are related to this moment of its life and are generally repeated whenever similar biological conditions occur. They are interpreted as evidence of senility.

STRATIGRAPHIC CONSIDERATIONS

In Plate 8 a range chart is given for the *Globotruncana* genus in northern Colombia, and in Plate 9, a compilation chart was prepared for the stratigraphic distribution of the whole genus as observed especially in Europe, Africa, and America.

With respect to the time boundaries for North America, the correlation charts were adapted from the Geol. Soc. of America Bull. 1942, although the stratigraphic boundaries are rather uncertain and may overlap the European time divisions.

Regarding the stratigraphic development of the genus, it is possible to reach some general criteria for a broad subdivision of the Cretaceous based on the morphologic trends as discussed previously without entering into the painstaking work of recognizing each single species (Pl. 10).

The stratigraphic range of the single species is well known in the lower part of Upper Cretaceous from Cenomanian to Lower Turonian. There is a fair agreement among the paleontological findings and detailed studies which have been carried out on the stratigraphy.

From the Upper Turonian to Santonian a more uniform distribution of species is shown by the authors without any apparent sharp change, but as already mentioned this is probably due to a certain lack of paleontological evidence than to an astonishing quiet evolutionary period. This would be rather peculiar in view of the generally rich variability of *Globotruncana*. Here certain discrepancies also occur among the authors with respect to the stratigraphic ranges of the single species.

Campanian and Maestrichtian species are better known and characterized, according to Glaessner, 1945, as the first appearance of *Glt. arca* and the full development of *stuarti* and *conica* forms respectively.

In view of these discrepancies, no definite stratigraphic conclusions were drawn as to the age of the sediments examined, inasmuch as most of the species and subspecies which were objects of this study are new or incompletely checked as to range.

Manaure shale (*Marginulina jonesi*).—*Glt. lapparenti longilocula* is rare. *Fornicata* tests are frequent and with evolved (*Glt. fornicata fornicata*) and primitive tests. (*Glt. fornicata manaurensis*), which are transitional to *Glt. lapparenti longilocula.* Other rare species are to be noted such as *Glt. bulloides bulloides, Glt. bulloides globigerinoides, Glt. thalmanni thalmanni, Glt. thalmanni flexuosa, Glt. intermedia intermedia, Glt. intermedia difformis.*

Since *Glt. fornicata* is shown by some authors (Cita, 1948) to begin in Santonian, this may suggest a possible Santonian age for this part of the section.

Colon shale (*Pullenia cretacea zone*).—The lowermost Colon shale is well marked by the first appearance of *Glt. arca arca, Glt. contusa patelliformis, Glt. stuarti stuarti, Glt. rosetta rosetta. Glt. fornicata plummerae* and, in general, forms with inflated chambers and more or less evident keels (transitional to *Rugoglobigerina*) are well developed. Some primitive species in the Manaure shale are rare and disappear upward like *Glt. contusa scutilla, Glt. tricarinata colombiana, Glt. marginata austinensis. Glt. bollii* is present in our section only in the lower portion of the Molino shale. *Glt. wiedenmayeri wiedenmayeri, Glt. wiedenmayeri magdalenaensis,* and *Glt. rosetta pettersi* disappear at the first *Glt. gansseri gansseri. Stuarti* and *arca* forms prevail together with their few chambered subspecies. Rare *Rugoglobigerina* are also present with generally only poorly developed ornamentation.

Forms which in Trinidad appear later, such as *Glt. mayaroensis, Glt. citae, Glt. ventricosa ventricosa, Glt. contusa contusa, Glt. arca arca,* begin in the lower *Pullenia cretacea* zone (Campanian); forms with mixed characteristics between *caliciformis* and *intermedia* occur already in the Manaure shale. *Glt. stuarti conica* White, *Glt. caliciformis* (typical forms), *Glt. gansseri gansseri* appear later more or less contemporaneously with the full spread of well-ornamented

Rugoglobigerina in the upper *Pullenia cretacea* zone. This may suggest already a Maestrichtian age for this part of the zone, with a fairly evident overlap between *Globotruncana* and *Siphogenerinoides* zonations. The transitional forms between *Globotruncana* and *Rugoglobigerina* disappear completely. *Glt. caliciformis sarmientoi* appears somewhat at the contact of the *Pullenia cretacea* and *Siphogenerinoides bramlettei* zones.

As seen, the discrepancies with Trinidad are remarkable, even if for *Glt. contusa contusa* this can be explained by different facies conditions and for the others by the uncertain stratigraphic boundaries of the Colombian local zonation.

If, however, the correlation is tentatively extended to North America and Europe the discrepancies are considerable. It is sufficient to point out the more outstanding ones, the range chart shown in Pl. 9 being sufficient explanation for the rest. *Glt. lapparenti lapparenti* is restricted to Turonian-Coniacian in the Apennines Alps, whereas in Trinidad it ranges into Campanian, and in Caucasus and Pyrénées even into Maestrichtian. *Glt. bulloides bulloides* is restricted to Coniacian-uppermost Turonian by some authors, whereas elsewhere its range extends into Campanian. The same observations can be made with respect to *Glt. tricarinata, Glt. ventricosa, Glt. fornicata.* Some species could eventually have a different stratigraphic range in different areas. The writer feels, however, that this is not sufficient to account for all the aforementioned discrepancies. A more exact knowledge of the rapidly evolving forms is needed. The names *Glt. fornicata. Glt. contusa, Glt. tricarinata,* as used by various authors, have been recognized as including different species. Also the name *Glt. lapparenti lapparenti* should probably be restricted to Turonian-Lower Coniacian ? forms; younger forms should be separated as other species or subspecies, for instance *Glt. lapparenti longilocula.* Detailed studies are necessary to establish subsequent fixed points in this continuous and rapid flow of evolutionary events and to express them also taxonomically. Their stratigraphic ranges may then be better checked in the different countries.

KEY FOR THE DETERMINATION OF GLOBOTRUNCANA

Genus **GLOBOTRUNCANA** Cushman, 1927

Calcareous trochoidal, perforated test; frequently ornamented with tubercles and keels; open umbilicus (at least from the second volution on), generally covered by lamellar expansions; interiomarginal-umbilical or only umbilical main aperture with additional umbilical apertures often present (diagnosis after Reichel, 1952, p. 600):

I. Test reminiscent of *Anomalina,* first traces of keel in the early chambers, interomarginal-umbilical main aperture and additional apertures: subgenus *Ticinella*:
   A. One single species: *T. roberti* (Gandolfi, 1942).

II. Test rotaliformis, entirely or partially keeled in the first stages of the last volution (single keel); interiomarginal-umbilical main aperture and umbilical additional apertures: subgenus *Thalmanninella*:
   A. Keel partially developed, eight to nine chambers in the last volution (radial depressed umbilical sutures): *Th. ticinensis* (Gandolfi).
   B. Keel entirely developed:
      1. Eight to nine chambers in the last volution as above: *Th. ticinensis typica* Gandolfi.
      2. Seven to eight chambers in the last volution, more overlapping and rapidly increasing in size, "bourrelet sutural" developed around the umbilicus and disappearing toward the periphery: *Th. brotzeni* Sigal.

III. Test rotaliformis, entirely or partially keeled in the first stages of the last volution (single keel), interiomarginal-umbilical main aperture and sutural additional apertures: subgenus *Rotalipora*.
   A. Flat chambers, test entirely keeled:
      1. Flattened, somewhat elongated test, radial depressed umbilical sutures, "bourrelet umbilical" occasionally present: *Rtp. evoluta* Sigal (=*Glt. appenninica* a Gandolfi).

  2. Test biconvex, periphery subcircular:
     a. Partially raised umbilical sutures: *Rtp. apenninica typica* (Gandolfi).
     b. More completely raised umbilical sutures: *Rtp. globotruncanoides* Sigal.
  3. High test with flat dorsal and protruding ventral side, lobate periphery (chambers irregularly developing): *Rtp. reicheli* Mornod (=*Glt. apenninica* 8 Gandolfi).

B. Inflated chambers, test entirely or partially keeled:
  1. Chambers moderately inflated as above, four to five chambered, lobate periphery: *Rtp. benacensis* Cita.
  2. Chambers moderately inflated as above, four to five chambered lobate periphery, chambers extremely high and protruding: *Rtp. montsalvensis* Mornod.
  3. Strongly inflated chambers, five to seven in the last volution: *Rtp. turonica* Brotzen.
  4. As above, but coiling more planispiral: *Rtp. cushmani* (Morrow).

IV. Test rotaliformis, single or double-keeled, umbilical apertures with arched lips: subgenus *Globotruncana*.

A. Single keeled:
  1. Inflated chambers, keel sometimes only partially developed:
     a. More convex dorsal side:
        a′. Moderately convex dorsally, keel often only partially developed and limited to the early chambers of the last volution, subglobular chambers, apertural system limited to a single thin lamellar plate around the umbilicus: *Glt. stephani* Gandolfi.
        b′. Strongly convex dorsally, keel well developed, chambers more flattened, apertural system as above: *Glt. turbinata* Mornod.
     b. Dorsal side nearly flat, inflated ventral side:
        a′. Strongly inflated side, rough test, rich orna-

mentation, four to six chambers in the last volution: *Glt. gansseri gansseri* (Bolli).
- b′. As above, six more globular chambers in the last volution: *Glt. gansseri subgansseri* n. subsp.
- c′. As above, test smoother, well developed and sharp keel, nearly concave dorsal side, inner coil somewhat protruding: *Glt. helvetica* Bolli.
- d′. Moderately inflated ventral side, five to six chambers in the last volution; rough test: *Glt. seranensis* (van der Sluis).
- e′. As above, four to five chambers in the last volution, test spinose: *Glt. rugosa* (van der Sluis).

c. Test flattened and thin:
- a′. Periphery highly lobate, chambers high and protruding: *Glt. citae* Bolli.

2. Flat chambers, keel generally well developed:
   - a. Periphery subcircular, polygonal chambers in the last volution:
     - a′. Biconvex, six to seven chambers in the last volution: *Glt. stuarti stuarti* (de Lapparent).
     - b′. As above, four to five chambers in the last volution: *Glt. stuarti parva,* n. subsp.
     - c′. Convex dorsal side, flat or concave ventral side, seven to nine chambers in the last volution: *Glt. stuarti conica* (White).
   - b. Lobate periphery, curved sutures, petaloid chambers in the last volution:
     - a′. Flat dorsal side, ventral side moderately convex, test smooth, five to seven chambers in the last volution: *Glt. rosetta rosetta* (Carsey).
     - b′. As above, four to five chambers in the last volution, ventral side strongly conical: *Glt. rosetta pettersi,* n.subsp.

c′. As above, four to six chambers in the last volution, ventral side less protruding, test provided with hantkeninoid spines: *Glt. calcarata* Cushman.

d′. Convex dorsal side, five chambers in the last volution, inflated on the ventral side, radial depressed umbilical sutures, umbilicus comparatively narrow: *Glt. caliciformis sarmientoi.*

B. Single-keeled, double-keeled in the early chambers (double keel limited to a faint trace of it in the earliest chambers or extending to the first chambers of the last volution):

1. Test biconvex, six to seven chambers in the last volution, sutures oblique and curved (intermediate between *stuarti* and *rosetta* types), wide umbilicus, raised umbilical sutures of *rosetta* type: *Glt. bollii,* n.sp.
2. Test biconvex, five to seven chambers in the last volution, sutures oblique somewhat of *stuarti* type, narrow umbilicus with sigmoidal raised sutures, thick somewhat double-keeled in the early chambers: *Glt. sigali* Reichel.
3. Flat dorsal side, convex (inflated) ventral side:
   a. Pronounced four chambered petaloid periphery, radial umbilical sutures: *Glt. aegyptiaca* Nakkady.
   b. As above, but pronounced three chambered periphery, chambers becoming more elongated as added: *Glt. aeyptiaca duwi* Nakkady.
   c. Flat (or slightly convex dorsally), slightly inflated ventrally, *lapparenti*-like raised umbilical sutures: *Glt. renzi* Gandolfi (not Thalmann).
   d. Flat dorsal side, strongly inflated ventral side (double keel narrow and closer to the dorsal side, test rough): *Glt. wiedenmayeri magdalenaensis,* n.subsp.

4. Convex dorsal side (flat or concave ventral side):
   - a. Chambers subglobular (radial depressed umbilical sutures): *Glt.* aff. *renzi* Reichel.
   - b. Flat chambers (raised umbilical sutures becoming later radial and depressed):
     - a′. Chambers becoming first elongated, later in the last stages large and petaloid, peripheral band generally present at least in the early stages of the last volution and inclined to the plane of coiling; sutures beaded dorsally and becoming radial and depressed ventrally: *Glt. fornicata fornicata* (Plummer).
     - b′. As above, but test convex dorsally, chambers becoming first extremely elongated, then more petaloid, peripheral band generally present at least in the early stages of the last volution and lying almost horizontal: *Glt. contusa patelliformis,* n.subsp.
     - c′. As above, but chambers becoming polygonal, test undulated in a more or less pronounced way: *Glt. contusa contusa* (Cushman).
     - d′. Test moderately convex four to six short, petaloid chambers in the last volution: *Glt. caliciformis trinidadensis,* n.subsp.

5. First convex and later flat dorsal coiling (ventral rapidly increasing convexity):
   - a. Chambers elongated of *fornicata* type (four to five in the last volution): *Glt. thalmanni thalmanni,* n.sp.
   - b. As above, chambers becoming in the more adult stage larger and petaloid, test undulated; *Glt. thalmanni flexuosa* (van der Sluis).
   - c. As above, test less flattened in the adult stages, spinose (beaded sutures): *Glt. cretacea* Cushman.

C. Entirely double-keeled:
  1. Peripheral band at right angle to the coiling plane.
    a. Test flat or slightly convex both on the dorsal and ventral side:
      a′. Radial and depressed umbilical sutures, wide peripheral band, keels, parallel, narrow umbilicus: *Glt. canaliculata* (Reuss).
      b′. As above, but wider umbilicus: *Glt. linnei* (d'Orbigny).
      c′. As above, narrow umbilicus, dorsal side slightly convex, keels diverging and dichotomic: *Glt. imbricata* Mornod.
      d′. As above, large umbilicus, sutures becoming more oblique and chambers more elongated: *Glt. mayaroensis* Bolli.
      e′. Raised umbilical sutures, sigmoidal as from *lapparenti* type, wide peripheral band, five to six chambers in the last volution: *Glt. lapparenti lapparenti* Bolli.
      f′. As above, but only four to five more rapidly elongated chambers in the last volution: *Glt. lapparenti longilocula,* n.subsp.
      g′. As *Glt. lapparenti lapparenti,* but peripheral band narrow, dorsal and ventral side slightly convex: *Glt. lapparenti augusticarinata* Gandolfi.
      h′. As above, but test flat, eight to nine chambers in the last volution: *Glt. lapparenti coronata* Bolli.
    b. Test protruding (truncoconical) on the umbilical side ("bourrelet umbilical" generally strongly developed):
      a′. Raised umbilical sutures, six to seven chambers in the last volution: *Glt. tricarinata tricarinata* Cushman, 1936 (not Quereau).
      b′. As above, but eight to nine chambers in the last volution (test more flattened and large): *Glt. tricarinata desioi,* n.subsp. (See page 27).

- c′. Umbilical sutures becoming radial and depressed, four to five chambers in the last volution: *Glt. tricarinata colombiana,* n.subsp.

- c. Test flat on both sides, but chambers inflated:
  - a′. Wide peripheral band, six to seven chambers in the last volution, generally raised umbilical sutures: *Glt. bulloides bulloides* (Bolli).
  - b′. As above, chambers shorter and subglobular, radial and depressed umbilical sutures: *Glt. bulloides globigerinoides* (Brotzen).
  - c′. As *Glt. bulloides bulloides,* but chambers in the last volution more loosely arranged and irregularly developing: *Glt. bulloides naussi,* n.subsp.
  - d′. Narrow peripheral band, slightly biconvex, six to seven short chambers in the last volution: *Glt. marginata marginata* (Reuss).
  - e′. As above, but four to five chambers in the last volution (increasing rapidly in size): *Glt. marginata austinensis,* n.subsp.
- d. Test flat on the dorsal side, convex (inflated on the ventral one):
  - a.′ Strongly inflated ventral side, narrow double keel, test rough with ornamentation, radial depressed umbilical sutures: *Glt. wiedenmayeri,* n.sp.
  - b′. Moderately inflated ventral side, five to six chambers in the last volution, wider peripheral band than above, umbilical raised sutures tending to become radial and depressed: *Glt. ventricosa* (White).

2. Peripheral band inclined as to the plane of coiling:
   - a. Test biconvex, flat chambers, peripheral band becoming large (raised umbilical sutures):
     - a′. Six to eight petaloid chambers in the last volution: *Glt. arca arca* (Cushman).

  - b′. As above, but four to five more elongated chambers in the last volution: *Glt. arca caribica,* n.subsp.
- b. As above, peripheral band becoming narrow:
  - a′. Four to five elongated chambers in the last volution, raised and elongated sutures in the umbilical side: *Glt. fornicata manaurensis,* n.subsp.
- c. Test convex dorsally, flat ventrally:
  - a′. Strongly convex dorsally, four to five very elongated chambers in the last volution: *Glt. contusa scutilla,* n.sp.
  - b′. Moderately convex dorsally, four to six short petaloid chambers in the last volution: *Glt. caliciformis caliciformis* (de Lapparent).
- d. Test flat or biconvex, inflated chambers (longitudinal inflation with more or less evident median inner marginal depression):
  - a′. Four to five chambers in the last volution becoming rapidly elongated, partially raised umbilical sutures: *Glt. fornicata plummerae,* n.subsp.
  - b′. As above but chambers shorter and more inflated umbilical sutures becoming definitely radial and depressed: *Glt. fornicata ackermanni,* n.subsp.
  - c′ As b′, but chambers becoming extremely elongated, three chambers in the last volution: *Glt. fornicata cesarensis,* n.subsp.
- e. Test convex dorsally, inflated chambers:
  - a′. Chambers slightly inflated and regularly increasing, faint diverging double keel: *Glt. intermedia intermedia* (Bolli).
  - b′. Chambers slightly inflated and irregularly developing (the second last one generally bigger than the last one), rounded, double keel sometimes strongly oblique as to the

plane of coiling: *Glt. intermedia difformis,* n.subsp.

c′. Chambers shorter and subglobular, diverging keels and oblique to the plane of coiling: *Glt. mariai,* (See page 33, new name for *Rosalinella globigerinoides* Marie, 1941)

V. Test reminiscent of *Globigerina* or *Globigerinella,* faint interrupted keels sometimes present, especially in the early stages, other ornamentation of various kind, tubercles, spines, rugose ridges, generally present; umbilical apertures with cover plates at least on the last chambers: subgenus *Rugoglobigerina.*

- A. Chambers regularly and moderately increasing in size and inflation:
  - 1. Six to seven chambers in last volution regularly arranged:
    - a. Without keels: *Rugogl. hexacamerata hexacamerata* Bronnimann.
    - b. With keels: *Rugogl. hexacamerata subhexacamerata,* n.subsp.
  - 2. Six to seven chambers in last volution irregul. ? developing (the last two generally smaller than the previous ones).
    - a. Without keels: *Rugogl. loetterli loetterli* (Nauss).
      With keels: *Rugogl. loetterli subloetterli,* n.subsp.
  - 3. Four to five chambers in last volution, test nearly planispiral:
    - a. Without keels: *Rugogl. beldingi beldingi,* n.sp., n.subsp.
    - b. With keels: *Rugogl. beldingi subbeldingi,* n.subsp.

    4. Four to five elongated chambers in last volution:
        a. Without keels: *Rugogl. circumnodifer circumnodifer* (Finlay)
        b. With keels: *Rugogl. circumnodifer subcircumnodifer,* n. subsp.
    5. Four to five petaloid and high chambers:
        a. Without keels: *Rugogl. petaloidea petaloidea,* n.sp.
        b. With keels: *Rugogl. petaloidea subpetaloidea,* n.subsp.
    6. As above, more inflated and narrower chamber:
        a. Without keels: *Rugogl. glaessneri glaessneri,* n.sp.
        b. With keels: *Rugogl. glaessneri subglaessneri,* n.subsp.

B. Chambers increasing rapidly in size and inflation:
    1. Three to four chambers in the last volution, the last chamber half of the test:
        a. Without keels: *Rugogl. macrocephala macrocephala,* n.subsp.
        b. With keels: *Rugogl. macrocephala submacrocephala,* n.subsp.
    2. Three to four chambers in the last volution, the second one strongly developed:
        a. Without keels: *Rugogl. ornata ornata,* n.sp.
        b. With keels: *Rugogl. ornata subornata,* n.subsp.
    3. Four to five chambers regularly increasing in size, strongly inflated ventral side and developed rugosity:
        a. Without keels: *Rugogl. rugosa rugosa,* n.sp.
        b. With keels: *Rugogl. rugosa subrugosa,* n.subsp.
    4. Five to six chambers less regularly increasing in size:
        a. Without keels: *Rugogl. pennyi pennyi,* n.sp.
        b. With keels: *Rugogl. pennyi subpennyi,* n.subsp.
    5. Five to six elongated chambers more trochoidal test:
        a. Without keels: *Rugogl. rotundata rotundata,* n.sp.
        b. With keels: *Rugogl. rotundata subrotundata,* n.subsp.

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PLATES

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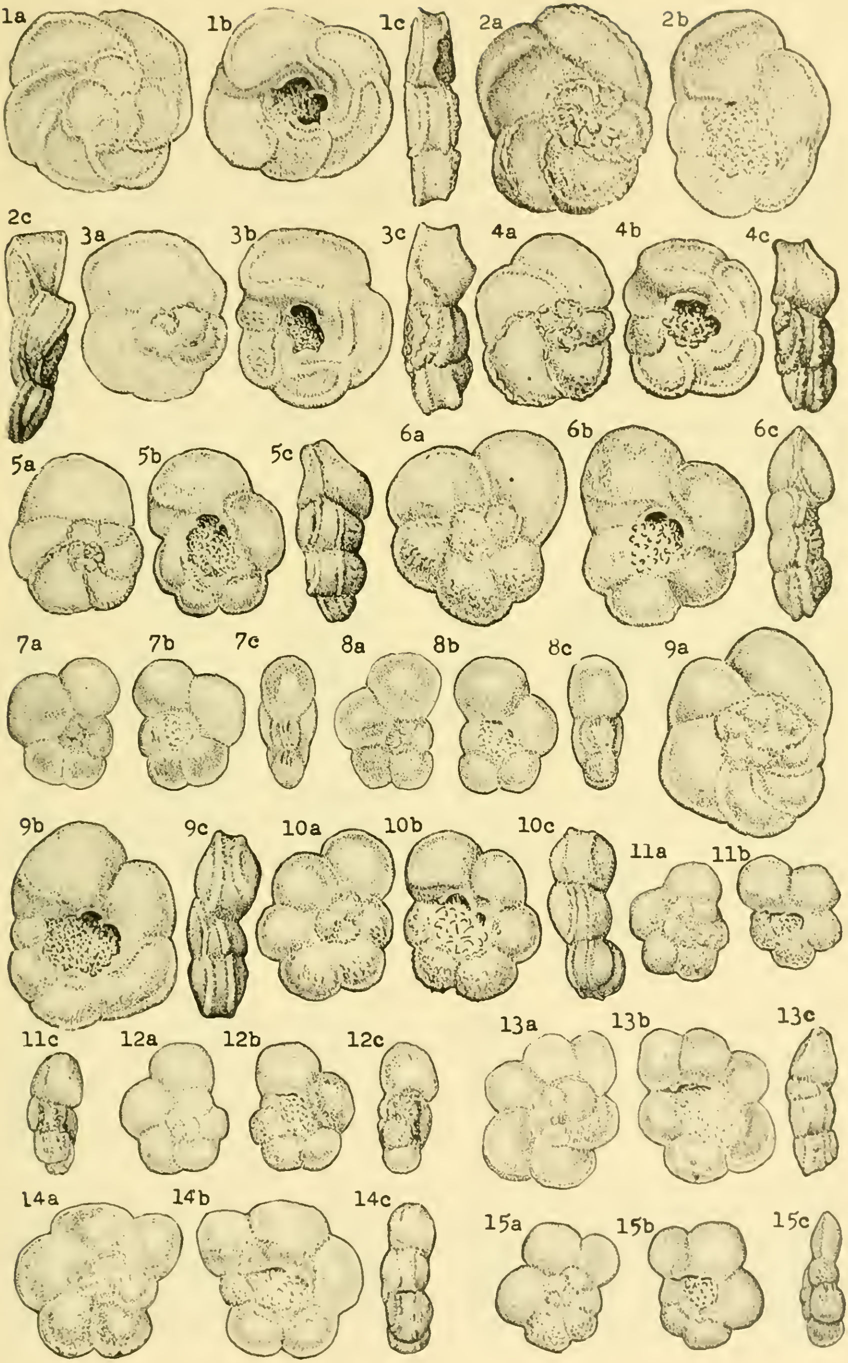
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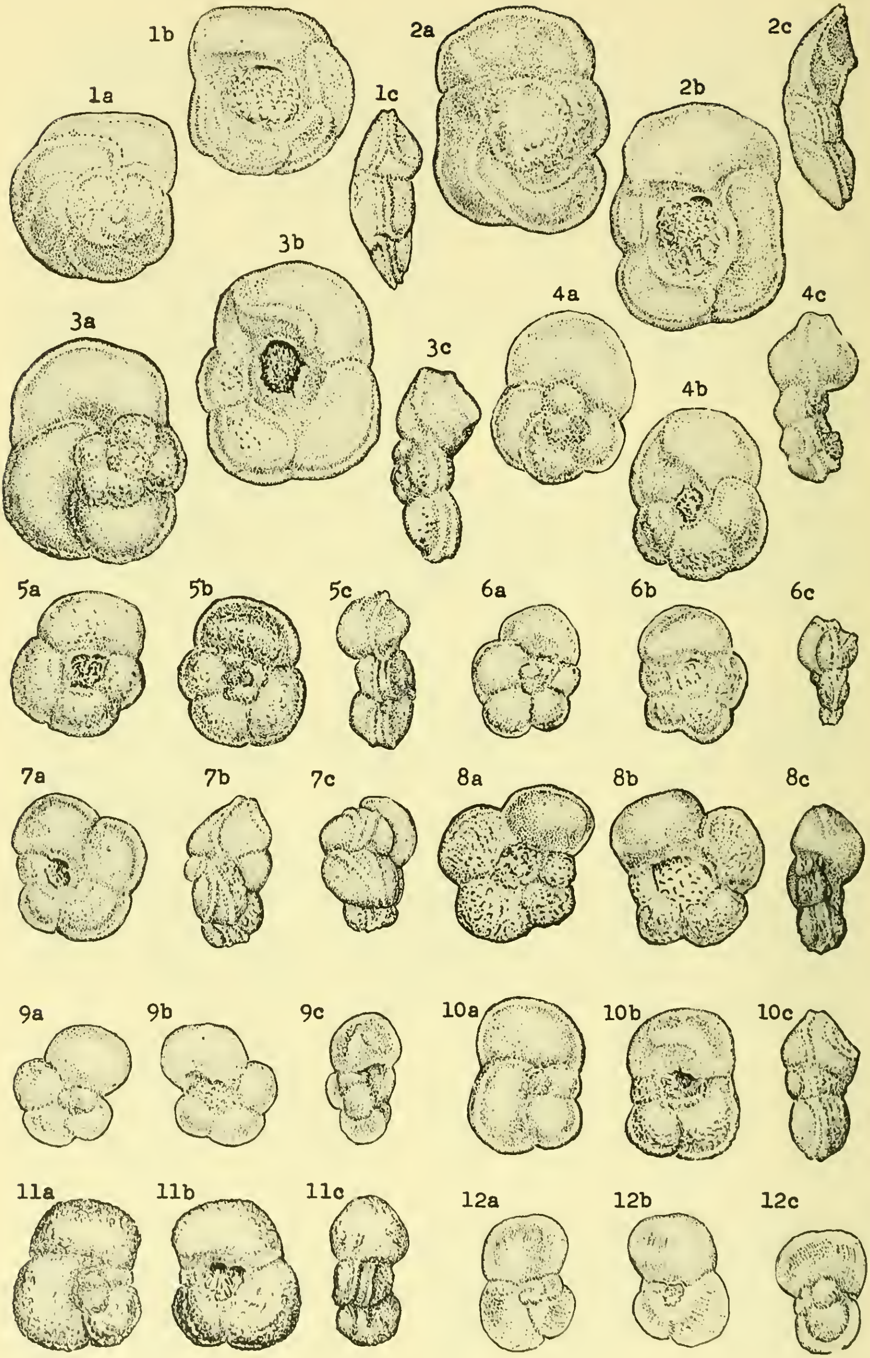
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Explanation of Plate 2

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2a-c. **Globotruncana caliciformis trinidadensis,** n. subsp. 47
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7a-c. **(Rugoglobigerina) ornata ornata** (Bronnimann) 49
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12a-c. **(Rugoglobigerina) petaloidea subpetaloidea,** n. sp., n. subsp. 52
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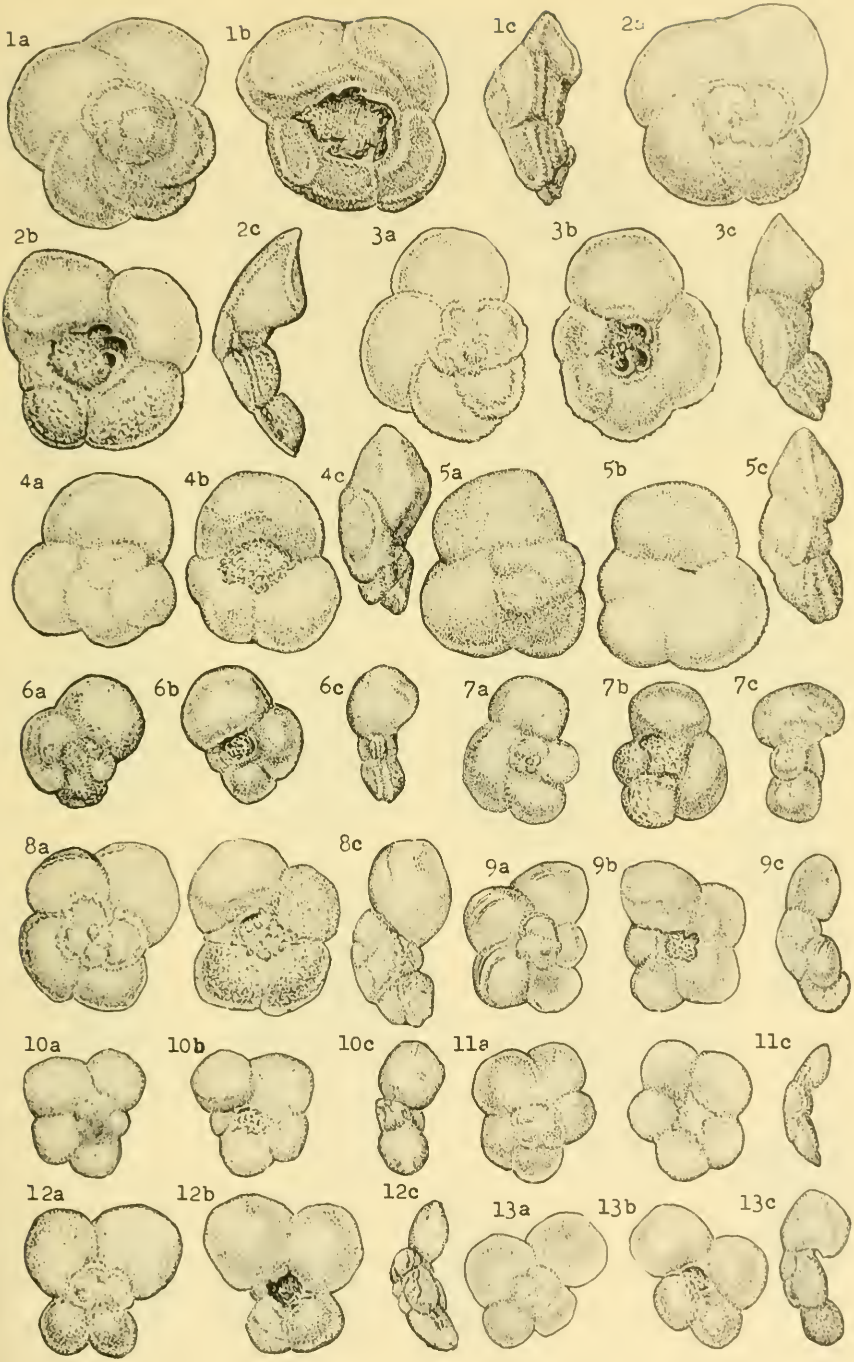
PLATE 3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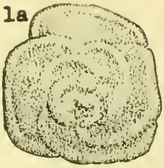

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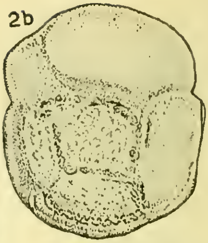

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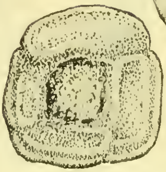

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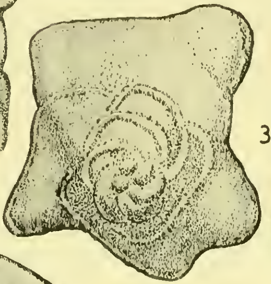

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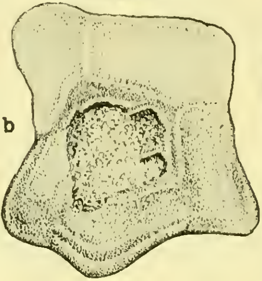

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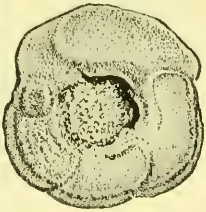

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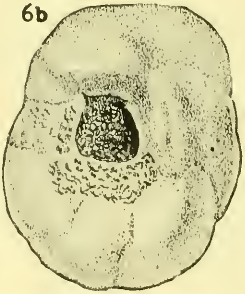

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Explanation of Plate 4

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1a


1b


1c


2a


2c


3a


3b


3c


4a

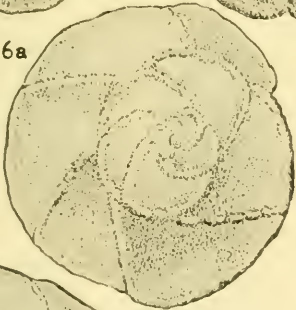

4c


4b


5a


5b


5c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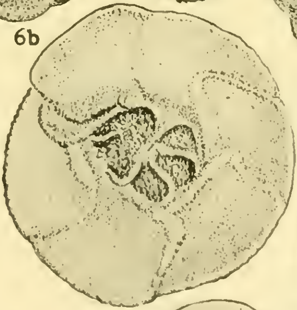
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8c


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1a

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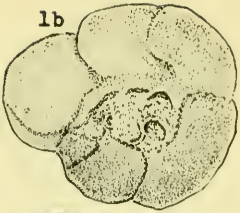

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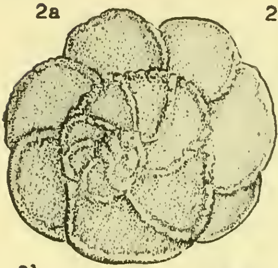

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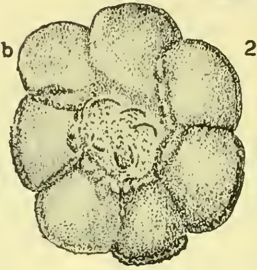

2c

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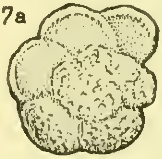

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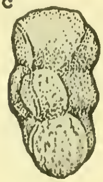

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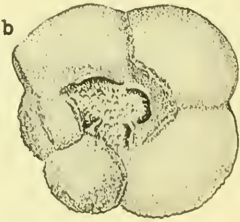

8c

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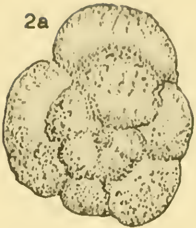
1a

1b

1c

2a



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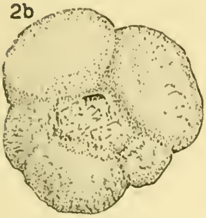

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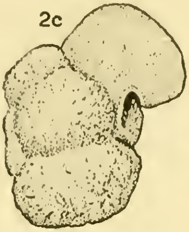

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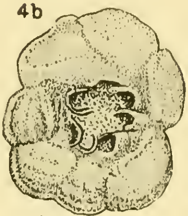

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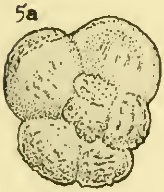

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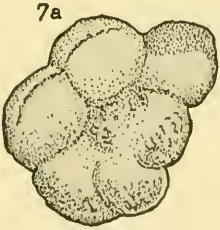

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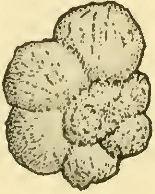

8b

8c

*	Globotruncana	lapparenti	longilocula n subsp
*	Glt	fornicata	manaurensis n subsp
	Glt	fornicata	fornicata (Plummer)
*	Glt	thalmanni	thalmanni n sp
	Glt	bulloides	bulloides (Vogler)
	Glt	thalmanni	flexuosa (van der Sluis)
	Glt	bulloides	globigerinoides (Brotzen)
	Glt	intermedia	intermedia (Bolli)
*	Glt	intermedia	difformis n subsp
	Glt	calciformis	calciformis (de Lapparent)
*	Glt	tricarinata	colombiana n subsp
*	Glt	contusa	scutilla n subsp
*	Glt	fornicata	plummeri n subsp
*	Glt.	marginata	austinensis n subsp
*	Glt	bollii	n sp.
*	Glt	fornicata	cesarensis n subsp.
	Glt	arca	arca (Cushman)
	[illegible]	stuart.	stuarti (de Lapparent)
	[illegible]	rosetta	rosetta (Carsey)
*	[illegible]	contusa	patelliformis n subsp
*	[illegible]	rosetta	pettersi n subsp
	Glt	citae	Bolli
*	Glt	fornicata	ackermanni n subsp
*	Glt	wiedenmayeri	wiedenmanyeri n.sp n subsp
*	Glt	wiedenmayeri	magdalenensis n subsp
*	Glt	bulloides	naussi n subsp
*	Rugoglobigerina	rugosa	subrugosa n subsp
*	Rugogl	loetterli	subloetterli n. subsp
*	Rugogl	pennyi	subpennyi n subsp
*	Rugogl	circumnodifer	subcircumnodifer n subsp
*	Rugogl	hexacamerata	subhexacamerata n. subsp
*	Rugogl	beldingi	subbeldingi n subsp
*	Rugogl	belding	beldingi n.sp. n subsp
	Rugogl	circumnodifer	circumnodifer (Finlay)
	Rugogl	loetterli	loetterli (Nauss)
	Rugogl	hexacamerata	hexacamerata (Bronnimann)
*	Rugogl	macrocephala	submacrocephala n.subsp
	Rugogl	macrocephala	macrocephala (Bronnimann)
*	Rugogl	ornata	subornata n subsps
	Rugogl	ornata	ornata (Bronnimann)
*	Globotruncana	stuarti	parva n subsp
	Glt	contusa	contusa (Cushman)
	Rugogl	rugosa	rugosa (Plummer)
*	Glt	arca	caribica n subsp
	Glt	ventricosa	(White)
*	Rugogl	glassneri	subglassneri n subsp
*	Rugogl	glassneri	glassneri n sp n subsp.
*	Rugogl	petaloidea	subpetaloidea n subsp
	Glt	mayaroensis	Bolli
	G.t	aff cretacea	Cushman
*	Glt	petaloidea	petaloidea n sp n subsp
*	Glt	gansseri	hexacamerata n subsp
	Glt	stuart.	conica (White)
	Glt	gansseri	gansseri (Bolli)
*	Rugogl	rotundata	subrotundata n subsp
*	Glt	rosetta	insignis n subsp
*	Glt	calciformis	trinidadensis n subsp
	Rugogl	pennyi	pennyi (Bronnimann)
	Rugogl	rotundata	rotundata (Bronnimann)
*	Glt	calciformis	sarmientoi n subsp

PLATE 8

DISTRIBUTION CHART OF GLOBOTRUNCANA IN COLOMBIA

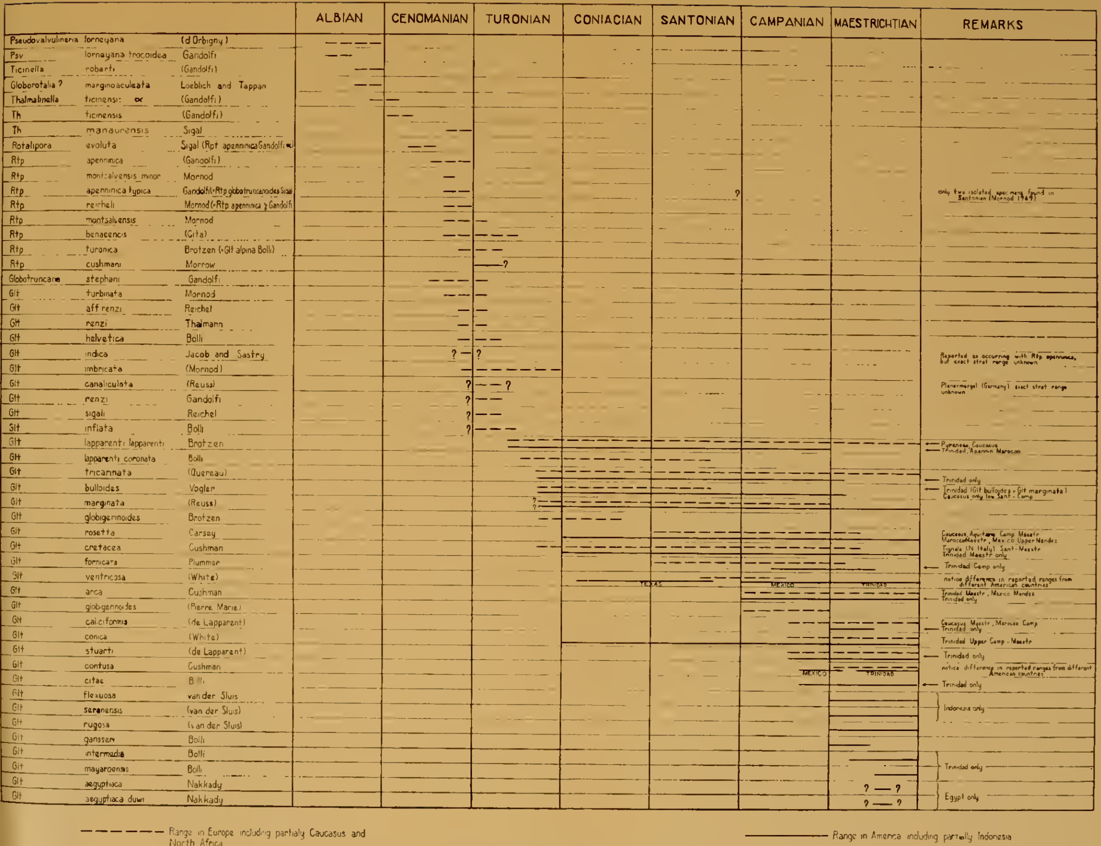

PLATE 9

Comparative Strathgraphic Range Chart of Globotruncana and Related Genera in Europe and America (excluding Colombia)

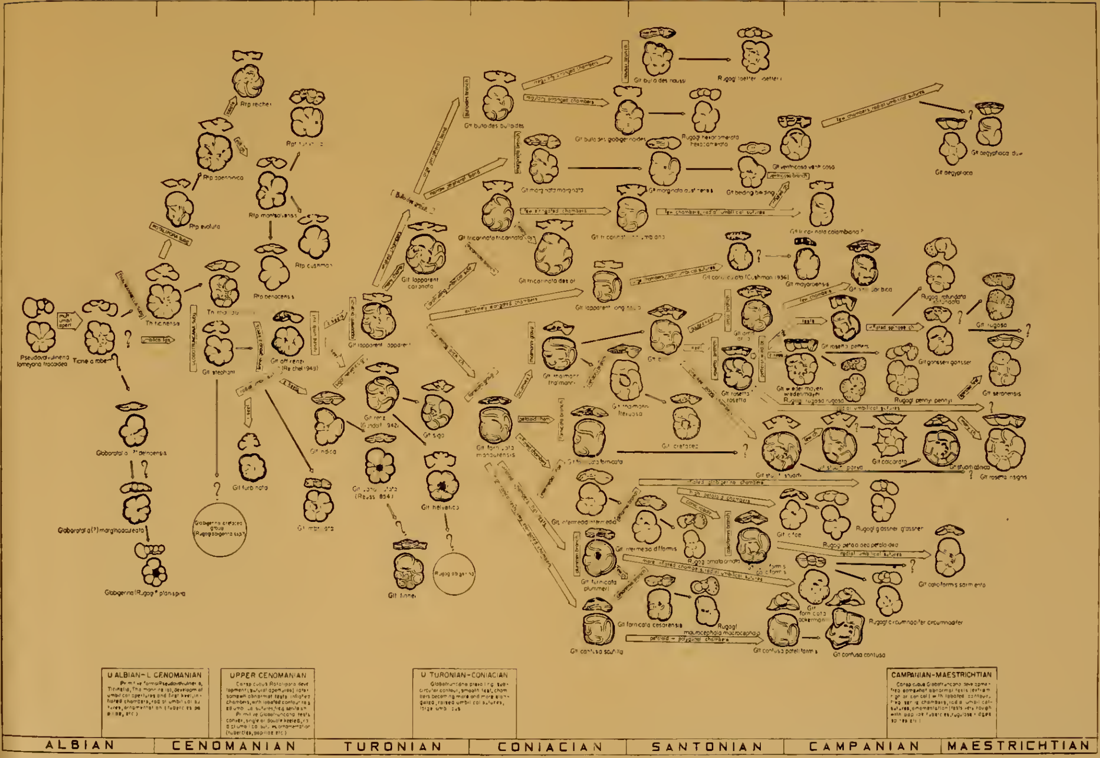

PLATE 10

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THE EOCENE FISHES OF ALABAMA

By

Errol I. White

British Museum (Natural History)

January 18, 1956

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THE EOCENE FISHES OF ALABAMA

By

Errol I. White

Department of Geology, British Museum (Natural History)

ABSTRACT

Two imperfectly known fish faunas from Eocene beds in the State of Alabama are described from old collections in the British Museum (Natural History), the larger from the Jackson formation of Clarke County, and a smaller series from the middle Eocene of Claiborne, Monroe County. While the former has a number of new species peculiar to it, neither fauna contains any pre- or post-Eocene forms. Such as have been recorded are shown to have been due either to misidentification or, more largely, to the admixture of European non-Eocene material in old collections.

Leriche's contention that the Tertiary fish faunas of the Atlantic Coast of the United States do not show precocious development compared with those of Europe, as has been widely held, is fully supported.

DISCUSSION

With the publication of Leriche's (1942) memoir on the Tertiary fish faunas of the United States Atlantic Coast, our knowledge of the comparable American forms has been extended. Even so not all the confusion that has so long existed concerning them has been straightened out. His material does not seem to have been so comprehensive as was desirable, and faunas richly represented in the British Museum collections are omitted. The two most important of these are from the Eocene of Alabama.

A. THE UPPER EOCENE OF CLARKE COUNTY, ALABAMA

A large collection of teeth labelled "Eocene, Alabama", was presented by Professor J.W. Mallet[1] in 1859, together with zeuglodont teeth; and further specimens, identical in colour and matrix with the additional information "Clarke's County", came with the collections of Lord Enniskillen and Sir Philip Grey-Egerton in 1882. Although no details are given it seems most likely that these came from the zeuglodont bed in the Jackson (upper Eocene) formation at "The Rocks", a famous early locality mentioned by Lyell (1846, p. 409; E.A. Smith, 1894, p. 639).

---

[1] J.W. Mallet F.R.S. (1832-1912), an Irishman, was at various times Chemist to the Alabama Geological Survey, and Professor of Chemistry at the Universities of Alabama, Louisiana, and Virginia.

Leriche mentioned only one species from the Eocene of Clarke County, Alabama, *Ginglymostoma obliquum* (Leidy), a correction of A.S. Woodward's record (1889, p. 348, pl. xvi, fig. 9) of *G. serra;* indeed the only other species from Alabama, all from the Jackson formation (upper Eocene) of Cocoa, Choctaw County, are (pp. 45-51):

"*Oxyrhina praecursor* var. *americana,* var. nov.
Carcharodon angustidens, praemut. cf. *sokolowi*
Sphyrna gilmorei, sp.nov.
Galeocerdo alabamensis, sp.nov.
Cylindracanthus rectus (Ag.)."

It is difficult to understand why Leriche ignored the numerous records, apart from the *Ginglymostoma,* made by Woodward in the first part of his Catalogue, even if the war prevented his personal examination of them. But it is perhaps just as well for many of the teeth were wrongly identified, and others did not come from the Eocene or even from America. The Mallet Collection contained a number of Upper Cretaceous forms from the same state. While the more obvious species, such as *Corax pristodontus* and *Ptychodus mortoni,* are properly attributed to that formation, others have been misidentified as Tertiary species. They are, however, not difficult to separate from the latter. But more important still is that in the Enniskillen Collection a number of European forms have been labelled "Alabama", and these account for the supposed occurrence in the Eocene of that part of such typical Miocene species as *Isurus hastalis* and *Carcharodon megalodon.*

The full list of species attributed to the Eocene of Alabama by Woodward (1889) is as follows:—

Page 348. *Ginglymostoma serra* (Leidy) P. 1216. Two teeth, one shown of the natural size in pl. xvi. fig. 9. Egerton Coll.

Referred to *G. obliquum* (Leidy) by Leriche (1942, p. 52).

Page 365. *Odontaspis elegans* (Ag.). No. 35611. Eight imperfect teeth. Mallet Coll.

These belong to *Scapanorhynchus texanus* (Roemer) from the (Upper) Cretaceous of Alabama, and were originally so labelled. There are no specimens of *O. elegans* (*O. macrota*) from these beds.

Page 371. *?Odontaspis cuspidata* (Ag.). No. 35611a. Eight specimens. Mallet Coll. P.1247. Ten specimens, Egerton Coll. P.5782. Three specimens. Enniskillen Coll.

The Mallet specimens belong to *Isurus praecursor americana* (Leriche), the others to *Odontaspis hopei* Ag. There are numerous other teeth of *O.hopei* in the collection (P.30262-91, P.30301-24), about 60 in all, many typical, similar to those figured from Europe by Leriche (1909, p. 238, pl. iv.). Others are smaller with worn denticles and resemble *O. teretidens* White.

Page 384. *Oxyrhina desorii* Ag. Nos. 35604-6, 35611-12. About 35 teeth. Mallet Coll. P.1261, P.1262. Sixty teeth. Egerton Coll. P.2374. 24 teeth. Enniskillen Coll.

All belong to *Isurus praecursor americana* (Leriche), except for six of P.2374, which are from the Miocene of Malta, one belonging to *I.hastalis* (Ag.), one to *I. retoflexa* (Ag), and four to *I.benedeni* (Leriche), re-registered as P.30492-7. The American teeth vary greatly in size, up to 4 cm. and more in height, and some are quite massive.

Page 387. *Oxyrhina hastalis* Ag. P.1262a. Seven small teeth. Egerton Coll. P.2368. Three teeth. Enniskillen Coll.

The Egerton teeth belong to *Isurus praecursor americana* (Leriche), the others are European and belong to *I.hastalis* (Ag.), two being from Antwerp and one from Malta.

Page 390. *Oxyrhina crassa* Ag. P.2374. Anterior tooth. Enniskillen Coll.

Correct but from the Miocene of Malta.

Page 413. *Carcharodon auriculatus* (Blainv.). Nos. 35598-603, 35612. Ten teeth. Mallet Coll. P.1200. Seven teeth. Egerton Coll. P.2386. Eighteen teeth. Enniskiller Coll.

These are teeth of *C.angustidens* Ag. Leriche (1942, p. 46, pl. iii, figs. 1-5) referred his specimens to *C.a.*praemut.? *sokolowi* Jaekel, but they do not seem to show any likeness to the original specimens described as *C.sokolowi*. In any case variation in form and coarseness of denticulation is so great as to make subdivision of this species impracticable. Fowler (1911, fig. 26) figured a good series of these teeth from New Jersey as *C.auriculatus*. Excellent wax casts of Morton's '*Squalus* sp.' (1834, pl. xii, figs. 3, 4), which must be among the first fossil sharks' teeth from the United States to have been figured, came to the British Museum (Nat. Hist.) in the Mantell Collection in 1839 (Nos. 7964-6; 10532-3).

Page 418. *Carcharodon megalodon* Ag. P.2388. Enniskillen Coll.

Correct but from the Miocene of Malta.

Page 424. *Corax pristodontus* Ag. No. 35609. Nine teeth. Mallet Coll. P.2350. Three teeth. Enniskillen Coll.

Correct but from the Upper Cretaceous of Alabama.

Page 428. *Corax affinis* Ag. P.2350a. Tooth of this or closely allied species. Enniskillen Coll.

This is the specimen noticed by Hay (1902, p. 309) and Leriche (1942, p. 52 footnote). It is black and unlike any of the teeth from Alabama in the collections, either Cretaceous or Eocene. It seems nearest to *C.kaupi* Ag.

Page 438. *Carcharias* (*Aprionodon*) *gibbesii* A.S.W. P.1220a. Eleven teeth. Egerton Coll. P.2338. Twenty teeth. Enniskillen Coll.

Correct but not the typical form—see *Negaprion gibbesi gilmorei* (Leriche) below.

Page 443. *Galeocerdo contortus* Gibbes. No. 35610. Five teeth. Mallet Coll. P.2349. Tooth. Enniskillen Coll.

The Mallet teeth are either correctly identified or belong to *G.alabamensis* Leriche, but all differ in appearance from the other Alabama fossils being black, worn, and are probably from phosphate beds. The Enniskillen tooth is a specimen of *G.aduncus* Ag. from Malta; there are two specimens registered under this number.

Page 446. *Galeocerdo aduncus* Ag. No. 35610. Two small hinder teeth. Mallet Coll. P.1211. Five teeth. Egerton Coll. P.2344. Three broad teeth. Enniskillen Coll. No. 35610a. Eight teeth. Mallet Coll.

The eight teeth from the Mallet Collection (35610a) are similar to those in the same collection (35610) recorded under *G.contortus* above.

P. 1211 and P. 2344 and one of the two small teeth (35610) are typical, pale-coloured like the other specimens from the Clarke County Eocene and are referred to a new species, *G.clarkensis.* The second "small hinder tooth" appears to be a specimen of *Physodon secundus* (Winkler).

Page 447. *Galeocerdo* (*?*) *minor* Ag. P.1211a. One tooth. Egerton Coll.

Probably a corner tooth of *?Physodon secundus.*

Page 451. *Hemipristis serra* Ag. P.1218a. Small tooth, doubtful of this species. Egerton Coll.

This specimen is referred to a new species, *H.wyattdurhami* (*q.v. infra*).

Page 455. Carchariid vertebrae. No. 35611a. Eight small vertebra. Mallet Coll.

In addition to the sharks, Woodward recorded in his second volume of the catalogue (p. 122) as probably *Cylindracanthus ornatus* Leidy "Several fragments" (P. 1769): this species is referred by Leriche to *C.rectus* (Ag.). And finally in the fourth volume (p. 368) Woodward mentioned 45 teeth in the Egerton and Enniskillen collections from the upper Eocene, Clarke County, as resembling *Sphyraena major* Leidy.

The corrected list of species from the upper Eocene of Clarke County, Alabama, derived from the volumes of A.S. Woodward's catalogue is as follows:—

Ginglymostoma obliquum (Leidy)
Isurus praecursor(Ler.) *americana* (Leriche)
Odontaspis hopei Ag.
Carcharodon angustidens Ag.
Negaprion gibbesi (A.S.W.) *gilmorei* (Ler.).
Galeocerdo clarkensis, n.sp.
?Physodon secundus (Winkler) = *?P.tertius*(Winkler)
Hemipristis wyattdurhami, n.sp.
Cylindracanthus rectus (Ag.).
Sphyraena cf. *major* Leidy

In addition to these there are many specimens that were omitted from the Catalogue, and these add considerably to the fauna.

UNRECORDED MATERIAL

Pristis sp.

A single fragment 2 cm. long from the tip of a rostral tooth shows a wide posterior sulcus (P. 1491. Egerton Coll.).

Myliobatis sp.

A score of teeth of various sizes, mostly broken and isolated (P.30967-92. Mallet Coll.) and several imperfect tail spines (P. 31041-52. Egerton Coll.).

Heterodontus cf. **woodwardi** Casier.

A single tooth (P. 30514) is almost identical with that figured as *Cestracion duponti* by Woodward (1891, p. 105, pl. 3, fig. 1) and subsequently referred by Casier to *H. woodwardi* (1946, p. 45).

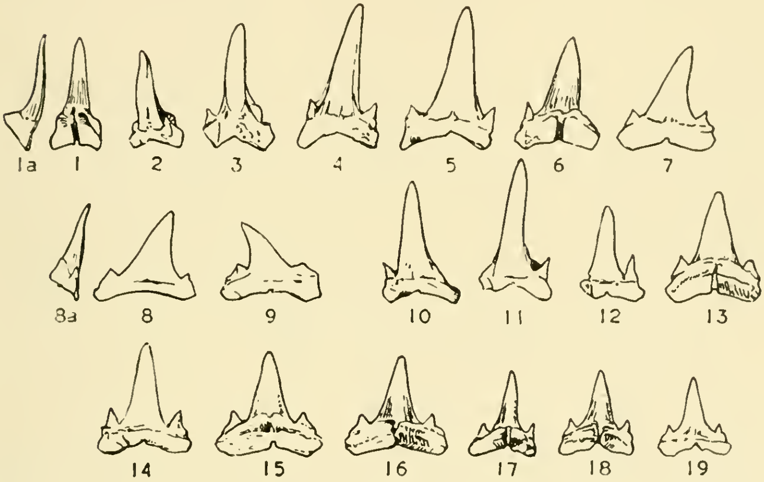
Scyliorhinus enniskilleni, n. sp. Text figs. 1-19; Pl. 11, fig. 1

There are about 35 large teeth of a dogfish in the Mallet and Enniskillen collections in various states of wear and repair. Their outstanding feature is their large size, the largest being no less than 1.5 cm. high, which, if in the same proportion to the body as the teeth of the common dogfish, represent a fish not less than 250 cm. (8 ft.) long.

On account of their unusual size these teeth could be easily mistaken for those of a *Lamna* or *Odontaspis*, especially the lateral teeth, were it not for the characteristic dead flat inner lower face of the roots divided by the clean-cut vertical groove. The front teeth are further distinguished by the shortness of the root-prongs.

The crown, particularly in the anterior teeth, is tall and narrow, with the outer face slightly convex and smooth except occasionally for irregular puckering at the base which is flush with the tooth. The inner face is rounded and largely ornamented with faint but characteristic, somewhat irregular vertical rugae. These naturally tend to disappear largely in worn specimens.

The teeth are divisible into an upper and lower series, much in the form of the dentition of *S.canicula*. The upper symphyseal teeth (Text figs. 1, 2) have narrow crowns on almost square roots, with no denticles or only one. The anterior teeth (Text figs. 3, 4; pl. 11, fig 1) have taller, more substantial crowns with a single pair of sharp, somewhat divergent lateral denticles and protuberant roots inwards. The following teeth (Text figs. 5-9) become successively broader and shorter and more and more curved towards the corner of the mouth. At the same time the inward curvature of the tip of the crown decreases until the corner teeth are actually concave vertically and across the roots, while the inner face of the root becomes less and less protuberant.



Scyliorhinus enniskilleni, n. sp.

Figs. 1-9. Upper teeth. 1,3,6,9, from left side, remainder from right. Holotype, fig. 4. (P.30633, P.30534, P.30614, P.30634, P.30611, P.30505, P.30576, P.30615, P.30577). 10-19. Lower teeth. 10,13,15-17. From right side, remainder from left. (P.30637-9, P.30613, P.30575, P.30616, P.30631, P.30636, P.30635, P.30632). 1,6,13,15-18. Show inner face. 1a,8a. Front view. All teeth from upper Eocene, Clarke County, Alabama. X 1 1/3.

The anterior lower teeth (Text figs. 10, 11) have relatively low, shallow roots but wide for the crown with the anterior prong the longer. Their crowns are slightly curved inwards, tall, upright and narrower than those of any of the teeth except the upper symphyseals. They have a pair of denticles which are pointed and narrow. The succeeding teeth (Text figs. 12-19) which are upright, become shorter and more triangular, and lose the inward curve.

Diagnosis.—A large species of *Scyliorhinus* with teeth up to 1.5 cm. in height; crowns moderately robust except in the upper symphyseals and lower anterior teeth, the former being extremely slender and having only one, or no lateral denticle; all other teeth with one sharply pointed pair; outer face of crown slightly convex and smooth except for occasional irregular puckering at base which does not overhang root; inner face convex with faint irregular vertical rugae; crowns upright except in upper lateral teeth which slope increasingly towards corner of mouth; inner face of root protuberant in anterior teeth but becoming less prominent towards corner of month; lower (attachment) surface dead flat and divided vertically by deep and straight median canal.

Holotype.—Right upper anterior tooth (P. 30634: Text fig. 4; Pl. 11, fig. 1)

Odontaspis malletiana, n.sp. Text figs. 20, 21; Pl. 11, figs. 2, 3

Two of Professor Mallet's specimens, P. 30242-3, are interesting as giving evidence of a new odontaspid shark. Neither tooth is perfect, but both show characteristic features. Both teeth are upper laterals from the left side, one from the front of the series, the second more from the middle of the jaw. In general they resemble teeth of the European and African species *O. lerichei* Casier (*Lamna vincenti* A.S.W. *non* Winkler, see Arambourg, 1952, Text fig. 19, p. 85). The form is similar, with smooth enamel on both faces of the crown and two pairs of lateral denticles, a large and a small, both finely pointed. On the whole the crowns in the Alabama teeth are taller, but most easily they are distinguished by a marked fringe of short fine pleats at the base of the enamel all round the crown. Such puckerings are not infrequently developed to some extent on the outer face of *Odontaspis* teeth, but not in my experience on the convex oral face.

Diagnosis.—A species of *Odontaspis* with teeth resembling those of *O. lerichei,* but with taller crowns and a fringe of fine short pleats all round the base of the enamel.

Holotype.—Anterior upper lateral tooth of left side (P. 30243; Text fig. 21; Pl. 11, fig. 3).

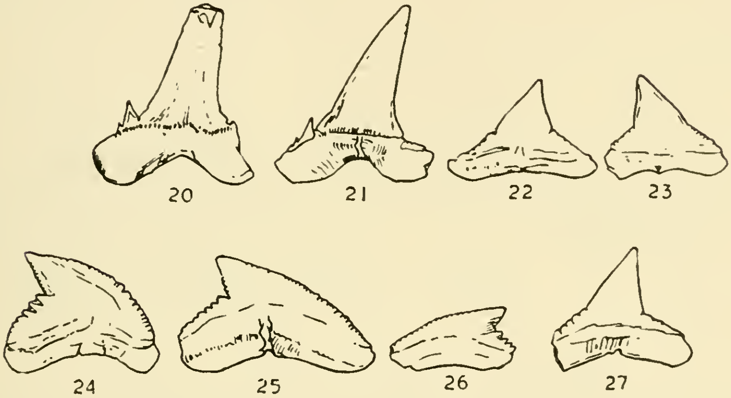


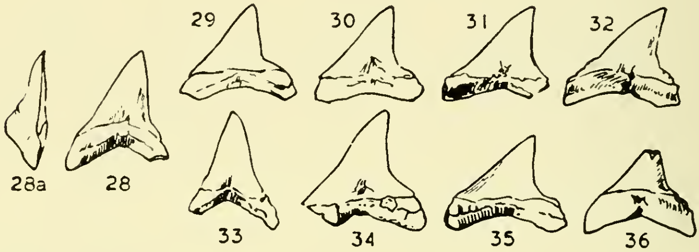
Fig. 20. *Odontaspis malletiana,* n. sp. Imperfect left upper anterior lateral tooth. (P.30242). 21. Left upper lateral tooth. Holotype. (P.30243). 22,23,27. *Negaprion gibbesi* (A.S.Woodward) *gilmorei* (Leriche). Unusually large upper lateral teeth from right, left, and right sides respectively. (P.31438, P.31437, P.31451). 24-26. *Galeocerdo clarkensis,* n. sp. Anterior, lateral, and posterior lateral teeth. Fig. 25 shows inner face. Fig. 24. Holotype. (P.30501, P.30467, P.30502). All teeth from upper Eocene, Clarke County, Alabama. X 1 1/3.

Odontaspis ? verticalis Ag.

A single tooth, P. 30261, from the Mallet Collection closely resembles in form and size that from the Bruxellian figured by Leriche (1906, pl. ix, fig. 27), except for a broken tip. There is, however, some question as to its provenance since it is differently coloured from the other Eocene teeth collected by Mallet. The species has already been recorded from the United States, from the earlier Pamunkey beds of Maryland by Leriche (1942, p. 29, pl. ii, fig. 13), so that it is possible that this specimen did come from the Alabama Eocene, if not from the same horizon or locality as the others.

Alopias latidens (Leriche) **alabamensis,** n.subsp.
Text figs. 28-36; Pl. 11, figs. 5, 6

The Mallet collection includes 11 teeth attributable to a thresher or fox-shark, which in size and general form come near to Leriche's (1910, p. 286, pl. xix, figs. 14-25) Oligocene species from Belgium. In turn *A.latidens* approaches closely in its dental characters the living *A.vulpinus* (Bonn.). However, the Alabama teeth do show constant, if minor, differences from the typical *A.latidens.* The roots are consistently smaller (or the crowns relatively larger), and the crowns, particularly of the more anterior teeth, appear more slender owing to the slightly sinuous anterior margin. I propose to distinguish the Alabama Eocene form as *A.l.alabamensis.*



Alopias latidens (Leriche) *alabamensis,* n. subsp.

Figs. 28-32. Right upper teeth (a) front view. 28. Holotype. (P.30853-7). 33-35. Left lower teeth. (P.30858-60). 36. Imperfect right lower posterior tooth. (P.30861). All teeth from upper Eocene, Clarke County, Alabama. X 1 1/3.

Among the syntypes of *Aprionodon gibbesi* (*q.v.infra*) are three teeth from the South Carolina phosphate beds, nos. P.31661-2, P.5747c, (Text figs. 37-39; Pl. 11, fig. 8) which belong to a related form of *Alopias latidens.* The first two are worn lower anterior teeth with broken roots and in their present condition do not differ substantially from the corresponding tooth from Alabama. But the third specimen is an upper lateral tooth of an individual type and indicates that the South Carolina specimens belong to a second subspecies. Roots are fully as large as those in corresponding teeth of the typical European form, but the crown, although broad at the base, narrows rapidly owing to the markedly sinuous front margin while the hinder margin is vertical and straight. For this small-crowned form I propose the name *A.l.carolinensis.*

Diagnoses of subspecies.—A.l.alabamensis, n.subsp. A subspecies of *Alopias latidens* with relatively smaller roots than in the typical form, and the crowns, particularly of anterior teeth, with slightly sinuous anterior margin.

Horizon and locality.—Upper Eocene, Clarke County, Alabama.

Holotype.—Upper anterior tooth, P.30853 (Text fig. 28; Pl. 11, fig. 5).

A.l.carolinensis, n.subsp. A subspecies of *Alopias latidens* with relatively larger roots than the typical form, the crown of lateral teeth narrowing rapidly, the anterior margin being markedly sinuous and the hinder straight.

Alopias latidens (Leriche) *carolinensis,* n. subsp.

Figs. 37-38. Worn lower anterior teeth; (a) front view. (P.31661-2). 39. Upper lateral tooth. Holotype (P.5747*c*). All teeth from phosphates, South Carolina. X 1 1/3.

Horizon and locality.—Phosphates of South Carolina.

Holotype.—Upper lateral tooth, P.5747c (Text fig. 39; Pl. 11, fig. 8).

Hemipristis wyattdurhami, n.sp. Text figs. 40-47; Pl. 11, fig. 4

A species of *Hemipristis* is represented by eight teeth coming from all three collections, Mallet, Egerton, and Enniskillen (P.1218a, P.30517-23). The first has been recorded under *H.serra* by Woodward (1889, p. 451) as a 'small tooth, doubtfully of this species'. Half of them have damaged roots, but all are nevertheless characteristic teeth. The enamel comes far down on to the roots on the outer face below the level of the top of the deep rounded notch that divides them, so that in fact only a narrow margin of root shows. On the inner surface the middle protuberant part of the root is pinched in and high, especially in the lower teeth, and the vertical canal is deep. When broken the internal cavity is seen to be large.

The dentition so far as it is known follows closely that of the living *H.elongata* (see Leriche, 1938, p. 14, text figs. 3, 4) in the variation according to position, but the teeth are shorter and dumpier with many fewer and far coarser denticulations.

There are no upper symphyseal or anterior teeth in the collections.

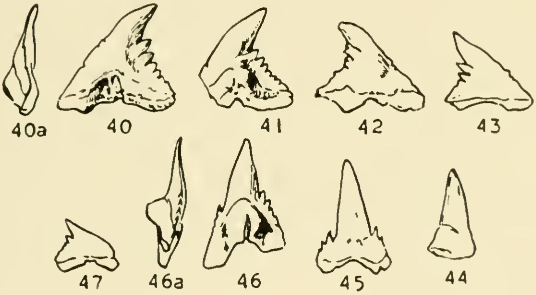
The upper lateral teeth (Text fig. 40-43; Pl. 11, fig. 4) are more or less triangular in form with the crown bending increasingly to the rear in the more posterior files. The front margin is gently convex towards the tip and smooth or with only a few vestigial coarse denticles in the lower half. The posterior margin is embayed, the tip smooth with some half dozen or less coarse denticles along the lower two-thirds, diminishing in size from above downwards. A marked feature of these teeth, especially the foremost, is the twisting outward of the anterior lower part so that the front edge is sigmoid. The blunt wide roots are almost in line, the anterior somewhat the narrower and divided by a well-marked median notch. The inner face is protuberant in the middle with a deep median groove.

The largest specimen is 1.0 cm. in height and 1.1 cm. across the base.

The only representative of the lower anterior teeth—there is none of the small symphyseals—is a rootless crown (Text fig. 44). As in the corresponding teeth of the living shark the crown is stout and narrow, almost rounded, in section, but differs in that there are no denticles and the slight cutting edges reach down almost as far as the crown is preserved, about the level of the top of the depression dividing the roots.

The two examples of the lateral teeth (Text figs. 45, 46) have narrow triangular outer faces to the crowns which slope only gently to the rear, the second slightly more so than the first, and are also gently sigmoidally curved. Each has two well-marked incurved lateral denticles and a vestige in front. The anterior tooth has the same number behind but somewhat larger, while the second has three. The anterior tooth has lost the exposed extremities of its roots, but they were probably similar to those of the second, in which the anterior prong is the more slender and much the shorter. In neither are they widely separated, so that they are from the front part of the lateral dentition.

The single lower posterior tooth (Text fig. 47), like the other three lower teeth, is from the right ramus. It is much curved towards the rear and has no anterior denticles but four or five graduated denticles behind, the largest being the highest.



Hemipristis wyattdurhami, n.sp.

Figs. 40-43. Upper lateral teeth. 40. Holotype, from right side, remainder from left. (P.30521-2, P.30519, P.30523). 44-47. Lower anterior (crown only), lateral and posterior lateral teeth. All from right side. (P.30518, P.30517, P.1218a, P.30520). 41, 46. Show inner face. 40a, 46a. Front view. All teeth from upper Eocene, Clarke County, Alabama. X 1 1/3.

As seen in aboral view, it resembles the teeth of *Galeus* (*Galeorhinus*) and *Galeocerdo,* but shows its origin in the pinched inner protuberant face. It is to all intents and purposes identical with corresponding teeth in the jaw of the living *H.elongatus* in the British Museum (Nat. Hist.) collection. Incidentally the teeth of this last specimen differ from those in the type jaws figured by Leriche in that there are fewer rows, two on each side, of the small symphyseal teeth, and that none of the lower teeth has more than a single denticle or a vestige in front of the lower teeth.

Remarks.—These teeth closely resemble in general form those from the Fayum figured by Stromer (1905, p. 174, pl. xvi, figs. 1, 3) and there seems little doubt that they are conspecific, and indeed in the original description of the species, Dames (1883, pp. 140-1) mentioned that the Berlin Collection also contained specimens from Claiborne, Alabama. The difficulty lies in the specimens Dames originally figured and described in detail. These, if anything, are upper teeth, judging by their broadly triangular form; but they have strong denticulations in front as well as behind, increasing in size upwards, which is certainly not a characteristic of the upper teeth from Alabama, nor of those described by Stromer, in which anterior denticulations are vestigial or absent. But unlike *Hemipristis* in general (cf. *H.serra* and *H.elongata* as figured by Leriche 1938, p. 14, fig. 3) is the sharp re-entrant angle between the smooth tip and the posterior denticles, and the depressed broad form of the tip except possibly in the more posterior teeth which these are obviously not, being too high. Moreover the inner face of the root lacks the median pinching-in so characteristic of the fossil *Hemipristis* teeth at least (the inner faces of the jaws of the living species cannot be seen in Leriche's figure, nor in a second specimen in the British Museum (Nat. Hist.), Dames' description does not square with the figures and his five specimens may have included true *Hemipristis* teeth (as subsequently figured by Stromer), but those figured do not seem to me to belong to this genus but rather to a *Galeorhinus*. Indeed, Arambourg (1952, p. 155) has already referred them to *G.minor*, but the specific attribution seems rather doubtful. It is interesting to note in this connection that among the first sharks' teeth recorded from the Eocene (Lutetian) of Nigeria, were some referred to "*Hemipristis curvatus*" (A.S. Woodward, 1922, p. 62). These were subsequently described as *Eugaleus semilevis*.

The name "*curvatus*" must go with the figured specimens of which I select the original of Dames' fig. 4a as the lectotype of the species *Galeorhinus curvatus* (Dames). The Alabama teeth, and with them, possibly Stromer's Egyptian specimens, I propose to designate *Hemipristis wyattdurhami*, n.sp.

Diagnosis.—A species of *Hemipristis* with teeth of moderate size, not known to exceed 1 cm. in height with relatively low crowns. Anterior margin of principal upper teeth markedly sinuous, the basal part and the front prong of the root being much curved outwards; posterior denticulations of upper teeth few and coarse, reaching up two-thirds of crown; anterior denticulations vestigial or absent.

Lower anterior teeth without denticles; lower anterior lateral teeth rather narrowly triangular, with two or three well-marked denticles only near the base behind, and two in front.

Holotype.—Upper anterior lateral tooth. P.30521 (Text fig. 40; Pl. 11, fig. 4).

Distribution.—The teeth in the collection are from Alabama, and from their colour and condition, all from the same area in Clarke County, although only the Egerton teeth are so marked. The formation is presumably Jackson (upper Eocene).

The teeth recorded by Dames from Claiborne could have come from either the Lisbon formation, Gosport sand (middle Eocene) or the Ocala limestone (upper Eocene), since all are present (C.W. Cooke, 1926, pp. 268, 271), but there is none in the collection of Claiborne teeth collected by T. Harris, so that they may be of the same age as the Clarke County teeth. However, a range covering the middle and upper Eocene is possible.

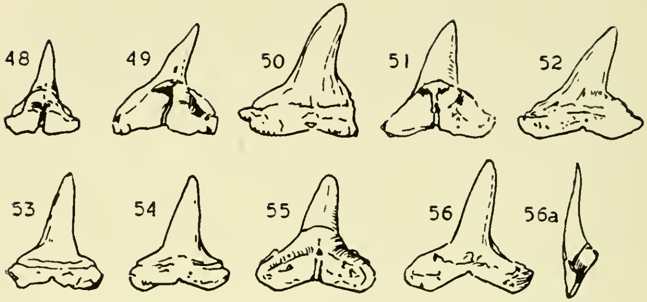
Hypoprion greyegertoni, n.sp. Text figs. 48-56; Pl. 11, fig. 7

This species is represented by nine teeth, all from the Mallet Collection. Five are from the upper dentition, four from the lower, and the tallest is 1.2 cm. high.

All have simple rather narrow crowns with sharp smooth cutting edges, flat or slightly convex outer (aboral) faces which are gently sigmoidal in profile, and convex inner faces.

The wide but shallow basal extensions of the upper crowns are somewhat wavy or faintly crenulated, but there are no true denticles; those of the lower teeth are straight and smooth but for a distinct shoulder at each end.

The roots are relatively massive and high in all teeth and are widely separated, almost in line with each other. The inner (oral) face is tumid, especially so in the most anterior teeth, with a deep, dead flat lower surface divided by a well-marked vertical canal into the top of which the nutritive foramen opens.



Hypoprion greyegertoni, n.sp.

Figs. 48-52, 55. Upper teeth. 50 and 52. Holotype, from right side, remainder from left and shows inner face. (P.30525-29, P.30532). 53,54,56. Lower teeth from left side. 56a. Side view (P.30530, P.30531, P.30533). All teeth from upper Eocene, Clarke County, Alabama. X 1 1/3.

The upper crowns are all somewhat asymmetrical and inclined to the rear, this margin being straight and the other curved, while the tips of the crown particularly of the foremost is much twisted; but both inclination and twist disappear towards the middle of the series. There are no posterior upper teeth.

The lower teeth have rather narrower and more upright crowns. The roots of the front teeth are short, but the length increases in the lateral teeth, and as it happens, so does the height of the crowns.

Remarks.—The form of the upper teeth varies greatly according to the living species, as witness those of the type species *H.macloti*, *H.hemiodon* (see Müller & Henle, 1841, pls. x, xix) and *H.signatus* (see Bigelow & Schroeder, 1948, text fig. 54), particularly in the size of the basal denticles. The only common factor in the various dentitions is that basal denticles are present in the upper teeth and not in the lower, all crowns being smooth. This denticular feature has almost disappeared (or had not developed) in the new fossil species, but the crowns of individual teeth do much resemble certain of those of the more obviously denticulated Eocene species from Nigeria, *H.overricus* White (1928, p. 39, pl. ix, figs. 1-16). It differs from that species in the greater twisting of the upper crowns and in the relative narrowness and uprightness of the lower. It may also be significant that the single anterior lower tooth of *H.greyegertoni* is smaller than the other teeth, as in *H.macloti,* whereas in the Nigerian species, the lower anterior teeth, of which nine specimens are known, are the tallest of all.

Diagnosis.—A species of *Hypoprion* with rather tall and narrow teeth, up to 1.2 cm. high, the upper teeth with only slight crenulations at base; the crowns gently inclined laterally, the tip twisted in the anterior teeth; crowns of lower teeth narrow and upright.

Holotype.—Upper lateral tooth. P.30529 (Text fig. 52; Pl. 11, fig. 7)

Negaprion gibbesi (A. S. Woodward)

Text figs. 22, 23, 27, 57-93; Pl. 11, figs. 9, 10

The history of this species is certainly curious. It was first described by Woodward (1889, p. 437) as *Carcharias* (*Aprionodon*) *gibbesi* without illustration, but with reference to three figures of sharks' teeth attributed by R.W.Gibbes (1849, p. 192, pl. xxv, figs. 63-65) to *Galeocerdo minor* and with doubt to another identified by Gibbes (pl. xxvii, fig. 164) as *Oxyrhina minuta.* The former were from the "Eocene of South Carolina and from the Miocene of Maryland", the latter from the "Eocene of South Carolina".

By definition of the subgenus *Aprionodon* (pp. 435-6) and of the species itself (p. 438) the characters of *Aprionodon gibbesi* given by Woodward were: "None of the teeth serrated. Teeth narrow on a broad base; the lower erect, the upper erect or only slightly oblique. A species of moderate size, the teeth comparatively robust and broad, the coronal margin often feebly crimped upon the basal extension."

This makes an accurate and clear diagnosis of the species to which belongs the great majority of the 121 teeth referred to it by Woodward, from the "Eocene, South Carolina and Alabama, U.S.A."

While Gibbes' tooth of *"Oxyrhina minuta"* doubtfully referred to Woodward's species, is probably a lower tooth correctly so identified, not one of Gibbes' three *"Galeocerdo minor"* teeth quoted by Smith Woodward are even congeneric, let alone conspecific with

Aprionodon gibbesi. According to both Gibbes' description and figures the crowns are fairly obvious teeth of *Sphyrna prisca,* presumably Leriche's subspecies *eastmani,* a possibility which Leriche failed to recognize. These teeth of Gibbes are not the types of the species, as Leriche seemed to suggest, the syntypes being the series of specimens originally quoted by Smith Woodward (1889, p. 438).

The great majority of these syntypes do belong to this one species, but not all. Of the 77 (not 75) teeth from the "Eocene", South Carolina (No. 28103),* six belong to a larger carcharinid, apparently *Negaprion magnus* (Cope), three resemble the teeth described as *Sphyrna americana* Leriche, two belong to *Sphyrna laevissima* (Cope), two to *Alopias latidens* (Leriche, *supra*); and the remaining 64 to *'Aprionodon' gibbesi* A.S. Woodward.

Both the teeth quoted by Woodward under No. 47006, also from South Carolina, seem to be worn lower teeth of *C.egertoni.*

The seven teeth, P.5747, *a-f* are referable to no less than four different genera and five species: two to *'Aprionodon' gibbesi,* one apparently to *Lamna verticalis* (Ag.), one to *Alopias latidens,* one to *Carcharinus egertoni,* and two to *C.magnus.* These South Carolina teeth, like the others quoted above from that state, are blue-black in colour and seem to come from the 'Phosphate Beds'. This chance assemblage of small teeth from these so-called "Eocene" beds clearly shows the mixed and derivative nature of these fossils, which Leriche (1942, pp. 54, 55) has already pointed out in respect of the whole fauna, the second species being an Eocene form, the third Oligocene and the last two Miocene. The age of this, the typical form of *A.gibbesi* is uncertain, since all the known specimens are from these phosphate beds and occur in varying stages of wear.

The remaining three lots of syntypes quoted by Woodward are all genuine teeth of *A.gibbesi,* six of them from South Carolina (P.1220) and the remaining 31 (P.1220a, P.1338) from Clarke County, Alabama. These 37 teeth are from the Egerton and Enniskillen collections, but the Mallet specimens, nearly 250 in number, all from Alabama, were not mentioned by Woodward. In addition

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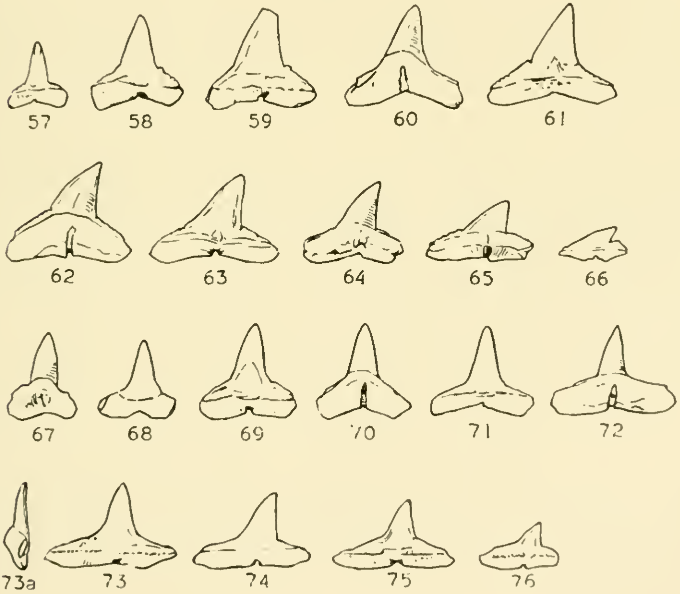
* These teeth are re-registered under the following separate numbers; P.31675-80, P.31727-9, P.31725-6, P.31661-2, P.31417-36 and P.31681-31724.

there are in the Museum collections a further 13 specimens from Alabama, believed also to be Egerton material from Clarke County (P.30839-51), and five collected by G.F. Harris from Claiborne. Altogether then there are some 370 teeth of this species in the British Museum (Natural History). It is curious that when Leriche (1942, p. 47, pl. ix, fig. 1) wrote his memoir on the marine fish faunas of the eastern United States coastal plain he came across only one such specimen, which he described as "*Sphyrna gilmorei*". This tooth, which came from the Jackson formation at Chocolate, Choctaw County, Alabama, is a typical specimen of the Alabama



Negaprion gibbesi (A.S.Woodward) *gilmorei* (Leriche)

Figs. 57-66. Upper teeth. All from side except figs. 60, 62, 65 which are from left and show inner face. (P.31459, P.31441-2, P.31462-6). 67-76. Lower teeth. All from left side except figs. 67,70,72 which are from right and show inner face. 73a. Front view. (P.31467-76). All teeth from upper Eocene, Clarke County, Alabama. X 1 1/3.

upper Eocene form of *'Aprionodon' gibbesi,* for undoubtedly these teeth can be distinguished from those of the South Carolina phosphates when unworn. While in the Alabama upper teeth the basal extensions of the crown are feebly but coarsely crimped, in those from the phosphates, when fresh, the crimping is much more definite and finer, and indeed in some teeth it amounts to clear denticulation: it may even be seen to some extent in a few lower teeth, which in the Alabama series are almost without exception smooth along all the margins. Moreover, the South Carolina teeth have in general relatively smaller crowns (or larger roots) especially in the upper dentition.

As no less than 74 out of 105 of Woodward's syntypes referable to this species come from the phosphates of South Carolina, I propose to take this as the typical form (Text figs. 77-96; Pl. 11, fig. 9), the Alabama series being treated as a subspecies for which Leriche's name "*gilmorei*" is available (Text figs. 22, 23, 27, 57-76; Pl. 11, fig. 10).

Five rather small rootless crowns from the middle Eocene of Claiborne (P.30295-9) show the characteristic features of the other, later, Alabama teeth and so are referred to the subspecies "*gilmorei*", making the known range middle-upper Eocene.

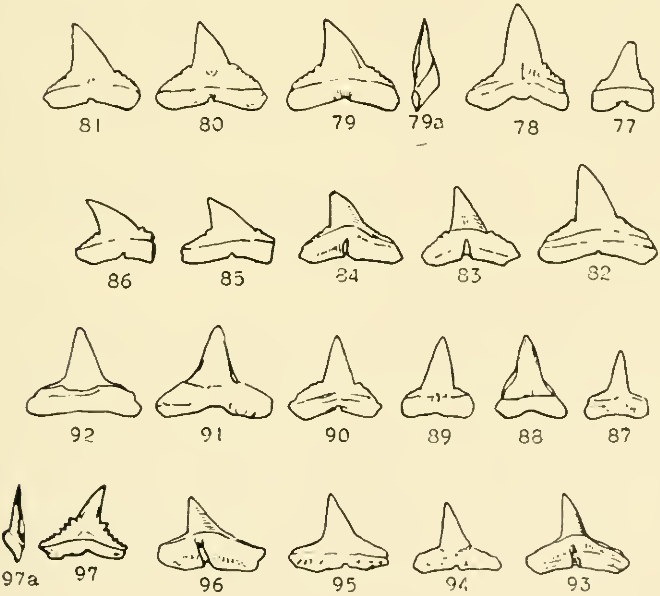
Both individually and in range of variation the teeth of *'Aprionodon' gibbesi* so clearly resemble those of the Lemon Shark, *Negaprion brevirostris* (Poey) as illustrated by Bigelow and Schroeder (1948, p. 310, text fig. 52) that there can be little doubt that the fossils must be referred to the same genus, *Negaprion* (seemingly one of the more successful erections of that uninhibited creator of synonyms, G.P. Whitley) rather than to *Aprionodon* in which the teeth of both jaws are narrow and erect, at any rate in the type species *A.isodon* (Müller & Henle). The generic dental characters of *Negaprion,* as detailed by Bigelow & Schroeder seem to be:

Teeth with flattish outer face, convex inner, and sharp cutting edges; upper teeth with rather narrow triangular cusps and broad bases, symmetrical and erect in anterior part of jaw but increasingly oblique with diminution in size towards corner of mouth; edges of cusps smooth, basal extensions faintly crenulated or finely serrated; symphyseal teeth small in both jaws; lower teeth with narrow crowns, erect except in corner teeth; basal extensions only exceptionally crenulated.

In the fossil teeth the nutritive foramen is large, and the median vertical groove deep and narrow, and the crowns of the lateral teeth slightly incurved at the tip.

The typical form of the species *Negaprion gibbesi* (A.S. Woodward) may be defined as follows:

A *Negaprion* with teeth up to 1.0 cm. in height and 1.2 cm.



Figs. 77-86. *Negaprion gibbesi* (A.S.Woodward), typical form. Upper teeth. All from left side, except figs. 83, 84 which are from right side, and show inner face. 79a. Shows front view. Lectotype, fig. 79. (P.31417-26). 87-96. Lower teeth. All from right side except figs. 93, 96 which are from left and show inner face. (P.31427-36). All teeth from phosphates, South Carolina. X 1 1/3. 97. *Galeorhinus recticonus* (Winkler) *claibornensis*, n. subsp. ? Upper anterior lateral tooth. Holotype. (P.30294). Middle Eocene, Monroe County, Alabama. X 1 1/3.

across the root. Teeth compressed, with slight groove along the margins of the crown and a faint median depression at base of outer face of the upper teeth. Basal extensions of upper teeth finely denticulated, the denticulations become fewer and less regular towards corner of mouth.

Lectotype.—No. P.31419 (Text fig. 79; Pl. 11, fig. 9).

Distribution.—Phosphate beds of South Carolina.

The diagnosis of *Negaprion gibbesi gilmorei* (Leriche) is as follows:

A subspecies of *N.gibbesi* with teeth attaining a slightly larger size than the typical form, up to 1.2 cm. in height. Crowns, especially of upper teeth, relatively somewhat larger. Basal extensions of crown in upper teeth only faintly but coarsely crimped, in lower teeth smooth.

Holotype.—Tooth in U.S. National Museum figured by Leriche (1942, p. 47, pl. iv, fig. 1).

Distribution.—Upper Eocene (Jackson) of Choctaw County and Clarke County, Alabama. Middle Eocene (Gosport sand) of Monroe County, Alabama.

Physodon secundus (Winkler)

There are four teeth from the Alabama Eocene of the larger type of *Physodon secundus*, usually recorded as *P.tertius*. Of these, three from the Mallet Collection have the narrow tips of the lower dentition (P.30245-7), while from the Egerton Collection comes an upper lateral (P.30650). In addition there is a long base without a crown, probably of this species, while the small tooth referred by Woodward (1889, p. 447, No. P.1211a) to *Galeocerdo ? minor* may well be a posterior lateral of *P.secundus*, as well as the second of the "two small hinder teeth" identified by the same author (*ibid.*, p. 446, No. 35610) with *G. aduncus*.

Galeorhinus cf. falconeri (White)

There is one remarkably long corner tooth (Enniskillen Coll., P. 2344) that resembles the corresponding teeth of this Nigerian Lutetian species, although larger than any known. It is 1.6 cm. long, but only 0.7 cm. high. It has the typical uptilted tip to the crown of the lower teeth of this genus, and this is also slightly twisted outwards.

The denticulations in front are fine but irregular and do not reach near the point which is smooth on both sides. The posterior denticulations on the base below the notch are coarse, the first behind subdivided. The inner face of the root has a flat lower surface divided by a well-marked vertical groove.

Galeocerdo clarkensis, n.sp. Text figs. 24-26; Pl. 11, figs. 12-14

As noted above the various lots of *Galeocerdo* teeth recorded from the Alabama Eocene as either *G. contortus* or *G. aduncus* by Woodward (1889, pp. 443, 446) fall into two series, pale-coloured specimens exactly like the teeth of the other species from the upper Eocene of Clarke County, and dark-coloured teeth like those from the South Carolina phosphate beds. The latter are mostly fragmentary and if they do come from Alabama, certainly do not come from the same beds as the pale series, for they seem to be a mixture of the Eocene *G.alabamensis* and the Miocene *G.aduncus*. All these are from Professor Mallet's collection.

There are nine of the typical pale-coloured teeth, five from the Egerton Collection (P.1211*), three from the Enniskillen Collection (P.2344*) and only one from Professor Mallet's collection (35610*). None of these belongs to *G.alabamensis*, Leriche's (1942, p. 48, pl. iv, fig. 2) upper Eocene species from Choctaw County, but to a different and apparently undescribed form. They are more compact than the other American teeth of this genus and in general have short, broad apices. The anterior denticulation are coarse, particularly in the middle of the well-arched anterior edge, but neither they, nor the finer denticulation above the posterior notch, reach the tip. Below the notch the denticulations are again coarse. The inner face is relatively flat.

The Miocene species *Galeocerdo contortus* Gibbes appears to be a good species and not just a race of *G.aduncus* Ag. as Leriche (1942, p. 88) supposed. At any rate specimens from South Carolina (*e.g.*, P.4098, P.5748) could not be confused with their fine and twisted points with specimens of *G.aduncus* from Malta (P.1212,

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* All re-registered separately as P.30500-4, P.30465-7, and P.30535, respectively.

P.2349, P.13803, P.19264-6) or from Patagonia (P.9083-4). Certainly they are as good a species as Leriche's *G.alabamensis,* based on a single tooth from Choctaw County. There is a series of 10 teeth from Farmingdale, New Jersey, (P.12754, P.30441-9) which includes one identical with his type and allowing for the usual variations according to position, all ten appear to be conspecific. From these the species seem close to both *G.aduncus* and *G.contortus,* but the crowns are smaller and shorter than in either. In shape they also resemble the series of *G.latidens* figured by Leriche (1906, pl. xi, figs. 19-28) but without the coarse anterior denticulations of that species. The teeth of *G.clarkensis* are readily distinguished from all these by their form.

Diagnosis.—A species of *Galeocerdo* with compact teeth, rather flat on the inner face; anterior margin well arched, and apices relatively short and broad, not denticulated near tip; anterior denticulations and those below posterior notch coarse; those above notch fine.

Holotype.—Anterior tooth (P.30501; Text fig. 24; Pl. 11, fig. 12).

Teleosts

There is a single worn irregularly shaped plate of *Ostracion* (P.30192), not specifically identifiable, in the Enniskillen Collection, but the worn dental piles of a *Diodon* from the Egerton Collection, labelled "Eocene, Alabama" (P.1910) and "Eocene of Clarke County, Alabama" (P.1911), are not typical in their yellow colour and may be of European origin.

The total list of fish remains from the Jackson formation (upper Eocene), of Clarke County, Alabama, compiled from Woodward's, Leriche's, and the new records is as follows:—

Pristis sp.
Myliobatis sp.
Heterodontus cf. *woodwardi* Casier
Ginglymostoma obliquum (Leidy)
Scyliorhinus enniskilleni, n.sp.
Isurus praecursor (Leriche) *americana* (Leriche)
Odontaspis hopei Agassiz

O. ? verticalis Agassiz
O. malletiana, n.sp.
Carcharodon angustidens Agassiz
Alopias latidens (Leriche) *alabamensis*, n.subsp.
Hemipristis wyattdurhami, n.sp.
Hypoprion greyegertoni, n.sp.
Negaprion gibbesi (A. S. Woodward) *gilmorei* (Leriche)
Physodon secundus (Winkler)
Galeorhinus cf. *falconeri* (White)
Galeocerdo clarkensis, n.sp.
Cylindracanthus rectus (Agassiz)
Sphyraena cf. *major* (Leidy)
Ostracion sp.

Of the 13 forms definitely identified, no less than nine are peculiar to the region and do not throw any light on the age; but of the remaining four, *Odontaspis hopei, Carcharodon angustidens, Physodon secundus* and *Cylindracanthus rectus,* all are Eocene species, but curiously enough of lower and middle Eocene age, rather than upper. But the important point is that there is no post-Eocene element anywhere and Leriche's contention that the supposed precocious occurrence in America of middle Tertiary European forms is based on misidentification is clearly upheld. If anything the contrary appears to be the case: they occurred a little later than in Europe.

B. THE MIDDLE EOCENE GOSPORT SAND OF CLAIBORNE, MONROE COUNTY, ALABAMA

In 1892 G. F. Harris presented to the British Museum a small collection of fish remains, chiefly sharks' teeth, from the "Middle Eocene of Claiborne" in a matrix of red sand. As no species seem to have been recorded from this formation and locality, the following notes are of interest.

Odontaspis macrota (Agassiz)

Four typical teeth (P.30219-22).

The species has already been recorded by Leriche (1942, p. 44).

Odontaspis cf. **rutoti** (Winkler)

A single tooth (P.30218) clearly denotes the presence of a second species of *Odontaspis*. This is a small upright tooth, 1 cm. high and the same across the roots. The enamel is smooth on both faces, except for fine puckering at the base of the outer face, where the base is straight and tends to overhang the root. The inner face of the root is strongly protuberant. It most resembles a lower posterior lateral of *O. rutoti* but is not typical.

Negaprion gibbesi (A. S. Woodward) **gilmorei** (Leriche)

There are five small teeth with weathered roots (P.30295-9) p. 142 (*Supra*).

Physodon secundus (Winkler)

A single tooth with the tip of the crown missing (P.30292) compares readily with the upper posterior lateral teeth of the larger specimens of this species which are generally recorded as *P.tertius* (Winkler).

Galeorhinus recticonus (Winkler) **claibornensis**, n.subsp.

A single perfect tooth (P.30294, Text fig. 97, Pl. 11, fig. 11) much resembles the European form with its nearly upright and smooth crown and more or less symmetrically disposed denticles along the base. But the denticles are much smaller and more numerous, seven in front and six behind. In the typical form three and four are the common number (see Leriche, 1905, pl. viii, figs. 44-53). It is an anterior lateral tooth, probably from the upper jaw.

Diagnosis.—A subspecies of *G.recticonus* with smaller and more numerous denticles, seven in front and six behind.

Holotype.—An ? upper anterior lateral tooth (P.30294, Text fig. 97, Pl. 11, fig. 11).

Galeorhinus cf. **falconeri** (White)

A single specimen with imperfect base (P.30293) much resembles the Nigerian Lutetian form. It is 1.1 cm. long and has a smooth-edged, backwardly directed triangular crown. There are small incipient crenulations in front and two or more sharp, large triangular denticles behind.

Lutianus intermedius (Koken).

A single otolith (P.6827) belongs to Koken's species, *O.* (*Sciaenidarum*) *intermedius* which Mr. Stinton informs me belongs to a *Lutianus.*

Summary.—

Odontaspis macrota (Agassiz)
*O.*cf.*rutoti* (Winkler)
Negaprion gibbesi (A. S. Woodward) *gilmorei* (Leriche)
Physodon secundus (Winkler)
Galeorhinus recticonus (Winkler) *claibornensis,* n.subsp.
*G.*cf.*falconeri* (White)
Lutianus intermedius (Koken)

This is a typical Eocene assemblage. *Negaprion gibbesi gilmorei* is a Jackson form in Clarke County, and *O.rutoti,* if the identification is correct, is a lower Eocene species in Europe. The remainder are noncommittal.

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PLATE

Figure Page

EXPLANATION OF PLATE 11

1. **Scyliorhinus enniskilleni**, n. sp. 128
Right upper anterior tooth. Holotype (P.3063). Upper Eocene, Clarke County, Alabama.

2. **Odontaspis malletiana**, n. sp. 130
Imperfect left upper anterior lateral tooth. (P.30242). Upper Eocene, Clarke County, Alabama.

3. **Odontaspis malletiana**, n. sp. 130
Left upper lateral tooth. Holotype (P.30243). Upper Eocene, Clarke County, Alabama.

4. **Hemipristis wyattdurhami**, n. sp. 133
Right upper lateral tooth. Holotype (P.30521). Upper Eocene, Clarke County, Alabama.

5. **Alopias latidens** (Leriche) **alabamensis**, n. subsp. 132
Right upper anterior tooth. Holotype (P.30853). Upper Eocene, Clarke County, Alabama.

6. **Alopias latidens** (Leriche) **alabamensis**, n. subsp. 132
Left lower lateral tooth. (P.30860). Upper Eocene, Clarke County, Alabama.

7. **Hypoprion greyegertoni**, n. sp. 137
Right upper lateral tooth. Holotype (P.30529). Upper Eocene, Clarke County, Alabama.

8. **Alopias latidens** (Leriche) **carolinensis**, n. subsp. 133
Upper lateral tooth. Holotype (P.5747c). Phosphates, South Carolina.

9. **Negaprion gibbesi** (A.S.Woodward) typical form 139
Left upper lateral tooth. Lectotype (P.31419). Phosphates, South Carolina.

10. **Negaprion gibbesi** (A.S.Woodward) **gilmorei** (Leriche) 139
Exceptionally large right upper lateral tooth. (P.31439). Upper Eocene, Clarke County, Alabama.

11. **Galeorhinus recticonus** (Winkler) **claibornensis**, n. subsp. 148
Upper anterior lateral tooth. Holotype (P.30294). Middle Eocene, Monroe County, Alabama.

12. **Galeocerdo clarkensis**, n. sp. 145
Anterior tooth. Holotype (P.30501). Upper Eocene, Clarke County, Alabama.

13. **Galeocerdo clarkensis**, n. sp. 145
Lateral tooth, inner face. (P.30467). Upper Eocene, Clarke County, Alabama.

14. **Galeocerdo clarkensis**, n. sp. 145
Posterior lateral tooth. (P.30502). Upper Eocene, Clarke County, Alabama.

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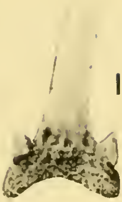
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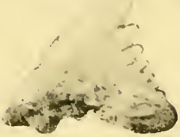
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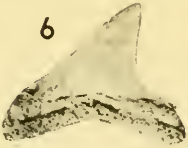
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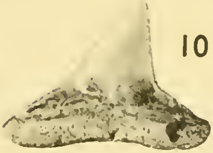
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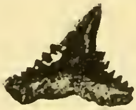
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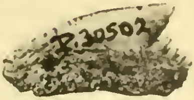

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NEW FOSSILS FROM THE CANADIAN-CHAZYAN (ORDOVICIAN) HIATUS IN TENNESSEE

Kenneth E. Caster
and
H. K. Brooks
University of Cincinnati

January 25, 1956

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NEW FOSSILS FROM THE CANADIAN-CHAZYAN (ORDOVICIAN) HIATUS IN TENNESSEE

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ABSTRACT

A new Lower Ordovician fauna from marine sediments deposited in a depression on the unconformity of the Canadian-Chazyan hiatus in Tennessee is described. Most abundant are the remains of *Chasmataspis laurencii,* n. genus, n. species, a merostomaceous arachnomorph for which the new order Chasmataspida and new family Chasmataspidae are required; a new bivalved crustacean, *Douglasocaris collinsi,* n. genus, n. species, shows sufficient affinities to the Phyllocarida to be tentatively assigned to this order, however, a new family, Douglasocaridae is required to accomodate it. A trail, problematic castings and a new foliaceous ctenophoran-like organism, *Cestites mirabilis,* n. form-genus and n. species, complete the assemblage.

INTRODUCTION

An unusual accumulation of sediment, in part volcanic, was discovered in the excavation for the foundation of the southeast abutment of Douglas Dam on the French Broad River, Sevier County, Tennessee, by the geologist of the Tennessee Valley Authority in 1942.

The organic remains of the deposit were at first interpreted by governmental specialists in Cambrian paleontology as pertaining to that period. The mistake is quite understandable for the overall aspect is highly reminiscent of certain elements of the famous Burgess shale deposit of the British Columbia Middle Cambrian. What seemed at first to be an aglaspid, a limulid buckler, and an onychophoran (*Aysheaia*) proto-arthropod, materialized later as parts of a single organism of merostomaceous affinities but fundamentally new. The new crustacean bears a superficial resemblance to *Burgessia,* a characteristic pseudocrustacean of the Burgess fauna.

Since the sediments were different from the country rock, and the fossils were apparently of Cambrian age, the logical conclusion was that the deposit had been faulted into its present position in the Ordovician sequence. Detailed field studies proved that these sediments could not be of Cambrian age. They occur in a depression on the Canadian-Chazy unconformity and thus represent an interval of time and volcanic activity not previously recorded. The fossil arthropods are new and unique and not closely related to the Cambrian forms. Both the merostome and the crustacean belong to phyletic races hitherto unknown.

In addition to his regular duties as resident geologist on the Douglas Dam project, Mr. Robert Laurence spent many hours studying and collecting from the newly discovered deposit. The information and specimens he acquired are invaluable since the dam now completely covers it. At the invitation of Mr. Laurence, Dr. R. Lee Collins visited the excavation soon after the significance of the rocks and fossils uncovered was recognized. Dr. Collins removed several hundred pounds of blocks of the fossiliferous zone. These blocks have subsequently yielded some of the most significant specimens discovered. After the untimely death of Dr. Collins, H. K. Brooks finished the search for fossils in the few remaining blocks and discovered the only completely articulated fossil merostome and a problematic specimen resembling a ctenophoran.

In recent years, the authors have visited the locality, but only blocks excavated and used as fill and rip-rap are now accessible. Upon being exposed to the elements, the fossiliferous sediments weathered rapidly. Only a few scraps can now be collected above the dam when the lake is low. Blocks of rock from the unfossiliferous zones are still common.

Before the first articulated specimens were discovered, K. E. Caster had, with the assistance of Anneliese Caster, pieced together the fragments of the merostome into a creature which was unlike anything known. Subsequently, articulated specimens have proven their early restoration to be essentially correct.

Dr. Leif Størmer has contributed to the study through information and suggestions freely offered in correspondence concerning the nature of the new merostome, however, the taxonomy here presented is the responsibility of the authors. Dr. John W. Wells kindly provided information and bibliographic reference on the only previously reported ctenophoran.

With the exception of six specimens belonging to the University of Cincinnati Museum, all of the type material has been placed in the collection of the United States National Museum. The collection was made available through the courtesy of Dr. G. Arthur Cooper,

Curator of Invertebrate Paleontology and Paleobotany.

The cost of the original illustrations and plates has been met by the Faber Fund for Paleontologic Research at the University of Cincinnati Museum and research fund from the Graduate School of Arts and Science of the University of Cincinnati.

Rosann Brooks generously gave assistance with the chores in the preparation of this paper. The authors especially acknowledge her contribution in the typing of preliminary and final copies of the manuscript.

STRATIGRAPHY AND ORIGIN OF DEPOSIT

The general description of the occurrence and nature of the deposit presented below is based largely on the published field observations of Laurence (1944). The original rock body is of limited extent. It is about 40 by 90 feet in plan and has a known thickness of 120 feet. The upper unit of the Knox dolomite (Mascot of Canadian age) surrounds and underlies it. The superimposed Lenoir limestone (Chazyan) has been removed by recent erosion from immediately over the deposit. An unconformity, believed to represent a considerable hiatus, separates the Knox dolomite and the Lenoir limestone throughout this region.[1]

The lithology of the deposit contrasts with that of the surrounding dolomite with which it has an irregular contact. The lateral surface of contact is approximately at right angles to the bedding of the Knox. To distinguish it, Laurence has termed these rocks the "33 formation" or the "33 beds" from the abutment excavation in which they were encountered.

Laurence recognized three units of the "33 formation." The upper unit designated as Unit A consists of thin-bedded, slabby reworked volcanic ash and carbonates (40 to 60% insolubles) with

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[1] A detailed study of the Knox (Mascot) dolomite—Lenoir limestone contact along the west shore of Douglas Lake north of the dam was made by the late Josiah Bridge. In a posthumous paper, Bridge (1955) describes other sinklike depressions which are filled with a basal rubble of dolomite and chert boulders and blocks overlain by a black, fine-grained, thin bedded dolomite which grades upward into the typical Lenoir. No volcanics are recognized. These basal sediments are termed the Douglas Lake member of the Lenoir formation. The dark, dolomitic upper unit of this member is correlated to the unit at the top of the accumulation exposed in the excavation for Douglas Dam which was designated as Unit A of the "33 formation" by Laurence.

green shale partings. This unit is variable in nature, but for the most part it is made up of beds 1/8 to 3/4 of an inch in thickness. The upper surfaces of some of the slabby layers are rippled and some of the surfaces have mud cracks and rill scour marks. The ripple marks are symmetrical with a distance between crests of from five to seven inches. Large, subrounded, erratic dolomite boulders are a curious feature of these beds. According to Laurence, this unit is at least 35 feet thick.

Underlying is a sequence of laminated, massive deposits. Concentrations of organic material at the top of varvelike graded beds emphasize the laminated appearance. There are 1 to 20 laminations per inch. This lithologic member, designated as Unit B, does not have shale partings. It is massive when fresh but weathers rapidly. The weathered material splits readily at the carbonaceous plane at the top of each "varve."

Layers and lenses of conglomerate and breccia are recurrent throughout this unit. These beds and lenses, usually 1/8 to 2 inches in thickness, contain angular to subrounded pebbles up to 2½ inches in diameter. Most of the graded beds have a basal zone of angular pyroclastic granules. The breccia fragments are predominately of volcanic origin whereas the subrounded pebbles are of a wide variety of lithologic types, some unknown in the vicinity.

In many places the laminations of this unit have been contorted by the soft rock deformational processes of sediment flowage and slumping. Laurence (1944, fig. 6A and 6B) figured contorted laminations between undisturbed beds and an angular unconformity within a sequence of conglomeratic beds.

Unit C, stratigraphically the lowest member, is composed of massive, blocky, fine-grained, pyroclastics without laminations. Evidences of reworking of these sediments by currents are absent. The upper 25 feet of this unit are composed of soft, gray and greenish-gray pyroclastics. Below is a hard, homogenous, white siliceous rock grading laterally into materials resembling the overlying zone. The upper zone and the materials near the contact with the country rock may represent an alteration product. There is a clean contact with the Knox dolomite at the base and no accumulation of breccia or conglomerate. The total thickness of Unit C is about 65 feet.

Laurence (1944, p. 244) described the structure of the deposit as "synclinal, with dips as high as 75° at the north and south boundaries . . . The contact with the adjacent dolomite is nearly vertical at the south and west borders. At the north and east this contact dips 70° toward the enclosed deposit in the upper part, but 60°-85° away from it at the bottom . . . Drilling . . . has shown that the deposit has a definite bottom contact with about 8 feet of relief . . . with a local depression in this floor extending . . . (downward 13 feet) in the northeast end of the deposit." The country rocks are dipping about 20° to the southeast.

The origin of this deposit stratigraphically between the Knox dolomite and the Lenoir limestone was interpreted by Laurence as an accumulation in a cenote-like sinkhole on a land surface now represented by the unconformity marking the Canadian-Chazyan hiatus (1944, p. 246-247). "During eruption of a volcano, probably at a moderate distance to the east, a shower of fine volcanic ash fell in this area, and much of it accumulated in the sink hole, forming the thick series of Unit C. As the hole filled and the supply of volcanic ash was reduced, some calcareous and argillaceous sediments were also deposited. In this shallow water (within the sink hole) certain types of invertebrate life thrived, but fossils were preserved only in the fetid muds now represented by the carbonaceous laminations. Conglomerate lenses were formed during times of torrential runoff. This period of deposition was followed by further erosion, during which all the beds of the same age as the '33 formation' were removed, except the small portions protected in the deep depressions. This was followed by submergence and renewed deposition of ordinary calcareous sediments."

It is probable in Pre-Chazyan time a basin of deposition of considerable depth but of limited areal extent was produced by solution of the Knox dolomite. Whether subareal or submarine cannot be proven. It would appear to us that the primary sedimentary features of the upper two units and the lack of a basal rubble are not in conformity with the sink hole interpretation.

The depression on the Canadian-Chazyan unconformity could represent the orifice of a large submarine spring fed by a channel or system of channels from the nearby land to the southeast. During the deposition of the Chazyan strata the sea is believed to have transgressed to the southeast in this area. If disturbances accompanying a volcanic eruption should stop such a spring from flowing, a clean-bottomed depression without the typical accumulation of sink hole rubble would exist for the reception of the volcanic sediments. Comparable recent submarine springs occur at many places off the west coast of Florida.

The primary features of deposition of the "33 formation" would seem to oppose the sink hole hypothesis. The uniformity of texture, thickness of the individual beds and "varves," and the absense of significant facies change toward the margins of the body are not the characteristics of sediments dumped into a hole by terrestrial surface wash. Not only is it inconceivable that ripple marks with lengths of from 5 to 7 inches from crest to crest could have formed within a cenote pool, but it is unlikely that scour rill marks could be formed under these conditions.

Fine-grained sedimentary materials are subject to considerable compaction, sometimes up to 80%, through reorientation of particles and expulsion of interstitial water. Slickensides at the contact of the "33 beds" with the Knox dolomite may be the result of differential compaction. This contact also proves quite conclusively that the Knox dolomite was consolidated previous to the origin of the cavity and the pyroclastic deposit. The synclinal structure of the "33 beds" appears to be due to contemporaneous and subsequent movement resulting from differential compaction. For a discussion of the reasons why these bordering slickensides cannot be due to faulting, see Laurence's (1944) paper.

The sedimentary environment of the "33 beds" would appear to have been on a wave-cut terrace in a sedimentary basin in open connection with the advancing Chazy episea. On this terrace erosion and sedimentary bypassing were dominant over deposition. Probably unit C represents an accumulation of volcanic ash in the orifice of a spring, the flowage of which was disrupted by diastrophic movements accompanying the eruption. As these sediments were slowly compacted, volcanic ash and other sediments being reworked by waves, tides, and other currents on the terrace were carried into the slight depression on the sea floor thus formed. A considerable thickness of sediments representing accumulation in a depression slightly below the surrounding area could be deposited in this way.

This interpretation is in accordance with the presence of large ripple marks, scour marks, mud cracks, the regularity of the bedding, and the lateral uniformity of the beds. Slumping and sediment flowage would be expected to occur in the upper aqueous layers of a deposit sinking into a deep depression because of compaction of the underlying part of sedimentary body slumping, scour, and subsequent deposition would also account for the angular unconformity within a conglomeratic zone of Unit B.

PRESERVATION AND PALEOECOLOGY

The fossils of the "33 beds" comprise a merostome, a crustacean, and problematica. All were collected from the "varve beds" of Unit B and most were found in the upper eight feet of this unit. Most of the specimens are preserved as compressions on planes between graded beds or within the fine-graded, calcarous sediments at the top of each varve. The superimposed coarse sediments of the succeeding graded bed are usually in contact with the specimens.

The arthropod fossils have retained some relief. The best specimens of the merostome are impressions of the details of the exoskeletal parts. All specimens have been deformed by compaction of the matrix. Dorsal and ventral surfaces of some of the merostome remains are now in the same general plane. Differential movement within the sediments has resulted in considerable disfiguration of many of the fossils.

No trace of sulphides of iron is present in the sediments, and it is, therefore, unlikely that the dark fossiliferous layers at the top of each graded bed represent deposition under fetid conditions as was suggested by Laurence. The dark zones at the top of the graded beds of Unit B are composed of fine-grained carbonates and pyroclastics. Scraps and fragments of altered organic material are present in these zones in considerable abundance and impart the dark color. These organic remains seem to represent triturated chitinous skeletons of arthropods and fragments of plants winnowed into the depression of accumulation between periods of sediment influx.

Most of the merostome fossils are sclerites of disarticulated individuals. The crustacea are articulated, but details of the exoskeleton are not well preserved. It is believed that these remains represent exuviae and the skeletons of cadavers carried by currents from the surrounding area into the depression. The remains were borne to the site during the quiescent intervals between periods of strong currents which transported the coarse clastics of the basal portions of the graded beds.

The limited number of forms in the biota, *i.e.,* vagrant merostomes and crustacea, problematical plant (or ctenophoran), algae (or fecal castings of an animal) and a trail, together with the absence of benthonic shell-bearers is probably due to the instability of the substratum of shifting volcanic ash on the broad, shallow wave eroded terrace. The bottom may even have been intermittently exposed at low tide. Absence of a fauna of typical marine animals with calcareous shells should never be construed as proof of a nonmarine environment of deposition. Positive evidence must be the basis of scientific reasoning. All things considered, it is believed the arthropods found in this deposit were marine animals.

BIOLOGY

DESCRIPTION OF THE MEROSTOME

Material.—Terms employed in describing the merostome are those in common usage (Størmer,1934A). The major body divisions, or tagmata, of merostomes are: prosoma (cephalothorax), preabdomen, and postabdomen. A telson is born at the posterior extremity.

This study is based on all of the known specimens. One poorly preserved individual was completely articulated (counterparts, Plate 14, fig. 1 S; Plate 15, fig. 1 S); one well-preserved specimen lacks only the telson (counterparts, Plate 12, fig. 1 S; Plate 13, fig. 1 S); and one consists of the prosoma and a portion of the preabdomen (Plate 12, fig. 2 S). This latter was the first specimen to be recovered which showed articulation at the tagmata, and in the absence of the postabdomen is very limuloid in appearance. Most of the specimens are pieces of disarticulated or partially articulated skeletons. All of the specimens seem to belong to one species.

Most of the counterparts have been separated, therefore, the number of incomplete specimens listed is only an approximation.

We have examined:

72	dorsal shields of the prosoma
3	specimens of appendages
50	pieces of the dorsal shield of the preabdomen
49	specimens of the ventral surface of the preabdomen
12	isolated postabdominal sclerites
4	articulated postabdominal tagmata
2	postabdomens with attached telson
9	telsons

Morphology.—The remains of the exoskeleton are carbonized, and there is no trace of it having been calcareously impregnated during life. A chitinous exoskeleton armor covered the dorsal surface of the prosoma, both surfaces of the preabdomen and encased the metameres and telson of the postabdomen. The ventral surface of the prosoma is unknown except for a narrow marginal doublour. The detached appendages are prosomal and were affixed no doubt around the mouth. The chitinous integument on the ventral surface of the preabdomen was thinner than that of the dorsal surface.

The prosoma is approximately semicircular with the lateral angles developed into genal spines. Because compression has spread the dorsal shields, the exact amount of original dorsal arching is unknown. Assuming that the amount of spreading is proportional to the amount of original vaulting and that the lateral edges of the genal spines were probably originally approximately parallel to the axis of the animal, then the present difference (between 8 and 18°) is due to greater spreading of the posterior portion of the shield than at the anterior. If this can be used as a criterion, the dorsal shield was moderately arched with maximum vault at the posterior.

No distinct rachus, *i.e.*, medial raised axis, is present on the dorsal shield. A portion of the inner ophthalmic area is devoid of tuberosity and may be designated as a glabella, *i.e.*, the equivalent of the cardiac lobe of most xiphosurans.

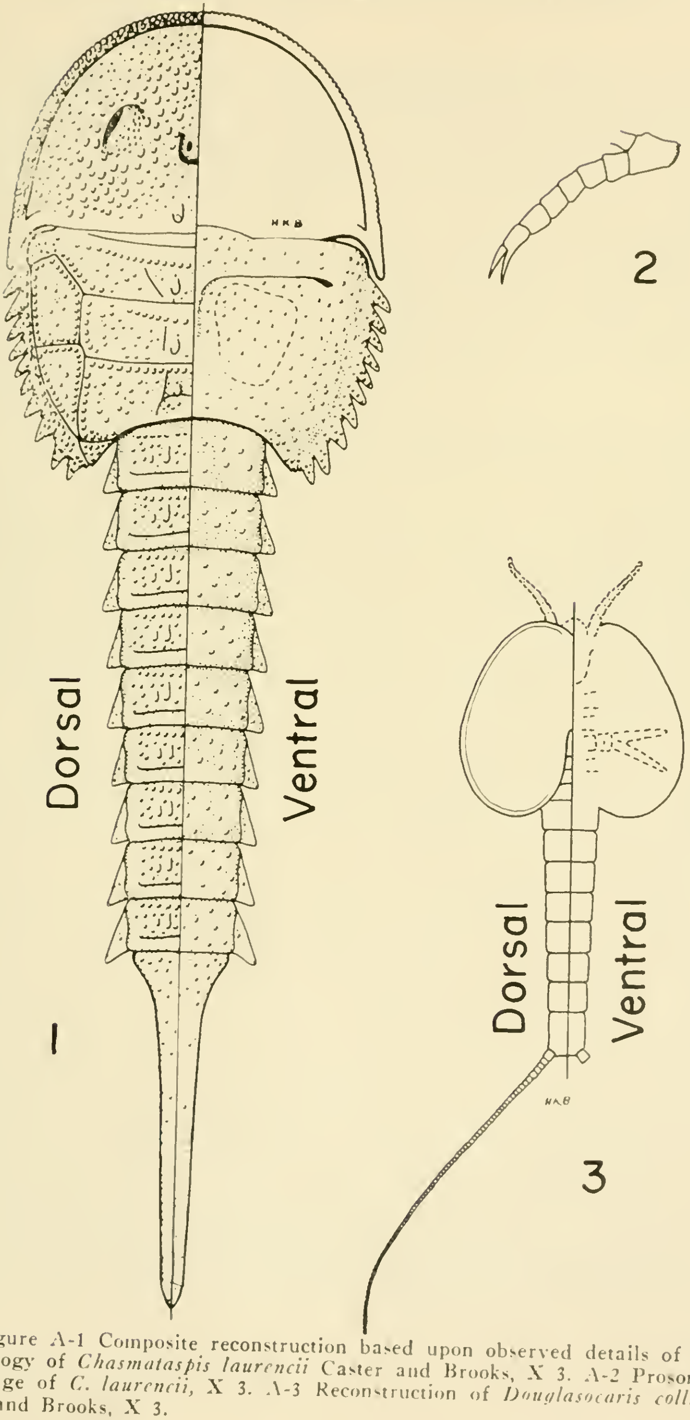
A large node at the anterior apex of the glabellar area appears to have been the site of a pair of medial ocelli. This bilaterally symetrical node has its greatest development near the posterior and resembles a slightly pendant maiden's breast sans the nipple. Two symetrically located, small, elliptical areas, believed to have been the sites of ocelli, are present on either side of the posterior crest. The nonvisual surface is covered with small granules.

A pair of lateral ocular nodes are subcentrally located on the dorsal shield slightly forward to the medial node. The visual surfaces are on the precipitous antero-lateral surfaces of prominent palprebral-like nodes raised above the general contour of the prosoma. The visual surfaces are not preserved but were no doubt compound. The nonvisual surfaces of the nodes are covered by closely spaced excresences which increase in size from granules to small tubercles near the base.

Except for what may have been an occipital groove paralleling the posterior margin of the prosomal shield, there is no trace of prosomal segmentation. A slight groove which may represent the anterior limit of an occipital segment is present on the holotype (Plate 12, fig. 1 S) but is absent on isolated shields, some of which are otherwise in a better state of preservation (Plate 17, fig. 1 S). It is possible that this groove in the articulated holotype is due to the impression of the anterior margin of the articulating surfaces of either the dorsal or ventral preabdominal exoskeleton onto the underside of the dorsal prosomal shield. Because of its dubiousness the occipital groove has been omitted from the restoration (Text fig. A-1).

A narrow marginal rim surrounds the prosoma. It is formed by a plait of the exoskeleton. The dorsal layer is covered by papillae. They become crowded together into an irregular tuberosity at the anterior where they have their maximum development. Laterally the tubercles are less crowded and arranged in a general biserial plan. Evenly spaced tubercles at the margin of the rim cause the edge to be serrated. The rim is narrow and of equal width throughout. The ventral surface or doublour is lacking in ornament and is of the same width as the dorsal rim.

The prosomal dorsal shield bears ornament of tubercles and granules. With the exception of the tuberosity of the marginal rim, the tubercles are restricted to a field lateral and anterior to the glabellar area. The number and size of the tubercles decrease toward the margins of the shield and toward the glabella. The area immediately inside the marginal rim and the area of the glabella



Text figure A-1 Composite reconstruction based upon observed details of the morphology of *Chasmataspis laurencii* Caster and Brooks, X 3. A-2 Prosomal appendage of *C. laurencii*, X 3. A-3 Reconstruction of *Douglasocaris collinsi* Caster and Brooks, X 3.

are devoid of tubercles. However, minute nodes completely cover the surface of the shield and impart an appearance of granulation. A pair of large tubercles is situated on either side of the midline near the posterior margin of the shield in the area of the "occipital segment."

Details of the ventral surface of the prosoma are not preserved on any of the specimens studied. This is probably due to the ventral integument being membranous.

Three separate appendages were discovered which are of the type and size situated around the mouth of xiphosurus merostomes. One of the appendages is complete (Plate 13, figs. 3, 4) except for the dactylus of the chela and the terminal portion of the preepipodite. Two specimens consist of complete chelae and three additional joints (Plate 13, fig. 5). One is poorly preserved and not figured. The chelate ambulatory or inner ramus consists of a large basal joint and an ambulatory ramus of seven additional joints; the last two joints are modified as the palm and dactylus of a chela. Only the basal joint of the preepipodite is preserved. It arises from the lateral side of the large basal joint. The inner surface of the basal joint is modified as a gnathobase.

Two distinct types of preabdominal shields, or bucklers, are present in the collection. Both have the same outline and bear a series of 9 or 10 fixed stylets on the lateral margins. One of the bucklers is comprised of unanchylosed sclerites, and the other is a continuous integument.

Most of the bucklers composed of sclerites have become disarticulated into pieces of one or more of the component parts (Plate 18). A medial series and paired lateral series of plates are bordered by a marginal girdle. Shoulders are formed at the anterior of the buckler by rounded constriction of the anterio-lateral portions of the first transverse sclerite. A smooth process (Plate 18, figs. 2, 3 S) extends anterior to the constriction. This process is separated from the main part of the sclerite by a shallow rounded groove. It constitutes a surface of articulation with the prosomal shield. Posterior to the groove, the first sclerite is ornamented with tubercles and granules. A second medical sclerite (Plate 20, fig. 4) is transversely rectangular, and it in turn is followed by a third rectangular transverse plate (Plate 18, fig. 4 S).

The lateral series of sclerites are not aligned with the medial series. The first lateral pair are unequally pentagonal and are situated lateral to portions of the first and second transverse sclerites. A pair of triangular sclerites border portions of the second and all of the lateral edges of the third transverse sclerite. A pair of small nearly equilateral triangular plates are articulated with the lateral portions of the posterior edge of the third transverse sclerite. The lateral series of sclerites probably represent pairs of plates which originally corresponded to the three sclerites of the transverse medial series. It is believed that these sclerites imply that the preabdomen consists of three metameres.

Posterior to the anterior shoulders, the buckler is bordered by a narrow girdle bearing fixed stylets. Nine and possibly ten stylets project in a posterior-lateral direction.

The dorsal buckler is believed to have had an arched rachis in the central part of the three transverse sclerites. The specimen figured in Plates 12 and 13 (figs. 1 S) has a continuous medial ridge. This ridge has its greatest width on the first sclerite and narrows progressively on each of the two succeeding sclerites. It is here assumed that this reflects an original dorsal buckler trait. However, there is always the chance that it represents the imprint of an intra-buckler organ in life, otherwise unknown. The rachises on the sclerites of the disarticulated bucklers are different in appearance (Plate 18). They occur as a medial transverse ridge at the rear of each sclerite (Plate 18, figs. 2, 3, 4). The apparent difference may be due to compression. A pair of large tubercles is present on the rachis near the posterior of each sclerite.

The surface of the buckler is ornamented with tubercles and granules of unequal size. All the sclerites have a uniserial concentration of tubercles around their margins. Tubercles literally cover the marginal girdle and the fixed stylets.

The second type of buckler (Plate 17, fig. 3 S, 4, 5, 6; Plate 19, figs. 2 S, 3 S) is composed of a thin chitinous integument not divided into sclerites. Tubercles and granules are more or less evenly distributed over its surface. A belt across the anterior fourth of the shield is more heavily chitinized. A narrow low keel extends back along the mid-central line from the anterior fortified zone. A pair of slits is situated just posterior to this chitinized zone a short distance inward from the margins of the shield (Plate 19, fig. 2 S). The narrowness of the slits would seem better to conform to genital pores than to openings to respiratory chambers. Most of the specimens bear evidence of a pair of large lateral chambers underlying the integument. Outlines of these chambers are impressed on the tegument of most specimens.

These two distinct type of preabdominal bucklers might *apriori* appear to belong to different species of animals, and as such they were first considered. There are other possibilities. They could be dimorphic forms of the same species, *i.e.*, sexual dimorphism, or they could be dorsal and ventral surfaces of the same species. The similarity in outline of these two buckler types, the identity of the marginal girdle and fixed stylets on both, and the mutual reflection on both shields of the different morphological features are evidences that they are the dorsal and ventral preabdominal skeletons of the same species of merostome. Proof of this interpretation is demonstrated by one individual. The specimen figured on Plate 19, fig. 4 S (also see Plate 17, figs. 5, 6). It is a ventral view of the exoskeleton of a preabdomen in which both dorsal and ventral surfaces are still in their respective relations to each other. Portions of the ventral surface have been broken away so portions of the interiors of the dorsal sclerites are visible. (Note: The ornament of the ventral surface is in positive relief and its characteristic random distribution can be seen. The ornament of the dorsal surface as reflected on the interior of the sclerites is in negative relief. Outlines of the individual dorsal sclerites are indicated by tubercle rows). There is no doubt that the buckler of unanchylosed sclerites with an axial rachis is a dorsal preabdominal shield, and that the thinner chitinous shield with slitlike openings and impressions of paired chambers is the ventral surface of the same animal.

Nine free segments and a telson make up the postabdominal tagma. The segments decrease slightly in size to the posterior. Each segment is enclosed by a ring formed by a dorsal tergite and a ventral sternite (Plate 15, fig. 4). A pair of pleural processes is developed on each tergite (Plate 14, fig. 2 S, outlined by dashes). Due to a bulge at the anterior and posterior of each tergite, preservation has resulted in the abdominal segments of some of the specimens having the appearance of pseudosegmentation. The true nature of the dorsal tergites is shown by the better preserved specimens (Plate 12, fig. 1 S; Plate 20, fig. 1 S; Plate 14, fig. 2 S). These specimens reveal that the tergite has a smooth anterior articulating surface which telescopes within the preceding skeletal ring, a broad anterior bulge bearing tubercles, a post-central slight constriction and a bulging posterior flange. A pair of prominent tubercles is present on the dorsal bulging surface of each tergite near the dorsal line of symmetry.

The telson (Plate 20, fig. 5, 7) is broad at the base but narrows to a long, lanceolate distal portion. The surface of the telson, as with other surfaces of the exoskeleton, bears tubercles and granules. Tubercles are concentrated at the base of the telson with only a few scattered on the blade.

The telson of merostomes is believed to be a dorsal outgrowth of the last metamere and is, therefore, not usually counted as a body segment.

Merostomes are generally believed to have a cephalothorax composed of an undetermined number of preoral vestigial segments fused with six appendiferous postoral segments. The merostome from the deposits at Douglas Dam undoubtedly had the standard number of prosomal appendages. No trace of appendages are present on the pre- and post-abdominal tagma. The preabdomen is comprised of three fused and the postabdomen is composed of nine free segments.

SYSTEMATICS

THE MEROSTOME

General.—The basic body organization of the foregoing arthropod corresponds to that of the animals classified in the Class Merostomata, the aquatic chelicerates. Two subclasses of merostomes are presently recognized (Pychnogonida excluded, Hedgpeth, 1954, p. 211): Eurypterida and Xiphosura.

Members of the Subclass Eurypterida (Ordovician to Permian) all have similar body organization. The body is divided into three tagmata: a prosoma, a wide preabdomen of six free segments and a narrow postabdomen of five[2] free segments; the last segment bears a telson. Imbricating scalelike tubercles characterize the chitinous exoskeleton. A pair of compound lateral eyes and a centrally located pair of ocelli are present on the dorsal shield of the prosoma. Six pairs of appendages are arranged around the mouth. The first pair are chelate, four pair are walking legs and the hind pair are differentiated usually as oarlike flippers. None of the metemeres posterior to the prosoma are anchylosed. Each segment of the preabdomen has a separate dorsal and ventral sclerite whereas the dorsal and ventral sclerites of each segment of the postabdomen are fused into a continuous ring. The first two[3] sternites of the preabdomen are modified as a genital operculum. This structure bears a median structure which is usually interpreted as a pair of appendages modified for reproduction. The four succeeding sternites are movable plates which are attached near the anterior of each somite. These plates are believed to have had gills on the inner surface (Størmer, 1934a, p. 52).

Members of the subclass Xiphosura have a greater diversity of body plan. Two orders are presently recognized. The Aglaspida (Text figs. B-4-6) (Cambrian-Ordovician) have a semicircular prosomal shield. Some genera have genal spines and a marginal rim on the prosoma. Lateral compound eyes are present on all forms. Median ocelli have never been detected on the fossils. Six pair of ventral appendages are allegedly present on a specimen described by Raasch (1939, p. 62). The first pair are chelate and the others are "walking legs." Posterior to the prosoma are 11 free somites and a telson. There is no abrupt change in size of the tergites and no other distinguishing features to justify a division into a pre- and postabdomen. The first six abdominal segments allegedly have paired appendages (Raasch, 1939, p. 65-66).

Størmer (1952, p. 638) classified all of the limuloid merostomes in the order Xiphosurida and recognized two suborders, the Suborder Synziphosurina, and the Suborder Limulina. The latter group

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[2] The Ordovician *Megalograptus* Caster and Kjellesvig-Waering, possess six post-abdominal segments plus a telson and cercal blades.

[3] Although it is customary to postulate the fusion of two sternites to form the eurypterid operculum, an exceptionally well-preserved late Silurian specimen *Dolichopterus* Hall (Caster and Kjellesvig-Waering, Jan., 1956, Jour. Pal.) demonstrates the presence of three. This may be the archaic condition.

contains the king crabs and their close relatives of the Upper Paleozoic and need not be characterized here. (Text fig. B-1).

Synziphosura (Text fig. B-2 and B-3) are a heterogeneous grouping of Silurian and Lower Devonian divergent pre-limulids. According to Størmer (1934b, p. 10) "it is probable that the Synziphosura possessed 10 abdominal segments of which the sixth and seventh were often anchylosed." The last three poorly differentiated abdominal segments have been designated as a postabdomen.

Classification of new material.—Merostomes are characterized by a prosoma with a dorsal shield upon which are a pair of lateral compound eyes and two median ocelli (lateral eyes are absent on some of the synziphosura and the ocelli have not been discovered on aglaspids), six pairs of appendages around the mouth and an abdomen composed of 12 or fewer metameres which may be free or anchylosed. Differentiation of the abdominal segments into tagmata is persistently different in each of the phyletic races. With the exception of the synziphosura all previously known species possess some vestiges of pre-abdominal appendages.

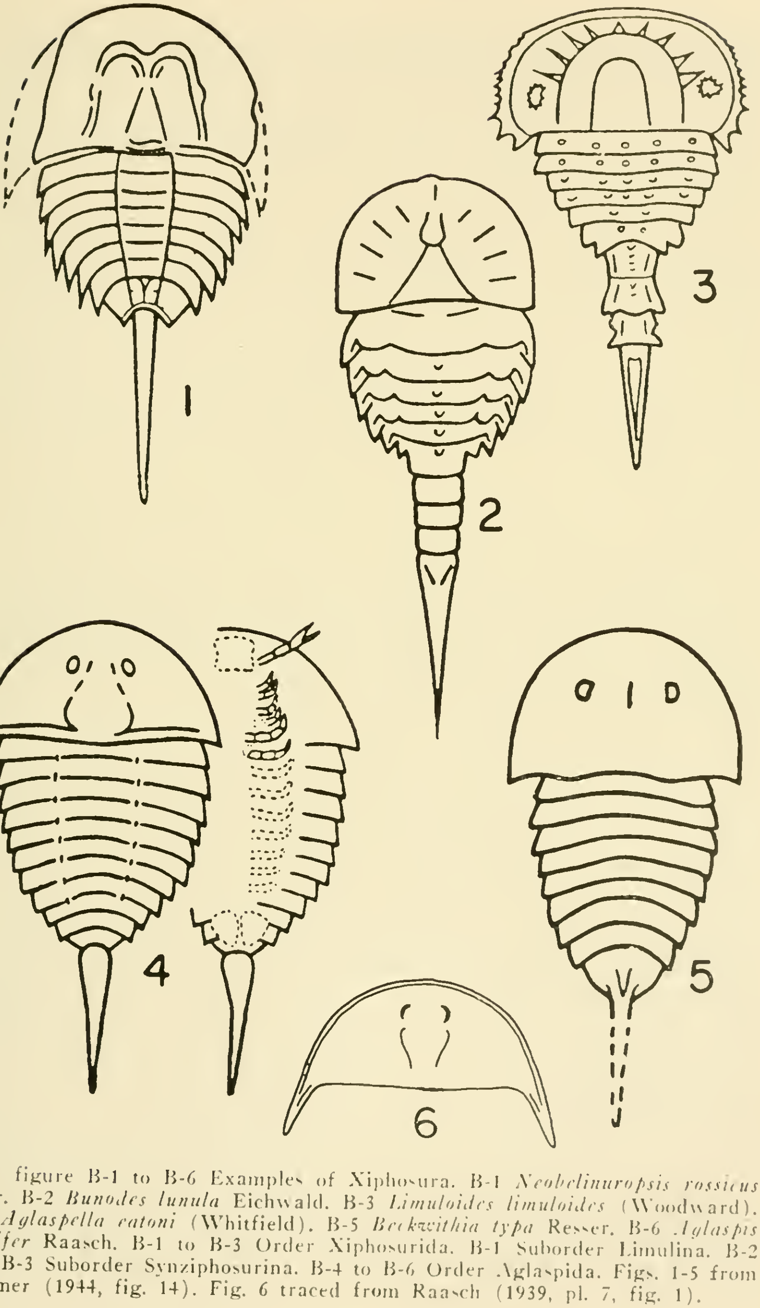
The fossil from Douglas Dam is unquestionably a merostome. However, it differs significantly from all presently known forms in the specialization of the 12 segments of the abdomen into a preabdominal tagma of three segments (covered dorsally by a buckler composed of a transverse medial series of sclerites and a lateral series of paired sclerites and ventrally by a continous integument devoid of traces of segmentation and appendages) and a postabdomen of nine ringlike free segments. Some terrestrial arachnids have the tergites of the abdomen divided into a lateral and medial series, *i.e.*, *Trigonitarbi* (Devonian of Scotland, Petrunkevitch, 1953, vol. 2, p. 207A) and *Dorothea* (a Recent member of the Order Ricinulei, *ibid*, p. 207B). Twelve abdominal segments are presumed to be the primitive condition in the Subphylum Chelicerata. Though having more abdominal segments than any of the merostomes presently classed in the subclass Xiphosura, *i.e.*, 12 *vs.* 9 or 10 in the Synziphosura and 11 in the Aglaspida, the new merostome seems to be most closely related to these forms. The tagmatization of its abdomen differs significantly from that of the stereotyped eurypterids.

In addition to the new generic and specific names, required by the new Douglas Dam merostome, new family and ordinal names are also required by its morphology which contrasts with that of other merostomes. The classification employed herein is related to that of Størmer (1952, p. 638) as follows:

Class **MEROSTOMATA** (Dana, 1852) Woodward, 1836
  Subclass **EURYPTERIDA** Burmeister, 1834
  Subclass **XIPHOSURA** Latreille, 1802
    Order **AGLASPIDA** Walcott, 1911
    Order **XIPHOSURIDA** Latreille, 1802
      Suborder **SYNZIPHOSURINA** Packard, 1886
      Suborder **LIMULINA** R. and E. Richter, 1929
    Order **CHASMATASPIDA** Caster and Brooks, new order

The new order Chasmataspida is distinguished by possessing the primative chelicerate number of abdominal segments and by the fusion of the first three segments into a preabdomen.

The differentiation of the anterior abdomen into an expanded region is a recurrent phenomenon among the arachnomorphs and apparently corresponds to recurrent physiologic needs or advantages, mainly associated it would appear with the housing of expanded gill-books and generative organs. Among eurypterids it is first encountered in *Megalograptus* (Upper Ordovician) according to data in manuscript (Caster and Kjellesvig-Waering); *Mixopterus* and *Carcinosoma* are the most familiar Silurian expressions of the preabdominal expansion. It is the basic scheme in the Scorpionida. *Megalograptus* expands the first six preabdominal segments; the other two eurypterids and scorpions the first seven. The Xiphosura show an analogous, recurrent tendency: in *Bunodes* and *Limuloides* (=*Hemiaspis*) of the Silurian the preabdominal region contains the primitive six segments of *Megalograptus*. In the Silurian forms the postabdomen is reduced to three annular segments. *Weinbergina* of the German Devonian appears to have the first seven abdominal segments expanded, and the postabdominal region abbreviated to the customary three rings. The bunodomorph plan, plus more postabdominal segments, is anticipated by undescribed forms from the



Text figure B-1 to B-6 Examples of Xiphosura. B-1 *Neobelinuropsis rossicus* Eller. B-2 *Bunodes lunula* Eichwald. B-3 *Limuloides limuloides* (Woodward). B-4 *Aglaspella eatoni* (Whitfield). B-5 *Beckwithia typa* Resser. B-6 *Aglaspis spinifer* Raasch. B-1 to B-3 Order Xiphosurida. B-1 Suborder Limulina. B-2 and B-3 Suborder Synziphosurina. B-4 to B-6 Order Aglaspida. Figs. 1-5 from Størmer (1944, fig. 14). Fig. 6 traced from Raasch (1939, pl. 7, fig. 1).

Upper Cambrian Hickory sandstone of Texas. It was not, however, until Permian time that any arthropod previously known developed a preabdominal buckler. Clearly, the phylogeny of the limulid buckler (Størmer, 1953) is quite different from the analogue here so long before anticipated.

The chasmataspid dorsal buckler appears, like the genital operculum of the eurypterus, *Dolichopterus* Hall (Silurian) (paper in press, Caster and Kjellesvig-Waering, 1956) to comprise an ankylosis of the first three abdominal sclerites. Conceivably the ventral homologue contains the sternites of the same three segments and thus may correspond directly to the genital operculum of *Dolichopterus* as interpreted by Caster and Kjellesvig-Waering. However *Chasmataspis*, like the bunodomorphs, shows no genital appendage.

Family **CHASMATISPIDAE** Caster and Brooks, new family

Until more is known about the evolution trends of this newly discovered phyletic line, family characteristics cannot be delimited. The characteristics of this family will encompass the morphological features of the new merostome described below.

Genus **CHASMATASPIS** Caster and Brooks, new genus

The development of the genal spines, marginal rim, distribution of the tubercles, the shape of the prosoma, the relative development and position of the lateral and medial ocular nodes, the relative development of the marginal girdle and fixed stylets, size and shape of the sclerites of the dorsal preabdominal buckler, and the development of the sclerites and pleural processes of the postabdomen, as described in the general description, characterize this genus. The name of the genus is derived from the Greek words *chasma* (dam) and *aspis* (shield). *C. laurencii* is the type species.

Chasmataspis laurencii, Caster and Brooks, new species

Plates 12-20, Text figs. A-1, A-2

Since there are no known close relatives of *C. laurencii*, it is impossible to present a short specific analysis at this time. The species as understood by the authors has all of the characteristics of the fossils described above in the general description. Difference in relative growth, size, and the development of minor features such as ornamentation are generally used as distinguishing criteria for the recognition of species of merostomes.

The following statistical information reflects the variation of the population as represented by the collection of fossils. Measurements were made only on specimens complete enough for accurate mensuration. Abbreviations have been employed for convenience of presentation: N=number of observations, Mo=approximate mode, Me=arithmetic mean, σ=standard deviation, Max=maximum size. The minimum size (Min) is of no specific value as growth stages are present in the collection, but it has been given as information of general interest.

The length of the prosoma was measured in the sagittal plane. The following data were obtained: N=57, Mo=1.1 cm., Me=0.9 cm., σ=0.24 cm., Max=1.3 cm., and Min=0.4 cm. The width of the prosoma was measured across the dorsal shield at the position of the posterior margin. The results are as follows: N=58, Mo=2.0 cm., Me=1.9 cm., σ=0.62 cm., Max=3.0 cm., and Min=0.6 cm. Distance between the lateral eyes was measured as the minimum distance between the visual surfaces. The data are as follows: N=44, Mo=0.75 cm., Me=0.67 cm., σ=0.18 cm., Max=0.97 cm., and Min=0.23 cm. The medial eye node is situated slightly posterier to the two lateral nodes. The following data are based upon measurements from the anterior edge of the prosoma to the crest of the medial eye node: N=44, Mo=0.65 cm., Me=0.55 cm., σ=0.13 cm., Max=0.72 cm., and Min=0.23 cm. When the last measurements are calculated as a ratio to that of the length of the shields one gets the following results: N=44, Mo=0.57, Me=0.57, σ=0.05. This means the crest of the median eye node is slightly posterior to the central position.

Ratios of length to width of the prosomal shield were calculated and the ratios range from 0.38 to 0.77. These are specimens which have been extremely deformed. Most of the shields had a ratio of about 0.50, *i.e.*, Mo=0.50, Me=0.50, σ=0.07.

Accurate measurements were possible on only twenty ventral bucklers of the preabdomen. Length measured in the sagittal plane gave the following results: N=20, Mo=1.1 cm., Me=1.0 cm.,

σ=0.32 cm., Max=1.35 cm., and Min=0.7 cm. The breadth immediately anterior to the first pair of fixed stylets is the greatest width. It is this measurement given: N=20, Mo=1.9 cm., Me=2.2 cm., σ=0.45 cm., Max=2.9 cm., and Min=1.6 cm. The length to width ratios of these shields were: Mo=0.43, Me=0.42, Max=0.52 and Min=0.35.

The total length of the one complete specimen (Plate 14, fig. 1 S; Plate 15, fig. 1 S) is approximately 5 cm. (Actually only 4.7 cm. is preserved. The tip of the telson has been broken off). This specimen was smaller than most of the specimens of the population. The holotype (Plate 12, fig. 1 S; Plate 13, fig 1 S) which lacked only the telson was 6 cm. long. Judging from the proportions of the one complete specimen, the telson of the holotype must have been slightly over 2 cm. in length. Restored, the holotype is estimated to have been between 8 and 8.5 cm. in total length. The measurements of the holotype are as follows: length of prosoma is 1.3 cm., width of prosoma is 2.33 cm., distance between the eyes is 0.83 cm., distance back to medial eye node is 0.75 cm., buckler length is 1.2 cm., buckler width is 2.2 cm., and the combined length of the nine segments of the postabdomen (minus the telson) is 3.5 cm. When these measurements are compared to the statistical data presented for the population, it is apparent that the holotype is one of the larger individuals.

When plotted graphically as frequency curves on arithmetic graph paper, all of the above measurements showed skewness toward the larger measurements. This skewness is characteristic of a natural population with immature individuals. It should be emphasized that the above statistical data are based on raw measurements in which no effort has been made to correct for distortion. Distortion has been considerable in many of the specimens (Plate 16) and accounts for the large standard deviations of the dimensions.

Graphic presentation based on two measurements of each individual showed a straight line relationship between any two measurements. Since relative growth in this case is apparently constant during ontogeny, proportion between any two measurements are of more significance than the size frequencies. However, when the proportions were calculated, the ratio of one measurement to another was in some cases considerable. Significant differences are obviously due to deformation.

The conclusions of the empirical study and the statistical analysis of the fossil merostome remains in the collection were that only one species was present and that the growth stages and deformation accounts for the considerable differences in size and proportions of the specimens.

The species is named in honor of Mr. Robert Laurence, former geologist for the Tennessee Valley Authority and now Regional ReRpresentative of the U. S. Geological Survey, Knoxville, Tennessee.

Types.—Holotype, No. 125099; paratypes, Nos. 125123, 125101, U. S. National Museum.

Horizon.—Sediments in a depression in the Canadian-Chazyan unconformity.

Locality.—East abutment of Douglas Dam, Sevier County, Tennessee.

DESCRIPTION OF THE CRUSTACEAN

Material.—Four specimens of a small crustacean were discovered in the fauna of the Douglas Dam site. These fossils are preserved as impressions of compressions with slight relief. Thin films of carbonaceous residue are all that remain of the original thin chitinous exoskeleton.

Morphology.—Tagmata of the body cannot be distinguished due to poor preservation of details. The anterior portion of the body was covered by a carapace developed as two large valves hinged dorsally. No nodes or other structures can be detected on its surface. The covered portion of the body undoubtedly represents the head and a portion of the thorax. Nine similar, tapering segments exposed posterior to the carapace will be termed the abdomen. The terminal segment of the abdomen is differentiated and bears a pair of long, annulate cercopods at the posterior-lateral corners. Three short body rings are exposed between the valves on one of the specimens (Plate 21, fig. 1 S). These may be thoracic segments.

Traces of appendages are preserved and are believed to have been biramous (Plate 21, fig. 2). These appendages are situated in a position that suggests they are thoracic. They appear to consist of a basipodite of two or three joints and two rami, an exopodite and an endopodite. The true nature of the rami cannot be determined. Only traces of one pair of short, annulate antennae are present. The nature and number of other appendages of the head remains in doubt. No trace of appendages are present on the abdomen of any of the specimens.

CRUSTACEAN SYSTEMATICS

The general body organization is a curious combination of crustacean characteristics.

Among the Pseudocrustacea from the Burgess shale of Middle Cambrian age, only *Burgessia* and *Waptia* bear any resemblance (Walcott, 1914, p. 177-182). The carapace of neither of these forms is bivalved and their appendages are allegedly of the trilobite type (Raymond, 1935, p. 219). The abdomen of *Burgessia* is composed of many segments, is narrow and tapers. It is terminated by a multisegmented telson without cercopods. *Waptia,* on the other hand, has an abdomen of six or more segments of which the terminal segments bears a pair of spatulate, jointed cercopods. The nature of the bivalved carapace and the presence of biramous appendages with a basipodite are true crustacean characteristics and support the conclusion that the fossil from Douglas Dam is not a crustacean homeomorph.

Branchiopoda (*i.e.,* Cladocera and Conchostraca), Ostracoda, and the Superorder Leptostraca of the Subclass Malacostraca are the only crustaceans with bivalved shells. Without exception, all previously known bivalved crustacea have a pair of cercopods developed as spikelike furcae. Only the Leptostraca do not have the abdomen reduced, aborted or modified so that the complete animal is enclosed by the valves of the carapace.

Malacostraca have a fixed number of segments per tagma. The abdomen is usually composed of six metameres though some primitive forms have seven. The abdomen of *Nahecaris* (Broili, 1928) allegedly has eight metameres.

The new crustacean differs from known Paleozoic malacostracans in having extra abdominal segments and in the annulation of the cercopods. Annulated cercopods are a characteristic of notostracan branchiopods, *i.e.*, *Triops*, (also trilobites and primitive insects), but are unknown in other crustacea. The abdominal segments appear to bear no appendages. This also is a feature of the Notostraca; however, many of the Paleozoic Leptostraca of the Order Phyllocarida do not have paired appendages on all the abdominal segments.

This new crustacean from the deposit at Douglas Dam cannot be classified as a branchiopod due to the supposed nonfoliaceous nature of the thoracic appendages. Its condition, however, could be a primitive phyletic characteristic. Some authorities believe the phyllopodous appendage to be degenerate. If a branchiopod, it is either related to the Conchostraca or the Notostraca. It differs significantly from both. Conchostraca have a bivalved shell but the postcephalic segments (10-27) are undifferentiated and all bear a pair of phyllopodous appendages; the cercopods are not annulated. Notostraca do not have a bivalved shell. All known forms have a prominent pair of sessile compound eyes upon the carapace.

It would be doing an injustice to the established classification of the crustacea to assign this new type of crustacean to the Branchiopoda. The authors believe the inferred extra segments of the abdomen, providing there has been no error in distinguishing the limits of the tagmata, represents a primitive phyletic divergence from the typical malacostracan body plan. Annulated cercopods are a primitive arthropod character and may not be of any significance in indicating relationships.

Possibly a new order of either the Subclass Branchiopoda or of the Subclass Malacostraca should be established. Until more is known about these new crustacea it is believed best tentatively to assign them to the Order Phyllocarida as follows:

Class **CRUSTACEA** Pennant, 1777

Subclass **MALACOSTRACA** Latreille, 1806

Superorder **LEPTOSTRACA** Claus, 1889

Order **PHYLLOCARIDA** Packard, 1879, **insertae sedis**

Family **DOUGLASOCARIDAE** Caster and Brooks, new family

Crustacea without eyes, muscle scars, nodes or other reflections of anatomical features upon a bivalved carapace; abdomen of nine (?) segments of which the first eight are similar. The last abdominal segment is differentiated and bears two annulate cercopods.

Genus **DOUGLASOCARIS** Caster and Brooks, new genus

Crustacea with the characteristics of the new family described above. In addition, the following details of the bivalved carapace will probably prove of value in distinguishing the genus. Carapace subovate, more or less reniform, greatest dorsal ventral dimensions near the posterior; hinge straight and slightly less than half the greatest length of the valves; anterior cardinal angle obtuse; posterior cardinal angle about 170°; valves broadly rounded anteriorly and ventrally; curvature of the posterior is strongly convex with a radius of 2 mm. and passing through an arc of about 150 to 160 degrees so that a portion of the free dorsal posterior margin is nearly parallel to the broad curvature of the ventral edge. The straight dorsal portion of the posterior margin extends forward. In the proximity of the posterior extremity of the hinge it turns abruptly dorsally thus eliminating the apex of the postcardinal angle. The valves are spread laterally and compressed. It is believed the greatest convexity was near the posterior. A distinct rim borders each valve. Marginal rims are a common feature of the chitinous carapaces of fossil phyllocarids. This feature is probably due to compression of a double thickness of the chitinous carapace at its margins.

The only fossil carapaces known which are comparable to that of *Douglasocaris* are some of the bivalved carapaces described as Conchostraca by Ulrich and Bassler (1931) from Cambrian strata. Of these, *Indianites* (pp. 68-84) is most similar in outline and surface features. The largest of these fossil bivalves are about the size of *Douglasocaris* but they are composed of "corneo-calcareous" materials instead of pure chitin.

The generic name *Douglasocaris* is a compound of the name of the dam site and the Latin word *caris,* a crab. *D. collinsi* is the type species.

Douglasocaris collinsi Caster and Brooks, new species
Plates 21, 22, Text fig. A-3

Characteristics of the species are those of the specimens described above. All specimens are approximately the same size. The following measurements are typical: total length of the body is 1.8 cm., total length of the carapace is 0.7 cm., maximum dorsal-ventral dimensions of each valve is 0.45 cm., length of hinge line is 0.3 cm. When complete the cercopods are only slightly less in length than that of the body. One specimen (Plate 22, fig. 1 S) had cercopods 1.7 cm. long.

This species is named in honor of the late Dr. Robert Lee Collins of Knoxville, Tennessee.

Types.—Holotype, No. 125096; paratypes, 125097, 125098, U. S. National Museum.

Horizon.—Sediments filing a depression on the Canadian-Chazyan unconformity.

Locality.—Douglas Dam, Sevier County, Tennessee.

PROBLEMATICA

Several problematical remains occur in association with *Chasmataspis laurencii* and *Douglasocaris collinsi.* All appear to have had an animal origin. Only one shows sufficient morphology to warrant a name.

Cestites mirabilis Caster and Brooks, new genus, new species
Pl. 23, fig. 5

A single specimen of most unusual aspect is illustrated on Plate 23. The appearance is that of a fringed ribbon now reduced to a carbonaceous film, and the resemblance is most strikingly like one blade of the modern ctenophoran Venus's Girdle, *Cestum veneris.* Longitudinal lines are present, and may well conform to the position of the meridional canals, pharyngean canals along one margin and subsaggital meridional canals on the opposite margin. The fringe on one side appears somewhat longer than on the other and may have been the tentacular row of the oral edge of the girdle, whereas the opposite fringe would correspond to the superimposed aboral double comb-row. The absence of the central region, with its transverse polypide structures, makes the identification of this problematicum as a cestid ctenophoran decidedly questionable.

Modern cestids are evanescent gelatinous bands of extraordinary length. Specimens 1.5 meters in length are not uncommon. Moreover, the transverse zone of the polypide represents a line of weakness; hence one might expect fracture along this line. The genus is today limited to tropical seas, and if properly interpreted, the fossil ribbon may give a clue to the temperature of the early Ordovician episea in Tennessee.

If this problematicum is a genuine ctenophoran, it may well be the first bona fide occurrence in the geological record. Gürich's *Pteridinium simplex* (1930) from the Nama beds of South Africa (Proterozoic or early Paleozoic) now appears (new material furnished by the Geological Survey of the Union of South Africa) to be more probably a conulariid (Scyphomedusa), rather than the ctenophoran he had suggested.

Holotype and sole specimen.—United States National Museum, No. 125087.

Organic scraps.—Specimens of compressed organic threads and narrow straps occur in some abundance on a few layers of the "33 formation." Typical examples are illustrated on Plate 23, figs. 1-4. These may be algal, but more probably are fecal castings of a swimming organism. Similar castings have been observed streaming as threads from swimming *Limulus* in the laboratory, and these may well pertain to *Chasmataspis.*

Spoor.—A definite bottom trail is shown on Plate 23, fig. 6. This is a cast of a trail on the under surface of a bedding plane. It suggests the place where a swimming organism descended. As usual when confronted by such *incertae sedis,* a polychete worm first comes to mind. Many other invertebrates can of course make much the same trails, and a small *Chasmataspis* is by no means ruled out. It does seem more likely, however, that this merostome was a vagrant surface scavenger rather than a burrower or swimmer.

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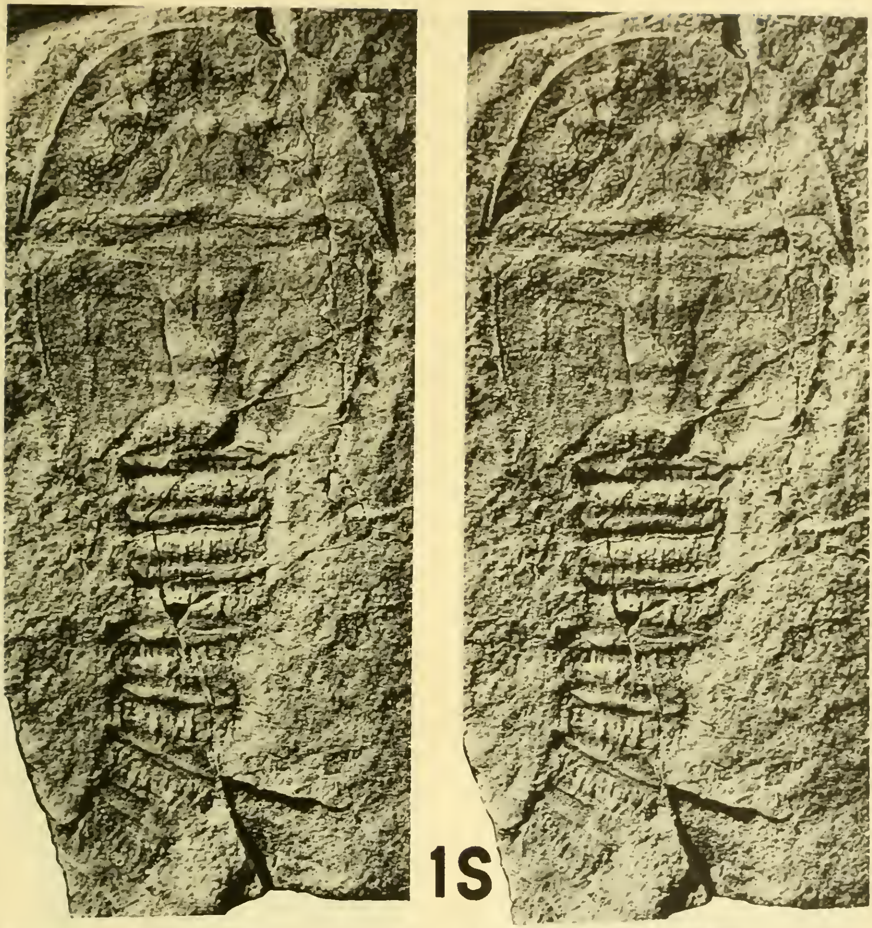
PLATES

EXPLANATION OF PLATE 12

Figure		Page
1S-2S.	**Chasmataspis laurencii** Caster and Brooks, n.gen., n.sp.	176
	1S. Holotype, dorsal view, complete except for telson, U. S. N. M., No. 125099, stereo, X2.	
	2S. Paratype dorsal surface consisting of only portions of the prosomal shield and the dorsal preabdominal buckler, U. S. N. M., No. 125123, stereo, X3.	



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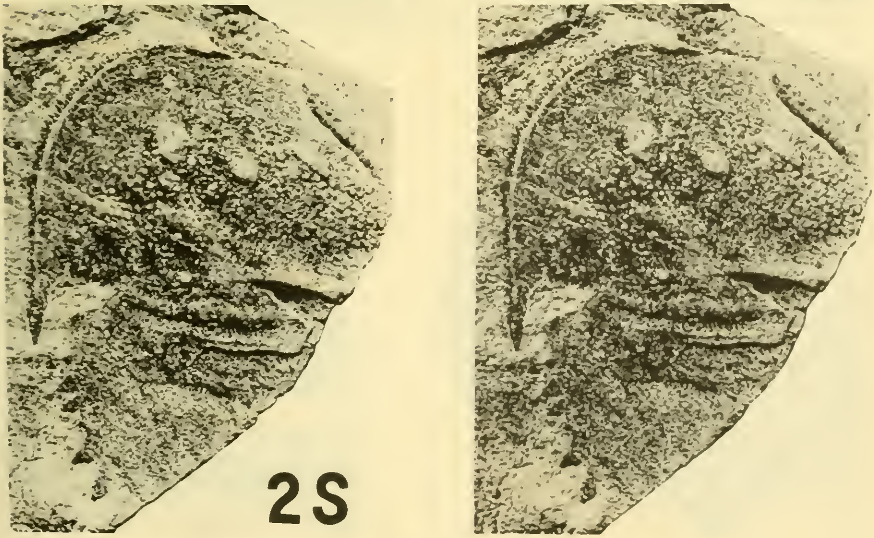

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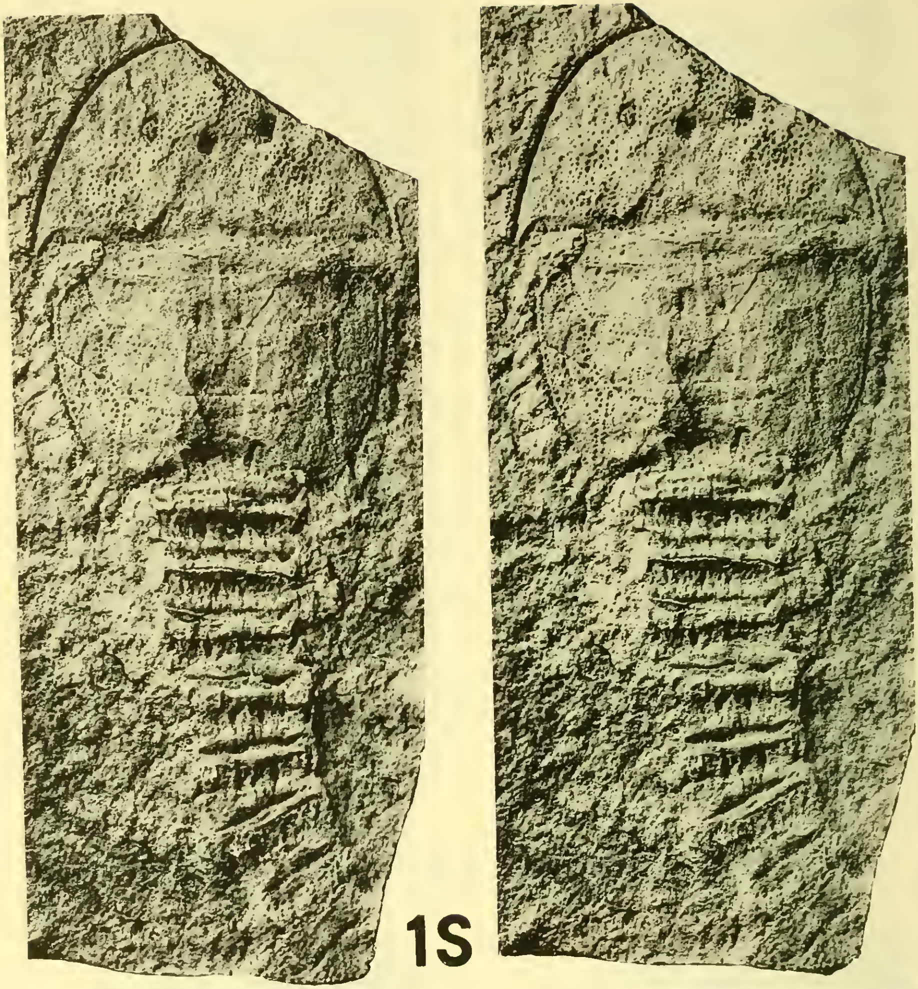

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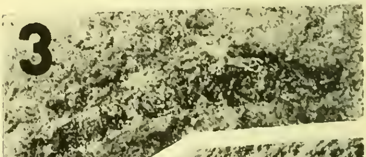

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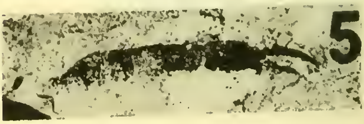

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EXPLANATION OF PLATE 13

Figure Page

1S-4. **Chasmataspis laurencii** Caster and Brooks, n.gen., n. sp. 176

1S. Counterpart of holotype, impression of surface features of exoskelton, U. S. N. M., No. 125099, stereo, X2.

2S. Counterpart of U. S. N. M., No. 125123, paratype X3.

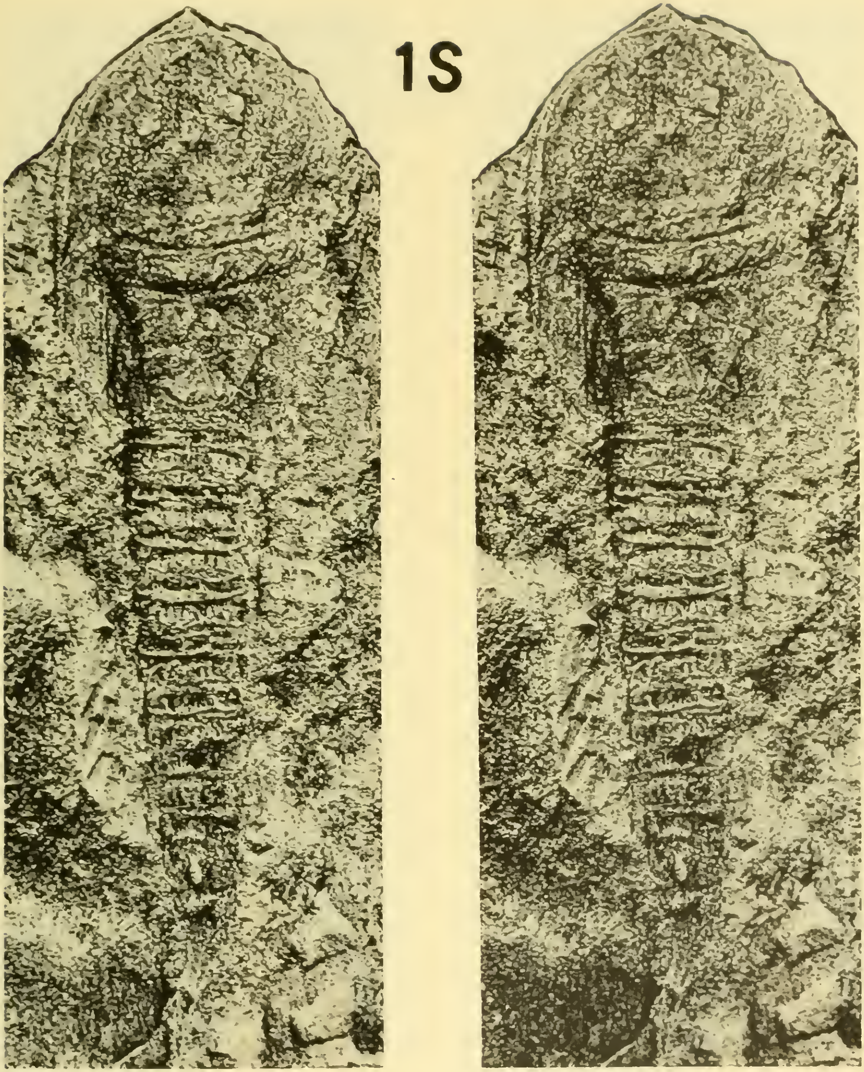
3. Prosomal appendage lacking only the extremity of the preepodite and the dactylus of the chela, photographed without coating NH_4Cl_4 to show carbonaceous residue of appendage, X 3. 168

4. Same as fig 3 but photographed with coating and oblique lighting to emphasize relief, X 3. 168

5. Prosomal appendage consisting of a terminal chela with dactylus and three additional joints, X 3 168

EXPLANATION OF PLATE 14

Figure		Page
1S-2S.	**Chasmataspis laurencii** Caster and Brooks, n.gen., n.sp.	176
	1S. Paratype, only specimen with all dorsal skeletal elements articulated, U. S. N. M., No. 125101, stereo, X 3.	164, 170
	2S. Right side of two postabdominal tergites bearing pleural processes (outlined by dashes), stereo, X 6.	170



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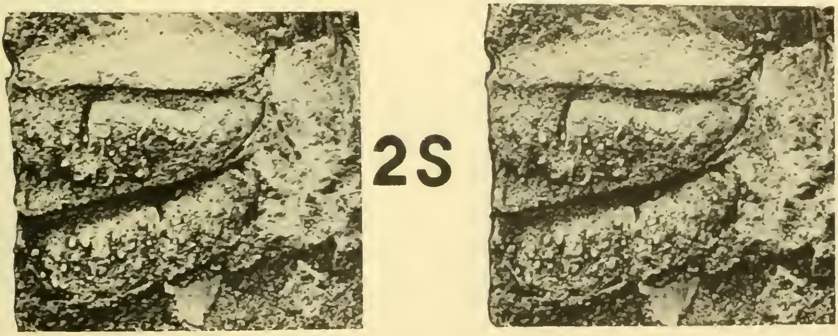

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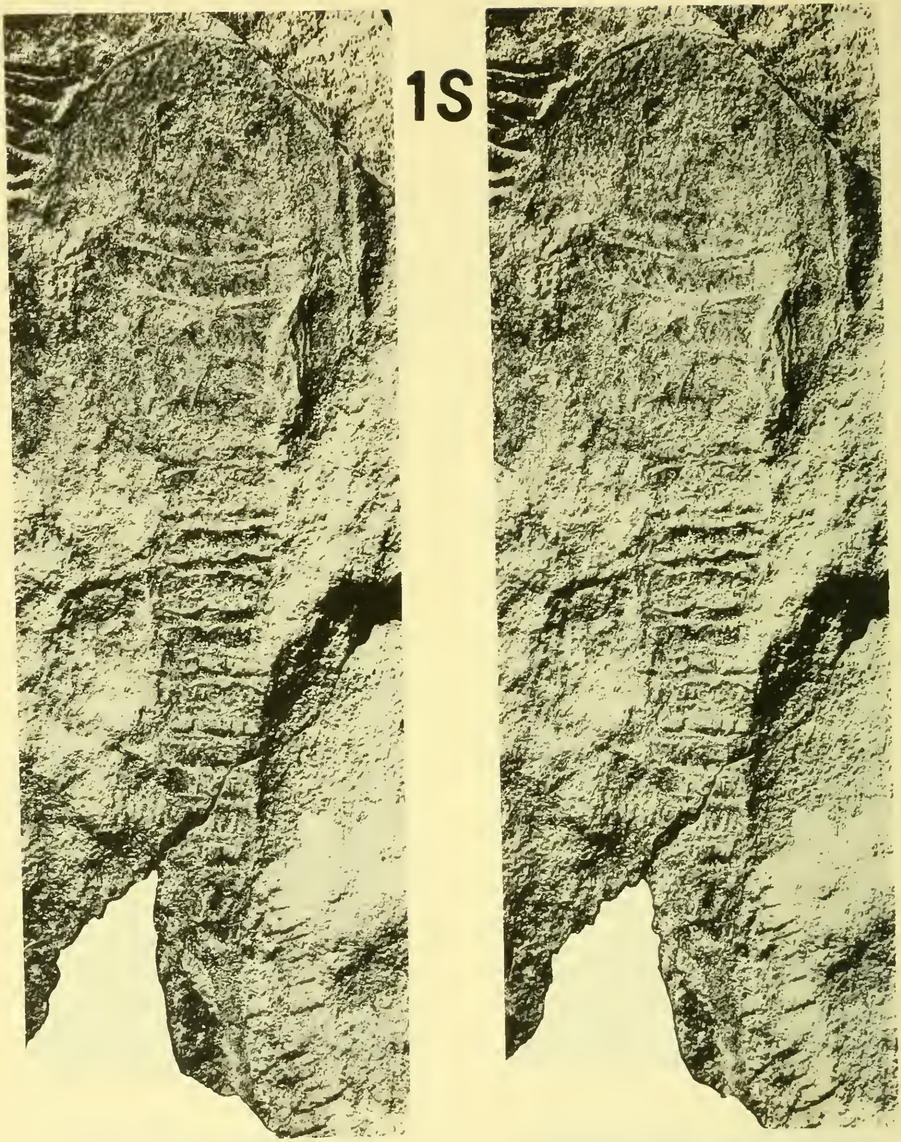

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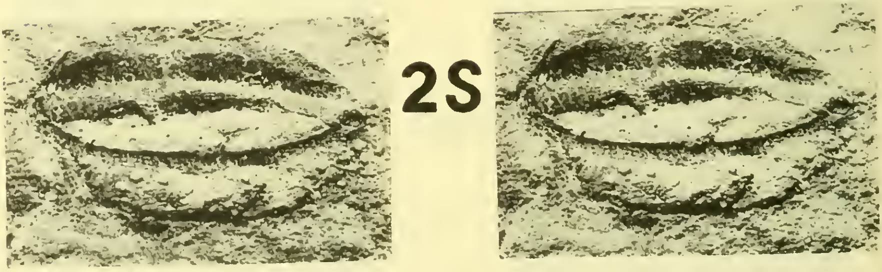

2S

Explanation of Plate 15

Figure		Page
1S-2S.	**Chasmataspis laurencii** Caster and Brooks, n.gen., n.sp.	176
	1S. Counterpart of paratype, U. S. N. M., No. 125101, stereo, X 3.	
	2S. Body ring of postabdominal segment consisting of a dorsal tergite and a ventral sternite, X 5.	170

EXPLANATION OF PLATE 16

Figure		Page
1-6.	**Chasmataspis laurencii** Caster and Brooks, n.gen., n.sp.	176

Prosomal shields selected to show extremes of distortion, X 5, X 4, X 3, X 4, X 2, and X 3 respectively.


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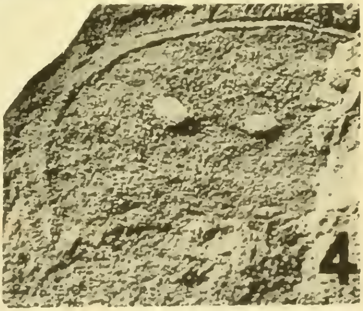
2


3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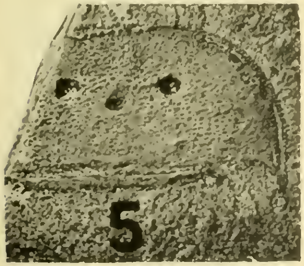
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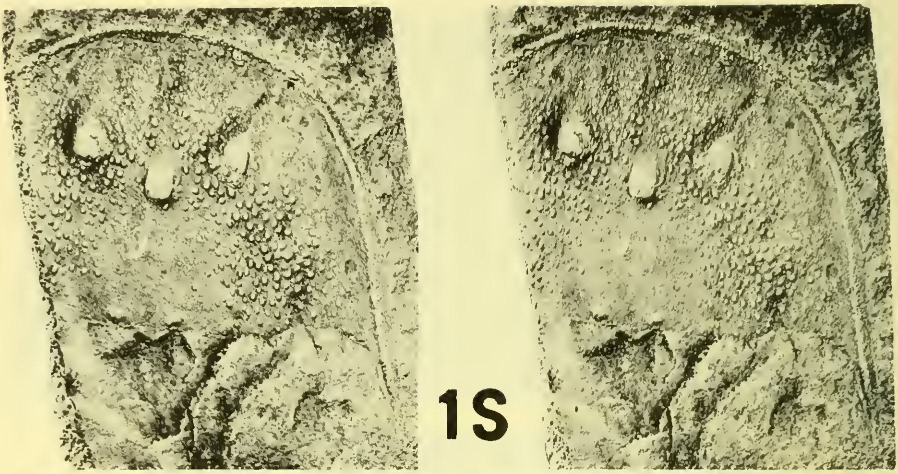
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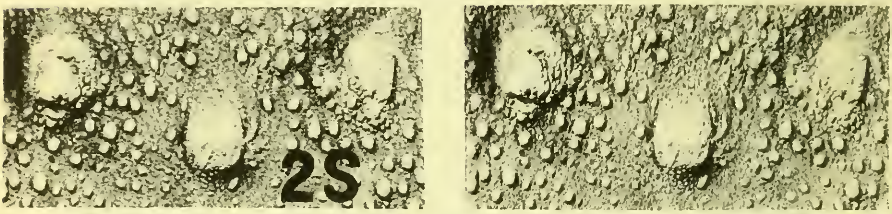
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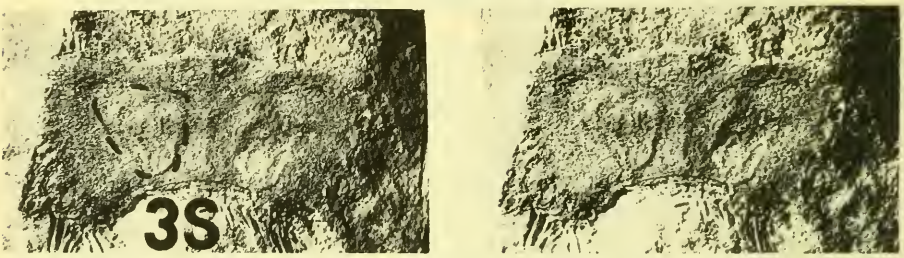
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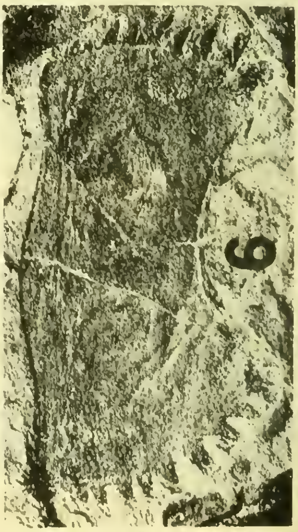
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EXPLANATION OF PLATE 17

Figure Page

1S-6. **Chasmataspis laurencii** Caster and Brooks, n.gen., n.sp., 165-168

1S. Rubber mold of a natural impression of the dorsal prosomal shield, note: tuberosity developed on the marginal rim at the anterior (the posterior portion of the rim has been broken away. The smooth surface of the rim is thus the ventral doublour), tubercle distribution pattern on the shield, "cardiac lobe" devoid of tubercles, median node believed to be the site of a pair of ocelli, a pair of lateral occular nodes, and absence of segmention of the "cardiac lobe," stereo, X 3.

2S. Portion of 1S enlarged to show nature of the eye nodes, note pair of elliptical areas on medial node, stereo, X 3.

3S. Ventral preabdominal buckler, note: anterior transverse "belt", slitlike pair of lateral openings, median keel, reflection of paired chambers (outlined by dashes), and the marginal stylets, stereo, X 3. 169-170

4. Ventral preabdominal buckler, X 3.

5-6. Counterparts of a ventral preabdominal buckler, note that compression has impressed the outlines of the marginal series sclerites of the dorsal buckler upon this continuous shield, X 3.

EXPLANATION OF PLATE 18

Figure		Plate
1-7.	**Chasmataspis laurencii** Caster and Brooks, n.gen., n.sp. sclerites of the dorsal preabdominal buckler	169
	1-3S. Two anterior sclerites of the medial transverse series bordered by the first lateral pair, X 3.	
	4S. An isolated posterior sclerite of the medial transverse series with a small pair of triangular plates articulated to it on the posterior edge, stereo, X 3.	
	5S. A portion of the third sclerite of the medial series articulated with the right sclerite of the second pair of lateral plates, stereo, X 3.	
	6S. Portion of 4S enlarged to show the right plate of the posterior triangular pair, stereo, X 6.	
	7. Portions of the second and third medial transverse sclerites articulated with the right sclerite of the second pair of plates of the lateral series, X 3.	


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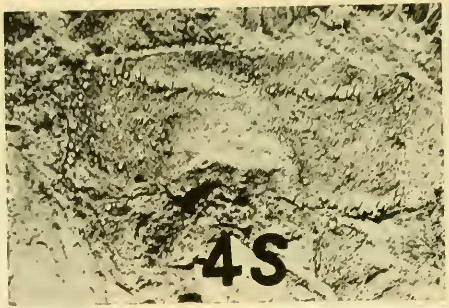
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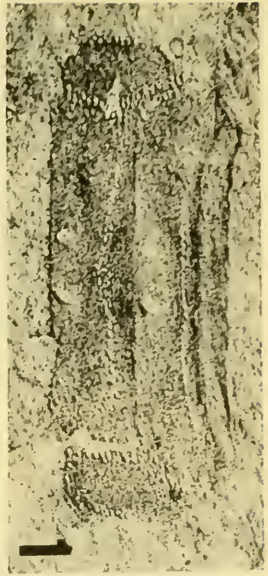
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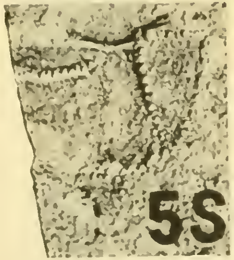
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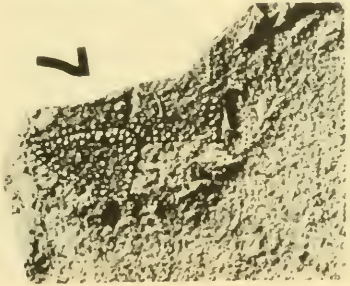
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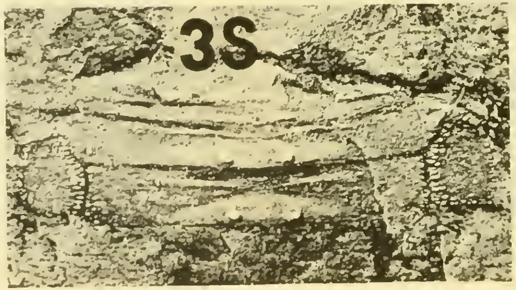
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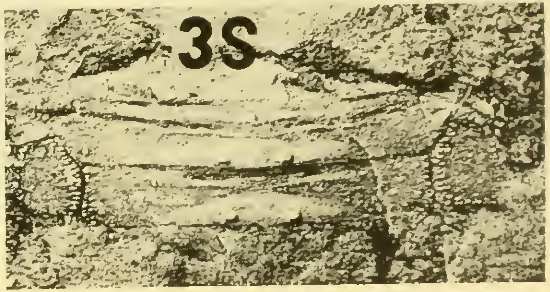
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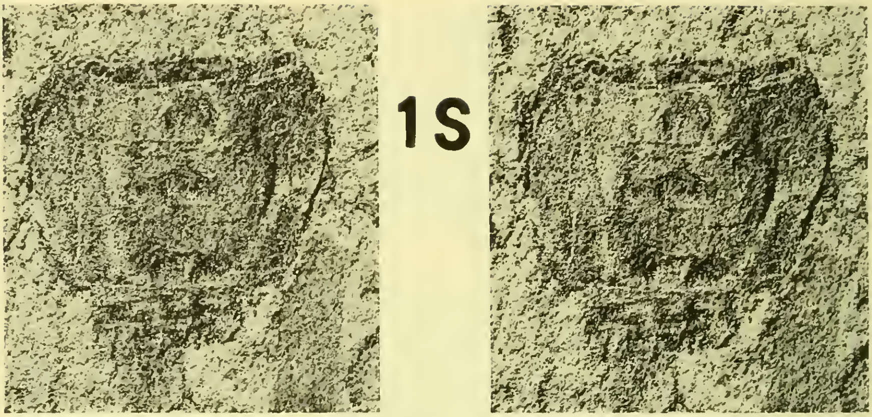
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2S


3S


4S

EXPLANATION OF PLATE 19

Figure		Page
1S-4S	**Chasmataspis laurencii** Caster and Brooks, n.gen., n.sp.	169-170
	1S. Dorsal preabdominal buckler articulated with two of the post-abominal segments, stereo, X 3.	170
	2S. Portion of a broken ventral preabdominal buckler showing one of the slit-shaped lateral openings, stereo, X 5.	170
	3S. Ventral preabdominal buckler with a different expression of the paired chambers, stereo, X 3.	169
	4S. Preabdominal bucklers in their respective positions, ventral view, portions of the ventral buckler have been broken away exposing the interior of the sclerites of the dorsal buckler, stereo, X 3.	170

EXPLANATION OF PLATE 20

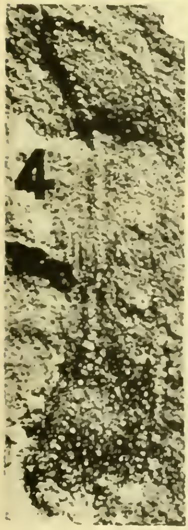
Figure		Page
1S-7.	**Chasmataspis laurencii** Caster and Brooks, n.gen., n.sp.	168-171
	1S. Postabdominal tagma with telson attached, stereo, X 5.	171
	2. First transverse sclerite of dorsal preabdominal buckler, X 5.	168
	3. Postabdomen of immature individual poorly preserved, X 5.	
	4. Isolated second transverse sclerite of dorsal preabdominal buckler, X 3.	168
	5. Telson, X 5.	
	6. Ventral preabdominal buckler with membrane of articulation, X 3.	169
	7. Telson, X 5.	171


1S


2


1S


3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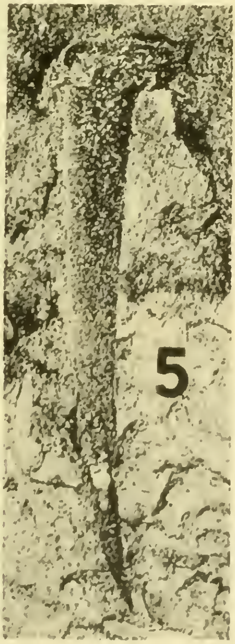
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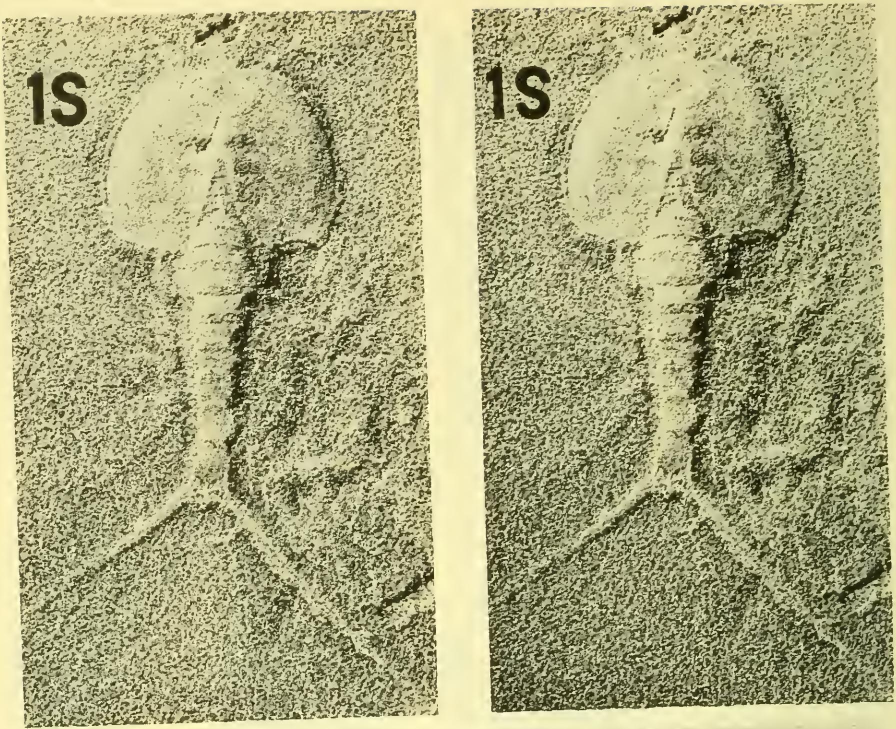
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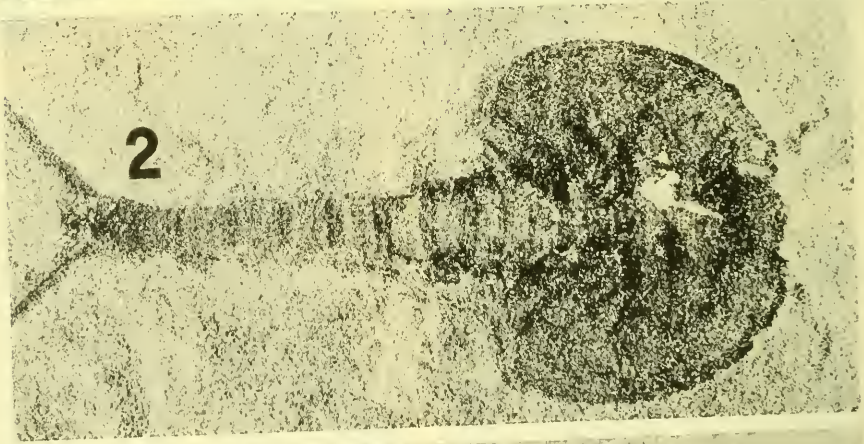
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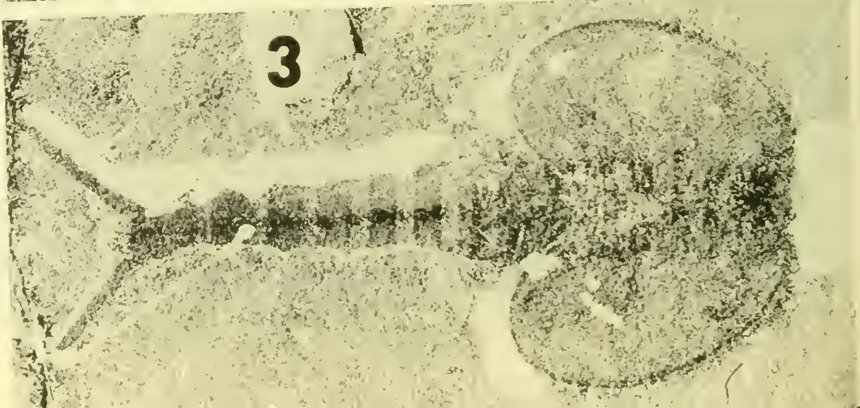
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EXPLANATION OF PLATE 21

Figure		Page
1S-3.	**Douglasocaris collinsi** Caster and Brooks, n.gen., n.sp.	183

1S. Holotype, dorsal view, coated with NH_4Cl_4; stereo, U. S. N. M., No. 125096, X 3.

2. Same as 1S but photographed to show carbonaceous residue of exoskeleton and appendages, note antenna and appendages, X 5.

3. Counterpart of holotype, note intestine, X 5.

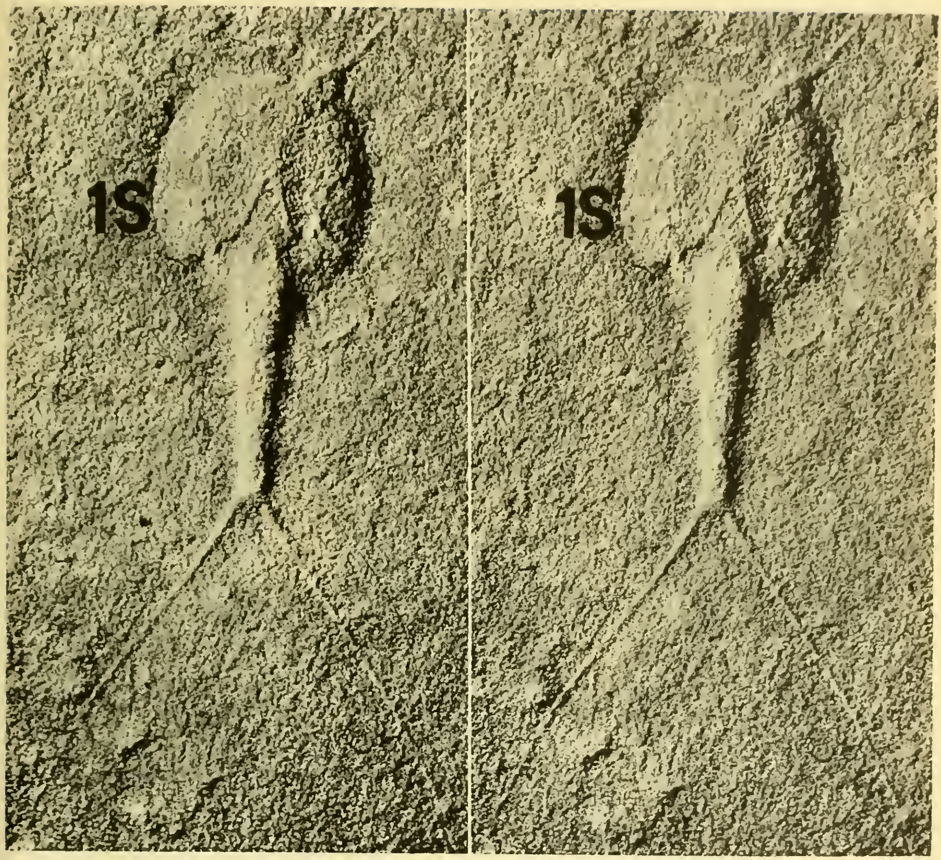
EXPLANATION OF PLATE 22

Figure Page

1S-2S. **Douglasocaris collinsi** Caster and Brooks, n.gen., n.sp. 183

1S. Paratype, U. S. N. M., No. 125097, note long annulate pair of cercopods, X 3.

2S. Paratype, U. S. N. M., No. 125098. X 2.



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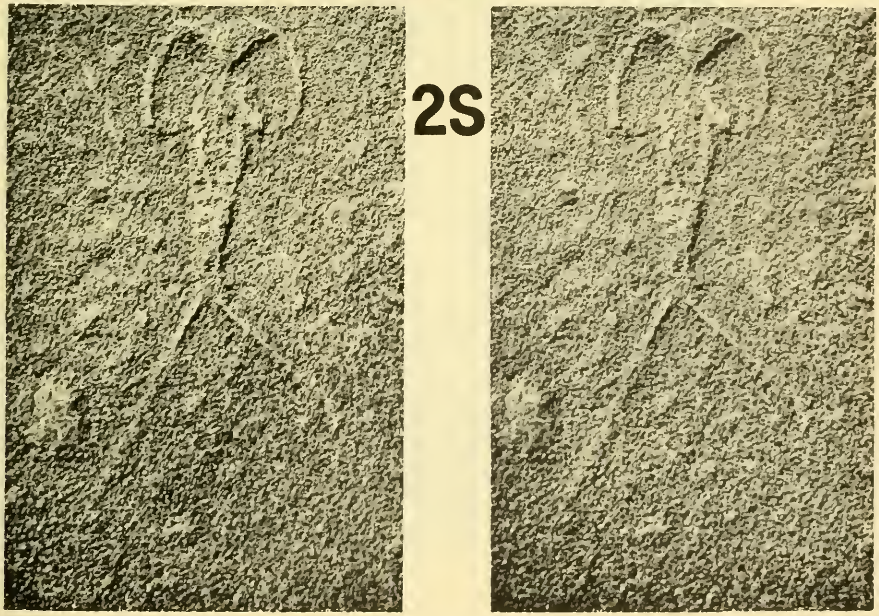

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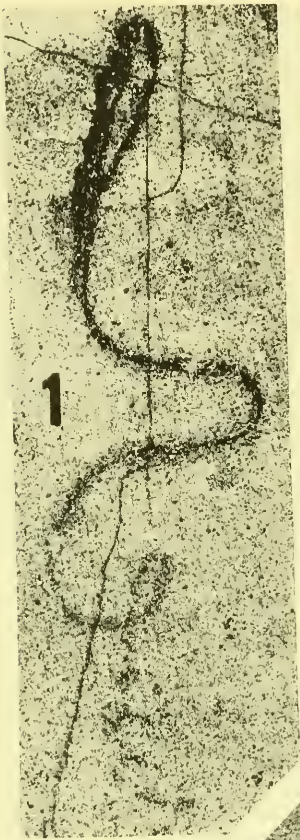

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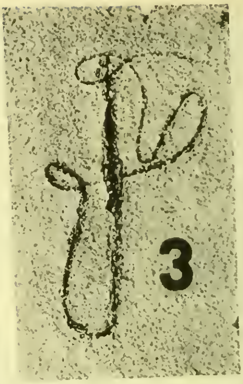

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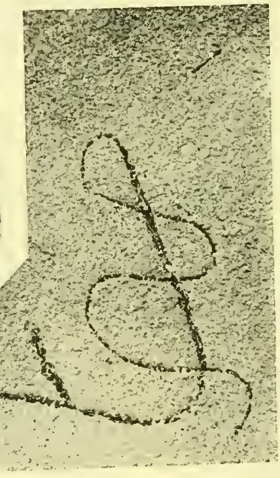

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EXPLANATION OF PLATE 23

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1-6.	**Problematica**	183
	1-4. Carbonaceous films believed to be pieces of algal threads or castings of some animal, X 3.	
	5. **Cestites mirabilis**, n.gen., n.sp.	183
	Holotype, U. S. N. M., No. 125087, believed to be a lobe of a fossil ctenophoran, X 3.	
	6. Underside of a slab with a trail changing to a burrow, X 1.	

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JAMAICAN LARGER FORAMINIFERA

By

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JAMAICAN LARGER FORAMINIFERA[1]

W. Storrs Cole
Cornell University, Ithaca, New York

ABSTRACT

The larger Foraminifera from 50 Jamaican localities are listed, many of them are illustrated, and a few are described in detail. Twenty localities are middle Eocene, 19 are upper Eocene, 10 are Oligocene and 1 is Miocene. Correlation with other areas is suggested. The problem of species which appear to be common to the middle and upper Eocene is discussed. Two new species, *Coskinolinoides jamaicensis* and *Fabularia verseyi,* are described and illustrated.

INTRODUCTION

Through the courtesy of H. R. Versey of the Jamaican Geological Survey samples from 50 localities in Jamaica, B.W.I., were sent to me for detailed study. Vaughan published the first detailed descriptions of Jamaican larger Foraminifera in one extensive article (1928a) and two subsequent shorter articles (1928b; 1929). Hanzawa (1937) discussed several Jamaican species in a short article. Recently, Davies (1952) listed and discussed larger Foraminifera from the "white limestone" of the Kingston District, Jamaica. He did not describe or illustrate any of the species.

The three tables which follow give the identifications of Vaughan, the names used for these same species in this article, and the designation of the localities at which Vaughan records these species.

All of the species mentioned by Vaughan were found in the present collection with the exception of the upper Eocene species *Discocyclina perkinsi* Vaughan and the Oligocene species *Lepidocyclina miraflorensis* Vaughan which may be a large specimen of *L. canellei.*

Inasmuch as Davies did not illustrate or describe the species he recorded, it is difficult to know in certain cases the exact species he had. However, it is possible to recognize many of the species by the names which he used. For example, his *Fabularia* aff. *discolithes* Defrance is without question the same as the one here designated *Fabularia verseyi* Cole, n. sp.

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[1] Published by permission of the Director of the Jamaican Geological Survey. The cost of the printed plates has been contributed by the William F. E. Gurley Fund for Paleontological Research at Cornell University.

Table 1. Middle Eocene ("Yellow Limestone") species identified by Vaughan.

Vaughan's identification	Name used in this article	Vaughan's locality numbers*									
		102	500	501	503	504	505	506	507	603	605
Borelis jamaicensis, var. *truncata* Vaughan	*Fabularia matleyi* (Vaughan)				X						
Borelis jamaicensis Vaughan	*Fabularia matleyi* (Vaughan)			X		X	X				
Borelis matleyi Vaughan	*Fabularia matleyi* (Vaughan)				X		X				
Camerina matleyi Vaughan	*Pellatispirella matleyi* (Vaughan)						X				X
Dictyoconus condon Woodring	*Dictyoconus americanus* (Cushman)					X	X	X			
Lituonella sp.	*Coskinolina elongata* Cole					X					X
Yaberinella jamaicensis Vaughan	*Yaberinella jamaicensis* Vaughan	X	X	X	X		X		X	X	X

*J and M omitted.

Table 2. Upper Eocene species identified by Vaughan.

Vaughan's identification	Name used in this article	Vaughan's locality numbers*									
		5	6	11	14	22	57	58	59	65	67
Asterocyclina georgiana (Cushman)	*Asterocyclina georgiana* (Cushman)		X								
sp. indet.											X
Camerina sp.	*Camerina striatoreticulata* (L. Rutten)							X			
Cushmania americana (Cushman)	*Dictyoconus americanus* (Cushman)					X					
fontabellensis Vaughan	*americanus* (Cushman)					X					
Discocyclina crassa (Cushman)								X			
perkinsi Vaughan	*Pseudophragmina* (*Prop.*) *perkinsi* (Vaughan)				?				X		
sp. aff. *D. pustulata* (Cushman)								X			
Dictyoconus puilboreauensis Woodring	*Dictyoconus americanus* (Cushman)							X			
Lepidocyclina (*Plio.*) *kinlossensis* Vaughan	*Lepidocyclina* (*Plio.*) *macdonaldi* Cushman				X						
(*Lep.*) *macdonaldi* Cushman	(*Plio.*) *macdonaldi* Cushman	X		X				X			
sherwoodensis Vaughan	(*Plio.*) *pustulosa* H. Douv.						X				
trinitatis H. Douvillé	(*Plio.*) *pustulosa* H. Douv.			X						X	
(*Neph.*) *haddingtonensis* Vaughan	(*Neph.*) *chaperi* Lem. & R. Douv.	X		X	X			X			X
sp. cf. *L. perundosa* Cushman	(*Neph.*) *chaperi* Lem. & R. Douv.							X			
Yaberinella trelawniensis Vaughan	*Yaberinella jamaicensis* Vaughan						X				

* J and M omitted.

The described specimens will be retained temporarily in the Cole collection but will be deposited eventually in the U. S. National Museum.

ANALYSIS OF THE FAUNAS

Middle Eocene.—Twenty localities with a total of 18 species are assigned to the middle Eocene. All of the species which have been described previously are known either in Jamaica or elsewhere to be middle Eocene in age. The distribution of these species is shown in Table 4.

M-376. Great River Bridge, Ducketts, St. James.
M-385. Spring Hill, St. James.
M-404. Road Section between Maldon and Summer Hill, St James.
M-409. Boghasey Spring, Summer Hill, St. James.
M-412. Grandy Hole, Summer Hill, St. James.
Z-172. Allsides Spring, Trelawny.
Sandy River. One-half mile southwest of Sandy River, Clarendon
V-224. Cutthroat Hill, St. James.
Z-171. One quarter mile northeast of Allsides Great House, Trelawny.
Z-217. Big Cave Spring, Tyre, Trelawny.
Z-155. Roof of the entrance to Carambie Cave, Trelawny.
V-294. Dutch Hill, Trelawny.
Z-203. Wilson Run, Trelawny.
V-192. Banana Spring, Mt. Zion, St. James.
V-109. Marl Pit at the foot of Swanswick Hill, Trelawny.
V-135. Hillside above the Hyde-Hampshire Road, Trelawny.
M-454 and M-454a. Overhill Cave, Cutthroat, St. James.
ZF-22. Negro River, ¾ mile south of St. Ann's Bay, St. Ann.
V-394. Lilyfield, St. Ann.

Of the 18 middle Eocene species listed in Table 6 seven occur in the middle Eocene Loma Candela formation of Cuba. These species are designated by asterisks. Five species, designated by daggers, occur in the Guayabal formation of Mexico and one species, *Lepido-*

Table 3. Oligocene species identified by Vaughan.

Vaughan's identification	Names used in this article	Vaughan's locality numbers*																			
		1	3	4	20	23	25	26	29	43	46	55	56	58	68	72	74	75	80	84	88
Miogypsina bracuensis Vaughan	*Miogypsina antillea* (Cushman)							X													
Lepidocyclina (*Lep.*) *canellei* Lem. & R. Douv.	*Lepidocyclina* (*Lep.*) *canellei* Lem. & R. Douv.							X	X	X			X								
forresti Vaughan	*supera* (Conrad)																	X			
matleyi Vaughan	*canellei* Lem. & R. Douv.				X																
miraflorensis Vaughan																		X			
parvula Cushman	*parvula* Cushman														X						
yurnagunensis Cushman	*yurnagunensis* Cushman			X																X	
(*Neph.*) *crassata* Cushman	(*Neph.*) *favosa* Cushman			X		X															
undosa Cushman	*undosa* Cushman	X	X	X			X			X	X	X		X†	X	X	X		X	X	X
gigas Cushman	*gigas* Cushman	X	X	X							X				X			X			
var.	*gigas* Cushman	X		X														X			

* J and M omitted.

† Misidentification: This is *L.* (*Nephrolepidina*) *chaperi*.

t
a
c

Table 4. Middle Eocene species and localities.

	M 376	M 385	M 404	M 409	M 412	Z 172	Sandy River	V 224	Z 171	Z 217	Z 155	V 294	Z 203	V 192	V 109	V 135	M 454	M 454a	ZF 22	V 394
Asterocyclina monticellensis Cole and Ponton*																				r
penonensis Cole and Gravell*																				r
Camagueyia perplexa Cole and Bermudez*																				r
Coskinolina elongata Cole				a	r	a	a	r	r	r										
Coskinolinoides jamaicensis Cole, n. sp.	r	r	c	c	r	r	c	r		r										
Dictyoconus americanus (Cushman)*										r	r						r	r		r
Fabiana cubensis (Cushman and Bermudez)*								r		c				r	r	c	a	a		c
Fabularia matleyi (Vaughan)							r	r	a											
Helicostegina gyralis Barker and Grimsdale*†			c					a							a		r	r		
Lepidocyclina (*Polylepidina*) *antillea* Cushman											r	c		r						a
Linderina floridana Cole															r	r				
Operculinoides cushmani Cole†																				c
Operculinoides jennyi Barker†															c					
Pellatispirella matleyi (Vaughan)									c	c	c	c	c							
Pseudolepidina trimera Barker and Grimsdale†															c	a				
Pseudophragmina (*Proporocylina*) *advena* (Cushman)																			a	
cushmani (Vaughan)*†																				r
Yaberinella jamaicensis Vaughan										a	a	a	a	c						

a = abundant; c = common; r = rare.

* Occurs also in Loma Candela formation of Cuba

† Occurs also in the Guayabal formation of Mexico.

yclina (*Polylepidina*) *antillea* Cushman, is found in the Cook Mountain formation from Texas to Florida. The Loma Candela, Guayabal, and Cook Mountain formations are approximately the same age and the localities in Jamaica at which these species occur are correlated with these formations.

Linderina floridana is associated in Florida with *Helicostegina gyralis*, and *Fabularia matleyi* occurs with *Asterocyclina monticellensis*. Therefore, the localities in Jamaica at which these species occur may represent the equivalent of the Cook Mountain formation. However, *Coskinolina elongata* which occurs with *Fabularia matleyi* in Jamaica appears in Florida to occur at a horizon below the Cook Mountain.

Pseudophragmina (*Proporocyclina*) *advena* is a marker for the Weches formation of Louisiana and Texas. It seems probable, therefore, that this locality in Jamaica represents a lower horizon than does the major number of the localities.

Upper Eocene.—The upper Eocene is represented by 19 samples.

The distribution of the species is shown in Table 5.

Z131. Gineppa Spring, Dromilly, Trelawny.
Z- 85. Coxheath Old Well, Trelawny.
VL-78. Deep bend in Mannings Hill—Stirling Castle road, St. Andrew.
VL-87. Swainspring—Stirling Castle road, St. Andrew.
VL-92. Corner of Montgomery Road, Stony Hill, St. Andrew.
V-134c and V-134cx. Good Design, Trelawny.
V-107. High cliff above the Kinloss-Duanvale Road, Trelawny.
V-111a and V-111b. Sections at roughly 100 yard intervals from south to north along the Swanswick-Vale Royal Road, Trelawny.
V-127. Cliff above the Reserve-Sherwood Road, Trelawny.
Crab Hill Point near Port Antonio, Portland.
M-448. Junction of Canaan-Gales Valley with Wemmys Road, St. James.
V-108. Hillside above the Kinloss-Clarks Town Road, Trelawny.
V-122. Jackson Town—Arcadia Road, Trelawny.
V-134. Good Design, Trelawny.
Z-10. Marl pit between Coxheath and Windsor, Trelawny.
Z-79a. Mouth of Windsor Cave, Trelawny.

Table 5. Upper Eocene species and localities.

	Z 131*	Z 85	VL 78	VL 87	VL 92	V 134 c	V 134 cx	V 107	V 111 a	Z 8	V 111 b	V 128	Crab Hill Point	M 448	V 108	V 122	V 134	Z 10	Z 79 a
Asterocyclina georgiana (Cushman)														r					
minima (Cushman)						r	r							r			r		
Camerina striatoreticulata (L. Rutten)															r				
Coskinolina floridana Cole		r							c	c									
Dictyoconus americanus (Cushman)	c	c	r	r	r	r		c											
cookei (Moberg)	r	r	c		r							r	r			r			r
Fabiania cubensis (Cushman and Bermudez)								r	r	c	r	r	r						
Fabularia verseyi Cole, n. sp.		r	a	a	r	c	c						r		r				
Heterostegina ocalana Cushman											r								
Lepidocyclina (Plio.) gubernacula Cole															r				
macdonaldi Cushman						a	a	c	c	r	a	r	a	r	c	r	a	c	
proteiformis Vaughan	c																		
pustulosa H. Douvillé		r						c	c		c		c	a		r			
tobleri H. Douvillé												a							
(*Neph.*) *chaperi* Lem. and R. Douv.															a	a	c	a	r
Operculinoides ocalanus (Cushman)															r				
Pellatispirella matleyi (Vaughan)			r	c	r	r	r												
Pseudochrysalidina floridana Cole	r		r		r														

* Also rare specimens of *Fabularia matleyi* (Vaughan).
a = abundant; c = common; r = rare.

There are 18 species recorded from these Jamaican upper Eocene localities of which five have been recorded in Florida (Cole, 1941, p. 20) as occurring only in the middle Eocene. These species are *Coskinolina floridana* Cole, *Dictyoconus americanus* (Cushman), *D. cookei* (Moberg), *Fabiania cubensis* (Cushman and Bermudez), and *Pseudochrysalidina floridana* Cole. In addition, *Pellatispirella matleyi* (Vaughan) which occurs abundantly in the Jamaican middle Eocene was found at a few localities which are assigned to the upper Eocene.

Fabularia verseyi Cole, n. sp. occurs at four localities in association with *Lepidocyclina* (*Pliolepidina*) *macdonaldi* Cushman, a supposedly upper Eocene species, but at five localities this species of *Fabularia* is associated with species which have been assumed to be restricted to the middle Eocene. Similar admixtures of middle and upper Eocene have been reported previously (Cole, 1952, p. 5).

Whether the ranges of such species must be extended or whether in many of these cases the introduction of these species into certain faunas is through reworking is still a question that cannot be settled without more evidence. The only sample which exhibited definite evidence of reworking is V-107. In this sample the middle Eocene species are not only eroded but have a different type of preservation.

The problem of the association of supposed middle Eocene species in association with assumed upper Eocene species has been troublesome in Cuba. Keijzer (1945, p. 44) stated "Little need be said about these samples except for the occurrence at loc. T. 1452 of *Lituonella inflata* n. sp., *Coskinolina cookei* and *Dictyoconus codon* in the upper Eocene, because at the hand of these fossils only, one should have concluded very probably to a middle Eocene age." Inasmuch as *Lituonella inflata* Keijzer is without question a synonym of *L. floridana* Cole, and *Dictyoconus codon* has been proven to be the same as *D. americanus* (Cushman), Keijzer encountered in Cuba the same association which is troublesome in Jamaica.

Woodring and Daviess (1944, p. 366) reported *Coskinolina* (?) sp. and *Dictyoconus* cf. *americanus* from the Cobre volcanics of upper Eocene age of Cuba and *Dictyoconus* (?) cf. *americanus* from the lower part of the Charco Redondo limestone also of upper Eocene age. Bermudez (1950, p. 239, 246) placed the Cobre formation in the lower Eocene and the Charco Redondo formation in the middle Eocene. However, the lists of large Foraminifera given by Bermudez especially for the Charco Redondo formation indicate an upper, rather than a middle Eocene age.

However, Bermudez (1950, p. 248) recorded *Coskinolina floridana, Dictyoconus americanus,* and *Lituonella floridana* from the Jabaco formation which he assigned to the upper Eocene. Therefore, it is apparent that certain middle Eocene species do occur in the upper Eocene of Cuba.

As 12 of the 18 species occurring in the samples assigned to the upper Eocene occur in the Gatuncillo formation of Panama, the upper Eocene of Jamaica is correlated with that formation.

Oligocene.—Ten samples listed in Table 6 are from definite Oligocene localities. These localities correlate with the middle member of the upper Oligocene Caimito formation of the Gatun Lake area of Panama (Cole, 1952, p. 7). The species and association of species are the same in both areas.

V-95.	Daniel Town, Trelawney.
V-97.	Hillside above Long Pond-Gibraltar Road, Trelawny.
V-102.	Exposure beside Hyde Hall-Stanford Road, Trelawny.
V-121.	Jackson Town-Arcadia Road, Trelawny.
V-170.	Between Dumfries and Content, St. James.
V-296.	Vale Royal-Hampshire Road, Trelawny.
V-297.	Carlton, St. James.
J-68M.	Rio Bueno Road, 0.75 miles north of Jackson Town, Trelawny.
Z-3.	Road section above the pond at Reserve, Trelawny.
Z-5.	About 27 chains above Water Boil, Potosi, Trelawny.

Miocene.— One sample, V-32, from a cliff above road, Southfield Trelawny, contains rather numerous specimens of *Operculinoides tamanensis* Vaughan and Cole. This is the only sample representing the Miocene.

Table 6. Oligocene species and localities.

	V						J		Z	
	95	97	102	121	170	296	297	68M	3	5
Heterostegina antillea Cushman	r	a		a		r			a	
panamensis Gravell									r	
Lepidocyclina (Lepidocyclina) canellei Lemoine and R. Douvillé	a		r	r	a	a	r	c	c	r
parvula Cushman	r					c				
supera (Conrad)						r				
yurnagunensis Cushman							r	c		
(Eulepidina) undosa Cushman							r	c		
gigas Cushman						r			r	
Miogypsina (Miogypsina) antillea (Cushman)	r			c		c			a	r
(Miolepidocyclina) panamensis (Cushman)		r	r		a	r			r	
Operculinoides vicksburgensis Vaughan and Cole								a		

a = abundant; c = common; r = rare.

DESCRIPTION OF SPECIES

The following species from Jamaica, B. W. I., which have been described completely elsewhere are illustrated and a reference particularly to other good illustrations is given:

Asterocyclina monticellensis Cole and Ponton (pl. 29, figs. 4, 5).
See: Cole and Gravell, 1952, pl. 97, figs. 1-11.
Asterocyclina penonensis Cole and Gravell (pl. 29, figs. 1-3).
See: Cole and Gravell, 1952, pl. 98, figs. 1-8.
Asterocyclina minima (Cushman) (pl. 30, fig. 9).
See: Cole, 1952, pl. 26.
Coskinolina floridana Cole (pl. 24, figs. 3-5).
See: Cole, 1941, pl. 4, figs. 1-9.
Dictyoconus cookei (Moberg) (pl. 25, figs. 6, 7).
See: Cole, 1941, pl. 6, figs. 1-8.
Lepidocyclina (Polylepidina) antillea Cushman (pl. 27, fig. 9; pl. 30, figs. 7, 8).
See: Cole, 1944, pl. 10; pl. 11.
Lepidocyclina (Pliolepidina) macdonaldi Cushman (pl. 27, figs. 3-5, 8; pl. 28, figs. 1-5).
See: Cushman, 1918, pl. 40, figs. 1-6.
Lepidocyclina (Pliolepidina) pustulosa H. Douvillé (pl. 27, figs. 1, 2; pl. 28, fig. 6; pl. 30, figs. 1-3).
See: Cole, 1952, pl. 13, figs. 1-20; pl. 14, figs. 1-10.
Lepidocyclina (Pliolepidina) pustulosa tobleri H. Douvillé (pl. 28, fig. 11).
See: Vaughan and Cole, 1941, pl. 24, figs. 1-10.
Linderina floridana Cole (pl. 30, figs. 4-6).
See: Cole, 1942, pl. 11, fig. 8; pl. 15, figs. 7-11.
Miogypsina (Miolepidocyclina) panamensis (Cushman) (pl. 30, fig. 10).
See: Cole, 1952, pl. 25, figs. 1-8.
Operculinoides cushmani (Cole) (pl. 30, figs. 11-13; pl. 31, figs. 5, 6). See Cole, 1927, pl. 2, fig. 13.

Family **VALVULINIDAE**

Genus **PSEUDOCHRYSALIDINA** Cole, 1941

1945. *Pseudogoesella* Keijzer

Pseudochrysalidina floridana Cole Pl. 24, figs. 1, 2; Pl. 25, figs. 1-5

1941. *Pseudochrysalidina floridana* Cole, Florida Geol. Survey, Bull 19, p. 36, pl. 1, figs. 10, 11; pl. 2, fig. 4.

Several additional thin sections of topotypes were prepared for comparison with the Jamaican specimens. As there are no significant differences in internal structure between these specimens and the Jamaican ones, they are considered to be this species.

Genus **COSKINOLINA** Stache, 1875

Coskinolina elongata Cole Pl. 24, figs. 6-11; Pl. 31, figs. 1-2

1942. *Coskinolina elongata* Cole, Florida Geol. Survey, Bull, 20, p. 20, 21, pl. 3, figs. 15-17; pl. 4, figs. 1-3; pl. 5, figs. 2-7; pl. 16, fig. 6.

This species is characterized by coarse internal structure. Measurements of five Jamaican specimens follow:

Specimen	1	2	3	4	5
Height .... mm.	2.03	2.37	1.85	1.2	1.95+
Diameter .... mm.	2.13	2.03	1.5	1.47	1.65
Marginal trough (near base):					
Height .... μ	130	100–130	100–120	50–90	100
Width .... μ	250	220–250	250–280	170–190	250–290
Thickness of floors and roofs .... μ	40-50	40-50	30	40	30
Diameter of central shield ...... mm.	1.5	1.4	0.93	0.9	1.0

Discussion.—Although the typical Jamaican specimens are slightly larger and have a more extensive central shield, the other features are so similar that there can be no doubt that they should be referred to the lower middle Eocene species described from Florida.

Genus **COSKINOLINOIDES** Keijzer, 1942

Coskinolinoides jamaicensis Cole, n.sp. Pl. 24, figs. 12-16; Pl. 31, figs. 3, 4

The test is small, conical, with the height generally about twice the diameter of the base. The wall of the cone is straight, and the basal part of the test is protuberant and rounded. The juncture of the conical wall and the base is not sharp. The test is encircled by rather evenly spaced concentric depressions which mark the position of the floors and roofs of the marginal troughs. Slightly abraided specimens show the vertical partitions of the marginal trough so that small rectangular areas cover the surface in these eroded places. The height and basal diameter of 15 specimens follow:

	Height (mm.)	Diameter of base (mm.)
	1.20	0.80
	1.25	0.84
	1.50	1.00
	1.50	0.86
	1.51	0.86
	1.55	0.95
	1.62	0.86
	1.65	0.85
	1.70	0.85
	1.70	0.80
	1.75	1.35
	1.80	0.91
	2.00	0.90
	2.20	1.05
	2.51	1.30
Average	1.68	0.94

Measurements of certain critical internal structures follow:

Specimen		1	2	3	4
Marginal trough (near base of test)					
Height	μ	90	100	100	90
Width	μ	200	190	210	180
Thickness of roofs and floors	μ	30	30	35	30
Diameter of central shield	μ	350	400	400	390

There are few perforations through the central shield, but those that occur are relatively large with a diameter of about 50 μ. The central shield is separated from the marginal trough by a continuous line of perforations on each side. Buttresses occur infrequently on the central shield and are formed usually by a sharp downward flexure of the central shield.

Transverse sections show the chambers of the marginal trough are subdivided by a single short vertical plate.

Discussion.—This species is similar to *Coskinolinoides adkinsi* Barker from clays of Walnut (Lower Cretaceous) age of Texas. *C. adkinsi* is much smaller and has the height of the test approximately equal to the basal diameter. The base of the test of *C. adkinsi* is flat and the conical wall joins the base at a sharp angle.

Genus **DICTYOCONUS** Blanckenhorn, 1900

Dictyoconus americanus (Cushman) Pl. 25, figs. 8-11

1919. *Conulites americana* Cushman, Carnegie Inst. Washington, Publ. 291, p. 43, text-fig. 3.
1928. *Dictyoconus codon* Woodring, Vaughan, Jour. Paleont., v. 1, p. 280, 281, pl. 43, figs. 1-5b.
1928. *Dictyoconus puilboreauensis* Woodring, Vaughan, *idem*, p. 281, pl. 43, fig. 6.
1928. *Cushmania americana* (Cushman), Vaughan, *idem*, p. 281, 282, pl. 44, figs. 1, 2.
1928. *Cushmania fontabellensis* Vaughan, *idem*, p. 282, 283, pl. 44, fig. 3.
1942. *Dictyoconus americanus* (Cushman), Cole, Florida Geol. Survey, Bull. 20, p. 21-24, pl. 3, figs. 12, 13; pl. 6, figs. 1-9; pl. 7, figs. 1-5; pl. 16, figs. 14, 15 [additional references].

In the original description of *Cushmania fontabellensis* Vaughan stated that the internal structure of this species is similar to that of *Dictyoconus americanus,* but the "short lamellae that project inward between the peripheral platforms is about seven for each interspace . . . ." He concluded that "There may in reality be only one species, but in the present stage of information different names are helpful."

Vaughan reported that *D. americanus* and *D. fontabellensis* occur at the same locality. This association was found in the present collection. Moreover, *D. americanus* is abundant and *D. fontabellensis* rare. The specimens of *D. fontabellensis* are large and have more numerous short lamellae, but otherwise they are entirely similar to *D. americanus.*

It is apparent, therefore, that *D. fontabellensis* represents only well-developed or gerontic specimens of *D. americanus.*

Family MILIOLIDAE

Genus FABULARIA Defrance, 1820

Fabularia matleyi (Vaughan) Pl. 26, figs. 7-14

1929. *Borelis matleyi* Vaughan, Jour. Paleont., v. 3, p. 377, 378, pl. 40, figs. 2. 3, 3a.
1929. *Borelis jamaicensis* Vaughan, *idem,* p. 378, 380, pl. 40, figs. 4-10.
1929. *Borelis jamaicensis truncata* Vaughan, *idem,* p. 380, pl. 40, figs. 11, 12.
1934. *Fabularia vaughani* Cole and Ponton, Amer. Midland Nat., v. 15, p. 139-141, pl. 1, figs. 1-9.
1937. *Fabularia vaughani* Cole and Ponton, Hanzawa, Jour. Paleont., v. 11, p. 111-113, pl. 20, figs. 1-4.
1945. *Fabularia vaughani* Cole and Ponton, Cole, Florida Geol. Survey, Bull. 28, p. 98-101, pl. 15, fig. 6; pl. 16, figs. 1-10.

All of Vaughan's (1929) illustrations of his "*Borelis*" are transverse sections with the exception of his figure 2 which is a tangential axial section. The axial sections of specimens from locality Z-171 are associated with transverse sections which are identical to Vaughan's transverse sections and, therefore, demonstrate that his "*Borelis*" is *Fabularia.*

The specimens named *F. vaughani* from Florida have each chamber divided into a single row of chamberlets which are bounded by relatively thick walls. Vaughan's figure 7 shows identical features. Although certain specimens have much thinner walls bounding the chamberlets, this represents individual and not specific variation as all gradations can be noted in individuals from the same locality.

Fabularia verseyi Cole, n.sp. Pl. 26, figs. 1-6

1937. *Fabularia* (?) sp. A, Hanzawa, Jour. Paleont., v. 11, p. 113, pl. 20, figs. 5, 6.
1937. *Fabularia* sp., Hanzawa, *idem*, p. 113, pl. 21, fig. 3.

The test is elongate, subcylindrical with gently rounded ends. Typical specimens have a length of 2.0 to 3.0 mm. and diameters from 1.0 to 1.56 mm.

Many sections show only a single large embryonic chamber. A transverse section (Pl. 26, fig. 6) with diameters of 0.9 by 1.1 mm. has a large embryonic chamber with diameters of 300 by 350 μ. There is a smaller chamber at one side of this chamber with diameters of 40 by 140 μ. Another transverse section (Pl. 26, fig. 5) with diameters of 1.0 by 1.56 mm. has a larger embryonic chamber with diameters of 380 by 420 μ which completely surrounds a smaller chamber with diameters of 170 by 190 μ. An axial section with a length of 2.05 mm. and a diameter of 1.1 mm. has a single embryonic chamber with diameters of 260 by 230 μ.

Transverse sections show the bilocular arrangement of the chambers. These chambers have thick walls and are normally subdivided into two rows of irregularly shaped chamberlets.

Axial sections which are centered show two or more rows of small, irregular, but more or less rounded chamberlets, but in axial sections which are not centered the chamberlets appear as elongate, irregular and sometimes bifurcate openings.

Discussion.—This species differs from *F. matleyi* in possessing two or more rows of chamberlets in each chamber. The chamberlet openings are small, irregular, and the bounding wall is thick, whereas the chamberlets in *F. matleyi* are normally square or rectangular in shape and regularly arranged.

Hanzawa's (1929, p. 113) *Fabularia* (?) sp. B represents a transverse section of *Yaberinella jamaicensis* Vaughan.

This species is without question the one identified by Davies (1952, p. 127) as *Fabularia* aff. *discolithes* Defrance. There is resemblance in certain sections (compare Cole and Ponton's (1934, pl. 1, fig. 10) figure with figure 1, Plate 26 of this article), but the transverse sections are different in that *F. discolithes* has normally only a single row of chamberlets as shown by figure 15, Plate 26.

Family CAMERINIDAE

Genus OPERCULINOIDES Hanzawa, 1935

Operculinoides jennyi Barker Pl. 31, figs. 7-9

1939. *Operculinoides jennyi* Barker, U. S. Nat. Mus., Proc., v. 86, No. 3052, p. 315, 316, pl. 12, fig. 7; pl. 14, fig. 7; pl. 17, fig. 3; pl. 19, fig. 7; pl. 21, fig. 9.

Measurements of three thin sections follow:

Height ......mm.	2.95	3.7	3.5
Width ......mm.	2.8	3.05	——
Thickness ......mm.	——	——	1.0
Diameters of initial chamber ......μ	160x180	180x200	——
Diameter of second chamber ......μ	120x150	140x200	——
Distance across both chambers ......μ	300	330	380
Number of coils	3	3	——
Number of chambers in first volution	8	9	——
Number of chambers in final volution	20	22	——

Discussion.—The types of this species came from Jenny's locality No. 1573 which Barker stated is "an outcrop 11 kilometers southeast of Sabaneta, Vera Cruz." At this same locality Barker and Grimsdale (1937, p. 172) recorded *Pseudolepidina trimera,* but stated "at Jenny station No. 1573, five kilometers E.S.E. from Sabaneta, State of Veracruz." This locality has in addition *Helicostegina gyralis* Barker and Grimsdale. The formation is given by Barker (1939, p. 316) as Guayabal.

The Jamaican specimens are identical with the types. This species has large embryonic chambers. Although Barker does not give the dimensions of these chambers, his figure 7, plate 19 shows these chambers to be large with the distance across both chambers at least 300 μ.

O. cushmani Cole has much smaller embryonic chambers and a much more fragile test.

Family **ORBITOIDIDAE**

Genus **LEPIDOCYCLINA** Gümbel, 1870

Subgenus **Pliolepidina** H. Douvillé, 1917

Lepidocyclina (Pliolepidina) proteiformis Vaughan

Pl. 27, figs. 6, 7; Pl. 28, figs. 7-10

1924. *Lepidocyclina* (*Polylepidina*) *proteiformis* Vaughan, Geol. Soc. Amer. Bull., v. 35, p. 810-812, pl. 32, figs. 1-7.
1929. *Lepidocyclina* (*Polylepidina*) *proteiformis* Vaughan, Nat. Acad. Sci., Proc., v. 15, p. 291, fig. 8.
1936. *Polylepidina proteiformis* Vaughan, Barker and Grimsdale, Jour. Paleont., v. 10, p. 241, pl. 33, fig. 3; pl. 36, fig. 5.
1938. *Lepidocyclina* (*Polylepidina*) *proteiformis* Vaughan, Cole, Florida Geol. Survey, Bull. 16, p. 47, pl. 10, figs. 6-9.

The equatorial section of *L.* (*P.*) *ariana* Cole and Ponton, *L.* (*P.*) *macdonaldi* Cushman, and *L.* (*P.*) *gubernacula* Cole are similar to those of *L. proteiformis*, a species long considered to belong to the subgenus *Polylepidina*. Therefore, *L. proteiformis* is transferred to the subgenus *Pliolepidina*.

During the restudy of topotypes of *L.* (*P.*) *proteiformis* from 0.5 kilometers southwest of Palma Sola, Vera Cruz, Mexico, specimens of *Triplalepidina veracruziana* Vaughan and Cole (1938, p. 167) were found in the same fragment of rock. Vaughan and Cole stated that this genus is found in the Tantoyuca formation of upper Eocene age. However, Barker and Grimsdale (1936, p. 244) placed *L.* (*P.*) *proteiformis* near the top of the upper middle Eocene.

Two vertical and one equatorial section of topotypes of *L.* (*P.*) *proteiformis* are illustrated for comparison with the Jamaican specimens assigned to this species.

The floors and roofs of the lateral chambers of *L.* (*P.*) *proteiformis* are relatively thin and straight and the cavities of the lateral chambers are open. *L.* (*P.*) *macdonaldi* has much thicker and curved floors and roofs of the lateral chambers and the cavities of the chambers are more appressed. *L.* (*P.*) *gubernacula* has thin and straight floors and roofs of the lateral chambers, and the cavities of the chambers are large, rectangular, and open. *L.* (*P.*) *ariana* has relatively thick but straight floors and roofs of the lateral chambers, and the chambers cavities are rather low. In addition there are slight differences between these species in the shape of the equatorial chambers although all are the arcuate type.

Genus **PSEUDOLEPIDINA** Barker and Grimsdale, 1937

Pseudolepidina trimera Barker and Grimsdale Pl. 31, figs. 10-16

1937. *Pseudolepidina trimera* Barker and Grimsdale, Ann. and Mag. Nat. Hist., ser. 10, v. 19, p. 172, 173, pl. 5, figs. 1-3; pl. 8, figs. 1-5.

The Jamaican specimens are identical with the types from Mexico. Barker and Grimsdale (1937, p. 169), however, stated that "a third chamber, which perhaps should be included as part of the nucleoconch, is large and partially embracing, and lies to one side of the equatorial plane . . ." This third chamber occurs in two of the vertical sections of the Jamaican specimens but does not show in the others. The position of this third chamber may be an individual character rather than a generic one as they imply.

Discussion.—Although *Pseudolepidina* and *Triplalepidina* Vaughan and Cole (1938) are based on distinct species, the question may be raised whether these two genera should not be combined The distinctive structure in each is the doubling of the equatorial layer near the periphery. It would seem that the middle Eocene *Pseudolepidina trimera* is the ancestor of the upper Eocene *Triplalepidina veracruziana*. Whether the two genera should be combined or not cannot be decided, but the relationship these two genera have to each other should be stressed at this time.

Family **DISCOCYCLINIDAE**

Genus **PSEUDOPHRAGMINA** H. Douvillé, 1923

Subgenus **PROPOROCYCLINA** Vaughan and Cole, 1940

Pseudophragmina (Proporocyclina) advena (Cushman) Pl. 29, figs. 6-10

1921. *Orthophragmina advena* Cushman, U. S. Geol. Survey, Prof. Paper 128-E, p. 139, pl. 22, figs. 1-5.
1938. *Discocyclina advena* (Cushman), Gravell and Hanna, Amer. Assoc. Petrol. Geol., Bull., v. 22, p. 1008-1010, pl. 6, fig. 8; pl. 7, figs. 4, 8.
1952. *Pseudophragmina* (*Proporocyclina*) *advena* (Cushman), Cole and Gravell, Jour. Paleont., v. 26, p. 721, pl. 100, figs. 4, 9.

The vertical section (Pl. 29, fig. 8) should be compared with the illustration (Cole and Gravell, 1952, pl. 100, fig. 9) of a topotype from the Cane River, Natchitoches, Louisiana. The structure of the vertical section of this species is much coarser than that exhibited by any of the other closely related species except *P.* (*P.*) *teres* Cole and Gravell, but this species has more appressed lateral chambers.

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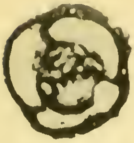
PLATES

Explanation of Plate 24

Figure		Page
1, 2.	**Pseudochrysalidina floridana** Cole Transverse sections, X 20, to illustrate the triserial character of the test and labyrinthic central axis; 1, Topotype, from the Peninsular Oil and Refining Company's J. W. Cory well No. 1 (W-445) near Pinecrest, Monroe County, Florida at a depth of 1500-1510 feet; 2, locality, VL 78.	215
3–5.	**Coskinolina floridana** Cole 3. 5, Axial sections, X 40; 4, Transverse section, X 40; 3, 4. Locality Z-85; 5, Locality, Z-79a.	214
6–11.	**Coskinolina elongata** Cole 6, 11. Transverse sections, X 20; 7-9, 10. Axial sections, 7, 8, 10, X 20; 9, X 40; locality, Sandy River.	215
12–16.	**Coskinolinoides jamaicensis** Cole, n. sp. 12, 13. Transverse sections, X 40; 14-16. Axial sections, X 40; 14, holotype; locality, Sandy River.	216

Unless otherwise stated, the localities are from Jamaica, B.W.I.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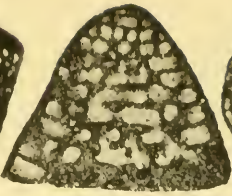
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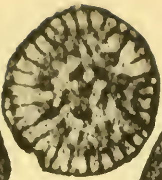
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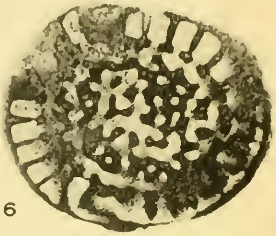
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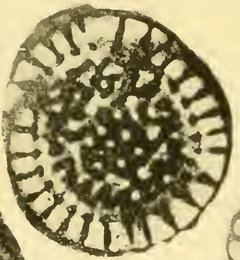
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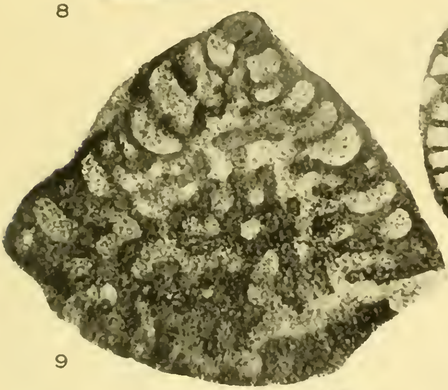
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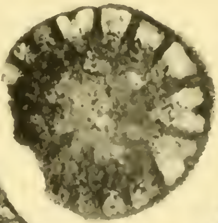

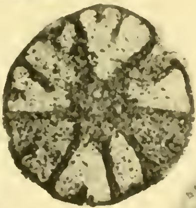
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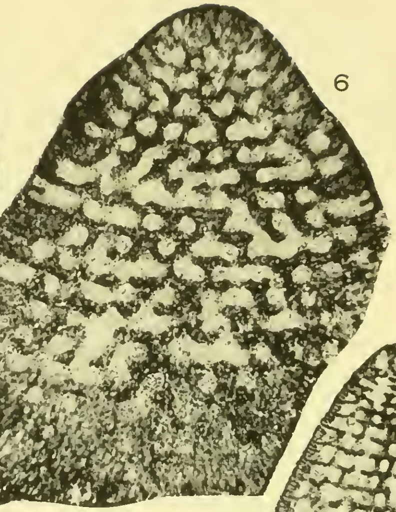
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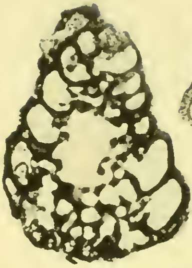
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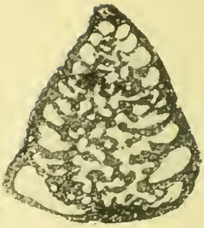
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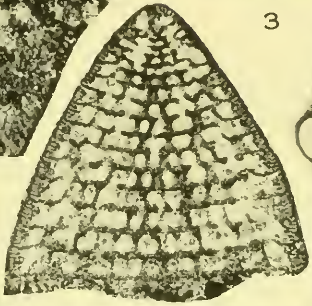
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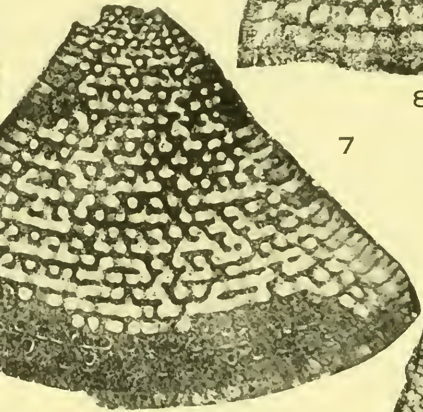
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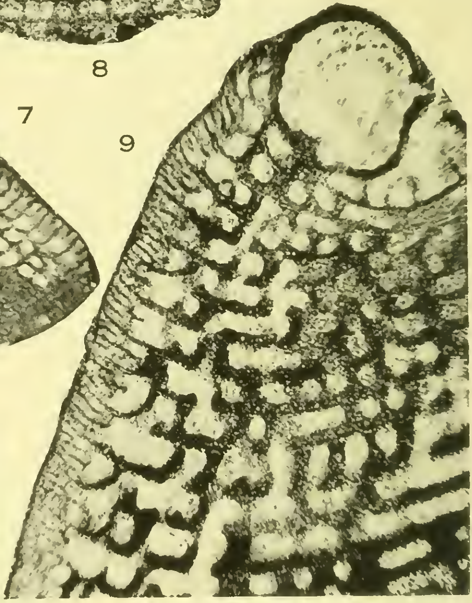
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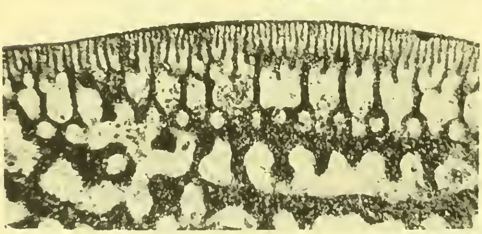
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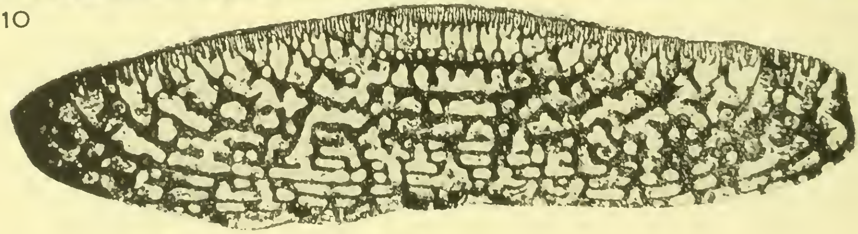
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Explanation of Plate 25

Figure Page

1-5. **Pseudochrysalidina floridana** Cole 215

Axial sections, X 20; 1, 2. Locality VL92; 3-5, topotypes from the Peninsular Oil and Refining Company's J. W. Cory well No. 1 (W-445) near Pinecrest Monroe County, Florida; 3, 5, at a depth of 1360-1370 feet; 4, at a depth of 1400-1410 feet.

6–7. **Dictyoconus cookei** (Moberg) 214

Axial sections, X 40, to show the single horizontal plate in each marginal chamber; locality Crab Hill Point.

8–11. **Dictyoconus americanus** (Cushman) 217

Axial sections; 8, 11, X 20; 9, 10, X 40; 10. Enlarged part of figure 11; 9, 10. Specimen similar to those named *D. fontabellensis* Vaughan; 8. Locality, Z-155; 9. Locality Z-131; 10. 11. Locality Z-85.

Explanation of Plate 26

Figure Page

1–6. **Fabularia verseyi** Cole, n. sp. 219

1-4. Axial sections, X 20; 1. Locality VL87; 2, locality, V-108; 3, 4. Locality VL78.

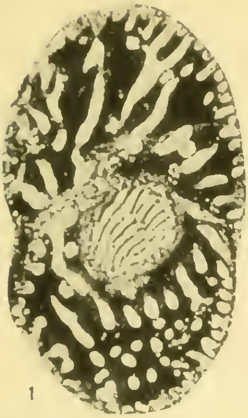
5, 6. Transverse sections, X 40; 6, holotype; localities VL78.

7–14. **Fabularia matleyi** (Vaughan) 218

7, 8, 11, 12. Axial sections, X 20; 9, 10, 13, 14. Transverse sections, 9, 10, 14, X 20; 13, X 40; 7-10. Locality, Z-171; 11-14, locality Sandy River.

15. **Fabularia discolithes** Defrance 219

Transverse section, X 40, introduced for comparison with the Jamaican specimens; Lutetien, Chaussy, France, presented to the writer by the late Joseph A. Cushman.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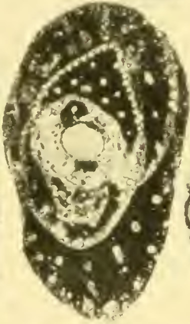
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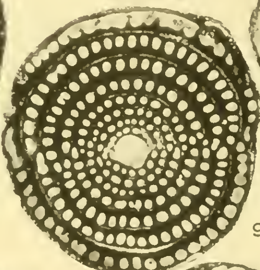
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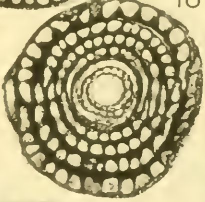
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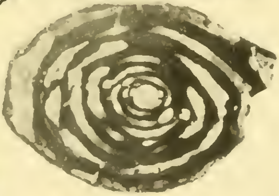
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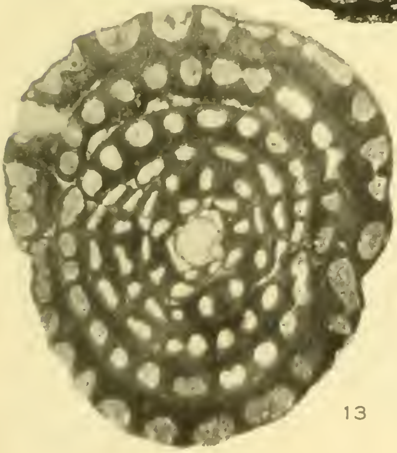
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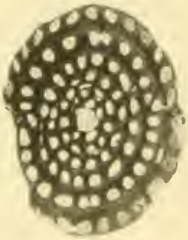
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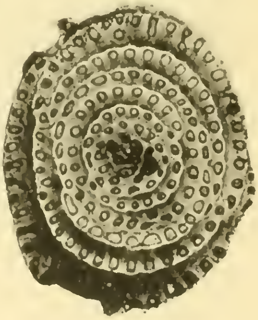
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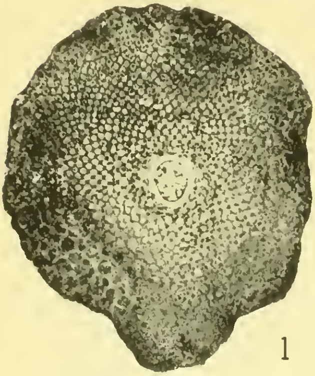
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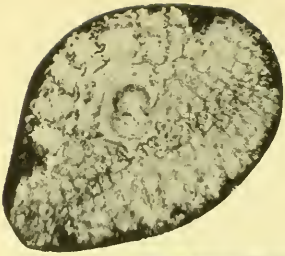
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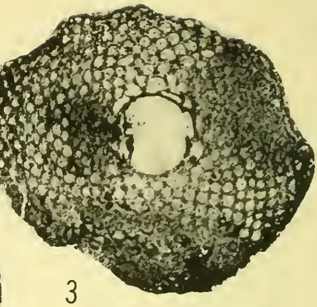
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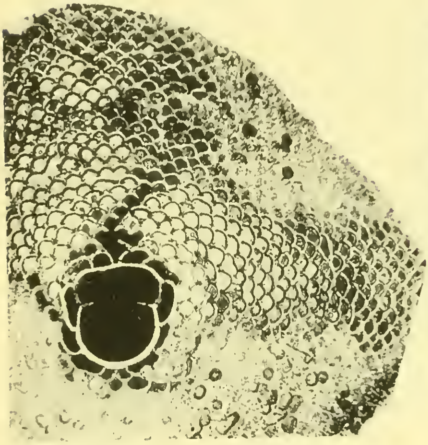
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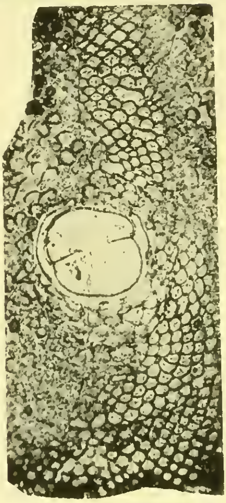
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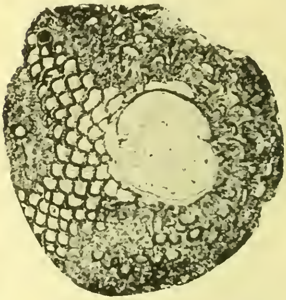
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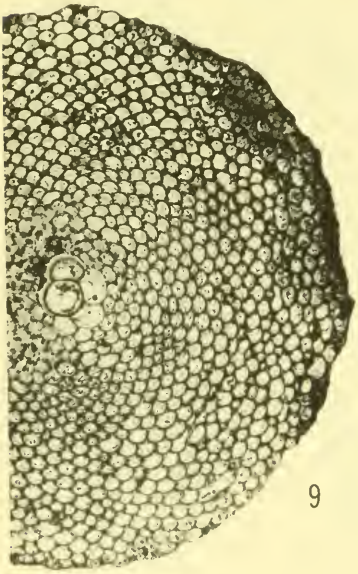
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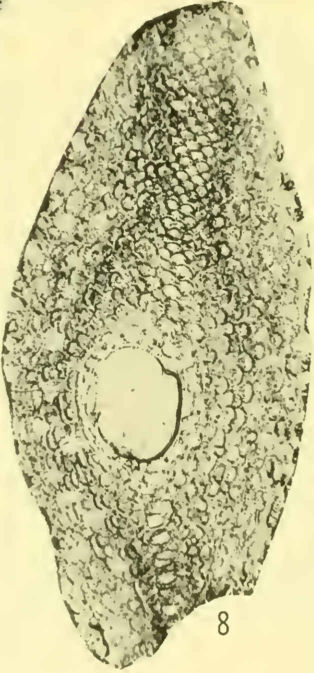
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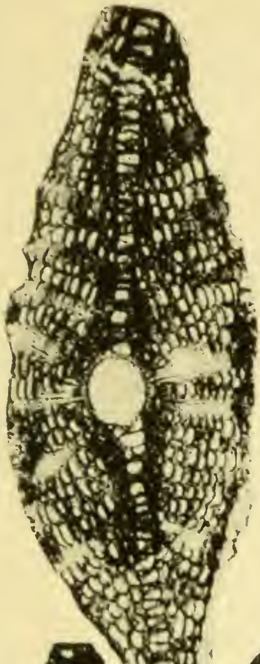
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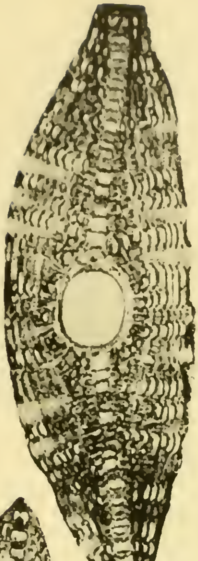
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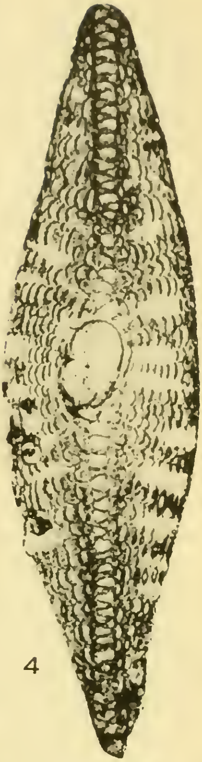
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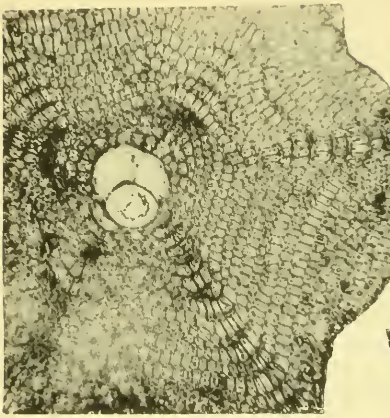
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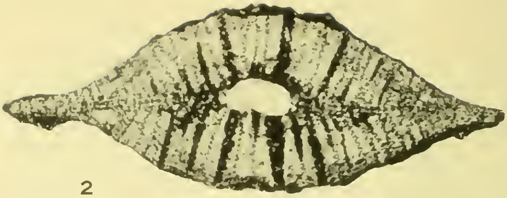
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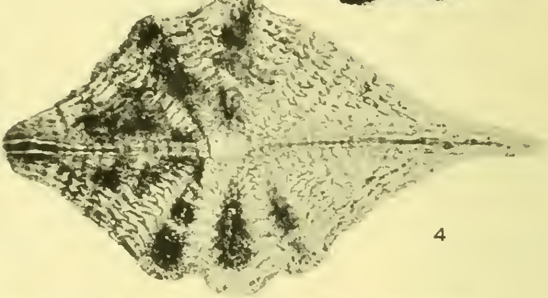
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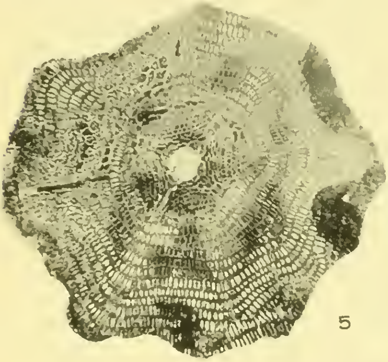
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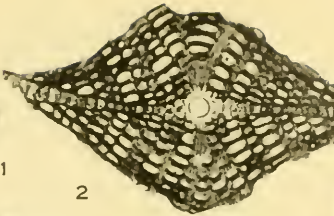
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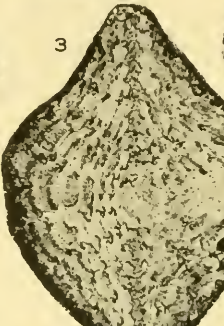
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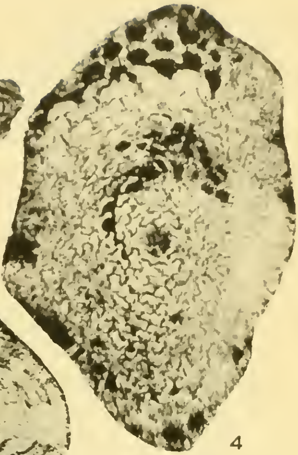
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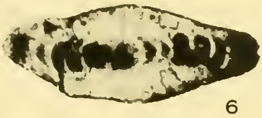
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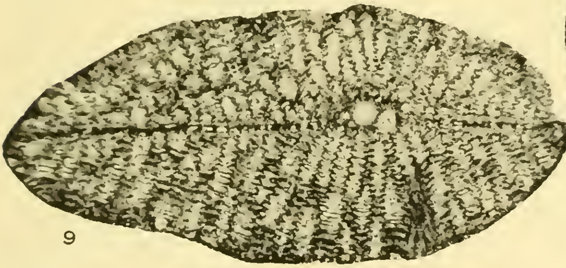
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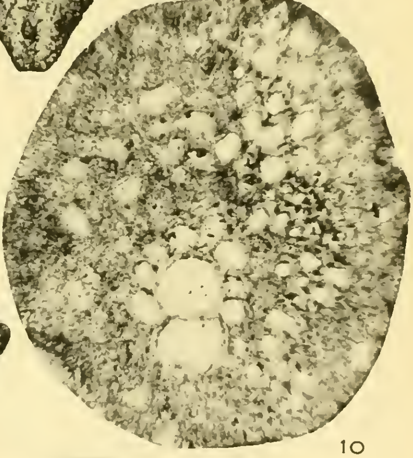
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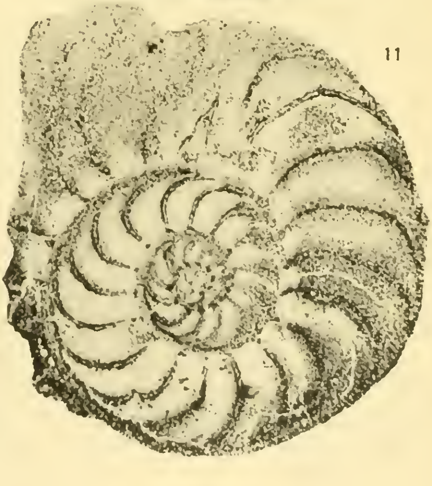
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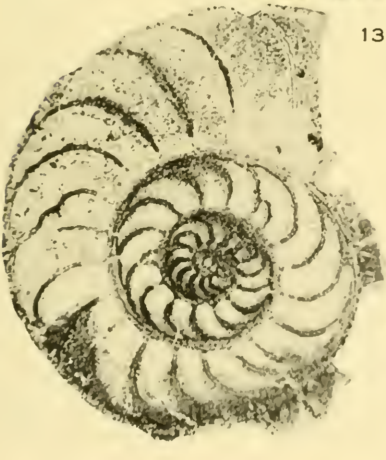
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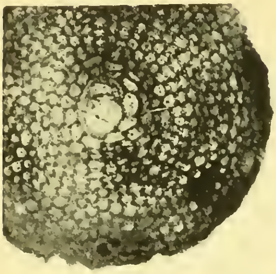

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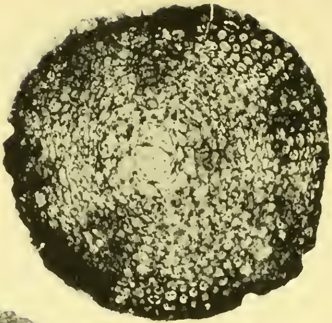

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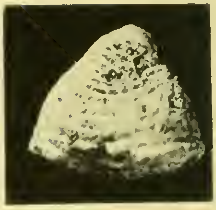

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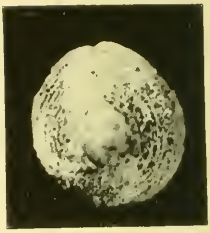

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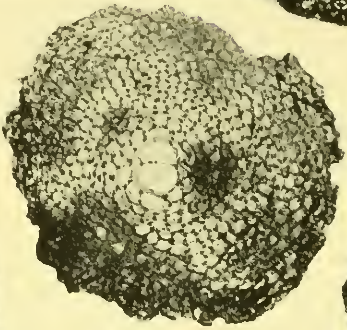

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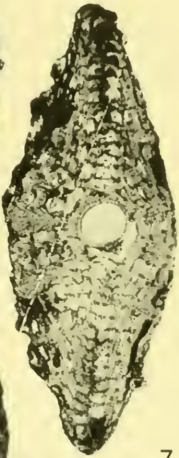

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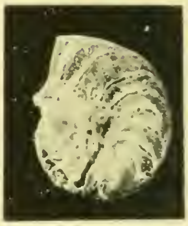

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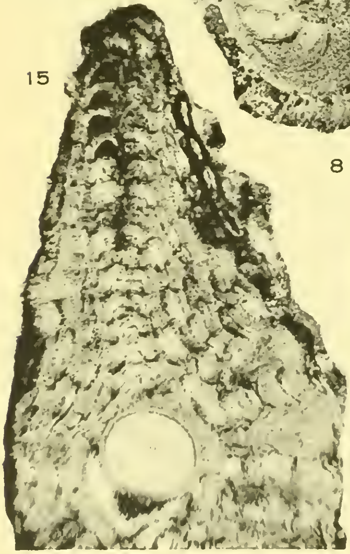

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THE GENERA MISCELLANEA AND PELLATISPIRELLA

By

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Cornell University, Ithaca, New York

May 15, 1956

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THE GENERA MISCELLANEA AND PELLATISPIRELLA[1]

W. Storrs Cole
Cornell University, Ithaca, New York

ABSTRACT

The criteria for the recognition of the genera *Miscellanea and Pellatispirella* by a restudy of the species *M. miscella* (d'Archiac and Haime) and *Pellatispirella matleyi* (Vaughan) are given and new illustrations of each species are presented. Certain species previously assigned to these genera are discussed.

INTRODUCTION

Recently, H. D. Versey of the Jamaican Geological Survey sent me a collection of specimens from a bore hole drilled by Alumina Jamaica near Kendal in Manchester Parish, Jamaica, B. W. I. At depths of 1470 and 1558 feet there were numerous, well-preserved specimens of *Pellatispirella matleyi* (Vaughan), a species which Hanzawa (1937) made the type of this genus.

As these specimens show the internal structures better than any specimens previously studied by me, they are described and illustrated in order to further clarify and establish the relationship of this genus and the structures which characterize it.

Cole (1947, p. 13; 1953, p. 29, 31) earlier suggested that *Pellatispirella* was related to the nonionids rather than the camerinids and that this genus was distinct from *Miscellanea* Pfender, 1935. Fortunately, specimens of *Elphidium* (fig. 9, Pl. 32; figs. 11, 12, Pl. 34) occur in the same samples from this well as does *Pellatispirella*. Moreover, these *Elphidium* have the same type of preservation, therefore, direct comparison is possible. In addition, five specimens of *Miscellanea miscella* (d'Archiac and Haime) from the Kohat District, near Shinki, Wazaristan, India, collected by the late L. M. Davies, were available for study.

Miss Ruth Todd of the U. S. Geological Survey kindly examined the *Elphidium* for me and tentatively identified them as

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[1] The expense of the plates and certain other costs have been defrayed by the William F. E. Gurley Foundation for Paleontology of Cornell University.

Elphidium lens Galloway and Heminway. As the exact determination of the species was not important for this study, she was requested to give an opinion only concerning the probable specific name. I am grateful for the time and information she gave.

DESCRIPTION OF SPECIES

Genus **MISCELLANEA** Pfender, 1935

Miscellanea miscella (d'Archiac and Haime)

Pl. 32. fig. 10; Pl. 33, figs. 2, 3, 10, 11; Pl. 34, fig. 1. 3.

1937. *Miscellanea miscella* (d'Archiac and Haime), Davies, Geol. Survey of India, Mem., n. s., v. 24, mem. 1, p. 43-45, pl. 6, figs. 1-3, 5, 7, 8 (references).

1941. *Miscellanea miscella* (d'Archiac and Haime), Vaughan and Cole, Geol. Soc. Amer., Sp. Paper 30, p. 32, 33, pl. 5, figs. 1, 2.

The test is inflated lenticular or has an inflated umbo with a slightly compressed peripheral area surrounding the inflated part. On the umbo there are numerous, raised, separated pustules. The major sutures are almost straight, radial, and raised. They are virtually continuous from the umbonal area to the periphery of the test, but occasionally they are broken by small pustules. Between each pair of major sutures there are radial rows of small pustules.

The median section available for this study has a height of 3.5 mm. and a width of 3.3 mm. The embryonic chambers are bilocular. The initial chamber has diameters of 280 by 340 μ, the second chamber has diameters of 140 by 350 μ, and the distance across both chambers is 430 μ. The wall of the embryonic apparatus encloses a canal which appears to encircle the embryonic chambers.

This test is composed of 2 3/4 volutions with 8 chambers in the first whorl, 31 chambers in the final whorl and 55 chambers in all the volutions.

The septal walls enclose a large canal and at their proximal ends expand into a looplike, hollow knob (fig. 3, Pl. 34). The major aperture occurs between the end of this septal loop and the revolving wall.

The two transverse sections have the following measurements:

Height	mm.	2.75	3.0
Thickness	mm.	1.7	1.4
Diameters across both embryonic chambers	α-	450 x 350	370 x 480
Umbonal plugs:			
Total diameter	μ-	650	700
Diameters of individual plugs	μ-	100-240	100-150

The wall of the spiral sheet is double (fig. 10, Pl. 33), composed of a thick inner wall which is pierced by numerous coarse radial canals and a thin outer wall. Between the inner and the outer wall there are vacuoles. A few coarse pectinations project above the surface of the outer wall, and these are continued inwardly into the inner wall. Most of the pectinations of the inner wall, however, stop before they reach the outer wall.

A semitriangular shaped canal (fig. 11, Pl. 33) occurs in the area of the marginal cord. This canal is bounded by a distinct wall, at the outer margin of which are found minute pores. This structure is interpreted as a modified marginal cord.

Genus **PELLATISPIRELLA** Hanzawa, 1937

Pellatispirella matleyi (Vaughan)

Pl. 32, figs. 1-8; Pl. 33, figs. 1, 4, 6, 8, 9; Pl. 34, figs. 2, 4-10

1929. *Camerina matleyi* Vaughan, Journ. Paleont., v. 3, No. 4, p. 376, 377, pl. 39, figs. 2-7.
1937. *Pellatispirella matleyi* (Vaughan), Hanzawa, *idem,* v. 11, No. 2, p. 115, pl. 21, figs. 4-7.
1941. *Miscellanea matleyi* (Vaughan), Vaughan and Cole, Geol. Soc. Amer. Sp. Paper 30, p. 32, 33, pl. 6, fig. 1.
1944. *Miscellanea matleyi* (Vaughan), Caudi, Bull. Amer. Paleont., v. 28, No. 114, p. 369-371.
1947. *Pellatispirella matleyi* (Vaughan), Cole, *idem,* v. 31, No. 126, p. 228, 229, 237.
1948. *Miscellanea antillea* (Hanzawa), Cizancourt, Bull. Soc. Géol. France, ser. 5. v. 18, p. 667, 668, pl. 23, figs. 4, 7, 12, not *Pellatispirela antillea* Hanzawa, 1937.
1948. *Miscellanea hedbergi* Cizancourt, *idem,* p. 669, pl. 23, figs. 1-3.
1948. *Miscellanea nicaraguana* Cizancourt, *idem,* p. 669, pl. 23, figs. 5, 6, 8-11, 13.
1953. *Pellatispirella matleyi* (Vaughan), Cole, Bull. Amer. Paleont., v. 35, No. 147, p. 28-30, pl. 1, fig. 1.
1954. *Miscellanea matleyi* (Hanzawa), Cizancourt, Soc. Géol. France, C. R. for 3 March.

The diameter of the test ranges from about 1 mm. to 2.4 mm. The cross-section is evenly lenticular to compressed. Well-preserved specimens have a smooth, finely perforate shell wall on which the sutures appear as slightly raised, gently recurved lines. On the umbos there is a small mass of clear shell material which represents the surface of the umbonal plug. Many of the sutures bifurcate a short distance beyond their proximal ends. Slightly weathered specimens have coarse pits over the central part and a zone of concentric raised ridges in the peripheral area. More intensely weathered specimens have an expanded zone of concentric ridges which extends from the periphery almost to the center of the test.

Measurements of five median sections from the well drilled by Alumina Jamaica near Kendal, Manchester Parish follow:

Depth ....ft -	1470			1558	
Height ....mm. -	1.35	1.95	2.03	2.4	2.37
Width ....mm. -	1.27	1.9	1.88	2.27	2.28
Diameters of initial chamber ....μ -	200 x 240	170 x 190	150 x 180	170 x 190	210 x 240
Whorls ....no -	2½	4	3¼	4¾	5
Chambers:					
First volution ....no -	9	9	8	10	13
Final volution ....no -	22	31	29	34	41
All volutions ....no -	43	84	71	105	140

The initial chamber is large. This is followed by a smaller chamber which seems to be the first chamber of the initial whorl rather than the second chamber of the embryonic apparatus (fig. 10, Pl. 34). Thus, the unilocular embryonic apparatus of this species is similar to that found in certain species of *Elphidium* (fig. 12, Pl. 34).

The septal walls are solid without any evidence of a canal. In exactly centered median sections a siphonate major aperture appears (figs. 4, 7, Pl. 32; fig. 2, Pl. 34) near the proximal ends of septal walls. This siphonate aperture is a distinctive feature of this genus.

Measurements of six transverse sections from the same samples as those from which the median section were obtained follow:

Depth ft -	1470			1558		
Height mm. -	1.25	1.7	2.32	1.85	2.29	2.13
Thickness mm. -	0.76	0.55	1.1	0.9	0.85	1.05
Diameters of initial chamber μ -	150 x 160	85 x 90	220 x 230	—	70 x 160	200 x 210
Surface diameter of umbonal plug μ -	220	280	180	270	270	300

In transverse sections the test is compressed lenticular (fig. 6, Pl. 33) to inflated lenticular (fig. 9, Pl. 33). Most specimens have a bluntly rounded periphery, but certain specimens (figs. 1, 4, Pl. 33) have a narrow peripheral flange developed by the contraction of the walls of the spiral sheet in the peripheral area so that these walls are parallel.

The major siphonate aperture appears in certain transverse sections (fig. 1, Pl. 32; figs. 6, 8, 9, Pl. 33) as an opening with a nearly flat proximal side and a gently arched distal side. Small secondary pore apertures occur along the distal margins of the spiral sheet (fig. 2, Pl. 32; fig. 8, Pl. 33). The pore apertures are similar to those found in certain species of *Elphidium* (fig. 7, Pl. 33) except in that genus these apertures occur both on the distal and proximal margins of the spiral sheet.

The wall of the spiral sheet is pectinate on the distal margin. Small transverse canals occur between each pectination. There is no marginal cord. The wall structure is similar to that of *Elphidium* (fig. 7, Pl. 33; fig. 11, Pl. 34) except the pectinations are more prominent in *Pellatispirella*.

DISCUSSION

Generic comparisons.—The table which follows was prepared in order to demonstrate the similarities and differences between *Pellatispirella*, *Miscellanea*, *Elphidium*, and *Operculinoides*, particularly specimens of this latter genus which have been assigned variously to *Pellatispirella* [*P. antillea* Hanzawa, 1937], *Miscellanea* [*M. antillea* (Hanzawa) Vaughan and Cole, 1941], and *Ranikothalia* [*R. antillea* (Hanzawa) Caudri, 1944].

TABULAR COMPARISON OF *PELLATISPIRELLA*, *MISCELLANEA*, *ELPHIDIUM*, AND *OPERCULINOIDES*

	Pellatispirella	*Miscellanea*
Maximum diameter	2.4 mm.	8.7 mm. or more
Embryonic apparatus	Unilocular	Bilocular
Marginal cord	Not present	Modified type
Septa	Without central canal	With central canal
Major aperture:		
Position	Above base of septum	At base of septum
Special features	Siphonate	Looplike base of septum above aperture
Secondary pore apertures	Present	Present
Wall of spiral sheet:		
Pectinations	Completely developed	Irregularly developed
Transverse canals	Small, numerous	Coarse, numerous
Character of wall	Single	Double

	Elphidium	*Operculinoides*
Maximum diameter	1.8 mm.	12 mm. or more
Embryonic apparatus	Unilocular	Bilocular
Marginal cord	Not present	Present
Septa	Without central canal	With central canal
Major aperture:		
Position	Not observed	At base of septum
Special features	Not observed	Slitlike
Secondary pore apertures	Present	None observed
Wall of spiral sheet:		
Pectinations	Completely developed	Not present
Transverse canals	Small, numerous	Coarse, infrequent
Character of wall	Single	Single

The general structure of *Pellatispirella* most nearly resembles that of *Elphidium* whereas that of *Miscellanea* is similar in many respects to *Operculinoides* although there are greater differences between the latter genera than the former.

Although the generic name *Miscellanea* had been applied to various American species by Vaughan and Cole (1941), Vaughan (1945), Cole (1947), and Cizancourt (1948), Caudri (1944) erected the generic name *Ranikothalia* for the species considered to be *Miscellanea* except the species *matleyi* which she retained under *Miscellanea*. As this study proves that the structure of *P. matleyi* is entirely different from that of *Miscellanea miscella*, there are no American species described to the present which are referrable to *Miscellanea*.

Cole (1953) considered that *Ranikothalia* is a synonym of *Operculinoides* inasmuch as the structures in the two genera are identical and differ only in degree. The American species referred to *Ranikothalia* by authors normally have a much coarser and larger marginal cord than do other specimens referred to *Operculinoides*. Although Cole (1953) demonstrated that the marginal cord was a variable feature in *Camerina* and also in *Operculinoides*, this variation was not so clearly shown for *Operculina*. An additional marginal cord from a specimen of *Operculina* is illustrated (fig. 5, Pl. 33). This should be compared with illustrations given by Hofker (1927, pl. 32, fig. 6) and Cole (1953, pl. 2, fig. 1) which prove that the same variability occurs in the marginal cord of *Operculina*. Therefore, it would seem that the degree of development of the marginal cord in any genus of the camerinids is a specific, not a generic, character and cannot be used to distinguish *Ranikothalia* from *Operculinoides*.

Comparison of species of Pellatispirella.—Vaughan (1929, pl. 39) illustrated four thin sections of *Camerina matleyi* of which three were sufficiently clear to furnish measurements. Hanzawa (1937, pl. 21) illustrated four specimens of *Pellatispirella matleyi* of which two could be used for measurements. Vaughan and Cole (1941, pl. 6) supplied an additional transverse section of *Miscellanea matleyi*. Eleven thin sections were available from the material supplied by H. R. Versey from the well of Alumina Jamaica. All of these specimens are thought to represent typical *Pellatispirella matleyi* (Vaughan) regardless of the generic assignments given them in the previous publications. In addition numerous specimens were available in the thin sections studied by Cole (1956) for the report on Jamaican larger Foraminifera.

The measurements obtained from the illustrations cited above and the specimens from the well of Alumina Jamaica were plotted on the scatter diagram (fig. 1) in order to graphically show the relationship of these specimens to each other. To the diagram were added the species described by Mrs. de Cizancourt (1948) from Nicaragua.

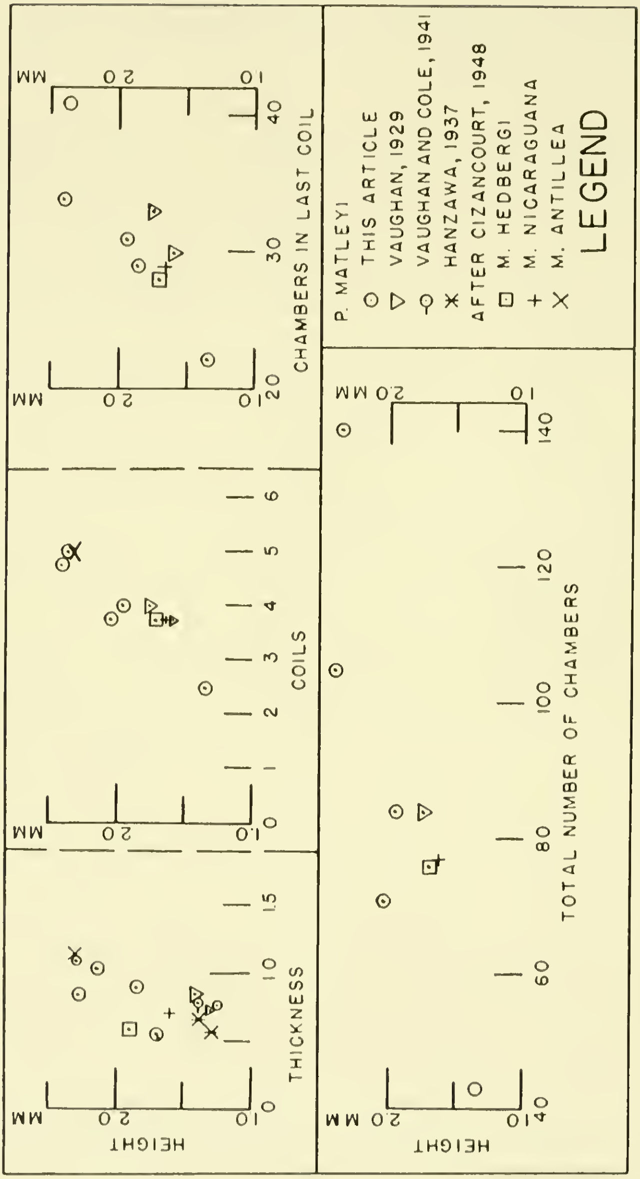

Fig. 1.—Scatter diagrams to show the relationship of the species considered to represent *Pellatispirella matleyi* (Vaughan)

She described under the generic name *Miscellanea* the following: *Miscellanea antillea* (Hanzawa), *M. hedbergi*, and *M. nicaraguana*. In this article she referred to specimens identified by Hanzawa (1937, pl. 21, figs. 4-7) as *Pellatispirella matleyi* (Vaughan) as *Miscellanea antillea* (Hanzawa), and at the same time she referred to specimens identified by Hanzawa (1937, pl. 20, figs. 8-10; pl. 21, fig. 1) as *Pellatispirella antillea* as *Nummulites* (*Nummulites*) *antillea* (Hanzawa). Thus, she used the specific name applied by Hanzawa to one species for two species. Therefore, Hanzawa is credited with a specific name used in one case for the species for which he intended to use it [*Pellatispirella antillea* Hanzawa, 1937 = *Nummulites* (*Nummulites*) *antillea* (Hanzawa) Cizancourt, 1948] and in the other case for a species which he considered to be a different one [*Pellatispirella matleyi* (Vaughan) Hanzawa, 1937 = *Miscellanea antillea* (Hanzawa) Cizancourt, 1948].

Later, Thalmann (1950, p. 43) wrote Mrs. de Cizancourt that Cushman (1919, p. 51) had used the name *Nummulites antillea* for specimens from St. Bartholomew. Therefore, he suggested that a new name be proposed for *Nummulites* (*Nummulites*) *antillea* (Hanzawa) Cizancourt 1948 = *Pellatispirella antillea* Hanzawa, 1937. The name given was *Nummulites* (*Nummulites*) *caraibensis* Cizancourt. Inasmuch as Cole (1953, p. 53) showed that *Pellatispirella antillea* Hanzawa, 1937, was a synonym of *Operculinoides bermudezi* (D. K. Palmer), 1934, the specific name *N.* (*N.*) *caraibensis* must be suppressed.

The name *Miscellanea antillea* (Hanzawa) Cizancourt (1948, p. 667), however, remains undisturbed by these changes. Even casual examination of the illustrations given (Cizancourt, 1948, pl. 23, figs. 4, 7, 12) of the specimens from Nicaragua which she called *Miscellanea antillea* (Hanzawa) shows that these specimens belong to a different genus than does *Pellatispirella antillea* Hanzawa, 1937. Numerous illustrations have been given of this species, originally described by Hanzawa, by Vaughan and Cole, 1941, Vaughan, 1945, and others. All of these specimens have an entirely different internal structure from that of the specimens from Nicaragua. But, the structure of the wall of the spiral sheet of the specimens from Nicaragua is identical with that of the Jamaican specimens (compare Cizancourt, 1948, pl. 23, fig. 4 with the Jamaican specimen illustrated in this article as figure 9, Plate 33 and with Vaughan's (1929) illustrations of the types).

Detailed examination proves that the three species from Nicaragua have the same internal structure and the same external appearance as do typical specimens of the type of the genus *Pellatispirella* represented by *P. matleyi* (Vaughan). Moreover, when the measurements of these specimens were plotted on the scatter diagram (fig. 1) they fall within the limits of this species. Therefore, only one species can be recognized, namely, *P. matleyi* (Vaughan). This species occurs in the middle Eocene of Jamaica, Nicaragua, Cuba, and the Dominican Republic (specimens identified by P. J. Bermudez and later sent to me).

The philosophy concerning the erection of specific and subspecific names for Foraminifera without a complete analysis of the variation which may occur in a single species was expressed adequately by Vaughan (1933, p. 7) when he wrote: "From the accounts given in this paper of variation in single lots of specimens of species of *Lepidocyclina* and from such work as that of Jennings, it is obvious that to attach a different specific name to every variant in a lot of specimens of *Lepidocyclina* is an absurdity".

Other American species resembling Miscellanea and Pellatispirella.—Applin and Jordan (1945, p. 139) described a species under the name *Miscellanea nassauensis* from the lower Eocene of Florida. Cole (1947, p. 227) made thin sections of topotypes and concluded that these small specimens should not be referred to *Miscellanea*. He recognized similarity in the internal structure to the elphidids, and, therefore transferred this species to the genus *Nonion*. Later, he (1953, p. 30) decided that this species "has a spiral lamina which shows pectinations similar to those found in *Pellatispirella*" and transferred this species to that genus.

Although this species is related to *Pellatispirella*, the major aperture is different. Externally and internally this Floridian species most nearly resembles *Fissoelphidium operculiferum* Smout (1955, p. 209) described from the Maestrichtian of Dukham Oilfield, Qatar Peninsula of Arabia, and probably should be assigned to this genus. With the data now at hand the Floridian species cannot be referred either to *Miscellanea* or *Pellatispirella*.

Family relationships.—Smout (1955) presented recently a thought provoking reclassification of the Rotaliidea. In the family Miscellanidae he placed *Miscellanea* and questionably *Pellatispirella* together with other genera "in which the canal system is strongly developed with subsutural and intraseptal canals and either vertical canals or a system of fissures. There is no differentiated marginal cord".

It would appear from the analysis of *Miscellanea* that this genus possesses a modified marginal cord, and that it represents a camerinid. The structure of the test of *Pellatispirella* more nearly resembles that of *Elphidium* and, therefore, this genus should be assigned either to the elphidids or a new family. So far as could be observed *Pellatispirella* does not possess an intraseptal canal or a marginal cord.

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PLATES

Explanation of Plate 32

Figure		Page
1-8.	**Pellatispirella matleyi** (Vaughan)	241

1, 2. Transverse sections of megalospheric specimens; 1, X 20; 2, X 40; these specimens show the pectinate character of the wall of the spiral sheet, the single large embryonic chamber and the major apertures, two of which show clearly in the upper part of figure 1.

3-8. Median sections; 3-5, 7, 8, X 20; 6, X 40; 3-7, megalospheric specimens; 8, probably a microspheric specimen; these specimens show the single embryonic chamber, the number and type of chambers and coils; 4, 7, show the siphonate major apertures; see figure 2, Plate 34 for enlargement of the siphonate major apertures which occur in the specimen represented by figure 7; see figure 10, Plate 34 for an enlargement of the embryonic chambers of the specimen represented by figure 3.

Figure		Page
9.	**Elphidium lens** Galloway and Heminway	243

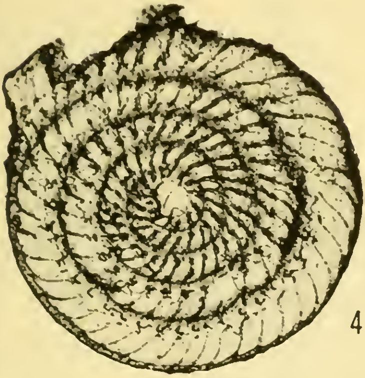
Transverse section, X 40, introduced for comparison with those of *Pellatispirella matleyi*.

Figure		Page
10.	**Miscellanea miscella** (d'Archiac and Haime)	240

Median section, X 20, which shows the bilocular embryonic chambers, the canal in the septal walls, and the granulations of the spiral sheet.

1-9. From a well drilled by Alumina Jamaica near Kendal, Manchester Parish, Jamaica, B.W.I.; 1-3, 5, 6, 9, at a depth of 1470 feet; 4, 7, 8, at a depth of 1558 feet.

10. From the Kohat District, near Shinki, Wazaristan, India, collected by the late L. M. Davies.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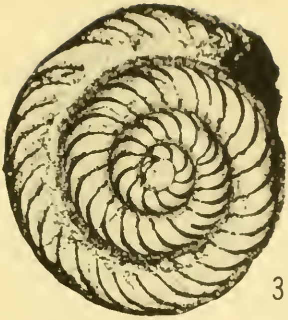
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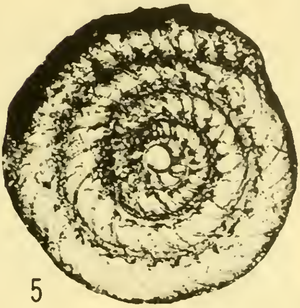
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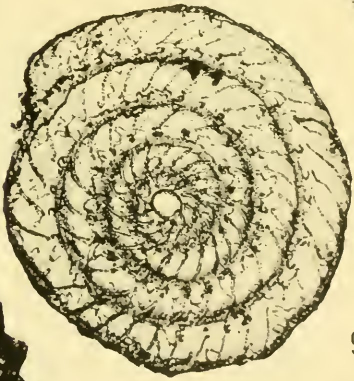
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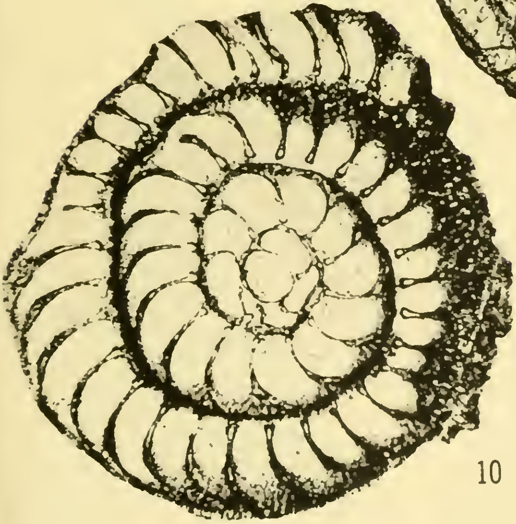
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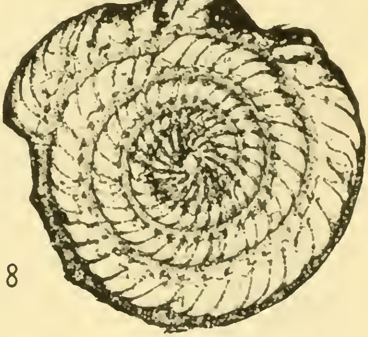
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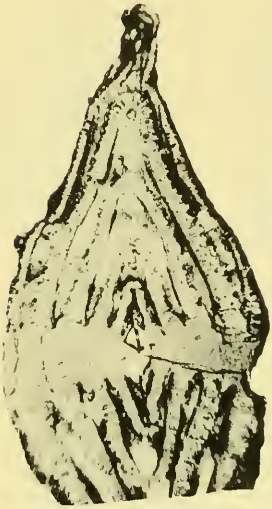

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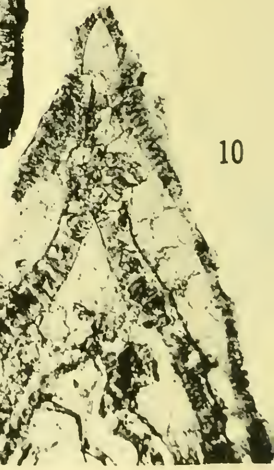

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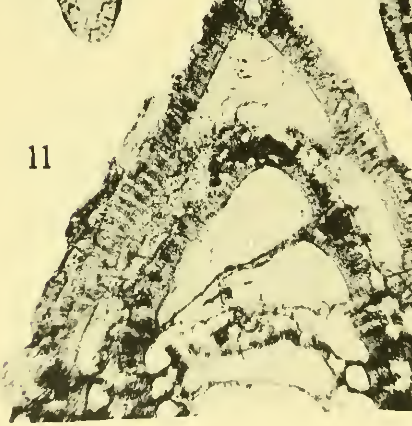

11

Explanation of Plate 33

Figure Page

1, 4, 6, 8, 9. **Pellatispirella matleyi** (Vaughan) 241
Transverse sections; 1, 6, 8, 9, X 40; 4, X 20; 1, enlargement of the upper portion of figure 4 to show the contraction of the walls of the spiral sheet to form a flange; 6, a compressed specimen; 8, a specimen which shows two major siphonate apertures and numerous secondary pore apertures bordering the margin of the spiral sheet; 9, an inflated specimen.

2, 3, 10, 11. **Miscellanea miscella** (d'Archiac and Haime) 240
Transverse sections; 2, 3, X20; 10, 11, X 40; 10, an enlargement of the upper part of figure 3; 11, an enlargement of the upper part of figure 2; these specimens show the large bilocular embryonic chambers, the semicircular canal of the marginal cord, the coarse vertical canals of the spiral sheet and the double wall of the spiral sheet between which occur vacuoles which feature is shown clearly in figure 10.

5. **Operculina complanata japonica** Hanzawa 245
Part of a transverse section, X 40, to show a broad, well-developed marginal cord.

7. **Elphidium** sp. 243
Transverse section, X 40, which shows the wall structure and pore apertures, introduced for comparison with *Pellatispirella*.

1, 4, 8, 9. From a well drilled by Alumina Jamaica near Kendal, Manchester Parish, Jamaica, B.W.I.; 1, 4, 8, 9, at a depth of 1558 feet; 6, at a depth of 1470 feet.

2, 3, 10, 11. From the Kohat District, near Shinki, Wazaristan, India, collected by the late L. M. Davies.

5. From sta. L 466, Oneata, Lau, Fiji.

7. Beach sand, Rimini, Italy.

Explanation of Plate 34

Figure — Page

1, 3. **Miscellanea miscella** (d'Archiac and Haime) 240

1. External view, X 10; 3, central part, X 40, of the specimen illustrated as figure 10, Plate 32, to show the embryonic chambers, major apertures and septal walls.

2, 4-10. **Pellatispirella matleyi** (Vaughan) 241

2. Two siphonate major apertures, X 230, from the median section illustrated as figure 7, Plate 32; 4-9, external views, X 10, to to show size differentiation and surface sculptures; 10, central part, X 40, of the specimen illustrated as figure 3. Plate 32, to show the embryonic chamber and the initial volutions.

11, 12. **Elphidium lens** Galloway and Heminway 242, 243

11. Transverse section, X 40, to show the single embryonic chamber, the wall structure of the spiral sheet and the umbonal plugs; 12, median section, X 40, to show the single embryonic chamber and the volutions.

1, 3. From the Kohat District, near Shinki, Wazaristan, India, collected by the late L. M. Davies.

2, 4-12. From a well drilled by Alumina Jamaica near Kendal, Manchester Parish, Jamaica, B.W.I.; 2, at a depth of 1558 feet; 4-12, at a depth of 1470 feet.


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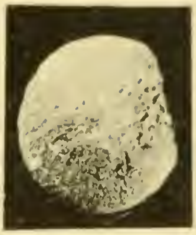
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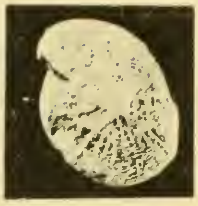
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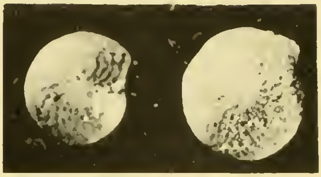
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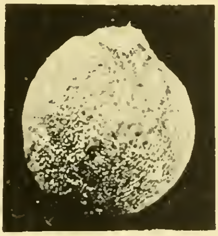
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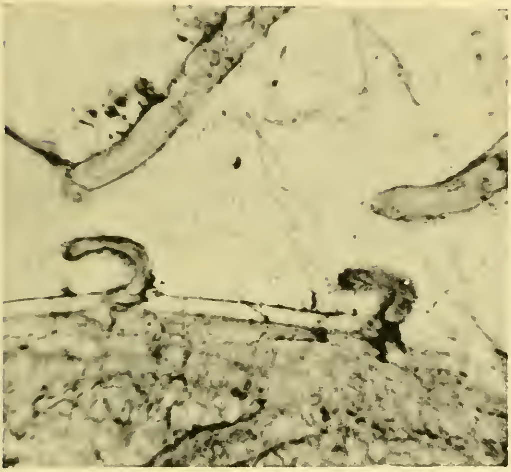
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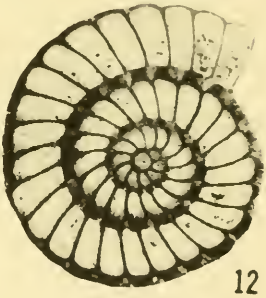
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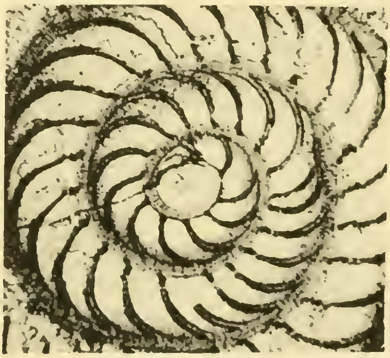

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THE FORAMINIFERA OF THE YORKTOWN FORMATION IN THE YORK-JAMES PENINSULA OF VIRGINIA, WITH NOTES ON THE ASSOCIATED MOLLUSKS

James D. McLean, Jr.

September 26, 1956

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THE FORAMINIFERA OF THE YORKTOWN FORMATION IN THE YORK-JAMES PENINSULA OF VIRGINIA, WITH NOTES ON THE ASSOCIATED MOLLUSKS

James D. McLean, Jr.

ABSTRACT

Foraminifera from the Yorktown formation (upper Miocene) of the York-James Peninsula, Virginia, are described. Ecologically, the Yorktown faunas prove to be from the upper and middle neritic as defined by Ladd, Gunter, and Revelle. The mollusk zonations, principally established by Mansfield and Gardner, seem to have little or no validity from either the mollusk or foraminiferal viewpoint. The age of the Yorktown formation appears to be topmost Miocene. Of 108 species of Foraminifera figured and described from the Yorktown, 29 forms are either new or require new names to set them off from forms erroneously identified with them in previous works. Taxonomic problems dealing with *Eponides*, *Buccella*, and the Globigerinidae are discussed. One new genus, *Rectocibicidella*, is described. Some results of studies of the pre-Yorktownian Miocene of the peninsula are given, including the zonations revealed by *Bolivina floridana* and *Siphogenerina lamellata*. Cross-sections are given, constructed from available subsurface data, and the extent of the formation is discussed.

SCOPE OF THE STUDY

Limits of time and financial support have forced the restriction of this report to the York-James Peninsula area geographically. A study of the entire Yorktown formation as delineated by others would require a greater time than at present available, not only because of the geographic extent of the formation, but also because the Foraminifera differ markedly from place to place as revealed by preliminary check of subsurface and surface samples.

Foraminifera of the Yorktown formation in the York-James Peninsula, described in this paper, include those of the classic outcrop from which the formation received its name. It is felt by the writer that all "zones" discovered in the peninsular area have been adequately covered by collections, although it proved impossible to secure samples revealing so minute a subzonation of the formation as has been reported by other workers.

Mollusk collections were made at the various localities, but as the primary objective was to assemble foraminiferal material, the mollusk collections may appear to be somewhat meager. The collected mollusks do, however, represent an attempt to obtain the entire fauna associated with the Foraminifera at the collection levels.

CHARACTER OF THE COLLECTED SEDIMENTS

From analysis of samples collected from well drillers and at outcrop, the Yorktown formation may be characterized as a fine sand and clay with considerable shell material which is more often fragmented than not. At two spots in the Carter's Grove outcrop, considerable gravel was found.

CONDITION OF THE OUTCROPS

Due to extensive bank conservation practices now common throughout the peninsula, most well-known collecting places have been obliterated; furthermore, at those spots still accessible, plant and debris coverage make it impossible either to observe or confirm the various disconformities or stratifications reported in earlier works.

Some areas, presumably still good collecting localities, are closed by private and governmental restrictions.

Lastly, descriptions of outcrop localities in the literature leave much to be desired as far as actually locating them in the field is concerned. One locality, the King's Mill Wharf of Gardner and Mansfield, is now so situated that even the present natives of the area have never visited it, being unable to reach the locality because of the destruction of the access road and the wharf.

CONDITION OF THE MOLLUSK AND FORAMINIFERAL MATERIAL

Much mollusk material is fragmented and heavily leached. Excellent collections of well-preserved shells are obtainable, often with the valves of pelecypods still closed and articulated. Ostracod specimens also are commonly articulated. One crushed echinoid was recovered which appears to retain some of its original form.

Foraminifera (and Ostracoda) are remarkably fresh and well preserved except for the miliolids and *Poroeponides lateralis* which appear to tend to be chalky and easily disintegrated. In no case is the concentration of Foraminifera and Ostracoda large—great quantities of sediment must be washed and the specimens concentrated by flotation in order to obtain representative faunas. The best faunas of microscopic forms have been obtained from sediments enclosed in articulated pelecypods and from sediments protected from leaching by large pectens and heavy forms of venerids. Specimens encased in the clayey sediment at the base of the Moore House Beach seem also to be well preserved though not in large concentrations.

ACKNOWLEDGMENTS

Writing a report such as this one entails the assistance of many people, many of whom cannot be given full credit for their help in the space allotted to an acknowledgment. Those who are herewith acknowledged for their generous help are not responsible for the conclusions and errors in this paper, for these are the author's own.

The National Science Foundation, through its assistance in the form of a research grant sponsored by the Paleontological Research Institution made possible the study of a problem which was first conceived in 1947 when collections of Foraminifera from the Yorktown formation were made by the author. Dr. H. K. Stephenson, Director of Earth Sciences of the National Science Foundation, is the only individual in that organization with whom the author has had direct contact—his kindness in solving some of the problems of administration of project affairs and other matters has been both appreciated and will be long remembered.

Dr. Katherine V. W. Palmer, Director of the Paleontological Research Institution, has not only administered the grant with every consideration for the author, but she was most helpful in the matter of submission of the project application. Through her interest and assistance, the Paleontological Research Institution agreed to act as sponsor of the project, and in her capacity as editor, she has guided the author in the final writing of this paper.

Dr. Harald Rehder, Curator, Division of Mollusks of the U. S. National Museum, is owed a special debt of thanks for his interest in the author's studies and his readiness to help wherever

possible, often far beyond his duties as a representative of the National Museum. He has additionally contributed to this paper by assisting in the determination of mollusk ecology so far as it was possible to render aid in that difficult field.

Dr. Julia Gardner, U. S. Geological Survey, Mr. Druid Wilson, also of the Survey, and Dr. Horace G. Richards of the Academy of Natural Sciences of Philadelphia, all contributed identifications of the several collections of mollusks made by the author. Dr. Richards was responsible for the author's realization of the Yorktown problem, for it was while a student under him that the author first collected at the Yorktown outcrops.

I am indebted to H. E. LeGrand and Philip Brown, U. S. Geological Survey Ground Water Branch, Raleigh, N. C., for samples from North Carolina; to Dr. J. C. Troelsen of the Mineralogisk-Geologiske Institut, Copenhagen, Denmark, for European Miocene samples and to W. T. Parrott, Geologist, Virginia State Highway Commission, for samples from the test holes of the New Coleman Memorial Bridge across the York River. The Virginia Geological Survey and Mr. Paul Schweitzer of the Layne-Atlantic Company, Norfolk, furnished well samples from the York-James Peninsula; and the Virginia Geological Survey also furnished out-of-print data from their publication files.

The librarians of the National Museum, the University of Virginia, and George Washington University have all assisted by allowing the author to use their facilities, including microfilming and photostating of rare or otherwise unobtainable material.

One of my constant inspirations during this work has been the unfailing interest and advice of Dr. Joseph Kent Roberts of the University of Virginia, whose own writings have served the author greatly in this task.

Mrs. Archibald McCrea kindly allowed access to her estate, Carter's Grove, the banks of which contain the best single outcrop of the Yorktown formation now available. Mr. George Barclay of Newport News gave the author the benefit of his many years of experience in collecting mollusks from the Yorktown formation. His systematic collection of mollusks is one of the most comprehensive made in American Tertiary material.

The author could not have completed this study without the cheerful aid given by his parents, who have taken him over the outcrops, and assisted in the collecting and other aspects of the work. Their tolerance of the annoyances of an author at work has been a great comfort.

Illustrations are the heart of a work such as this one. Mrs. Sally Kaicher, scientific illustrator, did a magnificent job of drawing the Foraminifera and also did most of the plate layout work. Mr. John A. Larsen, Instructor in Drawing at George Washington High School, constructed the charts, cross-sections and maps in this paper. Typing of the manuscript was done by Mrs. Edna Dove. Only those who have had to deal with such work can appreciate the service she rendered in that thankless task.

For their assistance in various phases of this work, the author thanks Mr. William McGill, Dr. D. J. Cederstrom, Mr. Allen Sinnott, Mr. G. Chase Tibbitts, Miss Ruth Todd, Dr. A. R. Loeblich, Jr., and Mr. Barth Conrath.

DEPOSITION OF SPECIMENS

Holotypes, paratypes, syntypes, and plesiotypes of Foraminifera are deposited in the Paleontological Research Institution. The entire foraminiferal fauna is contained on slides numbered from P. R. I. No. 22,000 to and including 22,484, and the arrangement of the slides under these numbers is such that the specimens are in systematic order (Cushman classification) when the numbers are in consecutive order. The exception to this arrangement is *Amphistegina* sp. which is a late acquisition resulting from a field trip in which the author was accompanied by Dr. Denise Mongin of the Centre National de la Recherche Scientifique—Paris. This specimen is given the last number of the series. The collection at the Paleontological Research Institution not only includes specimens of every species found, but also includes individuals of every species found at each locality and level examined.

Such paratypes as could be spared without interrupting either the locality groups or the taxonomic variants of this foraminiferal collection have been deposited at the U. S. National Museum, and these paratypes bear the numbers from P3104 to and including P3117 of that institution.

The greater part of the mollusks listed in this paper are at the Academy of Natural Sciences of Philadelphia, where they were deposited by the author some years before the inception of this research project. Mollusks collected during this project (and identified by Mr. Druid Wilson) are deposited at the Paleontological Research Institution. Mollusks collected by Dr. Denise Mongin, and identified by her, will be deposited at some institution selected by Dr. Mongin. Foraminifera isolated from her material (and identified by the author) are being held by the author pending selection of a suitable European depository agreeable to Dr. Mongin. Dr. A. R. Loeblich, Jr., and Mrs. Helen Tappan Loeblich ably sum up my reasons for selection of a European depository (1955, p. 5) as follows:

> As students of Foraminifera are to be found in almost every area of the globe, it would seem better to increase the frequency of exchanges of specimens, so that those wishing to make generic revisions can see at first hand the species or genera they are studying, and not depend solely on the literature.

While the scope of proposed generic revision envisaged by these two scientists is a matter with which I am not here concerned, I do believe it is important to give access to specimens in the manner suggested. If this should cause those close to the types of D'Orbigny and others to discover that my forms are not the same species as those to which they are referred, I count this as a desirable advance in the science which should be brought about. By such direct comparison essential relationships of faunas can be established, and the relationships of global stratigraphy can be furthered.

RESUME AND DISCUSSION OF PAST WORK ON THE YORKTOWN FORMATION

The Yorktown formation and its well-known mollusk fauna have been the object of much collection and many papers. The literature is too large to review fully, therefore, this discussion is limited to past development of stratigraphic knowledge of the area.

Clark and Miller (pp. 19-20, 1906) first defined the Yorktown as a formation as follows:

The Yorktown Formation

> The Yorktown formation, which receives its name from Yorktown, Virginia, apparently overlies the St. Mary's formation conformably. The infrequent exposure of the beds, due to the heavy cover of later sediments, renders it difficult to determine many of its characteristics and its entire area of outcrop. It does not appear at the surface in Maryland, although, perhaps, part of the great thickness of Miocene beds penetrated in the Crisfield well should be assigned to this formation.
>
> The deposits which consist of sands and clays are crowded with remains of calcareous shells, chiefly marine mollusca, and at Yorktown and on the James River afford the most highly fossiliferous beds in the Chesapeake Bay region. Thick beds almost entirely composed of broken shells, representing shallow-water deposition, form the most striking feature. The thickness of the formation is apparently in excess of 100 feet. The fossils show certain differences when compared with the underlying Miocene formations, and evidently represent a distinct faunal aggregate.
>
> The Calvert, Choptank, St. Mary's and Yorktown formations combined constitute the Chesapeake group. The deposits have many common characters, both physical and faunal.

Later study (McLean, 1950) revealed the existence of a Yorktown interval at Crisfield which is about 74 feet thick.

Clark and Miller were correct in calling attention to the shallow water character of the Yorktown formation. Even where there is no evidence such as their "thick beds almost entirely composed of broken shells" the fauna still shows a shallow water environment. (See section on ecology of this paper.)

In 1927 Wendell C. Mansfield completed a doctoral thesis[1] on the Miocene stratigraphy of Virginia "Based upon the study of the Faunas". In this thesis he established what was to be the basis for Yorktownian stratigraphy.

Mansfield divided the Yorktown into two zones: Zone I (*Pecten clintonius* zone) succeeded by Zone II (*Turritella alticostata* zone). He stated on page 134 (of typed copy) that Olsson's "Murfreesboro Stage" contained two horizons, one of which he assigned to Zone I *(Pecten clintonius)* and the other to Zone II (*Turritella alticostata*) of the Yorktown.

Zone II (page 136 of typed copy) is said to "include all the Miocene sedimentary deposits in Virginia above the *Pecten clintonius zone*". The *Turritella alticostata* zone is further divided into

---

[1] Unfortunately, it is impossible to follow his entire study, since three copies of the thesis have disappeared from George Washington University, and a fourth copy at the National Museum is not to be found. All that remains is a fragment typed from the National Museum copy and on file at the university.

three parts: "1. Lower part (beds below fragmental beds) 2. Middle part (fragmental beds) 3. Upper part (beds at and around Suffolk)" (page 138 of typed copy).

It is not possible at this writing to know how Mansfield defined the term "Zone" and perhaps he had a different concept of the term than its present-day geological connotation. As the term is interpreted by this writer, it denotes a stratigraphically limited factor wherein the "guide species" denotes an entity which can be used for correlation. The faunal assemblage accompanying the zone species should be distinct and correlative; the guide form ought to be a species whose name is a convenient reference point for the zone.

Some species from these two Yorktown "Zones" of Mansfield, as designated in U. S. Geological Survey Professional Paper 199-A, also may be located in the Maryland Miocene, although they are called characteristic of beds within zones of the Yorktown by Mansfield. Authority for this statement is the Maryland Survey's Miocene volumes, published in 1904 and available to Mansfield at the time he wrote his thesis and the outline in U. S. Geological Survey Professional Paper 199-A. Indeed, he listed these volumes in the thesis under discussion.

On page 10 of U. S. Geological Survey Professional Paper 199-A, Mansfield diagrammed the "beds" which he discriminated for the area near Yorktown. The bottom bed is designated as "bed a" and the top bed is "f", with four beds intervening. Mansfield listed "the more common and more significant species" of fossils for beds a-b, beds c, e, and f.

These beds are subdivisions of the *Turritella alticostata* zone (Zone II) as first defined by Mansfield in his thesis. Any attempt to utilize the fossil lists for correlation purposes soon shows the inapplicability of the lists to such use, and the "beds" would appear to be merely local facies which are discontinuous and are subject to disappearance upon extended bank erosion.

On page 9 of this same paper, is a diagram showing "Bed V" in Zone I (*Pecten clintonius* zone), and beds W to Z in Zones II (*Turritella alticostata* zone) at a section near old Kings Mill Wharf.

RELATION OF YORKTOWN FORMATION "ZONES" AS OUTLINED IN PROFESSIONAL PAPER 199-A BY MANSFIELD AND GARDNER. (U.S.G.S., PROF. PAPER 199-A, 1943, TABLE 1)

VIRGINIA	NORTH CAROLINA
Yorktown formation	
Zone 2 (*Turritella alticostata*)	Zone 2
Beds at Suffolk with beds at Biggs farm at top	Uppermost Yorktown with bed at Mt. Gould at top
	Duplin marl
Beds at Yorktown	Equivalent to beds at Yorktown, Va.
Chama-bearing bed (*Chama congregata*)	*Chama*-bearing bed
Zone 1 (*Pecten clintonius*)	Zone 1

CORRELATIONS AS OUTLINED BY MANSFIELD AND GARDNER

Yorktown formation = Sahelian of Europe = Upper Miocene of America

Zone 2 = Pontian of Europe = *Cancellaria* zone & "aluminous clay" of Choctawhatchee formation of Fla.

Zone 1 = Sarmatian of Europe = *Ecphora* zone of Choctawhatchee formation of Fla. = Raysor marl of South Carolina.

NOTE: *Turritella variabilis* var. *alticostata* Conrad is reported from the Choptank formation of Maryland (Md. Geol. Surv., Miocene Vols., 1904, p. 237, pl. 57, fig. 2), but this form as figured by the Maryland survey seems different from the *Turritella alticostata* of the Yorktown as figured by Gardner from North Carolina and as found by the author from the Virginia outcrops.

Chama congregata is reported from the Maryland Miocene (which is supposedly older than the Yorktown formation), and it is recorded as still living. The presence of *Chama congregata* beds, therefore, has no stratigraphic significance for the Yorktown formation unless such occurrence is supplemented by other stratigraphic evidence.

In 1932, Roberts published an excellent outline of the features of the Yorktown formation as it was then understood. The sections by Roberts (pp. 22-23, 1932) are of interest and have the merit that they can still be traced with fair success even with the present unsatisfactory overgrowths and modifications of outcrops by man and nature. The section at Carter's Grove is of particular interest to this present study in that it is the one section which the author has found which can be traced essentially as delineated, and Carter's Grove produced the most profitable foraminiferal faunas found.

Again, as in the case of Mansfield and Gardner, it is necessary to consider the meaning of the term "Zone" is it is used by Roberts. To judge from the cited section, it would seem that the term is used by Roberts in the sense that Mansfield used the term "Beds".

The "zones" of the Carter's Grove outcrop appear to be ecologic rather than "time" separations. There is a suggestion in the two *Chama congregata* "zones" separated by a *Venus tridacnoides* zone, that we are dealing with an exposure which shows a shift in environmental conditions which favors first one assemblage of forms and then another, only to revert at last to the first.

GEOLOGIC SECTION AT CARTER'S GROVE, ON JAMES RIVER, JAMES CITY COUNTY

From Roberts, 1932 p. 23:

	Feet
Quaternary	
Soil, yellow-brown, sandy	1-2
Sand, brown to yellow, mainly medium- to fine-grained, some coarse and well-rounded	8
Terrace gravel, mostly of rounded quartz boulders embedded in sand similar to that above	1¼
Sand, yellow-brown, bedding less apparent, and texture finer than in top layer; vertical jointing; uneven bottom surface	14
Miocene	
Yorktown formation:	
a. *Chama congregata* zone, containing a few other genera of fossils	7
b. *Venus tridacnoides* zone, containing very large shells of a few other genera and smaller shells of numerous genera	1
c. *Chama congregata* zone, main bed containing also many other genera	6
d. *Crassatellites* zone with *Venus, Glycimeris, Cardium,* and other genera	1½

e. *Pecten* bed with several species and numerous other genera	4
f. *Venus* zone, containing other species than *V. tridacnoides* and also other genera	1

Richards (1950, pp. 22-28) outlined the history and present knowledge of the Yorktown formation in North Carolina. He noted that *Pecten clintonius* is not a good index species for Zone 1 in the state, because it occurs only in the extreme northern part. In my map, I have used the data from Richards to determine the extent of the Yorktownian of North Carolina; the map may be considered to delineate the Zone 1 phase, since Richards noted that Zone 2 occurs only as "discontinuous patches across northeastern North Carolina". The Yorktown is largely exposed at river and creek banks and in some pits, being largely covered by thin Pleistocene beds. Richards' Table 3 is essentially the same as the one cited above from Mansfield and Gardner: The "Zone 2" at the base of the North Carolina column suggests a typographical error and should read "Zone 1" instead, and the column reading "Zone 2" on the left side should not extend to cover Zone 1.

I was informed (personal communication) by Richards that the Yorktown formation correlation in his Table 10 on page 54 was the result of typographical error, and that in this table the North Carolina Yorktown should correlate with that of Virginia, not above it as printed in the table. With this correlation established, the correlations by Richards are as follows:

Cohansey of New Jersey & Delaware	=Yorktown formation of Virginia	=Yorktown formation of North Carolina	=Raysor of South Carolina	=Pascagoula of Gulf Region

Apparently Richards correlated the Duplin marl with the Choctawhatchee of Florida and showed no Florida equivalent of the Yorktown, since the Duplin is listed above (or younger than) the Yorktown.

Two other publications seem especially significant in the study of Yorktown stratigraphy. The first of these is a circular on wells drilled in the Virginia Coastal Plains area, compiled in 1945 by D. J. Cederstrom. The essential data from this circular are por-

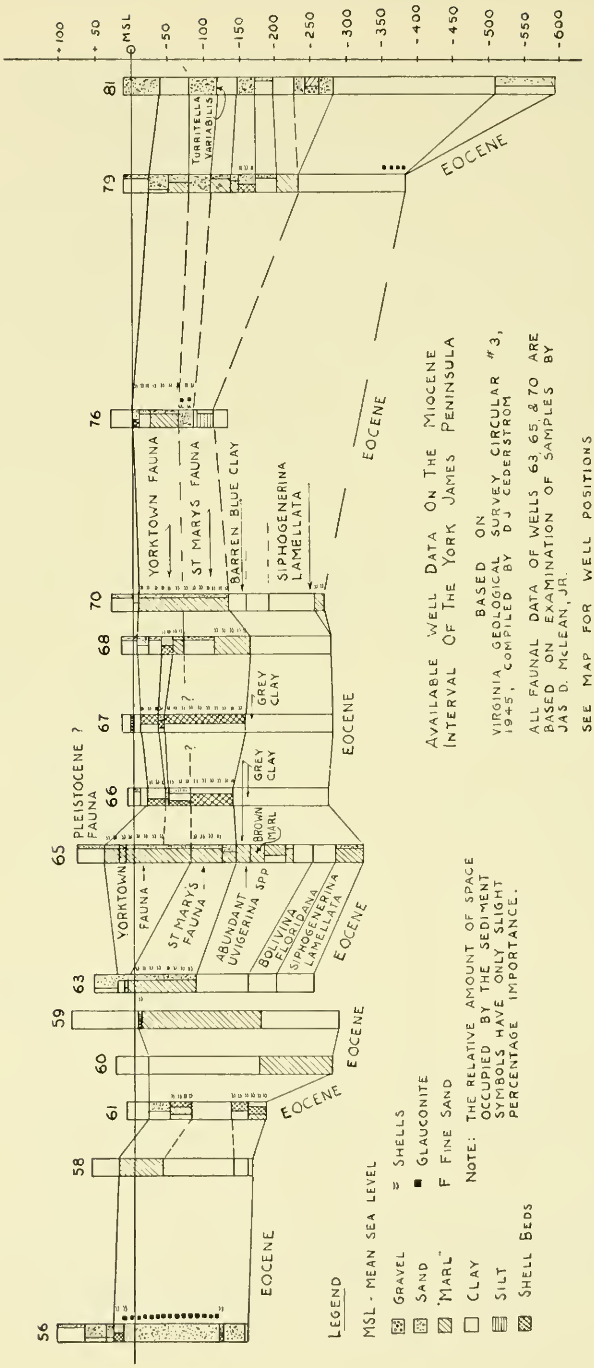

+100
+50
MSL
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-550
-600
56
58
61
60
59
63
65
66
67
68
70
76
79
81
TURRITELLA VARIABILIS
EOCENE
PLEISTOCENE ? FAUNA
YORKTOWN FAUNA
ST MARY'S FAUNA
ABUNDANT UVIGERINA SPP
BOLIVINA FLORIDANA
SIPHOGENERINA LAMELLATA
BROWN MARL
GREY CLAY
ST MARYS FAUNA
BARREN BLUE CLAY
?
LEGEND
MSL - MEAN SEA LEVEL
GRAVEL
SAND
"MARL"
CLAY
SILT
SHELL BEDS
» SHELLS
■ GLAUCONITE
F FINE SAND
NOTE: THE RELATIVE AMOUNT OF SPACE OCCUPIED BY THE SEDIMENT SYMBOLS HAVE ONLY SLIGHT PERCENTAGE IMPORTANCE.
AVAILABLE WELL DATA ON THE MIOCENE INTERVAL OF THE YORK JAMES PENINSULA
BASED ON
VIRGINIA GEOLOGICAL SURVEY CIRCULAR #3, 1945, COMPILED BY D J CEDERSTROM
ALL FAUNAL DATA OF WELLS 63, 65, & 70 ARE BASED ON EXAMINATION OF SAMPLES BY JAS D. McLEAN, JR.
SEE MAP FOR WELL POSITIONS

FIGURE 1

trayed in our section (Figure 1) along with additional well data developed by the writer as part of this project. Since this was the bulk of subsurface data available, it had to suffice, however, as the logs show the data available left a great deal to be desired. The correlations of the wells are the work of the writer, not of Cederstrom; the logs themselves are reduced to symbology as well as the published data permit, and may be called as good as conditions allow. Even so, there is little basis for correlation except for material developed by the writer.

TABLE I

LIST OF WELLS UTILIZED IN CONSTRUCTION OF CROSS SECTION

(Note: well log numbers correspond to those given by Cederstrom in Virginia Geological Survey Circular 3, 1945.)

Well No. 56.	Norge, James City County, Roseland Farm.
Well No. 58.	Dunbar Farm, Eastern State Hospital, James City County, Williamsburg.
Well No. 59.	Williamsburg, York County, J. Levinson subdivision.
Well No. 60.	Williamsburg, York County, R. W. Mahone.
Well No. 61.	Williamsburg, York County, Waller Pond.
Well No. 63.	Camp Peary, York County, U. S. Navy (well D-1)
Well No. 65.	Yorktown Navy Mine Depot, York County.
Well No. 66.	Lee Hall (Skiffs Creek), Warwick County, Newport News Water Co.
Well No. 67.	Lee Hall (reservoir), Warwick County, Newport News Waterworks.
Well No. 68.	Lee Hall, Warwick County, Ft. Eustis (No. 2).
Well No. 70.	Lee Hall, Warwick County, Ft. Eustis (No. 4).
Well No. 76.	Big Bethel reservoir, ¼ mile west of Harpersville, Elizabeth City County, U. S. Army.
Well No. 79.	Newport News, Warwick County, Gas Works.
Well No. 81.	Fort Monroe, Elizabeth City County, U. S. Army.

Stephenson and MacNeil (1954, pp. 733-738) extended the Yorktown formation for some distance, even into Maryland outcrops. Unfortunately, their paper either does not detail important known data, or the work is based on highly inconclusive material.

As indicated above, *Chama* beds are indicative of Zone 2 of the Yorktown only when other more definitive evidence corroborates that assignation. The impressions referred to *Halymenites major* Lesquereux by Stephenson and MacNeil, and the presence of glauconite may indicate shallow sea waters, but these are not necessarily indicative of a Yorktownian age. As a matter of fact, glauconite is not normally present in any great amounts in the Yorktown, and the mineral is more common in other age units, including the Pleistocene. The impressions of *Halymenites major,* as illustrated by Stephenson and MacNeil, could be almost anything, from concretions, to plant impressions, to animalian impressions. On page 736, moreover, they stated: "An oxidized ferruginous zone about 60 feet above the beach (at half a mile south of Jones Point, north of the Middlesex county line) yielded imprints of *Pecten jeffersonius* Say; Mansfield believed it represents the lower part (zone 1) of the Yorktown formation, ...". I much doubt that *Pecten jeffersonius* is capable of identification from an impression; further, it is not restricted to Zone 1 but occurs also in the Maryland Miocene.

The elevations of these beds are not conclusive without more detailed geological study and reconnaisance in the region. To assign gravel beds near Falls Church, Virginia, and the District of Columbia, to the Yorktown requires considerably more data than are enumerated in the work of Stephenson and MacNeil.

PAST WORKS ON FORAMINIFERA AND OSTRACODA

Four papers represent the bulk of work written on the Foraminifera and Ostracoda of the Yorktown formation as it is developed in the York-James peninsular area. Of these, one is an unpublished thesis on file at the University of Virginia, dealing with forms found on the York River side. The faunas are tabulated below. No attempt is made to bring these lists up to date in terminology, because of the uncertainties involved in renaming Foraminifera without access to the actual specimens themselves, and it has not proved possible or feasible to review the specimens in their scattered condition.

Sinnott and Tibbitts (1954, p. 18) cited two U. S. Geological Survey Manuscript Reports as sources of data on the Eastern Shore of Virginia, and these reports presumably contain faunas ascribable to the Yorktown formation. However, despite their citation these reports are not available for reference, being at present classified as interdepartmental memoranda with a restricted designation. The reports are entitled:

Sohn, I. G., "Ostracodes from rotary drill cuttings from test holes in the Eastern Shore Peninsula, Virginia." 1954.

Todd, Ruth, "Smaller Foraminifera from rotary drill cuttings from test holes in the Eastern Shore Peninsula, Virginia." 1954.

No details were given by Sinnott and Tibbitts as to the content of these reports.

FORAMINIFERAL SPECIES REPORTED BY ANDEREGG (UNIV. VA. MASTER'S THESIS) FROM "BLUE CLAY BED" BETWEEN YORKTOWN AND THE NAVAL MINE DEPOT IN THREE LOCATIONS (STOPS)

Nonion striatopunctata
Nonion scapha
Nonion bouena
Nonion depressula
Nonion extensa
Eponides broeckhiana
Eponides repandus
Rotalia beccarii var.
Rotalia soldanii
Rotalia beccarii
Discorbis rosacea
Discorbis globularis
Cibicides tenuimargo
Cibicides tumidula
Gaudryina rugosa
Truncatulina lobatula
Anomalina punctata
Discorbis vilardeboana
Truncatulina cf. alleni
Epistomina bradyi
Globotruncana concamerata
Globorotalia tumida
Bolivina spissa
Bolivina marginata
Globigerina bulloides
Textularia agglutinans
Epistonina partschiana
Uvigerina canariensis
Truncatulina lobatula ornata
Discorbis orbicularis
Truncatulina elevata
Discorbis isabelleana
Discorbis sp., n. sp.
Pulvinulina menardii (?)
Textularia sagittula
Buliminella elegantissima

SPECIES OF FORAMINIFERA LISTED BY J. A. CUSHMAN FROM THE YORKTOWN FORMATION IN U. S. GEOLOGICAL SURVEY BULLETIN NO. 676, 1918

Textularia gramen
Textularia abbreviata
Textularia sagittula
Globigerina bulloides
Spirillina orbicularis
Truncatulina lobatula
Truncatulina variabilis
Nonionina depressula
Nonionina scapha
Quinqueloculina seminulum
Spiroloculina planulata

From Suffolk, Virginia:

Textularia agglutinans
Polymorphina regina
Truncatulina lobatula
Truncatulina lobatula var. ornata

Globigerina bulloides
Globigerina apertura
Globigerina sp.
Discorbis vilardeboana
Discorbis bertheloti
Discorbis rosacea
Discorbis turrita
Truncatulina subloba
Truncatulina americana
Pulvinulina sagra
Nonionina depressula
Nonionina scapha
Polystomella subnodosa
Quinqueloculina seminulum

From "Horizon Not Definitely Known—James River"

Textularia gramen
Textularia abbreviata
Textularia subangulata
Textularia sagittula
Polymorphina compressa
Globigerina bulloides
Truncatulina lobatula
Nonionina scapha
Quinqueloculina seminulum

CHECK LIST OF YORKTOWN FORMATION FORAMINIFERA FROM CUSHMAN AND CAHILL (PROFESSIONAL PAPER 175-A). YORK-JAMES PENINSULAR AREA ONLY

Locality 1/188: York River 2 mi. below Yorktown, 1/8 mi. below Naval Fuel Sta., lowest *Turritella* bed.

Textularia mayori
Dentalina communis
Lagena marginato-perforata
Globulina inaequalis
Nonionella auris
Elphidium incertum
Bolivina marginata multicostata
Bolivina paula
Uvigerina cf. pigmea
Angulogerina occidentalis
Discorbis floridana
Discorbis consobrina
Eponides lateralis
Amphistegina lessoni
Cibicides floridanus
Cibicides concentricus

Locality 1/470a: Below Old Grove Wharf, 2 mi. below Camp Wallace, left bank of James River, lowest bed.

Textularia agglutinans
Guttulina austriaca
Buliminella elegantissima
Bulimina gracilis
Discorbis consobrina
Eponides mansfieldi
Eponides lateralis
Amphistegina lessoni
Cassidulina laevigata carinata
Cibicides floridanus

Locality 1/193: 1¼ mi. below Yorktown, lowest bed fragmental series ½ mi. below projecting point.

Textularia mayori
Quinqueloculina seminula
Massilina mansfieldi
Nonion pizarrense
Elphidium incertum
Buliminella elegantissima
Bolivina paula
Uvigerina cf. pigmea
Discorbis floridana
Discorbis consobrina
Eponides lateralis
Rotalia beccarii parkinsoniana
Cassidulinoides bradyi
Cibicides floridanus
Cibicides americanus

Note: Other localities for which Yorktown formation Foraminifera are reported in U.S.G.S. Professional Paper 175-A are from areas outside of the York-James Peninsula, and some of them are possibly of St. Marys age rather than Yorktown age.

CHECK LIST OF FORAMINIFERA AND OSTRACODA

Malkin, Doris S., "Biostratigraphic Study of Miocene Ostracods of New Jersey, Maryland and Virginia", Jour. Pal., vol. 27, No. 6, charts on pages 769-770, 1953.

Foraminifera and Ostracoda restricted to the York River cliffs near Yorktown, Virginia

Foraminifera

Elphidium cf. E. incertum
Elphidium sp. (papillose)
Nonion granosum
Uvigerina sp. (costate)
Buliminella curta

Ostracoda

Paracytheridea similis
Cytherura forulata
Cytheridea echolsae
Loxoconcha subrhomboidea
Favella rugipunctata
Cytherura wardensis
Cytherura elongata
Paracytheridea mucra
Paracytheridea vandenboldi

Foraminifera and Ostracoda common to both the Yorktown Cliffs and Carter's Grove

Foraminifera

Textularia mayori
Eponides repandus (?)
Eponides mansfieldi
Discorbis candeiana
Discorbis consobrina
Textularia articulata
Cibicides concentricus
Cibicides americanus
Cibicides lobatulus
Nonion pizarrense
Eponides aff. E. mansfieldi
Discorbis aff. D. assulata
Rotalia bassleri

Ostracoda

Bairdia spp.
Cytherideis rugipustulosa
Cytherideis subaequalis ulrichi
Eocytheropteron yorktownensis
Hemicythere conradi
Cytherideis agricola
Clithrocytheridea virginiensis
Anomocytheridea floridana
Paracytheridea shattucki curta
Leguminocythereis whitei
Campylocythere laevissima
Cytheretta burnsi
Trachyleberis martini
Loxoconcha reticularis
Cytherideis ashermani
Cytheromorpha warneri
Campylocythere laeva
Trachyleberis gomillionensis
Hemicythere schmidtae

Foraminifera and Ostracoda restricted to the Carter's Grove banks

Foraminifera

Quinqueloculina sp.
Nonion aff. N. pizarrense
Cibicides floridanus
Globulina gibba
Nonion incisum
Planulina depressa

Ostracoda

Trachyleberis vaughani
Pterygocythereis americana

MAP SHOWING AREA OF YORKTOWN FORMATION

In studying my map of the Yorktown formation, several things must be borne in mind. First, the area of outcrop is by no means as well defined as the line on the map might indicate; outcrops are actually quite sparse and are generally developed only where there are pits or river and streambank dissections of overlying strata.

Second, the records of Mansfield may be questioned; it is doubtful that his Petersburg fauna is Yorktown in age. Some of the inner (western) margin of the North Carolina record by Richards may be better correlated with the Petersburg fauna. Older mappers have delineated St. Marys formation for much of the region which has been here mapped as Yorktownian, and there is some reason to believe the St. Marys outcrops close to Williamsburg and Jamestown, Virginia.

Third, the records of Yorktown formation may be called highly tentative. Much of the North Carolina Yorktown subsurface needs further study and definition; the foraminiferal faunas leave much to be desired in such North Carolina wells as have been studied by the author, and these include the Hatteras Light No. 1 Esso well and several wells at Cherry Point. A well at Franklin, Virginia, yielded little that could be called Yorktownian in nature.

Last, the outcrop map does not discriminate "Zone I" from "Zone II" of the Yorktown formation, for the reason that in the author's opinion, these zones cannot be distinguished with any certainty. The work of MacNeil and Stephenson was not considered in construction of this map for the reasons enumerated in the discussion of that paper.

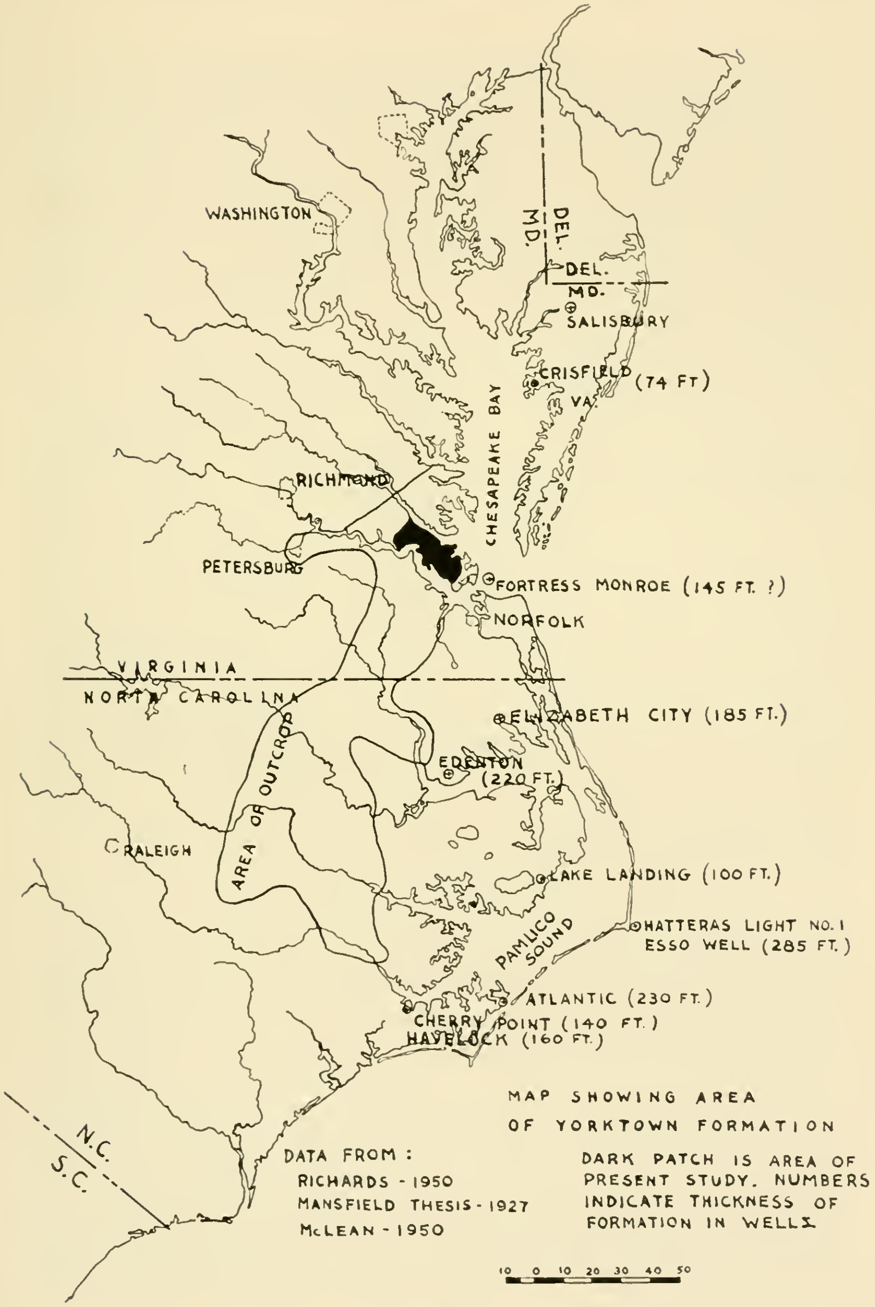

WASHINGTON
MD.
DEL.
DEL.
MD.
SALISBURY
CRISFIELD (74 FT)
VA.
CHESAPEAKE BAY
RICHMOND
PETERSBURG
FORTRESS MONROE (145 FT. ?)
NORFOLK
VIRGINIA
NORTH CAROLINA
AREA OF OUTCROP
ELIZABETH CITY (185 FT.)
EDENTON (220 FT.)
RALEIGH
LAKE LANDING (100 FT.)
HATTERAS LIGHT NO. 1
ESSO WELL (285 FT.)
PAMLICO SOUND
ATLANTIC (230 FT.)
CHERRY POINT (140 FT.)
HAVELOCK (160 FT.)
N.C.
S.C.
MAP SHOWING AREA
OF YORKTOWN FORMATION
DATA FROM:
RICHARDS - 1950
MANSFIELD THESIS - 1927
McLEAN - 1950
DARK PATCH IS AREA OF PRESENT STUDY. NUMBERS INDICATE THICKNESS OF FORMATION IN WELLS
10 0 10 20 30 40 50

FIGURE 2

THE YORKTOWN BRIDGE BORINGS

Careful microscopic analysis of sediments from the Yorktown bridge test borings was made by the writer, along with foraminiferal and ostracodal studies. While these detailed studies do not belong in this paper, certain stratigraphic considerations based on them have significance in determining the base of the Yorktown formation. Furthermore, the data acquired allow us to draw some definite conclusions from the scanty records extant on the subsurface of the York-James Peninsula.

GENERAL STRATIGRAPHIC CONSIDERATIONS

Taking the Miocene of Virginia and Maryland as a unit, I find that it is divisible into certain zones and formations. An unbroken section would comprise the following:

Yorktown formation
St. Marys formation
Choptank formation
Calvert formation

The subsurface record of the York-James peninsular area should (and does) contain elements of all of these formations; the outcrops are variously interpreted and cannot be defined for the area as yet. Miocene outcrops of North Carolina and Virginia have had numerous interpretations, with the trend in late years being to extend the Yorktown at the expense of other formations, most particularly the St. Marys.

The difficulty with interpreting outcrop (and subsurface) units is that past workers have failed to utilize techniques available and failed to appreciate certain facts about the materials encountered. In addition, we are not well advanced enough in geology to either understand or evaluate much data which are susceptible to ecological interpretation.

THE ZONES OF SHATTUCK RELATED TO VIRGINIA BORINGS

Miocene formations in Maryland were divided into a series of 24 "zones" by Shattuck in the Maryland Miocene volumes of 1904. Subsequent workers have found some difficulty in tracing these so-called zones, and from their descriptions, the writer concludes that most of the "zones" are local beds whose content is due to local environmental shifts.

Zones 20 and 21 of Shattuck appear to have considerable stratigraphic use in Maryland and Virginia. Shattuck described these two as being apparently devoid of fossils and of drab and greenish colors. Both are composed of sands and clays.

Zone 20 (the top of the Choptank), is about 15 feet of sand with some bands of clay, while zone 21 (the base of the St. Marys) is clay with some sand. Shattuck stated that the zones are conformable with each other.

Ann Dorsey Clapp, in Maryland Department of Geology, Mines, and Water Resources Bulletin 2 (1946, figure 28) recorded no Foraminifera for zones 20, 21 and 22. On figure 29, she recorded *Textularia gramen, Spiroplectammina exilis,* and *Textularia mayori* present in these same zones, and from this we conclude that the faunas of these zones, if any, are at least scanty. In this same bulletin (figure 25) Cushman recorded no Foraminifera from the L. G. Hammond No. 1 well at depths from 510 to 560 feet. The mineral chart of the L. G. Hammond well (Figure 2) showed an absence of mica in the samples from 540 to 550 feet, and also showed a scarcity of pyrite. This nonmicaceous sample is located at the top of the Choptank according to the correlation marked on the same chart. Pyrite is common in the bed above this interval and frequent in the bed below it.

THE YORK RIVER BRIDGE BORINGS COMPARED WITH THE MARYLAND RECORD

Four test borings from the York River Bridge site were made available to the author by W. T. Parrott of the Virginia Highway Commission. The results of study of these borings are graphically illustrated on Figure 3. Major sediment constituents are plotted within the log column in the percentage of total sediment of each constituent. Minor elements are noted by appropriate symbols beside each column for each sample. Without going into detail, it may be noted that the microfaunas of the samples are significant in separation of the formations as delineated in the figure.

Taking the formations in order, from the top down in the York River Bridge borings, the Pleistocene is represented by glauconitic, mainly coarser sands with gravels and clays. Small, nondescript

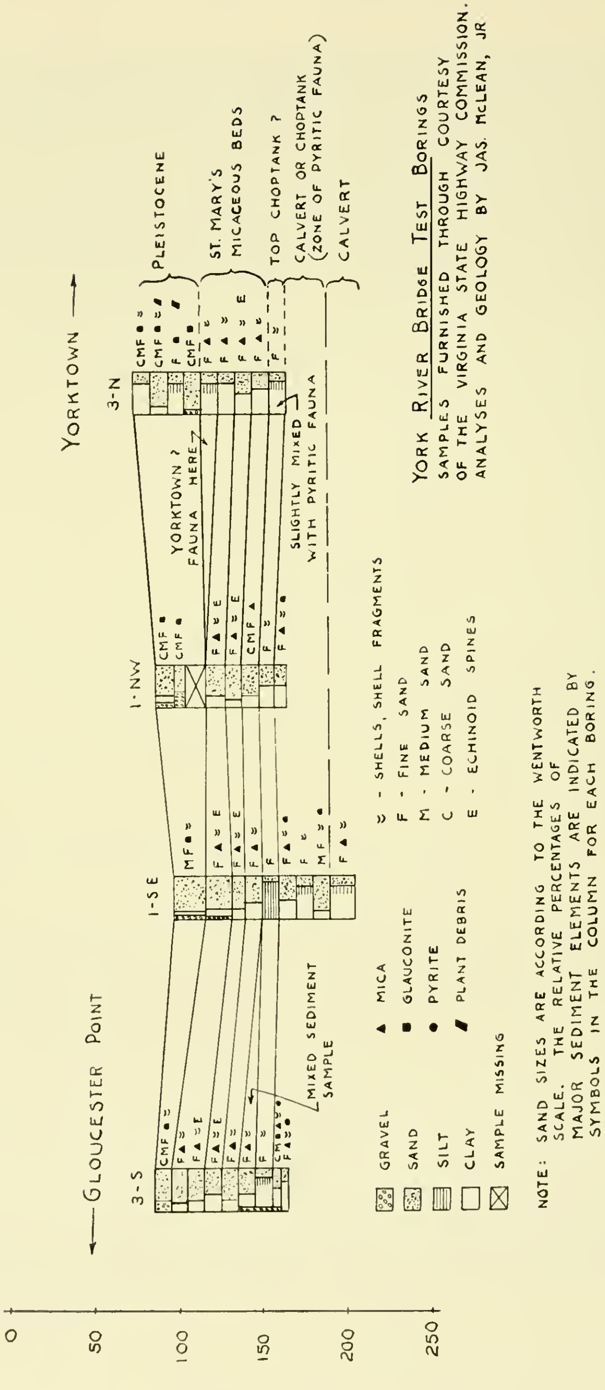

York River Bridge Test Borings
Samples furnished through courtesy of the Virginia State Highway Commission.
Analyses and geology by Jas. McLean, Jr
Gloucester Point
Yorktown
3-S
1-SE
1-NW
3-N
0
50
100
150
200
250
Pleistocene
St. Mary's micaceous beds
Top Choptank ?
Calvert or Choptank (zone of pyritic fauna)
Calvert
Yorktown ? fauna here
Slightly mixed with pyritic fauna
Mixed sediment sample
Gravel
Sand
Silt
Clay
Sample missing
▲ Mica
■ Glauconite
● Pyrite
Plant debris
» - Shells, shell fragments
F - Fine sand
M - Medium sand
C - Coarse sand
E - Echinoid spines
Note: Sand sizes are according to the Wentworth scale. The relative percentages of major sediment elements are indicated by symbols in the column for each boring.

FIGURE 3

Foraminifera are present in a few samples and plant debris in one part of the section attest to the brackish environment. The Pleistocene is unconformable with the underlying beds.

The Yorktown seems to be largely eroded from this section, with the exception of a sample in Boring No. 3-N, which appears to have typical Yorktownian Foraminifera in it. Boring 3-N is the closest subsurface material to the type locality outcrop of the Yorktown formation and for this reason, the York River Bridge section is important in that it limits the downward extent of the outcrop. There is no evidence in this section to support a "Zone 1" underlying the "Zone 2" which the outcrops are supposed to represent according to Mansfield and others.

The single Yorktownian sample appears to be mixed with the underlying St. Marys formation, which is considerably finer in texture than the Pleistocene, and additionally, contains no glauconite. The St. Marys is likewise distinctive in being extremely micaceous and in containing a definite foraminiferal and ostracodal fauna which agrees well with that listed by Ann Dorsey Clapp for the St. Marys fauna of her Maryland study (Chart of Foraminiferal distributions, fig. 28). In her opinion, the St. Marys represents a brackish water phase, and the York River faunas do not indicate otherwise. In several of the York River Borings, it is possible to note quite distinctly a beginning, climax, and decline of fauna that will bear more study.

The St. Marys is underlain by a distinctive bed which appears to be slightly unconformable to it. This bed is especially noteworthy because of its complete lack of Foraminifera or Ostracoda except for slight redepositional elements noted for boring 3-N, which seems rather uncharacteristic for the section. This bed has shell fragments in it, but these are sparse, indicating redeposition or contamination from upper samples by the drill. The bed is of uniform thickness and is of a grey color in contrast to the brown coloration of beds above and below it. It is distinctive in an absence of micaceous elements and in absence of pyrite which characterizes the beds below it. It is predominantly a clay bed with varying proportions of sand and silt. The bed is correlated with Zones 20 and 21 of Shattuck and with the nonfossiliferous intervals of Clapp and Cushman, as heretofore noted. On basis of this comparison, the bed is here called top Choptank.

Under the "Choptank" top bed, is a brown, micaceous, pyritic bed which is fossiliferous and contains Foraminifera and Ostracoda. The pyrite takes the form of small flaky incrustations and also replaces partly or completely the tests of Foraminifera, which it fills. *Robulus americanus spinosus* is present in one sample and a small gastropod and a crab claw are also found in other samples at this level. The nature of this bed, plus the "top Choptank" bed above it strongly suggest that a period of land-locked saline waters were succeeded by an interval of swampy or dry land conditions. The presence of pyritic incrustations and fillings are suggestive of a period in which a basin was fouled by waters containing hydrogen sulphides and their precipitants, fixed into pyrite after anaerobic bacterial activity.

Below this interval, is a series of beds which are less distinctive and are assigned to the Calvert and the "pyritic zone". Since these beds were penetrated only by test boring 1-SE, I would be unjustified in considering them in any detail.

RELATIONSHIP OF YORK RIVER TEST BORINGS TO OTHER YORK-JAMES PENINSULA WELLS

Unfortunately, well records from the rest of the peninsula are most remarkable for their lack of essential data. Certain features of these records are, however, significant in the light of the York River Test Borings. The suggestions of correlation are particularly tantalizing when one considers what careful study of the well samples would have accomplished, especially in delineation of the base of the Yorktown formation.

The author was supplied by the Virginia Geological Survey with samples from Cederstrom's well No. 65, largely in the form of floated Foraminiferal material. Some samples from well 63 and adjacent wells were also made available for study. The faunal record beside Well 70 is not, however, from that well but from samples of a well at Fort Eustis furnished by the Layne-Atlantic Company of Norfolk, through the kindness of Mr. Paul Schweitzer. Unfortunately,

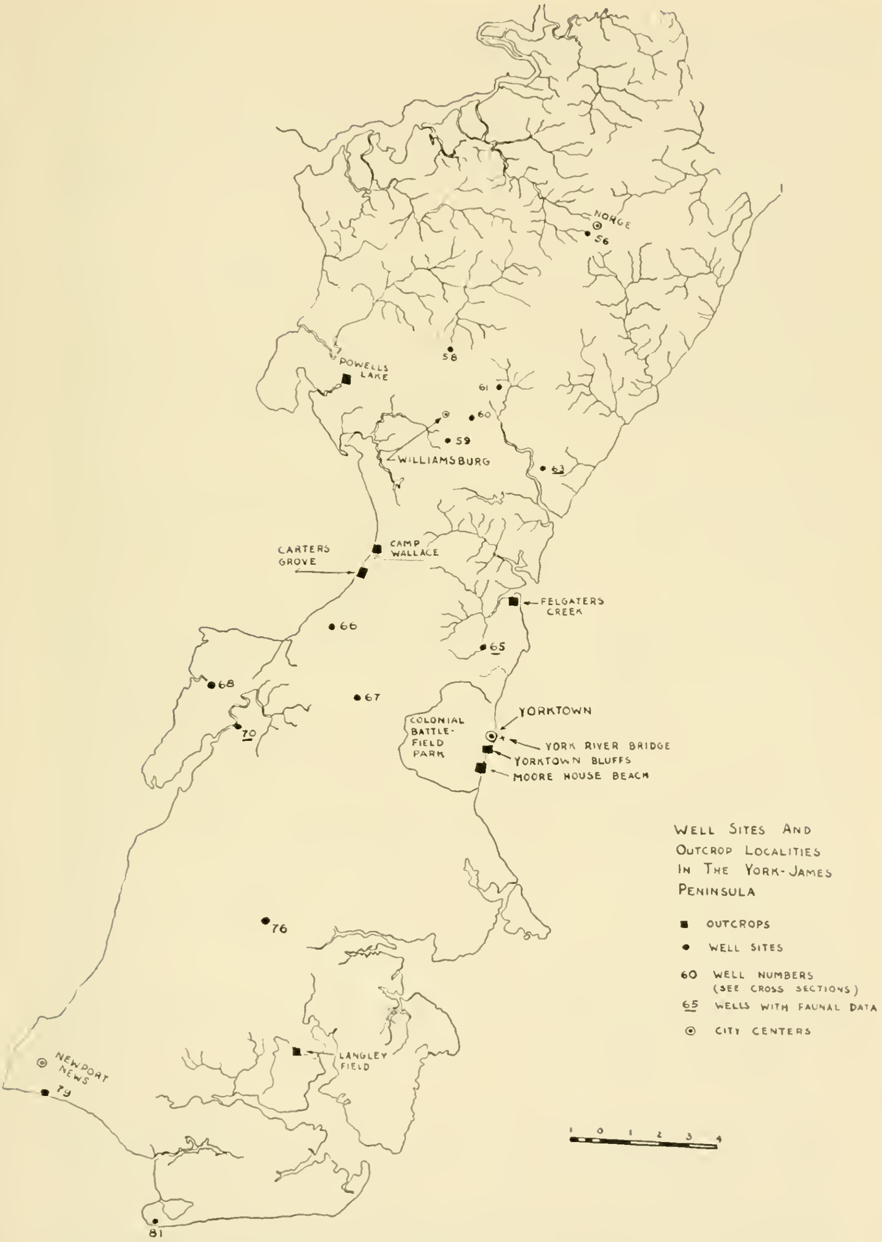

NORGE
56
58
POWELLS LAKE
61
60
59
WILLIAMSBURG
63
CAMP WALLACE
CARTERS GROVE
FELGATERS CREEK
66
65
68
67
70
YORKTOWN
COLONIAL BATTLE-FIELD PARK
YORK RIVER BRIDGE
YORKTOWN BLUFFS
MOORE HOUSE BEACH
Well Sites And Outcrop Localities In The York-James Peninsula
■ OUTCROPS
● WELL SITES
60 WELL NUMBERS (SEE CROSS SECTIONS)
65 WELLS WITH FAUNAL DATA
⊙ CITY CENTERS
76
LANGLEY FIELD
NEWPORT NEWS
79
81
1 0 1 2 3 4

FIGURE 4

at the time the author was given the samples, he was only interested in extraction of the Foraminifera, and no sediment record exists on this well except a few rough notes which suggest a strong similarity to well 70 both in location and in sedimentary constituents.

These records form the data available outside of the well records listed by Cederstrom in Circular 3 of the Virginia Survey (See Table 1).

Well 65 contains most of the available correlation criteria, especially with reference to the York River Bridge Test Borings. The Pleistocene fauna is equivalent to the one found in the York River section. The Yorktown fauna is typical of that of the outcrops at the Moore House Beach but is much more limited in numbers of species. Nothing suggests a division of the fauna into two "zones" and the Carter's Grove fauna is absent or was not furnished with the samples given the author. The St. Marys fauna is likewise sparse and unpromising.

Somewhat below the St. Marys fauna is a grey clay at the level which will correlate with the barren Choptank bed of the York River section. No fossils were reported from this interval, and none were found in samples furnished from the well. The grey clay seems to be a persistent unit in the mid-part of the peninsula, and in the well which we have placed near well 70, there is a barren grey clay, which the describer of well 70 calls "blue clay" in that well. This top clay bed is apparently a stratigraphically significant unit, the records below it generally change from a "marl" to a clay facies. Inasmuch as we are here dealing with drillers logs rather than with accurately determined sediment records, no great dependence can be placed on the differentiation between marl and clay. However, where the well records show "marl" there is also generally a reference to shell material, and the records of clay at and below the first "grey" or "blue" clays are generally devoid of mention of any shell material.

The next unit in well 65 is a "brown marl" which contains an abundance of Uvigerinas and other small forms. This *Uvigerina* fauna requires further study and identification or description of the dominant species. Somewhat below this *Uvigerina*-marl is the first appearance of *Bolivina floridana* which Ann Dorsey Clapp restricted to the base of the Choptank in Maryland, and which, from all present indications at least, seems to be an excellent marker for a stratigraphic horizon locally, and perhaps regionally as well, since all records assembled so far indicate that this species consistently occurs higher in the column than *Siphogenerina lamellata,* which is another species of wide geographic extent. The only case where the form *Bolivina floridana* was found below *Siphogenerina lamellata* is at the new Crisfield well, where *Bolivina floridana* occurs at 670-717 feet, and *Siphogenerina lamellata* is at 580-670 feet. Due to the known contamination of samples in this well (McLean, 1950) and the infrequent sampling, it is possible that this displacement in spatial relationships of these species is due to downward contamination from a bed not sampled.

TABLE 2

TABLE SHOWING OCCURRENCES OF SIPHOGENERINA LAMELLATA AND BOLIVINA FLORIDANA IN MARYLAND AND VIRGINIA

MARYLAND	*Bolivina floridana* Bottom Choptank	*Siphogenerina lamellata*
Clapp's outcrop chart	780-790 feet	Upper Calvert
Hammond Well	670-717 feet	1010-1020 feet
Crisfield Well (McLean)		580-670 feet
VIRGINIA		
Naval Mine Depot, Yorktown well* (Well 65)	310-320 feet	340-350 feet
Fort Eustis Well*	absent	215-240 feet
Camp Peary Well D-1** (Well 63)	240-270 feet	270-290 feet Mioc. to 310 feet
Camp Peary Well D-2**	260-285 feet	285-300 feet Mioc. to 300 feet
Camp Peary Well D-6**	absent	at 290 feet Eoc. Forams (Cushman)

*NOTE: The Naval Mine Depot well and the Fort Eustis Well reports are for *first sample* occurrences only, as the reported forms persist downward obviously as contaminations during drilling. **Cederstrom 1943.

Siphogenerina lamellata occurs in a "marl" bed of Well 65, and in a clay bed in well 63, directly below *Bolivina floridana*. Well 63 is Cederstrom's (1943) well No. D-1 from Camp Peary. Other adjacent wells in Camp Peary (see Table 2) confirm this relationship. These two faunas (*Bolivina floridana* fauna and *Siphogenerina lamellata* fauna) in well 63 are definitely separate. In Maryland, Ann Dorsey Clapp found *Siphogenerina lamellata* characteristically occurring at the top of the Calvert, and the author has found the species in beds containing distinctive Calvert Foraminifera. One notable exception is the presence of a specimen of *Siphogenerina* cf. *lamellata* in the Camp Wallace material. This occurrence is undoubtedly redepositional, as the species, when it is present, occurs characteristically in large numbers and is a major portion of the fauna.

Beds below the Calvert fauna are normally heavily glauconitic and contain an Eocene fauna which has been described by Cushman and Cederstrom. The type well for the fauna of Eocene age as designated by Cushman and Cederstrom is Well 65 (Cushman and Cederstrom, 1945).

From: Richards, Horace G., Jour. Paleont., vol. 21, No. 1, pp. 23-27, Pls. 11-15, 1947, "Invertebrate Fossils from Deep Wells along the Atlantic Coastal Plain".

Well at Old Point Comfort Hotel, Elizabeth City County, Va., elevation 10 ft.; (Pleistocene from 0-10 feet in well).

Top Occurrences:
at 50 feet. Dosinia acetabulum (Conrad)
Pecten jeffersonius Say
Phacoides trisulcatus (Conrad)
Yoldia laevis (Say)
Crepidula fornicata (Linne)
Olivella mutica (Say)
Polinices duplicata (Say)
Turbonilla sp.
Turritella variabilis Conrad
Cadulus thallus (Conrad)

at 80 feet: Drillia limatula (Conrad)
Polinices heros (Say)
at 90 feet: Balanus concavus Bronn.
Pecten madisonius Say
at 100 feet: Cardium laqueatum Conrad
Corbula inaequalis Say
Leda acuta (Conrad)
Phacoides crenulatus (Conrad)
Venus mercenaria Linne
at 110 feet: Dentalium attenuatum Conrad
at 120 feet: Astarte undulata Say
at 170 feet: Chione latilirata (Conrad)
Nucula proxima Say
Ostrea disparilis Conrad
Venericardia granulata Say
Ecphora tricostata Martin
at 260 feet: Turritella alticostata Conrad

NOTES ON RELATIONSHIP OF SAMPLES OF SUSPECTED YORKTOWN AGE FROM NORTH CAROLINA AND VIRGINIA

Philip M. Brown and H. E. LeGrand of the U. S. Geological Survey, Ground Water Branch, Raleigh, North Carolina, kindly presented samples from that state for comparison with the type locality Yorktown beds. In addition, the writer received one sample from near Petersburg, Virginia, from Dr. H. G. Richards, and has collected well samples referred to below from various sources.

Of the well samples from North Carolina (all east of the reported outcrop in the area of Yorktown strata) the Miocene intervals were studied. As might be expected, the Foraminifera from these wells (including the Esso Hatteras Light No. 1 and the Bogue and Atlantic wells) reveal a fauna considerably different from the typical Yorktownian. There is no doubt that these wells contain equivalent intervals to the Yorktownian; the problem is to determine which beds are equivalent.

The subsurface Miocene of North Carolina, by lithology and fauna, is from an ecologically different facies. Although some species such as *Nodosaria catesbyi* are found both in the Hatteras well and at the Yorktown outcrops, there are insufficient data for making precise correlations. This condition cannot be remedied with the limits of time and space imposed upon the present study.

The case is much the same for surface samples, but there is a small amount of information which may throw light on correlation. Results are summarized below:

1. Type locality of Duplin marl at Natural Well, Duplin County, North Carolina; "Equivalent of beds at Suffolk, Virginia." Sample from Brown and LeGrand:

   Foraminifera and Ostracoda are not sufficiently numerous or sufficiently similar to the Yorktown fauna to render opinion.

2. Murfreesboro, North Carolina "zone C of Dr. Julia Gardner's Prof. Paper 199-A, p. 11. Equivalent of *Chama* bed (in part) in Yorktown area". Sample from Brown and LeGrand:

   This sample is Yorktown age, possibly equivalent to the Moore House Beach fauna of the Yorktown formation, although evidence is meager.

3. Palmyra Landing on Roanoke River, Halifax County, North Carolina "Yorktown formation . . . . possibly the equivalent of Zone I of Yorktown formation" Brown and LeGrand sample:

   This sample of Yorktown age; zonation uncertain. Since Mansfield's classic zonation of the type Yorktown area is by no means as distinct or positive as one is led to believe, the uncertainity would exist despite a much better fauna than was obtained from this sample.

4. On Fishing Creek, West bank 11 miles North of Tarboro in Edgecombe County, North Carolina "Yorktown formation." Sample from Brown and LeGrand:

   The presence in this sample of *Trachyleberis clarkana* and *Cytheretta* cf. *plebia*, both of which are conspicuously absent from the Yorktown type locality and are reported by Malkin as being in the Calvert is rather suggestive that this is not Yorktownian. *Elphidium* cf. *falunicum* (Allix) reported no higher than the Helvetian of Europe is present. These facts together with the geographic location of the sample strongly suggest a Calvert age for this sample. In the course of the writer's investigations of surface and subsurface material from the York Peninsula and the Crisfield Well, *Trachyleberis clarkana* appears to be restricted, as stated by Malkin, to the Calvertian level.

5. Surface sample from near Petersburg, Virginia, from Dr. Horace G. Richards:

This fauna is not Yorktownian in aspect. The general complection of this fauna seems to relate it to the Tarboro, Fishing Creek sample above, and the geographic position of this sample suggests that the material is Calvert (Helvetian).

One well sample interval from "Well #4" at Franklin, Virginia, at a depth of 80 to 90 feet contains a fauna suggestive of the St. Marys fauna.

FORAMINIFERAL SPECIES RESTRICTED TO DEFINITE LIMITS WITHIN THE YORKTOWN FORMATION

In listing the following species, the author has accepted the definitions of Yorktownian zones I and II according to Mansfield (Thesis). In considering these ranges two points should be remembered: 1. The ranges of new species are subject to change as the new forms become better known; 2. Many restrictions of range are the result of rarity of specimens (this is especially true of species herein designated by the term "sp.").

Species restricted to Zone II of Mansfield and others

Nonion cf. grateloupi
Nonion sp. A
Nonion sp. B
Elphidium kaicherae
Loxostoma wilsoni
Uvigerina cf. tenuistriata
Angulogerina sp.
Planispirillina orbicularis
Discorbis sp.
Globigerina form B
Globigerina form C
Globigerina form D
Orbulina cornwallisi
Globigerinoides form G
Globorotalia sp.
Quinqueloculina seminulangulata
Dentalina sp. A
Dentalina sp. C
Dentalina kaicherae
Nodosaria sp.
Lagena substriata var.
Guttulina sp. A
Guttulina sp. B

Species whose range is restricted to Zone II and younger deposits

Quinqueloculina wheeldoni
Sigmomorphina concava
Sigmomorphina pearceyi
Bolivina striatula
Buccella hannai
Dyocibicides perforatus

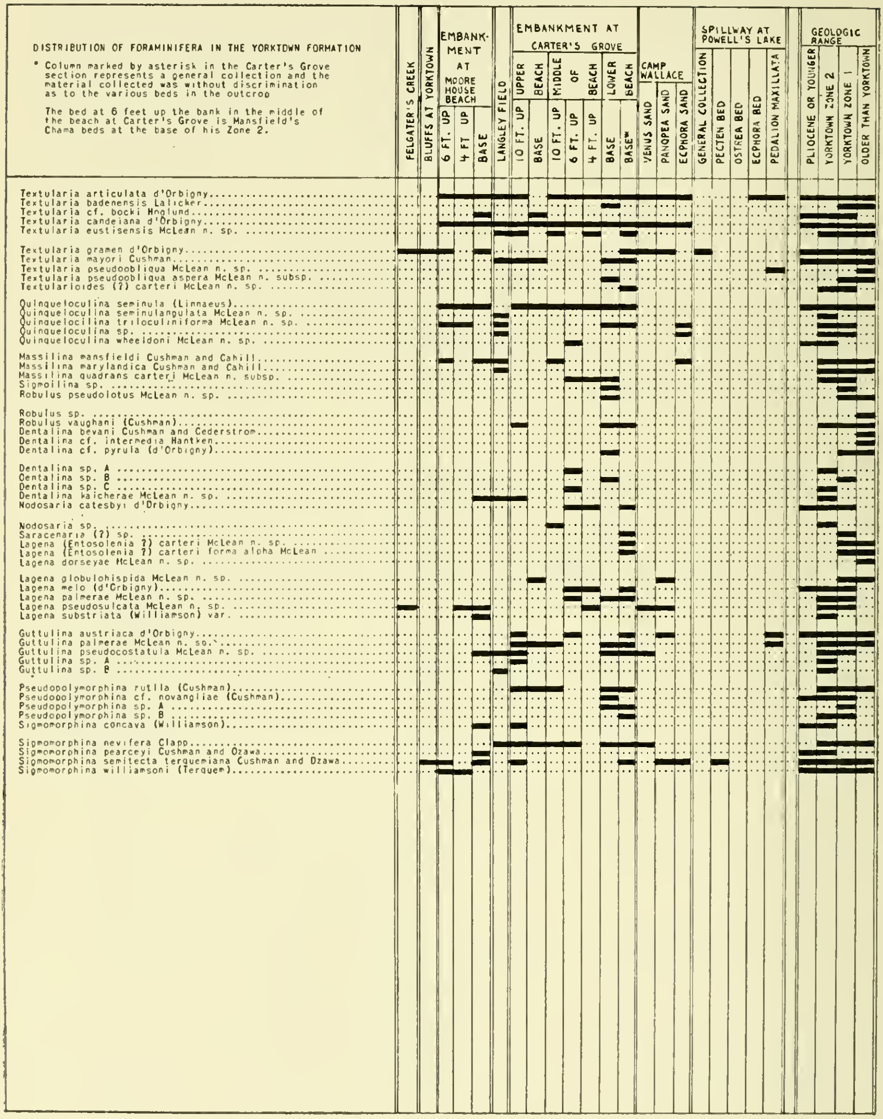

DISTRIBUTION OF FORAMINIFERA IN THE YORKTOWN FORMATION
* Column marked by asterisk in the Carter's Grove section represents a general collection and the material collected was without discrimination as to the various beds in the outcrop
The bed at 6 feet up the bank in the middle of the beach at Carter's Grove is Mansfield's Chama beds at the base of his Zone 2.
FELGATER'S CREEK
BLUFFS AT YORKTOWN
EMBANKMENT AT MOORE HOUSE BEACH
6 FT. UP
4 FT UP
BASE
LANGLEY FIELD
EMBANKMENT AT CARTER'S GROVE
UPPER BEACH
10 FT. UP
BASE
MIDDLE OF BEACH
10 FT. UP
6 FT. UP
4 FT. UP
LOWER BEACH
BASE
BASE*
CAMP WALLACE
VENUS SAND
PANOPEA SAND
ECPHORA SAND
SPILLWAY AT POWELL'S LAKE
GENERAL COLLECTION
PECTEN BED
OSTREA BED
ECPHORA BED
PEDALION MAXILLATA
GEOLOGIC RANGE
PLIOCENE OR YOUNGER
YORKTOWN ZONE 2
YORKTOWN ZONE 1
OLDER THAN YORKTOWN
Textularia articulata d'Orbigny
Textularia badenensis Lalicker
Textularia cf. bocki Hoglund
Textularia candeiana d'Orbigny
Textularia eustisensis McLean n. sp.
Textularia gramen d'Orbigny
Textularia mayori Cushman
Textularia pseudoobliqua McLean n. sp.
Textularia pseudoobliqua aspera McLean n. subsp.
Textularioides (?) carteri McLean n. sp.
Quinqueloculina seminula (Linnaeus)
Quinqueloculina seminulangulata McLean n. sp.
Quinquelocilina triloculiniforma McLean n. sp.
Quinqueloculina sp.
Quinqueloculina wheeldoni McLean n. sp.
Massilina mansfieldi Cushman and Cahill
Massilina marylandica Cushman and Cahill
Massilina quadrans carteri McLean n. subsp.
Sigmoilina sp.
Robulus pseudoiotus McLean n. sp.
Robulus sp.
Robulus vaughani (Cushman)
Dentalina bevani Cushman and Cederstrom
Dentalina cf. intermedia Hantken
Dentalina cf. pyrula (d'Orbigny)
Dentalina sp. A
Dentalina sp. B
Dentalina sp. C
Dentalina kaicherae McLean n. sp.
Nodosaria catesbyi d'Orbigny
Nodosaria sp.
Saracenaria (?) sp.
Lagena (Entosolenia ?) carteri McLean n. sp.
Lagena (Entosolenia ?) carteri forma alpha McLean
Lagena dorseyae McLean n. sp.
Lagena globulohispida McLean n. sp.
Lagena melo (d'Orbigny)
Lagena palmerae McLean n. sp.
Lagena pseudosulcata McLean n. sp.
Lagena substriata (Williamson) var.
Guttulina austriaca d'Orbigny
Guttulina palmerae McLean n. sp.
Guttulina pseudocostatula McLean n. sp.
Guttulina sp. A
Guttulina sp. B
Pseudopolymorphina rutila (Cushman)
Pseudopolymorphina cf. novangliae (Cushman)
Pseudopolymorphina sp. A
Pseudopolymorphina sp. B
Sigmomorphina concava (Williamson)
Sigmomorphina nevifera Clapp
Sigmomorphina pearceyi Cushman and Ozawa
Sigmomorphina semitecta terquemiana Cushman and Ozawa
Sigmomorphina williamsoni (Terquem)

FIGURE 5

DISTRIBUTION OF FORAMINIFERA IN THE YORKTOWN FORMATION (PART II)	FELGATER'S CREEK	BLUFFS AT YORKTOWN	EMBANKMENT AT MOORE HOUSE BEACH			LANGLEY FIELD	EMBANKMENT AT CARTER'S GROVE							CAMP WALLACE			SPILLWAY AT POWELL'S LAKE					GEOLOGIC RANGE			
							UPPER BEACH		MIDDLE OF BEACH			LOWER BEACH													
			6 FT. UP	4 FT UP	BASE		10 FT. UP	BASE	10 FT. UP	6 FT. UP	4 FT. UP	BASE	BASE*	VENUS SAND	PANOPEA SAND	ECPHORA SAND	GENERAL COLLECTION	PECTEN BED	OSTREA BED	ECPHORA BED	PEDALION MAXILLATA	PLIOCENE OR YOUNGER	YORKTOWN ZONE 2	YORKTOWN ZONE 1	OLDER THAN YORKTOWN
Nonion mediocostatus (Cushman)																									■
Nonion pizarrensis (W. Berry)	■		■		■	■	■	■	■	■	■	■	■	■	■	■					■	■	■	■	■
Nonion cf. grateloupi (d'Orbigny)				■																			■		
Nonion sp. A					■																		■		
Nonion sp. B					■																		■		
Nonionella auris (d'Orbigny)					■						■											■	■	■	■
Elphidium advena (Cushman)						■																■	■	■	■
Elphidium incerta (Williamson)	■												■				■		■	■		■	■	■	■
Elphidium johnstonae McLean n. sp.					■					■	■			■	■	■					■		■	■	■
Elphidium saicherae McLean n. sp.	■				■																		■		
Buliminella cf. elegantissima (d'Orbigny)		■																				■	■	■	■
Bulimina gracilis Cushman					■		■						■										■	■	■
Bulimina preacanthia McLean n. sp.							■						■										■	■	
Virgulina punctata d'Orbigny													■									■	■	■	■
Bolivina lafayettei McLean n. sp.					■								■										■	■	
Bolivina striatula Cushman					■																	■	■		
Loxostomum wilsoni McLean n. sp.				■	■																		■		
Uvigerina calvertensis Cushman				■	■										■								■	■	■
Uvigerina cf. carmeloensis Cushman and Kleinpell											■													■	■
Uvigerina cf. tenuistriata Cushman (not Reuss)			■			■																	■		
Siphogenerina lamellata Cushman															■									■	■
Angulogerina occidentalis (Cushman)													■									■	■	■	■
Angulogerina sp.				■																			■		
Planispirillina orbicularis (Bagg)			■		■																		■		
Discorbis floridana Cushman		■		■	■		■	■		■	■		■						■			■	■	■	■
Discorbis rehderi McLean n. sp.				■	■	■								■		■					■		■	■	■
Discorbis sp.										■													■		
Discorbis turrita Cushman					■								■										■	■	
Valvulineria washingtoni McLean n. sp.																	■				■				■
Buccella anderseni McLean n. sp.		■					■			■	■						■		■	■	■		■	■	■
Buccella depressa Andersen												■	■									■	■	■	
Buccella hannai (Phleger and Parker)	■																					■	■		
Buccella parkerae Andersen			■		■		■		■				■	■	■	■		■					■	■	■
Rotalia limbatobeccarii McLean n. sp.				■	■																		■		
Poroeponides lateralis (Terquem)			■	■	■	■																■	■	■	
Cancris sagra d'Orbigny				■	■	■	■				■	■	■									■	■	■	■
Globigerina sp. form A				■	■												■						■	■	■
Globigerina sp. form B					■																		■		
Globigerina sp. form C					■																		■		
Globigerina sp. form D					■																		■		
Globigerina sp. form E				■	■							■	■										■	■	
Globigerinoides sp. form F																									■
Globigerinoides sp. form G				■																			■		
Orbulina cornwallisi McLean n. sp.					■																		■		
Globorotalia sp.					■																		■		
Planulina depressa (d'Orbigny)							■	■	■		■	■	■									■	■	■	■
Cibicides cf. lobatulus Cushman (not Walker and Jacob)			■		■		■	■		■	■	■		■	■								■	■	■
Cibicides sublobus (Cushman)		■		■			■				■	■	■				■	■		■			■	■	■
Hanzawaia concentrica (Cushman)	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■
Dyocibicides biserialis Cushman and Valentine													■	■	■							■	■	■	
Dyocibicides perforatus Cushman and Valentine									■													■	■		
Cibicidella variabilis (d'Orbigny)		■	■		■			■	■	■		■	■				■	■	■			■	■	■	■
Pectocibicidella robertsi McLean n. sp.													■										■	■	

FIGURE 5 (PART II)

Species restricted to Zone 1 of Mansfield and others

Sigmoilina sp.
Dentalina sp. B
Saracenaria ? sp.
Pseudopolymorphina sp. A
Amphistegina sp.

Species whose range is restricted to Zone 1 and older deposits

Siphogenerina lamellata (redeposited)
Uvigerina cf. carmeloensis
Textularia badenensis
Textularia pseudobliqua aspera
Robulus pseudoiota
Dentalina cf. pyrula
Lagena carteri
Lagena carteri alpha

Species whose range is apparently restricted to the Yorktown Formation

Textularioides ? carteri
Quinqueloculina triloculiniforma
Quinqueloculina sp.
Massilina quadrans carteri
Lagena palmerae
Lagena pseudosulcata
Guttulina pseudocostatula
Pseudopolymorphina sp. B
Bulimina preacanthia
Bolivina lafayettei
Discorbis turrita
Rotalia limbatobeccarii
Globigerina form E
Cibicides subloba
Rectocibicidella robertsi
Buccella parkerae

Species whose range is throughout the Yorktown and older

Elphidium johnstonae
Bulimina gracilis
Uvigerina calvertensis
Discorbis rehderi
Buccella anderseni
Globigerina form A
Cibicides cf. lobatulus
Textularia eustisensis
Massilina mansfieldi
Massilina marylandica
Robulus vaughani
Guttulina palmerae
Pseudopolymorphina rutila
Sigmomorphina nevifera

Species whose range is throughout the Yorktown and younger

Textularia cf. bocki
Nodosaria catesbyi
Lagena melo
Pseudopolymorphina cf. novangliae
Buccella depressa
Poroeponides lateralis
Dyocibicides biserialis

STRATIGRAPHIC RELATIONSHIPS OF YORKTOWN FORAMINIFERA

Of 108 species of Foraminifera described in this study, 100 are from the Yorktown formation. *Siphogenerina lamellata,* which occurs as a single specimen in material from Camp Wallace, is considered to be a redeposited form. *Valvulineria washingtoni, Nonion mediocostatus, Textularia pseudobliqua, Robulus* sp., *Dentalina* cf. *intermedia, Dentalina bevani, Lagena dorseyae,* are all redepositional elements, or are described from beds older than the Yorktown.

Twenty-nine species from the Yorktown formation are still living; some of the species described as new here may prove to be living forms upon further studies of living faunas. The author feels that these living forms, as far as they are known, should be distinguished from fossil species in making stratigraphic comparisons, and this has been done below.

COMPARISON WITH THE CALOOSAHATCHEE (PLIOCENE) OF FLORIDA

Two figured species (still living) were reported by Cushman (1918) from the Caloosahatchee formation and are also found in the Yorktown formation: they are *Quinqueloculina seminula* and *Textularia gramen*. Because of poor illustrations and descriptions of these species, their identity is doubtful. No other Pliocene unit is close enough to merit direct comparison with the Yorktown.

COMPARISON OF THE ST. MARYS AND YORKTOWN FORMATIONS

Eleven species are common to both the Yorktown and the St. Marys foraminiferal faunas. Seven are still living; *Massilina mansfieldi, Lagena dorseyae, Bulimina gracilis,* and *Nonionella auris* appear to be fossil, the last two forms appear lower in the column than St. Marys formation.

COMPARISON OF YORKTOWN AND CHOPTANK FORMATION FAUNAS

Of 13 species common to both the Yorktown and Choptank formations, 8 are living forms; *Sigmomorphina nevifera, Textularia badenenis, Lagena globulohispida, Bulimina gracilis,* and *Nonionella auris* seem to be fossil forms.

COMPARISON OF YORKTOWN AND CALVERT FAUNAS

There are 12 forms common to the Yorktown and Calvert beds. *Siphogenerina lamellata* is redepositional into the Yorktown; the remaining species common to both formations which appear to be fossil are: *Dentalina pyrula, Robulus vaughani, Pseudopolymorphina rutila* (?), *Bulimina gracilis,* and *Nonionella auris. P. rutila* of Dorsey is possibly not the same as Yorktown species of this report. The remaining six species are still living.

COMPARISON OF YORKTOWN FAUNAS WITH THE MIOCENE OF FLORIDA

Thirty-one species are common to the Yorktown formation and the Miocene of Florida (from Puri, 1953). Twenty-one species are living. Study of the following table will show that the Yorktown correlates best with the *Arca* and *Cancellaria* facies of the Choctawhatchee as described in Puri's lists. It is of interest to note that Puri regarded the *Arca* and *Cancellaria* facies as contemporaneous; the *Arca* facies existing in the updip section, the *Cancellaria* facies in the downdip area.

In the opinion of the author, 10 fossil species, some of long stratigraphic range, would hardly be sufficient to establish a direct correlation between the Yorktown and the Choctawhatchee. Foraminifera of the Duplin marl are insufficiently known to merit correlation study at this time, and the relationship of the Duplin to the Yorktown formation may be quite close, though of different facies and climate. It is the opinion of the author that the Yorktown formation is uppermost Miocene in age and as the Pontian and Sahelian of Europe are continental or nonmarine beds it is difficult to utilize these as Yorktownian equivalents. The Sarmatian Foraminifera of Europe constitute a different group of species from those of the Yorktown to judge from the samples at the disposal of the author.

TABLE 3

SPECIES COMMON TO THE YORKTOWN FORMATION AND THE FLORIDA MIOCENE (FLORIDA DATA FROM PURI 1953)

PURI'S FACIES

CHOCTAWHATCHEE FM.

	Chipola	Oak Grove	Shoal River	Yoldia	Arca	Ecphora	Cancellaria
Textularia articulata	x				x	x	
T. candeiana					x		x
T. gramen	x				x		x
T. mayori			x	x		x	x
Quinqueloculina seminula					x		x

	Chipola	Oak Grove	Shoal River	Yoldia	Arca	Ecphora	Cancellaria
Robulus pseudoiota				x	x	x	x
Dentalina cf. pyrula					x	x	
Robulus vaughani	x				x		x
Nodosaria catesbyi					x	x	x
Pseudopolymorphina rutila						x	x
Guttulina austriaca	x					x	x
Sigmomorphina pearceyi	x	x					
Buliminella elegantissima	x				x	x	x
Bulimina gracilis			x				
Lagena carteri		x	x		x	x	x
Virgulina punctata						x	x
Siphogenerina lamellata					x		
Angulogerina occidentalis					x	x	x
Discorbis floridana					x		x
Poroeponides lateralis					x		x
Cancris sagra	x				x	x	x
Discorbis rehderi					x		x
Hanzawaia concentrica					x	x	x
Cibicidella variabilis	x						
Dyocibicides biserialis	x				x	x	x
Planulina depressa					x		x
Nonion grateloupi	x				x	x	x
Nonion pizarrense	x				x		
Nonionella auris	x				x	x	x
Elphidium advena	x				x	x	x
Elphidium incertum							x

NOTES ON ECOLOGY OF FORAMINIFERA FROM YORKTOWN FORMATION

There are two difficulties attending the consideration of ecology as it relates to Foraminifera, both have been abundantly referred to in the literature. The first difficulty is that foraminiferal genera are not good indicators of environmental occurrences, because certain species within given genera have widely different habits of occurrence. The second difficulty is that the identities of species of Foraminifera used as depth or other types of indicators are by no means certain.

However, even acknowledging these difficulties, it is not impossible to draw certain conclusions based on the growing ecological data. These hazards only impose on the researcher the duty of discrimination of data and the added duty of not using fossil forms as definite indicators until more is known about their associations with living forms. Fortunately, a number of species being actively studied in continuing ecological researches also occur in the Yorktown formation.

In the following pages and the accompanying chart, I show the known relationships of living Foraminifera which were also found in the Yorktown formation. These relationships are materially aided by the data furnished by Dr. Harald Rehder, Curator, Division of Mollusks, U. S. National Museum, who has kindly undertaken to outline the known depth and environmental significance of such mollusks as are still known to be living, and which occur in our Yorktown formation collections.

I cannot stress too greatly the necessity for caution in interpolation of the data into significant results for the determination of fossil species as indicators of environment. It would seem that the widest interpretation of depths and/or other points would be best in depth determination of fossil species associated with known living forms. The association in the strata of certain faunal elements may not be their association in the living state.

DATA OTHER THAN DEPTHS OF OCCURRENCE OF LIVING FORMS

Bolivina striatula.—This species is found rarely in bays and in the open Gulf: it is reported as being more common in the open

Gulf than elsewhere, but is present in reef, inter-reef, polyhaline bays, bay, sound, beach, and also in the moat at Fort Jefferson in the Tortugas. (Boltovskoy, 1954, Phleger, 1955, Cushman, 1922, Phleger, 1954, Post, 1951, Parker, *et al,* 1953, Bandy, 1954).

Buccella depressa.—See chart.

Buccella hannai.—Characteristic of depths down to about 65 meters; highest frequencies at 40 meters; rare in outer part of Breton Sound and into Gulf; common in open Gulf and rare in sound. (Phleger and Parker, 1951, Parker, 1954, Phleger, 1955, Phleger, 1954).

Buliminella elegantissima.—Present in Narragansett Bay; rare below 100 meters; more common in open Gulf, but also present in Texas Bays; rare in Breton Sound and open Gulf; present in open Gulf and a bit into Sound; rare in inter-reef facies, polyhaline bays, passes, open Gulf; present in Mason Inlet. (Said, 1951, Parker, *et al,* 1953, Phleger, 1955, Phleger, 1954, Post, 1951, Miller, 1953).

Cancris sagra.—Most records from 1-53 fathoms, common at 1 fathom, rare elsewhere; o to 5% concentration at 75 to 130 feet deep. (Cushman, 1931, Bandy, 1954).

Cibicides lobatulus.—Common to abundant at 2½ to 52½ fathoms (Cushman, 1931). The determination of this species is in doubt.

Discorbis floridana.—Common at less than 100 meters, rare at lower depths; frequencies of less than 5% to 110 meters, less than 1% deeper, one occurrence of 15% at inner end of a traverse; in moat at Fort Jefferson, Tortugas; restricted to open Gulf; rare in open Gulf, beach, Matagorda Island marsh, and bays; characterizes depths from 40 feet deeper, 1-14% at 55-75 feet, 1-10% at 75-130 feet. (Parker and Phleger, 1951; Parker, 1954, Cushman, 1922, Phleger, 1954, Parker, *et al,* 1953, Bandy, 1954).

Dyocibicides biserialis.—Present at Mason Inlet at opening to sea in 1 to 2 fathoms; at 276 and 417 fathoms; from shallow waters of California Channel islands. (Miller, 1951, Cushman, 1931, Cushman and Valentine, 1930).

Dyocibicides perforatus.—From shallow waters of California Channel Islands. (Cushman and Valentine, 1930).

Elphidium spp.—This genus is generally regarded as a shallow water form which tolerates a brackish water environment. It has certain species that are inhabitants of saline waters and in fact range from waters of normal salinity into brackish waters. Bandy (1954) finds the genus in high percentages throughout his three zones (30 to 130 feet) but in somewhat higher numbers in the deeper parts.

Elphidium advena.—Less than 115 meters; present in Narragansett Bay; rare in polyhaline bay of south Texas and widely distributed in warm waters of western Atlantic and Pacific; warm shallow waters; common in Gulf of Suez and in small numbers in coral reef areas of Red Sea; rare in open Gulf, beach, bays, and Matagorda Island marsh. (Parker, 1954, Said, 1951, Cushman, 1930, Post, 1951, Said, 1949, Parker, *et al,* 1953).

Elphidium incertum.—Present in inter-reef and polyhaline bay facies of south Texas, elsewhere known to be common in cold waters; Mason Inlet 0 to 3 fathoms; Narragansett Bay, finer silty bottoms essential to development. (Post, 1951, Miller, 1953, Said, 1951).

Guttulina austriaca.—See chart.

Hanzawaia concentrica.—(I have incorporated *Hanzawaia strattoni* in my records as this form seems confused with those of similar range as *H. concentrica.*) Common to abundant at 16 to 45 fathoms; greatest numbers at less than 100 meters, living forms from 22-78 meters; in Mason Inlet at 0 to 3 fathoms; greater than 20% at less than 50 meters, greater than 5% at less than 100 meters, less than 1% at depths of 220 meters; Breton Sound and more especially the open Gulf; most common in open Gulf, a few in Sound; rare in inter-reef facies, reef facies, polyhaline bays, passes of south Texas Coast; more common in open Gulf and beach samples, but also found in bays and in Matagorda Island marsh; present in Narragansett Bay from southern outer bay facies, probably controlled by salinity; at 55 to 75 feet in amounts from 10 to 45%, at 75 to 130 feet in 10-40%; maximum development at 57 to 166 feet. (Cushman, 1931, Phleger and Parker, 1951, Miller, 1953, Parker, 1954, Phleger, 1955, Phleger, 1954, Post, 1951, Parker, *et al,* 1953, Said, 1951, Bandy, 1954, Lowman, 1949).

Lagena melo.—See chart.

Nodosaria catesbyi.—See chart.

Nonion grateloupi.—See chart.

Ostracod spp.—Phleger finds this group common to the open Gulf with a few into the Sound (1954).

Planulina depressa.—Shallow waters of California Channel Islands (Cushman and Valentine, 1930). The genus *Planulina* seems to be another one in which individual species vary considerably in environmental adaptation; however, *Planulina depressa* as seen in present samples gives, by its demonstrated occurrence, an implication of deeper waters, as is most characteristic of the several species commonly referred to this form.

Polymorphina novangliae.—Rare in 1,395 and 1,917 fathoms; cold regions; present in Narragansett Bay. (Cushman, 1923, Cushman and Ozawa, 1930, Said, 1951).

Poroeponides lateralis.—(This form includes *Eponides repandus* of some authors). In Mason Inlet; in Narragansett Bay; 24 to 400 meters Gulf of Suez and Red Sea; rare at 30 to 130 feet in Gulf. (Miller, 1953, Said, 1951, Said, 1949, Bandy, 1954).

Quinqueloculina spp.—Neville M. Curtis, Jr., (1955 pp. 269-70) said, ". . .*Quinqueloculina* is most abundant from the beach out to approximately 90 meters. The literature on Recent or living Foraminifera appears to indicate highest frequencies to about 30 to 40 meters. This 30 to 40 meter depth interpretation is a general statement as *Quinqueloculina* does occur in much deeper water, but not abundantly". Some results seem to indicate that the genus is sensitive to salinity changes, being a distinctly salt water form; against this, Miller (1953) shows an occurrence of quinqueloculinids in subnormally saline waters of Mason Inlet.

Quinqueloculina seminulum.—Most common at 15 to 90 meters; common to rare in passes and the open Gulf, widely present in oceans and especially common in shallow water along the Atlantic Coast; forms 1 mm. or more are indicative of colder waters; present in Mason Inlet 0 to 3 fathoms; common in beach material, rarer in open Gulf and bays, rare in Matagorda Island marsh; present in Narragansett Bay where it is in a zone that seems to be restricted by salinity controls. (Parker, 1948, Post, 1951, Cushman, 1929, Miller, 1953, Parker, *et al,* 1953, Said 1951).

Quinqueloculina wheeldoni.—See chart and description in this paper.

Rotalia beccarii group.—(The several varieties of *Rotalia beccarii* are treated as a single entity, as their ranges are similar). Abundant at less than 70 meters; less than 1% at depths exceeding 70 meters, up to 34% at inner (shoreward) ends of traverses; common in Mason Inlet 0 to 3 fathoms; best development in Breton Sound and into open Gulf, but also in marsh; at 6 to 12 inches in moat at Fort Jeffereson, Tortugas; *R. beccarii* and var. *tepida* are found in following facies, bay head, inter-reef, reef, closed bays, polyhaline bays, passes, open Gulf of south Texas; smaller than typical specimens occur in Red Sea and Gulf of Suez; common and abundant in all facies of San Antonio region, including Guadalupe River; present in Narragansett Bay; 40% of fauna at 30-55 feet, 20-30% at 55-75 feet, 0-15% at 75-130 feet. (Phleger and Parker, 1951, Parker, 1954, Miller, 1953, Phleger, 1955, Cushman, 1922, Phleger, 1954, Post, 1951, Said, 1949, Parker, *et al,* 1953, Said, 1951, Bandy, 1954).

Sigmomorphina concava.—See chart.

Sigmomorphina pearceyi.—A few records from deep water samples of Red Sea, first records outside of North American Atlantic Coast (Said, 1949).

Sigmomorphina semitecta terquemiana.—See chart.

Sigmomorphina williamsoni.—In depauperate fauna (Boltovskoy, 1954).

Textularia candeiana.—Characteristic of "prominences" at 60-130 feet, one occurrence seems to correspond with maximum grain size ratio, but this does not hold true throughout area; found in large numbers in Gulf of Suez, Gulf of Aqaba and Red Sea proper at 60-90 meters; 90 to 300 meter facies off Atlantic Coast. (Bandy, 1954, Said, 1949, Parker, 1948).

Textularia gramen.—Common in shallow water samples and particularly in Gulf of Suez. (Said, 1949).

Textularia mayori.—Six percent up to 70 meters, scarce after 100 meters; usually occurs in less than 100 meters; rare in open Gulf; most common in open Gulf and rare in bays; present in samples from 30 to 130 feet in Gulf. (Parker, 1954, Phleger and Parker, 1951; Phleger, 1954, Parker, *et al,* 1953, Bandy, 1954).

Virgulina punctata.—See chart and description in this paper; mainly at depths less than 100 fathoms.

CONCLUSIONS

Species ranging into Breton and other sounds according to notes above, seem to be invading of seaward faunas as salinity and other factors are favorable to the invasion of such forms. The entire group seems to be in the "Middle and upper Neritic facies" of Ladd *et al* (1951), or in the neritic of Lowman (1949). The significance of results based on living species of Foraminifera found in the Yorktown formation are several:

1. The waters of Yorktown seas were in the upper and middle neritic facies and were sometimes less than 25 meters deep.
2. The Carter's Grove faunas were generally somewhat deeper than the others with certain exceptions which indicate a fluctuation of facies at about the level of the first abundant "*Chama congregata* beds".
3. Yorktown waters were saline as opposed to brackish.
4. Yorktown faunas suggest open waters rather than Sound facies.
5. Some rather well-defined depth facies are suggested for certain localities, but in the opinion of the author, these finer distinctions should await further ecological studies and better understanding of factors involved.
6. There is a slight suggestion of cold water facies in the case of some forms and warm water facies in others; in the opinion of the author, these suggestions do not warrant closer definition in the light of present knowledge.
7. Many features of the Yorktown faunas which would previously have passed for time-stratigraphic separations are

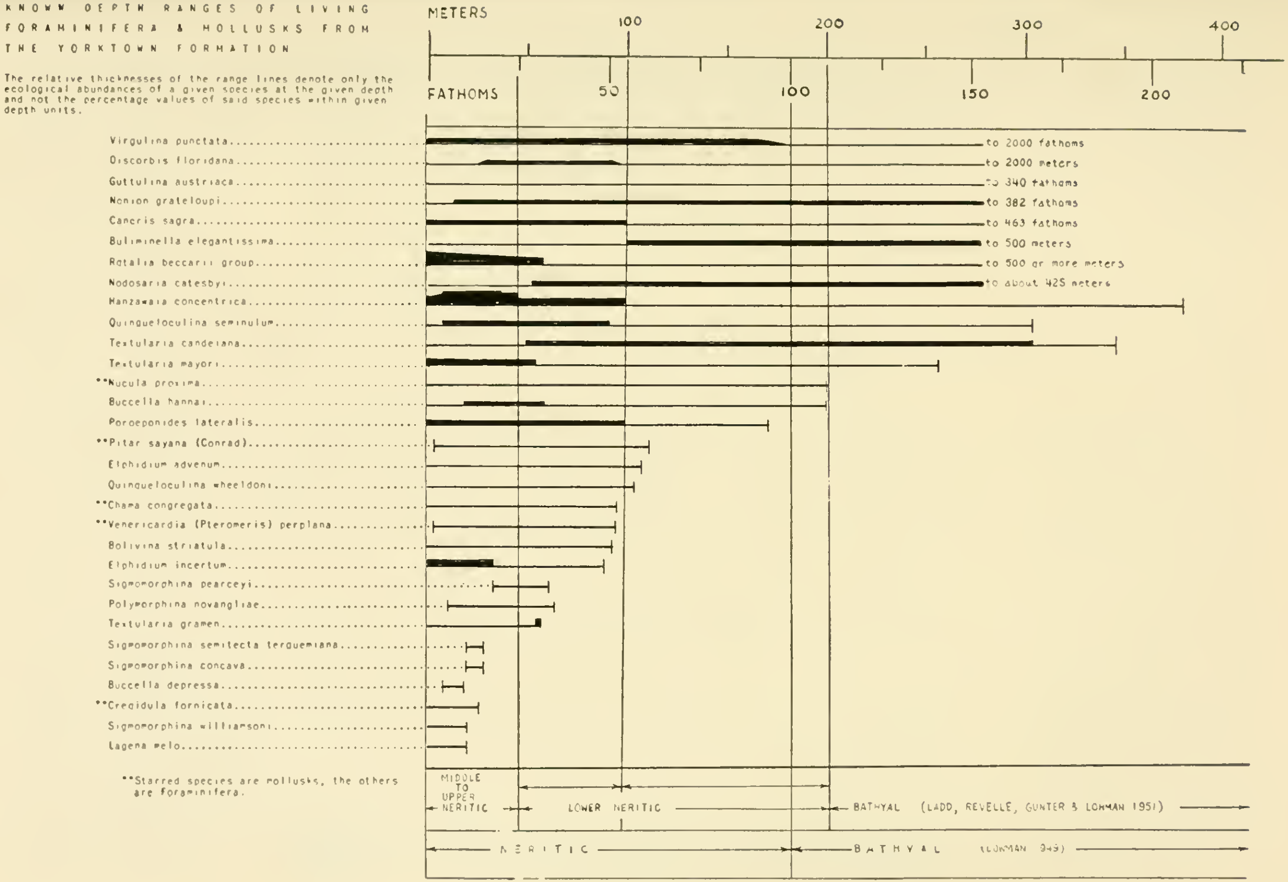
actually reflections of shifting environments which would be expected in shallow waters. Results obtained from consideration of ecological data now available indicate both the value and necessity of continued research into the ecology of modern foraminiferal facies as is exemplified by the excellent papers of Phleger and Parker, and others.

8. The absence of purely bathyal genera on the one hand defines the neritic environment of the Yorktown faunas, and the presence of deeper water groups (as per Norton, 1930) in the Carter's Grove locality both serve to indicate the value of definition by generic facies groupings. On the other hand, it is clear that species within genera are often capable of adaptation to environments not favored by a given genus. It is thus necessary to resort to the species in the last analysis and to carefully discriminate species so as to insure accuracy of identification.
9. At least as far as the Yorktown fauna is concerned, the depth of 100 meters seems to mark a definite boundary of some significance, thereby suggesting that this boundary may mark the bathyal neritic separation.

THE MOLLUSK COLLECTIONS FROM THE YORKTOWN FORMATION

The data on mollusks are tabulated in a chart (Figure 7) for comparison with the foraminiferal faunas from localities and from levels of collection within the beds of given outcrops. The absence of mollusks from the Yorktown Bluffs and at six feet up the bank at the beach below the Moore House do not indicate anything except that these two collections were made without reference to mollusks. These two samples were from early trips in the area and only yielded Foraminifera, Ostracoda, and broken shell fragments.

The Camp Wallace column represents three mollusk specimens found at Virginia Military Institute, which were labelled as being from Camp Wallace: the sands from the interiors of these shells yielded significant Foraminifera and Ostracoda, and these were included in this study.



KNOWN DEPTH RANGES OF LIVING FORAMINIFERA & MOLLUSKS FROM THE YORKTOWN FORMATION

The relative thicknesses of the range lines denote only the ecological abundances of a given species at the given depth and not the percentage values of said species within given depth units.

**Starred species are mollusks, the others are foraminifera.

FIGURE 6

Bryozoa, echinoid spines and fragments, and fish bones are found in various samples but were not studied or collected. One specimen of *Psammechinus philanthropus* (Conrad) was identified by C. Wythe Cooke from the six foot level at Carter's Grove. There are, in addition, finds of various whale remains and even one report of a walrus (Berry and Gregory, 1906) from the Yorktown formation, all attesting to the open sea nature of the sediments.

ECOLOGIC SIGNIFICANCE OF MOLLUSKS

According to Dr. Harald Rehder the ecology of Yorktown formation mollusks is little known and is a subject for fruitful study. Five species are recorded as to depth of habitat; these are in my ecologic chart showing the recorded depth of both Foraminifera and mollusks. Aside from these records, Dr. Rehder stated (personal communication) that the genera *Nucula, Corbula, Glycymeris, Calliostoma,* and (generally) *Astarte,* lived in deeper waters than did *Mya, Dosinia,* and *Crepidula,* to judge from their present-day congenera. The fauna as a whole indicates a shallow to moderately deep habitat. These observations coincide with my findings on the ecology of the Foraminifera. The reader may adduce further ecological details from a study of my several charts, but I feel it is best not to refine the gathered data until more and better evidence is at hand.

GEOLOGIC SIGNIFICANCE OF MOLLUSKS

In this study, the writer had in mind to test and corroborate or deny the zonations originally defined for the Yorktown formation by Mansfield (see earlier parts of this paper). The more minute zonations by Mansfield and Gardner proved impossible to verify and most of their localities are now either so altered or so inaccessable as to make a field comparison impossible.

The gross zonations of Mansfield proved possible to distinguish —my mollusk collections did show a separation and the criteria stated by Mansfield as distinguishing the Zone I from Zone II were found, particularly at Carter's Grove. I have already discussed the foraminiferal separations assuming that Mansfield's criteria are valid. The only question, and it is a serious one, is whether or not there are not better and more valid separation criteria of "zones" in the Yorktown formation than those given by Mansfield.

TABLE SHOWING DISTRIBUTION OF MOLLUSKS AND OTHER FORMS IN THE YORKTOWN FORMATION	FELGATER'S CREEK	BLUFFS AT YORKTOWN	EMBANKMENT AT MOORE HOUSE BEACH			LANGLEY FIELD	EMBANKMENT AT CARTER'S GROVE							CAMP WALLACE			SPILLWAY AT POWELL'S LAKE					GEOLOGIC RANGE			
							UPPER BEACH		MIDDLE OF BEACH			LOWER BEACH													
			6 FT. UP	4 FT UP	BASE		10 FT. UP	BASE	10 FT. UP	6 FT. UP	4 FT. UP	BASE	BASE*	VENUS SAND	PANOPEA SAND	ECPHORA SAND	GENERAL COLLECTION	PECTEN BED	OSTREA BED	ECPHORA BED	PEDALION MAXILLATA	PLIOCENE OR YOUNGER	YORKTOWN ZONE 2	YORKTOWN ZONE 1	OLDER THAN YORKTOWN
ECHINOID																									
Psammechinus philanthropus (Conrad)										■															
BARNACLE																									
Balanus concavus Bronn					■												■						■	■	■
MOLLUSKS (Pelecypods)																									
Nucula diaphana H. C. Lea				■	■																		■		
Nucula proxima Say				■	■				■													■	■	■	■
Nuculana acuta Conrad					■																		■		
Arca marylandica Conrad													■											■	■
Striarca centenaria (Conrad)				■	■			■		■		■						■					■	■	■
Noetia incile Say					■					■													■	■	■
Glycymeris parilis Conrad ?	■																						■	■	■
Glycymeris subovata Say	■				■		■	■	■		■	■	■										■	■	
Isognomon maxillatum (Deshayes) var.																	■				■			■	■
Ostrea disparilis Conrad				■			■		■		■	■					■						■	■	■
Ostrea percrassa Conrad					■												■						■	■	■
Ostrea sculpturata Conrad				■													■						■	■	■
Ostrea sellaeformis Conrad				■									■										■	■	■
Plicatula marginata Say				■			■	■				■											■	■	
Pecten gibbosus Lamarck	■																					■	■		
Pecten eboreus Conrad																	■					■	■	■	■
Pecten clintonius Say													■											■	
Pecten virginianus Conrad										■													■	■	
Pecten jeffersonius Say					■			■	■	■	■	■	■				■						■	■	■
Pecten jeffersonius edgecombensis Conrad				■	■												■						■	■	■
Pecten madisonius Say					■								■										■	■	■
Pecten santamaria middlesexensis Mansfield																		■							■
Pecten spp.	■																								
Astarte castrana Glenn ?	■												■										■	■	■
Astarte concentrica Say					■																	■	■		
Astarte cuneiformis Conrad													■											■	■
Astarte perplana Conrad	■																■					■	■	■	■
Astarte symmetrica Conrad							■		■		■	■					■						■	■	■
Astarte thomasii Conrad																	■						■		■
Astarte undulata Say							■	■	■		■	■					■						■	■	■
Astarte vicina Say													■											■	■
Astarte spp.	■																								
Crassatella meridionalis Dall ?							■		■		■												■	■	
Crassatella undulata Say												■											■	■	
Crassatellites marylandicus Conrad													■											■	■
Crassatellites sp.					■																				
Venericardia granulata Say	■				■		■	■	■		■	■	■				■						■	■	■
Chama congregata Conrad	■				■		■	■		■	■	■	■									■	■	■	■
Diplodonta acclinis Conrad					■																		■	■	■
Diplodonta berryi McGavock												■												■	
Phacoides anodonta (Say)							■					■											■	■	■
Phacoides cribrarius (Say)												■											■	■	■
Ctena microimbricata Gardner ?												■											■	■	
Ctena speciosa (Rogers and Rogers)								■		■													■	■	
Dosinia acetabulum (Conrad)				■	■												■						■	■	■
"Venus" tridacnoides (Lamarck)				■	■							■		■									■	■	
"Venus" tridacnoides rileyi Conrad												■	■											■	■
Macrocallista marylandica Conrad																	■								■
Pitar sayana (Conrad)					■																	■	■	■	■
Spisula confraga (Conrad) ?								■				■												■	■
Mulinia congesta Conrad																	■						■	■	■
Mya producta Conrad	■																						■	■	■
Corbula (Caryocorbula) conradi Gardner				■	■		■	■			■	■											■	■	■
Corbula conradi retusa Gardner								■				■											■	■	
Corbula cuneata Say					■																	■	■	■	■
Corbula inaequalis Say					■																	■	■	■	■
Kuphus calamus (H. C. Lea)				■	■							■											■	■	■
MOLLUSKS (Gastropods)																									
Fissurella spp.					■																				
Diodora redimicula (Say)					■								■										■	■	
Calliostoma basicum Dall				■																			■		
Calliostoma mitchelli (Conrad)												■												■	
Calliostoma philanthropum Conrad					■																		■	■	■
Crucibulum constrictum Conrad					■																		■	■	■
Crepidula aculeata costata Morton					■																		■	■	■
Crepidula fornicata Lamarck					■																	■	■	■	■
Turritella alticostata Conrad					■							■											■	■	
Turritella variabilis Conrad					■								■										■	■	■
Lemintina granifera (Say)												■										■	■	■	■
Ecphora quadricostata Say																	■			■				■	■
Ecphora sp.													■			■								■	
Siphonalia devexa Conrad					■																				
Busycon incilis (Conrad)					■																		■		

FIGURE 7

I am not inclined to separate the Yorktown formation into new or definite "zones", nor even to admit the validity of the old zones until two important points are clarified: 1. The distinction of stratigraphic from ecologic criteria, and 2, the mappability or stratal continuity of such zonations. I do not feel that Mansfield's work gives sufficient separations to trace over long distances, nor am I satisfied that the Foraminifera or Ostracoda can do it either. Until more proof is possible, it is my own belief that the Yorktown formation is best considered as a single unit embracing several ecological habitats which can be mistaken for stratigraphic zones in the absence of knowledge of the effects of different environments on the fauna of a region and a specific age. Richards, as cited earlier in this paper, stated that *Pecten clintonius* does not extend far enough into North Carolina to make it useful as a guide fossil for Zone 1 as it is discriminated in that state. I have already commented on the *Chama congregata* bed as an index for correlation. These difficulties plus the negative results of foraminiferal separations based on Mansfield's zonations (there are no foraminiferal species capable of designation as guides for Zone 1) seem to me to be conclusive evidence of the futility of separating the Yorktown formation into two distinct "zones".

There are, however, a number of foraminiferal species which are restricted to the Yorktown and sufficiently numerous so that one can expect to find a distinctive Yorktown fauna elsewhere.

MOLLUSKS AT CARTER'S GROVE

My charts show the presence of *Pecten clintonius* at Carter's Grove. At six feet above the base of the bank at this same locality is a *Chama congregata* bed which fits Mansfield's separation criteria, since he reported such beds as being basal to Zone 2. The charts will show other subsidiary criteria, including the generally older aspect of species below the six-foot level.

MOLLUSKS AT POWELL'S LAKE SPILLWAY

Not only are the foraminiferal faunas at Powell's Lake Spillway negative in aspect to the normal Yorktown formation fauna, but the mollusks suggest a St. Marys age for this outcrop. On one hand, the mollusks do not include diagnostic Yorktown species, and on the other hand, several of them are restricted to St. Marys or older formations. Dr. Denise Mongin identified species collected by her at Powell's Lake Spillway which are indicative of the St. Marys formation. Her collections will be listed and commented on in the paper to follow this one.

If the Powell's Lake outcrop is St. Marys in age, this makes localities to the west of the area somewhat suspect, since the Yorktown formation is intimately related to the St. Marys in molluscan content, and inland outcrops can be one or the other. Foraminifera from an outcrop near Petersburg seem older than Yorktown species as reported earlier in this paper. As also reported earlier in this paper, the St. Marys has suffered from encroachment of the Yorktown as interpreted by some workers. Perhaps the earlier interpretations are somewhat more valid than they are now believed to be.

NOTES ON THE DESCRIPTIONS OF SPECIES

In the descriptive portion of this paper, two principles are followed: 1. the synonymy is not exhaustive but represents those references checked by the author for similarity to Yorktown forms. 2. The description cited is the one most closely resembling the form found and is, therefore, not necessarily the original description for the species.

There is an amount of error in synonymies and in descriptions of Foraminifera which makes it difficult to rely on published works. The older a named species is, the greater the error of subsequent assignment of forms to it. This margin of error is peculiarly emphasized in the case of the Textulariidae.

The genus *Textularia* has been the subject of fine discrimination as to species, if one is to judge from the literature. It is here that direct comparison with specimens of *Textularia* in the collections of the U. S. National Museum has been most instructive. For, while the literature distinction has been minute, assignments of species in the textularids as revealed by the actual specimens have been erratic. This is not the work of one group or individual—the difficulty is basic and widespread.

In some cases, illustrations of certain textularids are too highly stylized to be of much use. Evidently, distrust of illustrations because of stylization has led to misinterpretation of certain forms which are, in fact, quite accurately delineated. Cushman's *Textularia mayori* from the Tortugas region seems to be such a case of misinterpretation.

To partially eliminate the effect of misinterpretation, forms illustrated in this paper are figured both by artist's drawings and by photomicrographs. Both types of illustration are accurate. However, to understand any given form it seems necessary to note the differences revealed by these two kinds of illustration. The artist sees the foraminiferal test in its structural form, and delineates features which are not quite so readily seen as the drawing would indicate. On the other hand, the photomicrograph tends to suppress detail, especially if it is below the surface of the test wall. The actual appearance of the form is somewhat between these two extremes. Additionally, the texture of the test wall is revealed better by photomicrograph than by drawing. This is not to say that either form of illustration is superior to the other. It seems better to employ both media for adequate delineation of form.

In the case of the Globigerinidae and of the genus *Buccella,* the technique of photomicrography was insufficient to acquire an adequate picture of any specimen. These forms are thus illustrated by means of drawings alone. In other cases the photomicrograph was sufficient to render drawings unnecessary. Where these two different situations are encountered, comparisons of drawings to photomicrographs of forms illustrated both ways will enable the reader to make an accurate reconstruction of the form by a little study.

THE GENUS EPONIDES

In searching the literature concerning *Poroeponides lateralis* (Terquem) which is common to the Yorktown formation, it was found that the figure by H. B. Brady of "*Eponides repandus*" has a marked similarity to forms in the Yorktown material which are apparently only end-forms of a gradual series at the other end of which is *Poroeponides lateralis,* the type species of *Poroeponides* Cushman, 1944. Reference was made to the original *Nautilus repandus* as figured by Fichtel and Moll, the type species of *Eponides.*

C. D. Redmond (Micropaleontologist, vol. III, No. 4, pp. 18-21, 1949) has carefully gone into the basic question of whether *Eponides*, as we know it today, is valid. His conclusion, which seems inescapable, is that the selection of figures of *repandus* subsequent to those of Fichtel and Moll and Montfort (who erected the genus on *N. repandus*) has been a major source of error. As Redmond points out, the written description of the genus and of the original *N. repandus* supports the improbable figures themselves; so, the subsequent choice by Cushman and others of later figures for the genus, does violence to the generic description and its type species.

Hofker's attempt to correct this discrepancy (Micropaleontologist, vol. IV, No. 1, pp. 15-16, 1950) unfortunately overlooked several important facts. First, he failed to specify what he meant by "*Eponides repandus* from the coast of Chile" which needs clarification and designation as a species before it can be used as a type species for anything—and it cannot, in any case, be the type species of *Eponides,* as Montfort's designation stands for the genus. Second, *Eponides frigidus* belongs to the genus *Buccella* and is characteristic of the genus as erected by Anderson, and in any event, *E. frigidus* cannot be a replacement for the same reason; Montfort's designation preoccupies this position. In justice to Hofker, the genus *Buccella* was erected subsequent to his suggestion, so that question would have been decided in his favor, had there not been a prior designation of the type species for the genus by Montfort, Cushman, and others.

So far everyone concerned has failed to note an important point about the figures of Brady (and Jones, Parker and Brady). Reference to their figures (reproduced by Redmond in his discussion) show that "*Pulvinulina repanda*" is marked with definite basal pores, which is a generic characteristic of *Poroeponides* Cushman, 1944. Hence these forms are not available for *Eponides* which has no basal pores on the final chamber's apertural face. Neither Cushman, nor anyone else, has included apertural face pores in describing *Eponides.*

To further complicate matters, Asano and Uchio (in Stach, L. W., "Illustrated Catalogue of Japanese Tertiary smaller Foraminifera" Part 14, Rotaliidae, p. 18, tfs. 134-135, 1951) described

Poroeponides cribrorepandus, which they said differed from *Eponides repandus* in having "the numerous scattered rounded openings typical of *Poroeponides*". Reference could have been made to Cushman's reproduction of Brady's *repandus* in his Foraminifera textbook; the figure Cushman reproduced has apertural face pores also. D. N. Miller, Jr., (Contr. Cushman Found. Foram. Res., vol. IV, pt. 2, p. 59, 1953) described "*Poroeponides repandus* (Fichtel and Moll)" and put the descriptions of Montfort and of Fichtel and Moll in synonymy with it and on the same page he noted that the type species of *Eponides* is their form which he included under *Poroeponides repandus* as a synonym.

In the Yorktown material, I found specimens which grade from the typical *Poroeponides lateralis* (with open umbilicus, many apertural pores, and broad chambers) to forms with closed umbilicus, few pores, and pointed final chambers, quite typical of specimens figured by Brady. I am convinced that these forms are the same species, *i.e.*, *Poroeponides lateralis*. Not only can the gradual changes be observed in a series of specimens, but all of them have a peculiar chalky test wall underlain by a glassy test. The forms most covered with "chalk" also are the forms exhibiting a closed umbilicus and few apertural pores.

Orville Bandy (U. S. Geological Survey Professional Paper 254-F, p. 137, pl. 30, figs. 1a-c and 3a-c, 1954) figured two forms of *Poroeponides; P. lateralis* and *P.* sp., which he noted that he counted together in the frequency counts. These two forms represent the two extreme end-forms of *Poroeponides lateralis* as found in the Yorktown formation. Between these end-forms are numerous individual variants indicating that the species has the ability to change markedly.

Such cases of form plasticity should be expected. *Eponides* as a genus seems to be a case of mistaken assignment. Its usefulness is impared not only by the confusion now existing but by a changing concept of classification in which more species are withdrawn from it to be placed in newer genera. This is not to condone or praise the narrowing of generic divisions. In the case of *Eponides* the genus has been destroyed in validity by misinterpretation and incorrect establishment of types. There is, therefore, no choice but to erect a new genus or several genera to take care of the forms hitherto assigned to *Eponides*. This has been partially accomplished with *Poroeponides* and *Buccella;* possibly one or several new genera need to be designated.

TRIMORPHISM AND THE BUCCELLIDS

The writer has approached the subject of trimorphism with some reservation, inasmuch as a general application of the principle must certainly confuse an already badly mixed nomenclature, and inasmuch as application of this principle raises serious problems on the generic level.

Nevertheless, in studying and describing the forms from the genus *Buccella* which are present in the Yorktown formation, a series of forms presented themselves so as to provide an almost academic demonstration of Hofker's basic principle called "trimorphism". What is certainly worse from a standpoint of denying the principle, one cannot assign these forms to different genera—they are all in the genus *Buccella.*

Buccella anderseni McLean, n.sp., occurs in three distinct forms, which are related; their differences may be explained on the basis of Hofker's three basic forms. The microspheric form is typically developed—a small proloculum followed by comparatively numerous chambers. In the megalospheric form, however, there are two basic developments which I characterize as A_1 and A_2 after Hofker.

In the A_1 generation, the proloculum is the smaller of the two generations but is considerably larger than the microspheric proloculum of *B. anderseni.* The A_1 generation has a greater number of succeeding chambers than the A_2 form, though fewer than the microspheric test. In *B. anderseni,* the A_1 form is markedly thick, with a high spire.

Generation A_2 of *B. anderseni* has a larger proloculum, fewer coils and chambers, a spire similar to the microspheric form and is the larger of all three forms.

What is important to note is that in all other details, these forms are similar—too much so to give any basis for species-separation, or generic-separation.

Concerning trimorphism, Hofker's discussions (The Foraminifera of the Siboga Expedition, Part II, 15-26, 1930) indicated that the two different megalospheric forms of a species are at least partly caused by seasonal conditions such as density of seawater. In this respect, the trimorphic development may be cut short by, say, a tropic environment, in which the A_2 generation is skipped. In the case of apogamy, the microspheric forms are absent, due to nonformation of microspores, according to Hofker.

Despite the questions involved in naming species of Foraminifera, due to trimorphism, Hofker's findings do not erase the basic megalospheric-microspheric alternation of generations; where he has rendered a distinct service is to bring to our attention that certain structural features of the form are in fact due to environmental reaction of the individuals—not generic-differentiation, nor even specific-differentation. Perhaps in "trimorphism" we have a real reason to revive such names as "*Cristellaria*" in preference to the more restricted later genera which will not allow for these changes of shape within a single species.

Hofker and other micropaleontologists may, incidentally, find much profit in reading Darwin's "Origin of Species", for in this work in Volume I (pp. 55-56, 6th edition, 1892, D. Appleton and Co.) Darwin drew attention to dimorphism and trimorphism in the case of Crustacea, Insecta, and plants; and on pages 29-34 of Volume II of this same edition he discussed the effects of this set of conditions on fertility of a mating between different dimorphic and trimorphic individuals. His remarks do little to assist in defining a species on the basis of sexual compatibility.

As Cushman, (1950, p. 55) pointed out, the difficulty in applying trimorphism is that it will be applied too widely. To properly qualify as one species, the three forms of a given series must have certain limiting qualifications. The first of these is that the forms to be combined must have the same locality and distribution. A second qualification, indicated, but not stressed by Cushman on page 53 of the same chapter, seems to me to be of even greater significance at least in the case of the Buccellidae. This is the agreement of ornamentation and chamber shape following the proloculum. To correctly apply trimorphism in naming a species, details of the entire test must be considered.

Reference to the figures of *Buccella anderseni* will illustrate my meaning. As can be seen, the three trimorphic forms differ in several respects; degree of spiral development, number of chambers following the proloculum, size of proloculum, and number of coils to the test. As shown by Hofker, the A_1 form differs most from the microspheric form, and the A_2 form returns to some closer conformity with the microspheric form, but differs in acceleration of early development. This is the case with *Buccella anderseni.*

In angularity of periphery, in basic test structure, and in the degree of pustulation, *Buccella anderseni* is the same in all three forms, as is also the case with the degree of sutural limbation, inclination of sutures in the early coils on the dorsal side, and the chamber shape on the ventral side.

On page 364 of the 1950 edition of Cushman's textbook is found the following statement: "*Nephrolepidina* and *Eulepidina* intergrade. This has been demonstrated particularly in *L. undosa* Cushman. *Eulepidina* also intergrades with *Trybliolepidina*". In justice to Cushman, this portion of the text it should be noted, was written by W. Storrs Cole and T. Wayland Vaughan, and subsequently revised by Cole. The difficulty raised by the fact that *L. undosa* embraces two subgenera within one species is easily explainable if the so-called "subgenera" are actually recognized as being different trimorphic (or polymorphic) forms of the same species, and hence the same genus. A species is supposedly the last separatable zoological unit, and cannot, by definition, transgress units of a higher order.

The basic difficulty is that too much emphasis has been placed on the embryonic apparatus (proloculum and immediately succeeding chambers) in foraminiferal classification and not enough attention has been paid to the whole animal. Classifiers should have been forewarned by the accepted fact of microspheric and megalospheric generations in the Foraminifera and should have been aware of the plasticity of the embryonic apparatus. The adult animal embraces the entire "habit" or evolutional development of the form— to emphasize any one or any single group of characters at the expense of the rest, must lead us astray from what we call "natural" classification. No classification is natural if the animal does not conform to it.

SYSTEMATIC DESCRIPTIONS

The classification utilized in this paper is that of Cushman as revealed in his textbook (1950 edition). Such changes as are necessary to bring this classification up to date (such as inclusion of the genus *Buccella*) have been made.

FORAMINIFERA

Family TEXTULARIIDAE

Genus TEXTULARIA Defrance, 1824

Textularia articulata d'Orbigny

Pl. 35, figs. 1-2; Pl. 36, figs. 4-6, 9, 11, 15-16

Textularia articulata d'Orbigny, 1846, Foram. Foss. Bass. Tert. Vienne, p. 250, pl. 15, figs. 16-18; Bagg, 1904, Maryland Geol. Surv., Miocene vol., p. 471, pl. 132, figs. 6-7; Cushman & Ponton, 1932, Florida Geol. Surv., Bull. 9, p. 40, pl. 1, figs. 1a-b; Cushman & Cahill, 1933, U. S. Geol. Surv., Prof. Paper 175-A, p. 8, pl. 1, figs. 12a-b; Lalicker & McCulloch, 1940, Allan Hancock Pac. Expedition, vol. 6, No. 2, p. 118, pl. 13, figs. 3a-d; Cushman & Ellisor, 1945, Jour. Pal., vol. 19, No. 6, p. 547, pl. 71, fig. 11.

Test elongate, two or three times as long as broad, compressed, rather evenly tapering, with the greatest breadth toward the apertural end, periphery acute and slightly keeled; chambers distinct, ten or more pairs in the adult, high and increasing in height toward the apertural end; sutures distinct, somewhat curved, extending strongly backward; wall distinctly arenaceous, with much cement, smoothly finished; aperture fairly large, at the base of the inner margin of the chamber. Length 0.60-0.75 mm.; breadth 0.30-0.35 mm.; thickness 0.18-0.20 mm.—(Cushman and Cahill, 1933.)

Yorktown specimens agree well with the description by Cushman and Cahill except that the chambers are fewer than ten pairs. Specimens show some of the test wall variation discussed below under *Textularia candeiana*.

Occurrence.—T. articulata is a common to frequent species in material from the Moore House Beach, Carter's Grove, Camp Wallace, and the base of the outcrop at Powell's Lake Spillway.

Textularia badenensis Lalicker Pl. 35, figs. 3a-c

Textularia partschii Czjzek (not Reuss), 1848, Haidinger's Naturw. Abh. 2, p. 148, pl. 13, figs. 22-24.

Textularia badenensis Lalicker, 1935, Contrib. Cushman Lab. Foram. Res., vol. 11, pt. 2, p. 44, pl. 7, figs. 1a-c.

Textularia cf. *badenensis* Clapp, Ann Dorsey, 1948, Maryland Dept. Geol. Mines, & Water Resources, Bull. 2, p. 276, pl. 27, figs. 8a-c.

Test large, conical, tapering, slightly compressed in early portion, subcircular in top view, periphery broadly rounded; chambers numerous, inflated, rapidly increasing in height as added; sutures distinct, depressed, except in early portion, nearly straight, somewhat oblique; wall rather coarsely arenaceous with a large proportion of cement, smoothly finished in early portion, but otherwise rough; aperture a broad, rather high arched opening at the inner margin of the last-formed chamber, and in a distinct reentrant. Length of holotype 1.20 mm.; greatest width 0.76 mm.; thickness 0.56 mm. (Lalicker 1935.)

Occurrence.—A single specimen was found at Carter's Grove at the base of the bank, lower beach section.

Textularia cf. **bocki** Hoglund Pl. 36, figs. 10a-b

Textularia bocki Hoglund, 1947, Uppsala Univ. Bidrag. Bd. 26, p. 171, pl. 12, figs. 5-7.

Test free, of medium size, elongate, tapering, somewhat compressed, broadest at the oral end, apical end obtusely rounded in the megalospheric form, more acutely pointed in the microspheric; initial end occupied by the proloculum in the megalospheric form, immediately followed by a biserial arrangement of the chambers, in the microspheric form with a single whorl of three chambers before the biserial chambers follow; periphery sharpened, slightly carinate; chambers broader than high, in the apertural end slightly inflated, up to 23 in the microspheric form, up to 18 in the megalospheric; sutures fairly distinct, only slightly depressed; wall arenaceous, composed of scattered sand grains of medium size with much cement, exterior rather neatly finished, inner surface lined with chitin; aperture interio-marginal forming an oblong, narrow opening at the inner margin of the last chamber; colour greyish white. Length up to 1.12 mm. in the microspheric form; the megalospheric somewhat smaller in all respects; breadth ½ to 2/3 of length; thickness ¾ of breadth. (Hoglund 1947.)

The single specimen found at Carter's Grove is about 1.43 mm. long and has fewer chambers than Hoglund's form but is otherwise close to the megalospheric form of his species.

Occurrence.—Single specimens were found at the bank base of both the Moore House Beach and the upper beach at Carter's Grove.

Textularia candeiana d'Orbigny Pl. 35, figs. 4, 6, 7, 10, 11

Textularia candeiana d'Orbigny 1839, in De La Sagra, Hist. Fisc. Pol. Nat. Cuba, "Foraminiferes" p. 143, pl. 1, figs. 25-27; Cushman, 1922, Carnegie Inst. Washington, pub. 311, p. 23, pl. 2, fig. 2; Cushman, 1922, U. S. Nat. Mus., Bull. 104, p. 8, pl. 1, figs. 1-3; Cushman & Ponton, 1932, Florida Geol. Surv., Bull. 9, p. 41, pl. 8, figs. 4a-b; Puri, 1953, Florida Geol. Surv., Bull. 36, p. 80, pl. 30, figs. 9-10.

Test elongate, club-shaped, the early portion narrow, much compressed, the edges almost carinate, slightly tapering to the round-pointed apex, the later chambers enlarging rapidly, much inflated; chambers numerous; wall rather coarsely arenaceous; aperture in a broad but shallow sinus at the base of the inner margin of the chamber; color dark grey. Length about 1 mm. (Cushman, U. S. Nat. Mus. Bull. 104, 1922.)

There are two or more descriptions of this species by Cushman, of which the one here cited seems to best describe Yorktown specimens. The Yorktown forms average 1.40 mm. in length and show considerable variation in the composition of the test wall.

Slama (Micropaleontologist, vol. 8, No. 1, pp. 33-4, 1954) reported an interesting experiment in which several species of *Ammobaculites* showed preference for particles of silicon carbide and larger sizes of material for inclusion in their test walls. Further experimentation seemed to show that availability of sediment constituents plus selectivity play an important part in the make-up of the arenaceous test of *Ammobaculites.*

Specimens of *T. candeiana* (as here figured) show distinct differences in the coarseness of the test wall and also in selection of mineral grains, one highly evident choice being for large black mineral grains where they are available in the sediment. Fine sand makes up a large part of these tests, but where the sediment allows selection of both large white particles and dark ones, these elements show up in *T. candeiana* tests. Those tests that show little or no coarse material came from sediments largely lacking such material. The extreme difference in test wall constituents is the only difference to be noted between these forms.

Occurrence.—Cushman records this form as rare in depths from 79 to 104 fathoms of the present oceans. It is common to frequent in all samples from Carter's Grove, Moore House Beach, Camp Wallace, and in the base of the outcrop at Powell's Lake Spillway.

Textularia eustisensis McLean, n.sp. Pl. 35, figs. 5a-b

Test elongate, about 2½ times as long as broad, slightly compressed, sides almost parallel; chambers distinct, somewhat globulate, increasing gradually in size as added, 16 chambers visible in holotype; sutures distinct, depressed, straight to slightly curved, inclined downward slightly; wall rather smoothly arenaceous, with considerable cement; aperture an arched slit in a slight reentrant at the base of the final chamber. Length of holotype, 1.89 mm.; breadth, 0.68 mm.

In the U. S. National Museum (Slide P2028) labelled as "*Textularia gramen*" are a number of typical specimens of this form as found in the St. Marys formation at Langley's Bluff, Maryland. It is possible that this is the *T. gramen* cited in the chart by Cushman and Cahill (U. S. G. S. Prof. Paper 175-A) for their Langley's Bluff locality.

Textularia eustisensis differs from the *T. consecta* of Clapp (Md. Dept. Geol. Mines & Water Res., Bull. 2, 1948 pp. 227-8) in its inclination of sutures, larger size, and configuration of aperture. It differs from *T. recta* Cushman, *T. midwayana* Lalicker, and *T. plummerae* Lalicker in having more inflated chambers, inclined sutures, and a more compressed test.

Types.—Holotype, P.R.I., No. 22,055; paratypes, P.R.I., Nos. 22,051-22,054 and 22,056-22,059; U.S.N.M., No. P3104.

Occurrence.—*Textularia eustisensis* is best developed in a well in Fort Eustis, Virginia, at a depth of 101 to 135 feet, from which sample the holotype was taken. It also is present at Langley Field, sporadically in samples from Carter's Grove, and at the base of the Powells Lake Spillway outcrop. As noted above, it is present in the St. Marys of Maryland at Langley's Bluff. Its present range is from the St. Marys formation and the Carter's Grove facies of the Yorktown formation.

Textularia gramen d'Orbigny Pl. 36, figs. 7, 12-13

Textularia gramen d'Orbigny, 1846, Foram. Foss. Bass. Tert. Vienne, p. 248, pl. 15, figs. 4-6; Cushman, 1918, U. S. Geol. Surv., Bull. 676, p. 8, pl. 9, figs. 4-5 (not figs. 2, 3, 6); Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 17, pl. 1, figs. 5a-b; Puri, 1953, Florida Geol. Surv., Bull. 36, p. 81, pl. 30, figs. 7-8.

Test slightly longer than broad, compressed, periphery subacute, sides strongly divergent; chambers distinct, comparatively few, fairly high, the earlier ones strongly overlapping; sutures distinct, slightly depressed; wall finely arenaceous, smoothly finished; aperture elongate, in a definite groove at the base of the inner margin of the last-formed chamber. Length 0.60-0.75 mm.; breadth 0.35-0.45 mm.; thickness 0.22-0.25 mm. (Cushman, 1930.)

A feature of *T. gramen*, not described by Cushman, which seems to be a feature of D'Orbigny's original form, is the downward curve of the sutures, noted in Yorktown specimens. D'Orbigny is conceded to have been careful about such features, and there is no reason to think *T. gramen*, as he designated it, has straight sutures, as his figure shows them to be curved. *Textularia gramen*, to judge from the numerous forms assigned to it, has been so generally abused that it would probably be advisable to suppress the name.

Occurrence.—In the Yorktown formation, *T. gramen* is sporadically present in all outcrop localities except the Langley Field sample.

Textularia mayori Cushman Pl. 36, figs. 1-3

Textularia mayori Cushman, 1922, Carnegie Inst. Washington, publ. 311, p. 23, pl. 2, fig. 3; Cushman, 1922, U. S. Nat. Mus., Bull. 104, pt. 3, p. 7; Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 17, pl. 1, figs. 6-8; Cushman & Ponton, 1932, Florida Geol. Surv., Bull. 9, p. 40, pl. 1, figs. 2-3; Phleger & Parker, 1948, Geol. Soc. Amer., Memoir 46, pt. 2, p. 5, pl. 2, figs. 1-5; Puri, 1953, Florida Geol. Surv., Bull. 36, p. 82, pl. 20, figs. 7-8.

Test compressed, increasing rapidly in breadth, initial end rounded, apertural end obliquely truncate; surface fairly smooth; chambers rather indistinct; sutures slightly depressed; periphery of each chamber with an elongate, conical, spinose projection, often broken at the tips, those of the early portion directed backward, the later ones extending straight outward; wall arenaceous, of angular sand-grains with much fine cement; aperture very low, elongate, at the inner border of the last-formed chamber, in a reentrant of the border, with a thin lip above; color grey. Length up to 0.80 mm. (Cushman, Carnegie Inst. Publ. 311, 1922.)

Yorktown specimens range from 0.75 to 0.95 mm. long and from 0.47 to 0.58 mm. wide, and are typical.

Occurrence.—The form seems to be restricted to the Langley Field and Carter's Grove localities.

Textularia pseudobliqua McLean, n.sp. Pl. 35, figs. 8-9; Pl. 36, figs. 17a-b

Test triangulate, stubby, slightly compressed, periphery rounded, test outline somewhat lobate due to deeply depressed sutures; chambers generally distinct, broader than high, increasing gradually in size as added, final chambers quite high, nine visible chambers in holotype; sutures deeply depressed in later portion of test, indistinct in early portion, slanted downward; wall coarsely arenaceous, with much cement; aperture a low arch within a distinct reentrant at the base of the last formed chamber. Length of holotype, 1.38 mm.; breadth, 0.78 mm.

Textularia pseudobliqua differs from *T. obliqua* Clapp in the irregular juxtaposition of the chambers along the central axis, in its less slanted and more distinct sutures, and in its coarser test.

Types.—Holotype, P.R.I. No. 22,078; paratype, P.R.I. No. 22,069.

Occurrence.—Base of the Powell's Lake Spillway outcrop and at depths of 101 to 135 feet in the Fort Eustis well.

Textularia pseudobliqua aspera McLean, n.subsp. Pl. 36, figs. 8, 14

Subspecies differs from the typical form in having an extremely rough test which completely obscures the details of the form.

Types.—Holotype, P.R.I., No. 22,081; paratype, P.R.I., No. 22,080.

Occurrence.—Carter's Grove Beach, base of bank, lower part of beach; also in the Fort Eustis well at 101 to 135 feet. The form may be present in the York River Bridge test borings as a juvenile form, although these may be the preceding species.

Genus **TEXTULARIOIDES** Cushman, 1911

Textularioides (?) **carteri** McLean, n.sp. Pl. 35, figs. 12a-e

Test apparently attached, one side flat, the other somewhat globular in chamber relief; outline of test triangulate; test consists of a rounded proloculum with a small whorl of supplementary chambers, then becoming biserial with nine large chambers in the biserial portion; sutures depressed, nearly straight on free side, but curved and only slightly depressed on flat attached side; wall smooth; aperture a small indistinct opening at the base of the last formed chamber. Length, 0.78 mm.; width, 0.42 mm.

This species differs from *Textularioides inflata* Cushman in the triangular outline, smoothness of wall, and the less wedge-shaped chambers.

Named in honor of Charles Carter, builder and original owner of Carter's Grove.

Type.—Holotype, P.R.I., No. 22,087.

Occurrence.—The single, but distinctive specimen, was found at the base of the bank, lower portion of beach, at Carter's Grove.

Family **MILIOLIDAE**

Genus **QUINQUELOCULINA** d'Orbigny, 1826

Quinqueloculina seminula (Linnaeus) Pl. 37, figs. 12, 14

Serpula seminulum Linnaeus, 1767, Syst. Nat. ed. 12, p. 1264.
Miliolina seminulum Williamson, 1858, Rec. Forams. Great Britain, p. 85, pl. 7, figs. 183-185; Heron-Allen & Earland, 1932, Discovery Reports, vol. 4, pp. 313-314, pl. 6, figs. 25-40.
Quinqueloculina seminulum Cushman, 1929, U. S. Nat. Museum, Bull. 104, p. 24, pl. 2, figs. 1-2; Boltovskoy, 1954, Revista Inst. Nacional Invest. Ciencias y Mus. Argentino Ciencias Nat. "Bernadino Rivadavia", Tomo 3, No. 4, p. 258, pl. 20, figs. 1a-c.
Quinqueloculina seminula Cushman & Cole, W. S., 1930. Contrib. Cushman Lab. Foram. Res., vol. 6, pt. 4, p. 95, pl. 13, figs. 1a-c; Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 19, pl. 2, figs. 1a-c (not 2).

Test longer than wide, greatest width near the middle, chambers distinct, of nearly uniform diameter, periphery rounded; sutures distinct, very slightly depressed; wall smooth, polished; aperture large, with a simple tooth. Length up to 1 millimeter or more in larger cold-water specimens. (Cushman, 1929.)

It is difficult to see how this cosmopolitan form can be referred to the drawing by Linnaeus of *Serpula seminulum*. This species is one of those in which numerous types of test form have been included, and the specimens present in the Yorktown formation seem to agree well with those pictured in papers here cited in synonymy (with the exception of Linnaeus's description). Boltovskoy reports *Q. seminulum* from a depauperate fauna of San Blas Bay at a depth of 5-25 meters.

Occurrence.—This form is common to rare in most outcrops of the Yorktown formation. Its range is greater than Miocene, extending upward to the present.

Quinqueloculina seminulangulata McLean, n.sp. Pl. 37, figs. 8a-b

Quinqueloculina venusta ? Cushman, 1918, U. S. Geol. Surv., Bull. 676, p. 70, pl. 29, figs. 3a-c.

Test somewhat longer than broad, chambers distinct, sharply triangular in cross-section, angles pronounced but not carinate; chambers distinct, triangulate in end view; sutures distinct, depressed; wall smooth and polished; aperture an elongate, rather large oval opening with no lip, situated on a nonprojecting, truncate end of final chamber, with a long thin, simple, tooth. Length, 1.00 mm.; breadth, 0.65 mm.; thickness, 0.45 mm.

Except for the angulation of the chambers and the nonprojecting apertural end, this form greatly resembles *Quinqueloculina seminula* (Linnaeus), and has probably often been confused with that species. Cushman figured the form from Jackson Bluff, Florida, and noted that it is found in the Miocene of Virginia. The single specimen is typical and I have described the form because of its demonstrated geographic range.

Types.—Holotype, P.R.I., No. 22,103; paratype, P.R.I., No. 22,104.

Occurrence.—Holotype from Langley Field house excavation; others from the well at Crisfield, Maryland.

Quinqueloculina triloculiniforma McLean, n.sp. Pl. 37, figs. 9-11

Test round, about 4/5 as broad as long; four chambers visible on one side and only two on the other (sometimes a small part of a third chamber projects between the two chambers); chambers distinct, rotund; periphery rounded; sutures distinct, depressed; wall smooth, white, chalky; aperture large with a broad, simple tooth. Average length, 0.50 mm.; breadth, 0.40 mm.; thickness, 0.25 mm. or more.

This form resembles *Triloculina* except for the small fourth chamber on one side and the occasional projection of a chamber on the opposite side between the two larger ones. It appears to be quite uniform as to size and arrangement. Superficially it resembles *Q. seminula* on the four-chambered side but is more rotund and does not show the fifth chamber so well.

Types.—Holotype, P.R.I., No. 22,111; Paratypes, P.R.I., Nos. 22,107-22,110 and 22,112-22,113; U.S.N.M., No. P3109.

Occurrence.—Langley Field house excavation; Moore House Beach 6 and 4 feet up the bank; Camp Wallace, and the base of the bank, lower part of beach Carter's Grove.

Quinqueloculina sp. Pl. 37, figs. 7a-b

Two specimens of this interesting little form were found; one at Camp Wallace, and the other at the Langley Field house excavation. The sparseness of the specimens, plus the fact that they could be assigned to a number of species, makes it best not to attempt to name or describe this form on the basis of present material.

Quinqueloculina wheeldoni McLean, n.sp. Pl. 37, figs. 13a-c

Test large, about 1½ times as long as broad, test strongly quadrate in cross-section, sides depressed; five chambers visible on one side, four on the other, chambers irregular, slightly keeled; sutures distinct, depressed, curved irregularly according to development of chambers; wall white, chalky, with faint striations on surface of test, striations appear as faint, irregular, discontinuous scratches; aperture large, quadrate, with a long tooth which is slightly bifid in the tip of the holotype. Length of holotype, 1.75 mm.; breadth, 1.15 mm.; thickness along largest chamber, 0.58 mm. Paratypes are considerably smaller in all dimensions, but otherwise are similar.

This species resembles *Triloculina quadrilateralis* d'Orbigny except for the chamber arrangement and the quadrate aperture.

Heron-Allen and Earland (Trans. Linnean Soc., 2nd Series—Zool. vol. XI, pt. 13, p. 214, pl. 40, figs. 1-9, 1916) figured as *Miliolina ferussacii* (d'Orbigny) a form which may be identical with *Q. wheeldoni.* They report the species from dredging samples from the West of Scotland in waters ranging from "low water to 60 fms". Not only is their form different in the respects they note from D'Orbigny's species, but the apertures of the two forms differ significantly.

Named in honor of Dr. Thomas Wheeldon of Richmond, Virginia, who kindly introduced the author to the owner of Carter's Grove.

Types.—Holotype, P.R.I., No. 22,114; paratype, P.R.I., No. 22,115; U.S.N.M., No. P3112.

Occurrence.—Carter's Grove, midbeach, 6 feet up the bank, rare.

Genus **MASSILINA** Schlumberger, 1893

Massilina mansfieldi Cushman and Cahill Pl. 37, figs. 1, 4-5

Massilina mansfieldi Cushman and Cahill, 1933, U. S. Geol. Surv., Prof. Paper 175-A, p. 11, pl. 2, figs. 11a-c; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines, and Water Resources, Bull. 2, p. 281, pl. 29, figs. 4a-c, 5a-c.

Test about twice as long as broad, much compressed, periphery broadly rounded; chambers distinct, nearly circular in transverse section; sutures distinct but very slightly depressed; wall smooth and polished; aperture large with a very slight rounded border. Length 1.00-1.10 mm.; breadth 0.60-0.65 mm.; thickness 0.18-0.20 mm. (Cushman and Cahill, 1933.)

Some of the Yorktown formation specimens seem to deviate from the typical form and agree with those illustrated by Ann Dorsey Clapp.

Occurrence.—Moore House Beach; Langley Field house excavation; Carter's Grove (doubtful). Also reported from the St. Marys formation of Maryland.

Massilina marylandica Cushman and Cahill Pl. 37, figs. 2a-c

Massilina marylandica Cushman and Cahill, 1933, U. S. Geol. Surv., Prof. Paper 175-A, p. 10, pl. 2, figs. 9a-c.

Test much compressed, periphery rounded; chambers distinct, especially the later ones, which gradually become developed on one plane; sutures distinct, depressed; wall ornamented by numerous longitudinal costae, nearly parallel to the periphery of the chamber; aperture not projecting but with a distinct tooth, which projects beyond the outline of the aperture. Length 1.00 mm.; breadth 0.70-0.75 mm.; thickness 0.15 mm. (Cushman and Cahill, 1933.)

Occurrence.—Two specimens from the Langley Field house excavation are typical of the form described by Cushman and Cahill from the St. Marys formation of Maryland.

Massilina quadrans carteri McLean, n.subsp. Pl. 37, figs. 6a-c

Test compressed, somewhat depressed in central part, about 1½ times as long as broad, periphery truncate; slightly keeled on edges, cross-section quadrate; chambers numerous, about seven in the holotype; sutures distinct, marked by chamber ridges; wall smooth; aperture a long, rather quadrate opening with a long thin tooth. Length, 0.90 mm.; breadth, 0.55 mm.; thickness, 0.20 mm.

Differs from *M. quadrans* Cushman and Ponton in the central depression of test, ridged chamber edges, and the quadrate aperture.

Types.—Holotype, P.R.I., No. 22, 132; paratypes, P.R.I., Nos. 22,129-22,131; U.S.N.M., No. P3108.

Occurrence.—Carter's Grove Beach, abundantly at midbeach 6 feet up the bank, rare at midbeach 4 feet up bank and at lower part of beach, bank base.

Genus SIGMOILINA Schlumberger, 1887

Sigmoilina ? sp. Pl. 37, figs. 3a-b

This single specimen seems close to *Massilina mansfieldi* Cushman and Cahill but differs from it in the sigmoid arrangement of chambers and in apertural details. It may be an aberrant form of *M. mansfieldi*. It was found at Carter's Grove, lower part of beach at bank base. The absence or questionable identity of *M. mansfieldi* at Carter's Grove suggests that this form is not present in typical form at the locality.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

Robulus pseudoiota McLean, n.sp. Pl. 38, figs. 2, 4

Robulus iotus Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 25, pl. 4, figs. 1a-b; Cushman and Ponton, 1932, Florida Geol. Surv., Bull. 9, p. 58; Cushman and Cahill, 1933, U. S. Geol. Surv., Prof. Paper 175-A, p. 12, pl. 4, figs. 1a-b.

Robulus iota Puri, 1953, Florida Geol. Surv., Bull. 36, p. 97, pl. 29, figs. 1--2.

Test compressed, close-coiled, but final coil does not cover earlier ones completely, periphery subangular with a small but distinct keel; 10 or more chambers in final whorl, chambers fairly distinct, not completely embracing, enlarging gradually in size as added; sutures somewhat limbate, flush with surface of test, fairly distinct; unbonal area smooth and glassy, with earlier chambers showing through; wall smooth, vitreous; aperture a well-developed radiate opening situated a bit below the peripheral angle, projecting, with a small robuline slit. Largest diameter of holotype, 0.75 mm.; thickness, 0.24 mm.

Although only two specimens of this form were found in the Yorktown, its occurrence in the Choctawhatchee and Shoal River formations of Florida makes it advisable to formally name it. The species differs from *Cristellaria iota* Cushman in the exposure of earlier chambers and in not having a prominent keel. The holotype is smaller than the form figured as *Robulus iotus* from Florida and has fewer chambers but otherwise seems identical.

Types.—Holotype, P.R.I., No. 22,134; paratype, P.R.I. No. 22,135.

Occurrence.—Holotype and paratype from Carter's Grove, lower portion of beach at the base of the bank; Florida Miocene occurrences are noted above.

Robulus vaughani (Cushman) Pl. 38, figs. 3, 5, 7-9

Cristellaria vaughani Cushman, 1918, U. S. Nat. Mus., Bull. 103, p. 61, pl. 22, fig. 3.
Robulus vaughani Cushman and Ponton, 1932, Florida Geol. Surv., Bull. 9, p. 59, pl. 8, figs. 5-10; Puri, 1953, Florida Geol. Surv., Bull. 36, p. 98.
Lenticulina vaughani Bermudez, 1949, Spec. Publ. No. 25, Cushman Lab. Foram. Res., p. 135, pl. 8, figs. 17-20.

Test much compressed, with a slight tendency to uncoiling in the last-formed chambers, periphery slightly keeled, not lobulated, rounded, about nine chambers in the last-formed whorl, sutures slightly curved backward, extending in to the umbilicus so that only the last-formed coil is visible from the exterior, surface smooth except for lines of beads along the sutures extending from the umbilicus to the periphery; apertural face truncated or even slightly concave, aperture radiate, peripheral with a short cylindrical neck. Diameter 0.75 mm. (Cushman, 1914.)

Except for generally having a triangulate rather than compressed cross-section, Yorktown specimens are close to this species; some indeed are even similar in compression of test, the graduation being gradual and within the realm of species variation. Yorktown forms are identical to the forms figured from the Florida Miocene.

In the U.S. National Museum collections there are a number of dissimilar forms assigned to this species, the agreement being that all specimens have beaded tests. Ann Dorsey Clapp (Maryland Dept. Geol., Mines, and Water Res., Bull. 2, p. 284, 1948) combined this species with a number of others in her synonymy for *Planularia vaughani*. Included in the synonymy was Bragg's *Cristellaria wetherelli* which decidedly does not belong either to this species or to *C. wetherelli*, as specimens from the new Crisfield Well (McLean, 1950) show this form to be distinct.

Occurrence.—Robulus vaughani is found only at Carter's Grove in our material from the Yorktown formation; other records (which are subject to some doubt because of the situation described above) are from the Oligocene and Miocene of Panama and the Dominican Republic, and the Miocene of Florida and Louisiana.

Robulus sp. Pl. 38, fig. 1

This form, represented by two specimens from the 37 to 160 foot interval of the Fort Eustis well, does not seem distinctive enough to assign it definitely to any known species.

Genus DENTALINA d'Orbigny, 1826

Dentalina bevani Cushman and Cederstrom Pl. 38, figs. 10, 20

Dentalina bevani Cushman and Cederstrom, 1949 (1945), Virginia Geol. Surv., Bull. 67, p. 15, pl. 2, figs. 15-18.

This species and the following one are both from the 37 to 101 foot interval in the Fort Eustis well. With *Robulus* sp. listed above, they may be either redepositional elements in the sample or may come from contamination of samples. In this connection, it should be pointed out that all operations carried out in the McLean laboratory are specifically guarded against any possible laboratory contamination.

Dentalina cf. **intermedia** Hantken Pl. 38, fig. 16

Dentalina intermedia Cushman and Cederstrom, 1949 (1945), Virginia Geol. Surv., Bull. 67, p. 14, pl. 2, figs. 11-12.

The single specimen from 37 to 101 feet in the Fort Eustis well seems to be equivalent to the form illustrated by Cushman and Cederstrom. It may be redepositional in the sample or contamination as noted above.

Dentalina kaicherae McLean, n.sp. Pl. 38, figs. 14-15, 18-19

Test slender, arcuate, slightly compressed, with relatively large proloculum for the genus; six to seven chambers, chambers cylindrical and rather unevenly developed, slightly lobulate in final portion of test; sutures slightly or not at all depressed, slanted, showing as thin dark lines; wall smooth, white; aperture a rather large, radiate opening on a sloping summit of last chamber, situated toward the inner curved part of test. Length of holotype, 1.20 mm.; diameter of largest chamber, 0.20 mm.

This species belongs to the large class of smooth unornamented dentalinids in which group there are many species within which convenience would permit assignment of our form. After thorough study and search, it was concluded that the nonpointed proloculum and the rather large aperture, plus the stable development of the form through several localities, sufficiently set the form aside for description as a new species. The uneven development of chambers is another constant feature of this species.

Types.—Holotype, P.R.I., No. 22,145; paratypes, P.R.I., Nos. 22,144 and 22,146-22,147; U.S.N.M., No. P3117.

Occurrence.—Rare in all localities in which it is found, which are: Moore House Beach bank base, Carter's Grove Beach, 10 feet up the bank at midbeach.

Dentalina cf. **pyrula** (d'Orbigny) Pl. 38, fig. 11

A single specimen from Carter's Grove seems to belong to this species and seems identical to the fragment figured by Cushman and Ponton (Florida Geol. Surv., Bull 9, pl. 9, figs. 5, 6, 1932) and refigured by Puri in Florida Survey Bulletin 36. None of the fragments seem worthy of specific assignment.

Dentalina sp. A. Pl. 38, fig. 13

One broken fragment was found at the midbeach portion at Carter's Grove six feet up from the base of the bank.

Dentalina sp. B. Pl. 38, fig. 17

The figured specimen is from the base of the bank, lower part of beach, at Carter's Grove.

Dentalina sp. C. Pl. 38, fig. 21

This single specimen was from Carter's Grove, midbeach, six feet up the bank.

Genus **NODOSARIA** Lamarck, 1812

Nodosaria sp. Pl. 38, fig. 12

This is the only *Nodosaria* outside of *N. catesbyi* found at any outcrop locality from the Yorktown formation, and it is represented by only one specimen. Found at Carter's Grove, midbeach, 10 feet up bank.

Nodosaria catesbyi d'Orbigny Pl. 39, figs. 1-4

Nodosaria catesbyi d'Orbigny, 1839, in De La Sagra, Hist. Fisc. Politica y Natural de la Isla de Cuba, Foraminiferes, p. 16, pl. 11, figs. 8-10; Cushman, 1930, Florida Geol. Surv., Bull. 4, pp. 28-29, pl. 5, fig. 4; Cushman and Cahill, 1933, U. S. Geol. Surv., Prof. Paper 175-A, p. 14, pl. 5, fig. 5; Puri, 1953, Florida Geol. Surv., Bull. 36, p. 101, pl. 26, fig. 6.

Nodosaria sp. ? Cushman, 1922, Carnegie Inst. Washington, vol. 17, No. 311, p. 32, pl. 4, fig. 2.

Test composed of two chambers, the proloculum subglobular, with a short basal spine, the second chamber more pyriform apertural end somewhat prolonged; suture distinct and depressed; wall ornamented with numerous very distinct costae, which extend the entire length of the two chambers to the aperture. Length 0.45 mm.; diameter 0.17 mm. (Cushman and Cahill.)

Specimens from the Yorktown were found only at Carter's Grove and seem to be identical with the species as shown in synonymy and description cited, except that some of the Yorktown forms develop three chambers instead of two. The writer has found this species also in the Miocene section of the Esso Hatteras Light Well No. 1 in North Carolina.

Occurrences.—Carter's Grove only, and rare. At midbeach, four feet up the bank, at six feet up bank, and at the base of the bank, lower beach.

Genus **SARACENARIA** Defrance, 1824

Saracenaria ? sp. Pl. 38, figs. 6a-b

These two interesting forms are triangular in cross-section. They occur only at Carter's Grove, at the base of the bank, lower beach portion, and the specimens are insufficient in numbers or morphological features to warrant description. They do not seem to match any known species.

Genus **LAGENA** Walker and Jacob, 1798

Lagena (Entosolenia?) carteri McLean, n.sp. Pl. 39, figs. 13a-b

Lagena cf. *marginato-perforata,* Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 32, pl. 5, fig. 5; Cushman and Cahill, 1933, U. S. Geol. Surv., Prof. Paper 175-A, p. 17, pl. 5, figs. 15a-b.

Test pear-shaped from side view, considerably compressed; apertural end almost transparent, showing a thick glassy development with a small channel leading to aperture; wall smooth and glassy, finely perforate all over; aperture a simple lens-shaped opening with a small lip. Length of holotype, 0.50 mm.; breadth, 0.20 mm.; thickness, 0.12 mm.

Species differ from *L. marginato-perforata* (Seguenza) in not having the broad peripheral border figured by Seguenza.

Types.—Holotype, P.R.I., No. 22,157; paratypes, P.R.I., No. 22,156 and U.S.N.M., No. P3115.

Occurrence.—Carter's Grove, base of bank, lower part of beach, Reported by Cushman and Cahill from the Choctawhatchee, Oak Grove, and Shoal River formations of Florida, and the Yorktown formation of Virginia and North Carolina.

Lagena (Entosolenia?) carteri McLean, n. sp. forma **alpha** Pl. 39, fig. 9

Forma similar to the species except that the forma is coarsely perforate. Found only at Carter's Grove in association with *L. carteri.*

Type.—Holotype, P. R.I., No. 22,158.

Lagena dorseyae McLean, n.sp. Pl. 39, figs. 8a-b

Lagena sp. D. Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Minees, and Water Res., Bull. 2, p. 291, pl. 30, figs. 19-21 (not 22 and 23).

Test globular, ornamented with numerous fine striations, some discontinuous; neck long, ornamented with rings or spirals or close irregular rugosities. Length of holotype, 0.50 mm.; diameter, 0.25 mm.

Lagena dorseyae, reported by Clapp as being common in the Calvert formation of Maryland, is rare in the Yorktown. The specimen is typical, and the form differs from all recorded similar species in the neck ornamentation.

Named in honor of Ann Dorsey Clapp who first encountered the form.

Type.—Holotype, P.R.I., No. 22,159.

Occurrence.—Fort Eustis well at 37 to 101 feet in the subsurface; rare.

Lagena globulohispida McLean, n.sp. Pl. 39, figs. 7a-b

Lagena sp. E, Clapp. Ann Dorsey, 1948, Maryland Dept. Geol., Mines, and Water Res., Bull. 2, p. 291, pl. 31, fig. 24.

Test globular, flask-shaped, with a stout extended neck; entire wall covered with a sugary or frosty appearing fine hispidation. Length, 0.55 mm.; diameter, 0.35 mm.

Reported by Clapp from the Choptank formation of Maryland, this species is rare in the Yorktown and seems to be unique in its degree of hispid ornamentation.

Types.—Holotype, P.R.I., No. 22,161; paratype, P.R.I., No. 22,160.

Occurrence.—Carter's Grove, upper portion of beach, base of bank; also at Camp Wallace. The Carter's Grove locality is in a gravel bed. Rare.

Lagena melo (d'Orbigny) Pl. 39, figs. 12a-b

Oolina melo d'Orbigny, 1839, Voy. Amer. Meridionale; Foraminiferes, tome 5, pt. 5, p. 20, pl. 5, fig. 9; Boltovskoy, 1954, Revista Inst. Nacional Invest. Ciencias Nat. y Mus. Argentino Ciencias Nat. "Bernadino Rivadavia", tomo 3, No. 4, pp. 268-9, pl. 23. fig. 3.

Test ovate-globular in shape; aperture a small opening in the center of a button of smooth test surface; wall completely covered with strongly developed longitudinal costae between which are cross-ridges almost as strongly developed, the total appearance being that of a test completely covered with square, rather deep pits. Length of plesiotype, 0.40 mm.; diameter, 0.25 mm. (emended diagnosis by McLean.)

Lagena hexagona scalariformis as figured by Cushman and Cahill in U.S. Geological Survey Professional Paper 175-A may possibly be confused with *L.melo.* My form resembles D'Orbigny's figured species in those respects where it differs from *L. scalariformis*, *i.e.*, in being more strongly costate, with more numerous longitudinal costae, and in the stronger development of the cross-ridges. The aperture is much smaller than that of *L. hexagona scalariformis.* Boltovskoy reports the form from a depauperate fauna from San Blas Bay at a depth of 5-25 meters.

Occurrence.—D'Orbigny reported the species from the Falkland Islands; Yorktown formation specimens occur rarely at the following places: Carter's Grove, midbeach, four and six feet up the bank and at the bank base, lower beach portion of same locality.

Lagena palmerae McLean, n.sp. Pl. 39, figs. 5-6

Test globular, flask-shaped, with a long extended neck; test wall smooth over large part of test; basal portion of test ornamented with fine, but well-developed costae which extend almost halfway up the test; neck fluted. Length of holotype, 0.62 mm.; diameter, 0.35 mm.

This interesting form seems to have a tendency to develop a truncated base as is shown in the figured paratype. It belongs to a large group of basally costated forms but differs from all in having a fluted neck and in being more globe-shaped.

Named in honor of Mrs. Katherine V. W. Palmer, Director of the Paleontological Research Institution.

Types.—Holotype, P.R.I., No. 22,166; paratypes, P.R.I., Nos. 22,165 and 22,168.

Occurrence.—Carter's Grove, lower portion of beach, at bank base; midbeach six feet up the bank at same locality.

Lagena pseudosulcata McLean, n.sp. Pl. 39, figs. 11a-b

Test globular to ovate, with the apertural end somewhat produced and pointed; base of test has a small button of material from fusion of the costae, apertural end smooth and glassy, showing a small channel in the center of a thick-walled apertural process; channel leads to the simple apertural opening which is small; wall glassy, ornamented for the most part by heavy longitudinal costae which are occasionally interspersed with lesser, more discontinuous costae. Length of holotype, 0.50 mm.; diameter, 0.35 mm.

This form, as with all similar species, is easily confused with *Lagena sulcata* (Walker and Jacob) to which dissimilar forms have been assigned. The thick nonproduced apertural portion and the basal button of fused shell material serve to set the species aside from *L. sulcata.*

Types.—Holotype, P.R.I., No. 22,174; paratypes, P.R.I., Nos. 22,168-22,173 and U.S.N.M., No. P3110.

Occurrence.—This is the most common species from the entire family of the Lagenidae to be found in the Yorktown formation and is present at the Moore House Beach, Carter's Grove, Felgater's Creek, and Camp Wallace.

Lagena substriata (Williamson) Pl. 39, figs. 10a-b

This single specimen agrees with Williamson's *Lagena substriata* as it is figured by Cushman and Cahill in U. S. Geological Survey Professional Paper 175-A, except that the Yorktown specimen is costate along the extended neck which is not the case with the figured form of Cushman and Cahill. The specimen is 0.60 mm. long and has a diameter of 0.35 mm. It came from the base of the bank at the Moore House Beach.

Family POLYMORPHINIDAE

Genus GUTTULINA d'Orbigny, 1839

Guttulina austriaca d'Orbigny Pl. 40, figs. 1-3

Guttulina austriaca d'Orbigny, 1846, Foram. Foss. Bass. Tert. Vienne, p. 223, pl. 12, figs. 23-25; Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc., vol. 77, art. 6, pp. 29-30, pl. 4, figs. 3-5.

Test fusiform to oblong, more or less rounded at the base, rather acute at the apertural end, often botryoidal, greatest breadth usually above the middle; chambers oval to clavate, slightly embracing, arranged in a clockwise, quinqueloculine series, each succeeding chamber removed much farther from the base; sutures depressed and very distinct; wall smooth, translucent; aperture produced, radiate. Length 0.60-1.15 mm.; breadth 0.40-0.55 mm.; thickness 0.35-0.50 mm. (Cushman and Ozawa, 1930.)

Yorktown formation specimens seem to be typical of this species, which is recorded from shore sands to 340 fathoms in Recent materials, and which is also recorded as far back as the Eocene.

Occurrence.—Carter's Grove, Camp Wallace, and Powell's Lake Spillway.

Guttulina palmerae McLean, n.sp. Pl. 40, figs. 4-7, 13

Test fusiform, elongate, slender and a bit compressed; chambers added in quinqueloculine fashion with each succeeding chamber considerably larger than the preceding one and removed from the base, chambers elongate and raised from general test outline, giving an irregular appearance to the test; four chambers visible to a side in holotype; wall smooth, glassy; aperture radiate, much produced at end of tapering final projection of the last chamber. Length of holotype, 1.30 mm.; breadth, 0.40 mm.

This species is somewhat irregular and tends to develop chambers that protude quite markedly from the general test configuration. It differs from all Guttulinas studied in its elongate form and tapering apertural end.

Named in honor of Mrs. Katherine V. W. Palmer, Director of the Paleontological Research Institution.

Types.—Holotype, P.R.I., No. 22,187; paratypes, P.R.I., Nos. 22,181-22,186 and 22,188-22,189 and also U.S.N.M., No. P3111.

Occurrence.—Carter's Grove and one broken specimen questionably assigned to *G. palmerae* from Powell's Lake Spillway.

Guttulina pseudocostatula McLean, n.sp. Pl. 40, figs. 8, 10-11

Test elongate, fusiform, acute at both ends; chambers inflated and somewhat elongate, not embracing, arranged in typical guttuline fashion with each succeeding chamber removed from base; initial chamber ornamented with a short but generally distinct spine; sutures distinct, depressed; wall ornamented with fairly numerous costae which traverse the entire length of the test, costae are somewhat rounded rather than acute or bladelike and are low; aperture radiate and produced and large. Length of holotype, 1.00 mm.; breadth, 0.40 mm.

Guttulina pseudocostatula is close to *G. costatula* Galloway and Wissler but differs in having a stubby initial spine and in having uniform costae rather than having five of them more greatly developed than others as in the case of *G. costatula.*

Types.—Holotype, P.R.I., No. 22,193; paratypes, P.R.I., Nos. 22,190-22,192 and 22,194-22,196 and also U.S.N.M., No. P3114.

Occurrence.—Moore House Beach, Langley Field, and Carter's Grove.

Guttulina sp.A Pl. 40, fig. 9

This single specimen seems to be close to *Guttulina hantkeni* Cushman and Ozawa, but more specimens are needed to establish the form. *Guttulina hantkeni* has hitherto been largely reported from Eocene deposits; the figured specimen is from Carter's Grove, upper part of the beach, at ten feet from the base of the bank.

Guttulina sp. B Pl. 40, fig. 12

A single, finely striate specimen was found in the Langley Field material but was not noted elsewhere. Although it is a distinctive form, it seems best to reserve assignation of it to a known or new species until more material is available.

Genus **PSEUDOPOLYMORPHINA** Cushman and Ozawa, 1928

Pseudopolymorphina rutila (Cushman) Pl. 41, figs. 6-9, 16-17

Polymorphina regina var. *rutila* Cushman, 1923, U. S. Geol. Survey, Prof. Paper 133, p. 34, pl. 5, figs. 7-8.

Pseudopolymorphina rutila Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc. vol. 77, art. 6, p. 100, pl. 26, figs. 3a-b; Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 36, pl. 5, fig. 20; Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 67; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 19, pl. 6, fig. 11; Puri, 1953, Florida Geol. Survey, Bull. 36, pp. 105-106, pl. 21, fig. 18.

Test compressed, elongate, fusiform, with a strong spine at the base; chambers more or less elongated, not much embracing, alternating; sutures more or less depressed, distinct; wall marked with a few strong longitudinal costae; aperture radiate. Length 1.05 mm.; breadth 0.30 mm. (Cushman and Cahill, 1933.)

Specimens from Carter's Grove are somewhat variable in their features and some are much elongated and slender, but all appear to belong to the species as it is described by Cushman and Cahill. The forms all bear the strong spine and all have elongated chambers, in which respects they differ from the *P. rutila* as figured by Ann Dorsey Clapp in the Maryland Bulletin of 1948. Because of Clapp's figures, I have not placed her form in the present synonymy.

Occurrence.—All specimens from the Yorktown formation are from Carter's Grove; the form occurs in the lower Oligocene of Mississippi and the Choctawhatchee formation (Miocene) of Florida.

Pseudopolymorphina cf. novangliae (Cushman) Pl. 40, fig. 14

A single fistulose specimen from the base of the bank, lower part of the beach at Carter's Grove may be questionably referred to *P. novangliae* (Cushman), but additional nonfistulose specimens are needed to confirm this assignment.

Pseudopolymorphina sp. A Pl. 41, figs. 1-2

These two irregular specimens may be individual monstrosities rather than distinctive species. Further material is needed to determine their position as species, and for this reason they are here figured for future reference. Both specimens are from the base of the bank, lower section of beach, at Carter's Grove.

Pseudopolymorphina sp. B Pl. 41, fig. 10a-b

A single specimen, here figured, seems to be related to *Pseudopolymorphina rutila,* but it differs markedly in test outline. It could be the microspheric form of *rutila* or a different species. It was found at the base of the bank, lower part of beach, at Carter's Grove.

Genus **SIGMOMORPHINA** Cushman and Ozawa, 1928

Sigmomorphina concava (Williamson) Pl. 41, figs. 14, 18

Polymorphina lactea var. *concava* Williamson, 1858, Recent Foram. Great Britain, p. 72, pl. 6, figs. 151-152.

Sigmomorphina concava Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc., vol. 77, art. 6, p. 139, pl. 38, figs. 5-7.

> Excepting the last attached part, the test is oval and much compressed; chambers elongate, much embracing unequally on either side, each succeeding chamber extending down to the base, attached part (or chamber?) generally highly convex, leaving a large space between the test and the foreign object, but without visible aperture; sutures not depressed, distinct; wall smooth, rather thin and almost transparent; aperture radiate. (Cushman and Ozawa, 1930.)

This form is reported by Cushman and Ozawa from Pliocene beds of Monte Mario near Rome, and from England, the Belgian Coast, the Mediterranean, and from 10-14 fathoms off the island of Delos. The Yorktown formation specimens agree closely with the description cited here which seems more satisfactory than the one given by Williamson.

Occurrence.—Base of bank and 10 feet up same bank, beach below the Moore House.

Sigmomorphina nevifera Clapp Pl. 41, figs. 3-5, 11

Pyrulina albatrossi Cushman and Cahill, 1933, (not Cushman and Ozawa), U. S. Geol. Survey, Prof. Paper 175-A, p. 18, pl. 6, figs. 5a-b.

Sigmomorphina nevifera Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines and Water Resources, Bull. 2, p. 298, pl. 34, figs. 6, 7a-b.

Test elongate, compressed, greatest breadth at the middle, apertural end acute, initial end subacute to rounded; chambers elongate, compressed, not much embracing, arranged in a sigmoid series, each succeeding chamber removed farther from the base; wall rather thick, ornamented with very fine granules giving a frosted appearance; sutures indistinct, slightly depressed; aperture radiate. Length 0.80-2.00 mm.; breadth 0.40-0.55 mm.; thickness 0.30 mm. (Clapp, 1948.)

The form figured by Cushman in Florida Survey Bulletin 4 and in Puri's Florida Bulletin 36 as *Pyrulina albatrossi* differs from Clapp's *S. nevifera* in wall structure and other details. Clapp did not include this form in her synonymy. The *Pyrulina albatrossi* of Cushman and Cahill they recorded from the Choptank and Calvert of Maryland, the Yorktown (?) of North Carolina, and the Choctawhatchee of Florida. Clapp restricts *S. nevifera* to the Choptank of Maryland.

Occurrence.—Langley Field excavation and Carter's Grove are the only Yorktown formation occurrences; the form is frequent at Carter's Grove.

Sigmomorphina pearceyi Cushman and Ozawa Pl. 41, figs. 13, 15

Sigmomorphina pearceyi Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc. vol. 77, art. 6, p. 132, pl. 35, figs. 2-3.

Test elongate, clavate, the greatest breadth in the upper half, tapering toward the base, apertural end rounded; chambers more or less compressed, early ones elongated, later becoming rounded, generally the last one much inflated and large, arranged in a contraclockwise sigmoid series, each succeeding chamber, especially the last one or two, removed farther from the base; sutures depressed, distinct; wall smooth, thin, translucent; aperture near the center of the last chamber, with short entosolenian tube. Length of largest specimen 0.80 mm.; breadth 0.50 mm.; thickness 0.45 mm. (Cushman and Ozawa, 1930.)

This species is reported from 18 and 30 fathoms in modern waters and from the Eocene. Yorktown formation specimens seem to be typical.

Occurrence.—Base of bank at beach below the Moore House.

Sigmomorphina semitecta "var." **terquemiana** (Fornasini)
Pl. 41, figs. 12, 19-24

Sigmomorphina semitecta "var." *terquemiana*, Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc. vol. 77, art. 6, pp. 129-130, pl. 33, figs. 4-5, pl. 34, figs. 2-3, pl. 35, fig. 1.

Variety differing from the typical in its more elongate lanceolate test consisting of elongated chambers and more acute initial end. (Cushman and Ozawa, 1930.)

The specimens from the Yorktown formation are closest to the ones figured by Cushman and Ozawa in plate 33 from the Pliocene of Italy and the Eocene of France. This "variety" is reported from 10-14 fathoms off the island of Delos.

Occurrence.—Moore House Beach locality (common), also Yorktown Bluffs, Carter's Grove, Camp Wallace, and Powell's Lake Spillway.

Sigmomorphina williamsoni (Terquem) Pl. 42, figs. 1-4

Polymorphina lactea var. *oblonga* Williamson, 1858, Recent Foram. Great Britain, Ray Soc. London, p. 71, pl. 6, figs. 149-149a; Millett, 1903, Jour. Roy. Micr. Soc., p. 262, pl. 5, fig. 5; Cushman, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 147, pl. 40, figs. 7 (?), 8a-b.

Polymorphina williamsoni Terquem, 1878, Mem. Soc. Geol. France, ser. 3, vol. 1, p. 37; Heron-Allen and Earland, 1932, Discovery Reports, vol. 4, pp. 393-394, pl. 12, figs. 26-28.

Sigmomorphina williamsoni Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc. vol. 77, art. 6, p. 139, pl. 38, figs. 3a-b, 4a-b; Boltovskoy, 1954, Revista Inst. Nacional Invest. Ciencias Nat. y Mus. Argentino Ciencias Nat. "Bernadino Rivadavia", tomo 3, No. 4, p. 272, pl. 24, figs. 2a-b.

Shell oblong; ovate; of nearly equal diameter throughout its entire extent; rounded at each extremity; compressed; consisting of numerous, narrow, oblong segments arranged in two opposed alternate series; each segment extending nearly to the superior extremity of the shell; not reaching the median line, but leaving uncovered nearly all the preceding convolutions. Septal orifice round; at the obtuse anterior extremity of each segment; surrounded by a large coronal of radiating grooves. Septal plane oblong, narrow, convex. Septal lines scarcely depressed, but distinct. Texture hyaline when young, becoming more opaque with age. Long, 1/35. (Williamson, 1858.)

The form figured by Cushman as *S. williamsoni* in Florida Survey Bulletin 4 (plate 6, figure 4) does not correspond with Williamson's description. This error persists in U. S. Geological Survey Professional Paper 175-A and in Puri's Florida Survey Bulletin 36. Boltovskoy's report of the species is from a depth of 5-25 meters in the San Blas Bay in a depauperate fauna. The form also is found in the Recent of Belgium and from the Naheola formation (Paleocene). The specimens have the entosolenian tube figured in some views of the species, but the aperture is an elongate radiate slit instead of the rounded orifice of Williamson. In other respects the agreement with his figures and description is striking, and I have placed this form here with confidence that it is the form of Williamson.

Occurrence.—Beach below the Moore House at the base of the bank and at six feet higher up the bank.

Family **NONIONIDAE**

Genus **NONION** Montfort, 1808

Nonion mediocostatus (Cushman) Pl. 42, figs. 5a-c, 7

Nonionina medio-costata Cushman, 1926, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 4, pp. 89-90, pl. 13, figs. 1a-c.

Nonion medio-costatum Cushman, 1939, U. S. Geol. Survey, Prof. Paper 191, p. 15, pl. 4, figs. 7-8; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines, and Water Res., Bull. 2, p. 300, pl. 35, figs. 4a-c.

Test slightly longer than broad, periphery rounded to subacute, compressed, umbilical regions depressed, apertural face generally heart-shaped to oval; chambers distinct, numerous, 15 or more in the adult coil, very slightly if at all inflated, of rather uniform shape, increasing gradually in size in the last part of the adult coil; sutures distinct, slightly limbate, often slightly depressed, somewhat curved; wall with the areas between the sutures toward the umbilical region raised, otherwise smooth; aperture a low, curved opening at the base of the apertural face. Length, 0.65 mm.; breadth 0.40 mm.; thickness 0.20-0.25 mm. (Cushman, 1939.)

This form recorded from the St. Marys formation into the Calvert in Maryland, is conspicuously absent in known Yorktown outcrop material but is present in the subsurface of the St. Marys immediately preceding the Yorktown formation. It may prove to be a valuable guide for the separation of the St. Marys from the Yorktown, hence I am figuring and recording it here. The proximity to Yorktown beds of the form also suggests the possibility that the species may be found in basal Yorktown beds when and if they can be delineated.

There is yet another reason for recording this species. The description that is here cited differs in details from the original description which is more restrictive. The figures of the original description likewise differ from those of U. S. Geological Survey Professional Paper 191 from which I cite the description. Furthermore, Ann Dorsey Clapp's figures and specimen for *N. mediocostatus* likewise differ from the original and the figures of Professional Paper 191. In the opinion of the writer, Cushman's two descriptions are worthy of comment. The description of Professional Paper 191 is considerably broader in terminology than is that of the original description—so broad that Clapp's specimen can safely fall in the category of *N. mediocostatus.* Both the figure and written description of *Nonionina mediocostata* specify costae in the intersutural region near the umbilical region; the later description modifies this to a mere raised portion. The original description states that the apertural face is "gently convex, definitely higher than broad", whereas Professional Paper 191 states it to be "generally heart-shaped to oval". Sutures in the original description are not noted as being limbate, whereas they are stated to be so in Professional Paper 191.

Cushman's later description not only does terminological violence to the one he originally gave, but in doing so the new description erases some of the points which can be used to separate *N. mediocostatus* from similar forms.

Nonion pizarrensis (W. Berry) Pl. 42, figs. 6, 8, 10, 12

Nonionina boueana, Cushman, 1918, (not d'Orbigny), U. S. Geol. Survey, Bull. 676, p. 68, pl. 25, fig. 3.

Nonion pizarrensis W. Berry, 1928, Jour. Pal., vol. 1, p. 269, Text figure I, figs. 1-3; Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 37, pl. 6, figs. 7-8; Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 69; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 20, pl. 7, figs. 2a-b.

Nonion pizarrense Cushman, 1939, U. S. Geol. Survey, Prof. Paper 191, p. 24, pl. 6, fig. 27; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines, and Water Res., Bull. 2 p. 300, pl. 35, figs. 6a-c; Puri, 1953, Florida Geol. Survey, Bull. 36, p. 145.

Test slightly longer than broad, nearly bilaterally symmetrical, periphery broadly rounded, umbilical regions depressed but not open; chambers distinct, twelve to fifteen in the adult coil, of uniform shape, increasing gradually in size, somewhat inflated; sutures distinct, somewhat depressed, gently curved; wall smooth, polished, except the umbilical region, which is often roughened, very finely perforate; aperture a low opening at the base of the apertural face, often tending to become slightly asymmetrical. Length up to 0.60 mm.; breadth 0.45-0.50 mm.; thickness 0.22-0.25 mm. (Cushman, 1939.)

The species ranges from the Recent to the Calvert Miocene and is one of the commonest elements of the Yorktown foraminiferal faunas.

Occurrence.—Common to abundant in all Yorktown formation samples.

Nonion cf. grateloupi (d'Orbigny) Pl. 43, figs. 7a-b

One specimen, questionably assigned to D'Orbigny's species, comes from four feet up the bank at the beach below the Moore House. Cushman and Cahill reported some similarly dubious specimens from the Yorktown formation in U. S. Geological Survey Professional Paper 175-A.

Nonion (?) sp. A. Pl. 44, figs. 1-2

This single specimen is figured from the base of the bank, beach below the Moore House, Colonial Battlefield Monument, near Yorktown.

Nonion (?) sp. B. . Pl. 43, figs. 6a-b

This small form is figured from Carter's Grove, where three specimens were found. In this species and the one previously listed above, the presence of the *Elphidium*-like aperture at the base of the apertural face, and also the slight sutural irregularities (retral processes ?) make generic placement of the forms doubtful, and additional material is needed to determine the exact place for these interesting forms.

Genus **NONIONELLA** Cushman, 1926

Nonionella auris (d'Orbigny) Pl. 43, figs. 1, 4

Valvulina auris d'Orbigny, 1839, Voyage dans l'Amerique meridionale, vol. 5, pt. 5, Foraminiferes, p. 47, pl. 2, figs. 15-17.

Nonionina auris Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 44, pl. 7, figs. 3a-c.

Nonionella auris Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 38, pl. 7, figs. 1a-c; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 21, pl. 7, figs. 6a-b; Cushman, 1939, U. S. Geol. Survey, Prof. Paper 191, p. 33, pl. 9, fig. 4; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines and Water Res., Bull. 2, p. 301, pl. 35, figs. 3a-c.

Test asymmetrical, slightly trochoid, the spire not raised, periphery in the adult broadly rounded; chambers nine to eleven in the adult, low and broad, very distinct, slightly inflated, in the adult with the last-formed chamber having an enlarged portion extending over the umbilicus on the ventral side; sutures distinct, depressed, gently curved; wall smooth, polished, very finely perforate; aperture at the last-formed chamber, extending from the periphery ventrally, low and broad. Length 0.35 mm.; breadth 0.25 mm.; thickness 0.10 mm. (Cushman, 1939.)

Nonionella auris is reported from the Recent to the Calvert formation and has world-wide distribution. Yorktown specimens seem typical.

Occurrence.—Fort Eustis well at 37-101 feet and 135-160 feet; Carter's Grove, and beach below the Moore House.

Genus **ELPHIDIUM** Montfort, 1808

Elphidium advena (Cushman) Pl. 43, figs. 5a-b

Polystomella crispa, Cushman, 1918, U. S. Geol. Survey, Bull. 676 pp. 69-70, pl. 27, figs. 5a-b.

Polystomella advena Cushman, 1922, Carnegie Inst. Washington, Publ. No. 311, p. 56, pl. 9, figs. 11-12.

Elphidium advenum Cushman, 1930, U. S. Nat. Mus., Bull. 104, pt. 7, p. 25, pl. 10, figs. 1-2; Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 40, pl. 7, figs. 7a-b; Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 70, pl. 11, figs. 1a-b; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 22, pl. 7, figs. 10a-b; Cushman, 1939, U. S. Geol. Survey, Prof. Paper 191, pp. 60-61, pl. 16, figs. 31-35; Puri, 1953, Florida Geol. Survey, Bull. 36, pp. 146-147.

Test of medium size for the genus, strongly compressed, periphery acute, with a narrow carina, somewhat lobulate, sides nearly parallel in peripheral view, umbilical region depressed, often with a small central boss of clear shell material but in peripheral view not projecting beyond the contour of the test; chambers distinct, ten to fifteen in the last-formed coil, slightly inflated, especially in the last-formed portion; sutures depressed, marked by the retral processes which are short, about one-fourth the width of the chamber, twelve to fifteen in number; wall smooth, translucent, finely and distinctly perforate; aperture composed of a series of small rounded pores at the base of the apertural face. Diameter up to 0.50 mm.; thickness 0.15 mm. (Cushman, 1939.)

This form is a warm water species, widely distributed in present waters and is recorded from the Oak Grove and Choctawhatchee formations in Florida.

Occurrence.—A single specimen came from the Langley Field sample.

Elphidium incertum (Williamson) Pl. 43, figs. 2-3

Polystomella umbilicatula var. *incerta* Williamson, 1858, Recent Foram. Great Britain, p. 44, pl. 3, figs. 82, 82a.

Elphidium incertum Cushman, 1930, U. S. Nat. Mus., Bull. 104, pt. 7, p. 18, pl. 7, figs. 4-9; Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 39, pl. 7, figs. 2a-b; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 21, pl. 7, fig. 8; Cushman, 1939, U. S. Geol. Survey, Prof. Paper 191, p. 57, pl. 15, figs. 21-24.

Test of small size for the genus, compressed, periphery broadly rounded, margin entire or with the last two or three chambers lobulate, umbilical regions slightly depressed, often with a slight knob or irregularly arranged slits at the base of the sutures; chambers few, usually less than ten in the last-formed whorl, slightly if at all inflated, distinct; sutures distinct, mainly marked by the openings, which are in a single row, retral processes very few, usually not more than five or seven, distinct, the inner ends of the sutures slitlike; wall thick, usually opaque; aperture composed of several small, rounded openings at the base of the apertural face. Diameter 0.50 mm.; thickness 0.23 mm. (Cushman, 1939.)

Geologic range of this species is from the present to the Calvert Miocene; it inhabits the colder waters of the present oceans. Fairly typical specimens are found rarely in the Yorktown formation.

Occurrence.—Felgater's Creek, Carter's Grove, and Powell's Lake Spillway.

Elphidium johnstonae McLean, n.sp. Pl. 42, figs. 9, 18; Pl. 44, figs. 3-5, 7

Test rather small for the genus, periphery lobulate, rounded, the test somewhat thick in transverse view, with a projecting umbilical boss area; eight to twelve chambers in final whorl, each chamber uniformly larger as added, distinct; sutures distinct, depressed, with indifferently developed and irregular retral processes or even sutural folds in some portions of test; wall smooth and coarsely perforate, umbilical area ornamented with irregularly developed granulations or buttons which spread outward along the sutural processes in some specimens; aperture a row of small arches at the base of the apertural face of the final chamber. Length of holotype, 0.65 mm.; thickness, 0.27 mm.; lesser diameter about 0.50 mm.

The retral processes are weakly developed in this species, and the umbilical granulations are distinctive. In general appearance the form resembles *Nonion ornatissimus* Cushman from the Eocene of Kressenberg, Germany, but the presence of retral processes and the apertural features are not characteristic of the genus *Nonion.* In this connection, however, it may be noted that some forms figured by Cushman in U. S. Geological Survey Professional Paper 191 as Nonions have multi-arched apertural processes.

The species is named in honor of Mrs. Mary Johnston McCrea, *nee* Johnston, who has been most gracious in permitting the author to collect at her estate, Carter's Grove.

Types.—Holotype, P.R.I., No. 22,279; paratypes, P.R.I., Nos. 22,275-22,278 and 22,280-22,281.

Occurrence.—Moore House Beach, Carter's Grove, Powell's Lake Spillway.

Elphidium kaicherae McLean, n.sp. Pl. 42, figs. 11, 13-17

Test round, in cross-section the periphery is broadly rounded and the sides parallel and somewhat compressed; chambers numerous, 16 in the final whorl of the holotype, chambers thin, distinct but not inflated, not embracing in final portion; sutures distinct, limbate, slightly curved, with numerous retral processes, the sutural pores rather large; wall glassy, finely perforate, rather irregularly surfaced, with an irregular development of the umbilical plug; aperture a fine slit at base of final chamber if at all present. Diameter of holotype, 0.55 mm.; thickness, 0.24 mm.

This species is structurally similar to *E.* (?) *ellisi* Weiss but differs in having prominent retral processes and a less conspicuous umbilical plug.

Named in honor of Mrs. Sally Kaicher, illustrator of this paper.

Types.—Holotype, P.R.I., No. 22,282; paratypes, P.R.I., Nos. 22,283-22,284 and U.S.N.M. No. P3116.

Occurrence.—Felgater's Creek and base of bank at beach below Moore House.

Family **BULIMINIDAE**

Genus **BULIMINELLA** Cushman, 1911

Buliminella cf. **elegantissima** (d'Orbigny) Pl. 44, figs. 11a-b

A single specimen from the Yorktown Bluff (fragmental beds) at Yorktown, Virginia, seems to be identical with *Buliminella elegantissima* (d'Orbigny), but additional specimens would be necessary to confirm the identification due to an incrustation on the specimen which obscures the details. This species has, however, been reported from the Yorktown formation by others. It has also been recorded from the Wilcox Eocene to the present.

Genus **BULIMINA** d'Orbigny, 1826

Bulimina gracilis Cushman Pl. 44, figs. 6, 8-10

Bulimina gracilis Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 43, pl. 8, figs. 5a-b; Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 76; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 24, pl. 7, figs. 16a-b; Cushman, 1936, Geol. Soc. Amer., Bull. 47, p. 431, pl. 5, figs. 8a-b.

Bulimina elongata, Cushman and Parker, 1937, (not d'Orbigny), Contr. Cushman Lab. Foram. Res., vol. 13, pt. 2, p. 49, pl. 7, figs, 1a-b, 3a-b, (not 2a-b); Cushman, 1946, (not d'Orbigny), U. S. Geol. Survey, Prof. Paper 210-D, pl. 25, figs. 16a-c (not others).; Clapp, Ann Dorsey, 1948, (not d'Orbigny), Maryland Dept. Geol., Mines and Water Res., Bull. 2, p. 303, pl. 36, figs. 5-6.

Test elongate, slender, of nearly uniform diameter for most of its length, about 3½ times as long as wide in the adult; chambers generally triserial, inflated; sutures distinct, depressed; wall smooth, polished; aperture elongate, narrow. Length 0.60 mm.; diameter 0.18-0.20 mm. (Cushman, 1930.)

In transferring this form into synonymy with *Bulimina elongata,* Cushman stated (U. S. Geological Survey, Professional Paper 210-D, p. 109, 1946): "The specimens from the Miocene of Florida called *B. gracilis* Cushman are somewhat more slender and attenuated but identical ones may be found in the Vienna Basin material." He further noted that *B. elongata* may be recognized by its long narrow test with angled chambers that are not regularly arranged.

John Haynes (Micropaleontologist, vol. 8, No. 3, p. 57, 1954) showed that the placement of specimens in classification with *B. elongata* has been confused by the fact that Fornasini figured a clavulinid as D'Orbigny's form, taking it from the "Planches inedites" of D'Orbigny. Reference to Cushman's plate 25 of Professional Paper 210-D shows that Cushman copied Fornasini's *B. elongata* (actually an arenaceous clavulinid according to Haynes) instead of the figure given by D'Orbigny in his 1846 Vienna Basin paper, which, according to Haynes, is still the valid figure for *B. elongata.*

D'Orbigny's description and figure of *B. elongata* do not reveal a form similar to *B. gracilis.* In the first place, the test is more pointed and is curved; secondly, the test is figured as being distinctly perforate, which *B. gracilis* is not. The chambers of *B. elongata* are figured by D'Orbigny as being angulate, which *B. gracilis* is not. The accuracy of D'Orbigny's figure is attested by the figure of *B. elongata* found by P. Marks (Contr. Cushman Found. Foram. Res., vol. 2, pt. 2, pl. 7, fig. 12) and by Mark's description which specifically noted the perforate character of the test.

For these reasons, I am restoring *B. gracilis* as a distinct species whose validity is upheld by the Yorktown formation occurrences.

Occurrence.—Carter's Grove; Moore House; Fort Eustis Well at 135-160 feet; Crisfield well (Maryland) at 248-287 feet; Calvert through St. Marys formation.

Bulimina preacanthia McLean, n.sp. Pl. 45, figs. 2-3, 7

Test medium-sized for the genus, only slightly tapering, greatest diameter in upper portion of test; chambers distinct, inflated, globular in later portion of test, rather irregularly arranged but in a definite spiral whorl from initial end to aperture; sutures distinct, depressed; wall smooth; aperture a rather elongated comma-like opening extending from the basal portion of final chamber well up the side toward the apex. Length of holotype, 0.85 mm.; diameter, 0.50 mm.

This form resembles *Bulimina acanthia* Costa in general arrangement and appearance but differs from that species in having a simpler aperture and in lacking the basal spines on the chambers.

Types.—Holotype, P.R.I., No. 22,293; paratypes, P.R.I., Nos. 22,292 and 22,294.

Occurrence.—Carter's Grove at base of the bank, lower portion of beach; also at 10 feet up the bank, in the upper part of the beach.

Genus **VIRGULINA** d'Orbigny, 1826

Virgulina punctata d'Orbigny Pl. 44, figs. 12a-b; Pl. 45, figs. 1a-c

Virgulina punctata d'Orbigny, 1839, in De La Sagra, Hist. Politique et Nat. de l'ile de Cuba, Foraminiferes, p. 139, pl. 1, figs. 35-36.; Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 31, pl. 3, fig. 9.; Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 44, pl. 8, figs. 7a-b; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 25, pl. 8, figs. 8a-b.; Cushman, 1937, Spec. Publ. No. 9, Cushman Lab. Foram. Res., pp. 23-24, pl. 3, figs. 25-27.; Puri, 1953, Florida Geol. Survey, Bull. 36, pp. 118-119, pl. 29, figs. 6-7.; Parker, 1954, Bull Mus. Comp. Zool, Harvard Univ., vol. 3, No. 10, p. 513, pl 7, fig. 11.

Test elongate, about 3½ times as long as broad, tapering, somewhat fusiform. greatest breadth toward the apertural end, compressed, periphery rounded, lobulate; chambers numerous, the early ones distinctly twisted, later becoming biserial, usually with only four to six biserial chambers, the earlier ones somewhat irregular; sutures distinct, depressed, particularly in the later portion, strongly oblique; wall smooth, finely perforate; aperture elongate, narrow, reaching to or nearly to the base of the last-formed chamber. Length up to 0.75 mm.; breadth 0.20 mm.; thickness 0.10 mm. (Cushman, 1937.)

This species ranges from the Oligocene to the present and is found from 0 to more than 2000 meters deep, with the greatest numbers at less than 100 meters.

Occurrence.—Carter's Grove, lower portion of beach, at base of the bank.

Genus **BOLIVINA** d'Orbigny, 1839

Bolivina lafayettei McLean, n.sp. Pl. 45, figs. 6, 8

Test small, slightly more than two times as long as broad, compressed, periphery rounded, somewhat irregular in outline, test tapering, broadest toward apertural end; chambers numerous, 20 visible in holotype, chambers irregular, broader than high, only slightly inflated; test marked by a series of ridges which are partially discontinuous and marked by downward-projecting chamber processes along the path of the ridges; sutures distinct, depressed, irregular; wall glassy, coarsely perforate; aperture bolivine and simple. Length of holotype, 0.40 mm.; breadth, 0.21 mm.; thickness, 0.14 mm.

This form differs from *Bolivina pseudoplicata* Heron-Allen and Earland in its simpler aperture and in a noticeably lesser development of ridges and chamber infolds. It is probably ancestral to *B. pseudoplicata.* Named in honor of General Lafayette who fought as a volunteer for the cause of American Liberty.

Types.—Holotype, P.R.I., No. 22,299; paratype, P.R.I., No. 22,298.

Occurrence.—Carter's Grove and Moore House beaches, at base of the banks.

Bolivina striatula Cushman Pl. 45, figs. 4a-b

Bolivina striatula Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 27, pl. 3, fig. 10.; Cole, 1931, Florida Geol. Survey, Bull. 6, p. 41, pl. 2, fig. 9.; Cushman, 1937, Cushman Lab. Foram. Res., Spec. Publ. 9, pp. 154-155, pl. 18, figs. 30-31.; Post, 1951, Publ. Inst. Marine Science, vol. 2, No. 1, p. 174, pl. 1, fig. 19.; Boltovskoy, 1954, Revista del Inst. Nacional Invest. Ciencias Nat. y Mus. Argentino Ciencias Nat. "Bernadino Rivadavia," tomo 3, No. 4, p. 281, pl. 26, figs. 2a-b.

Test elongate, about three times as long as broad, much compressed, microspheric form tapering throughout, megalospheric form often with the adult portion of the test with the sides nearly parallel, periphery rounded; chambers numerous, distinct, very slightly inflated, earlier ones much broader than high, relative height increasing toward the apertural end, where height and breadth are often about equal; sutures distinct, slightly limbate, obliquely curved, forming an angle of about 30-40° with the horizontal, slightly depressed in the adult portion; wall finely perforate, smooth, except for the early portion, which has numerous, fine, longitudinal costae, sometimes running up halfway of the length of the test; aperture elongate, narrow at the base, and somewhat expanded at the upper end. Length 0.35 mm.; breadth 0.10 mm.; thickness 0.03-0.04 mm. (Cushman, 1937.)

This species is recorded from the Pleistocene to the Recent. It is said to occur in 93 fathoms off the British Isles, and in 0-25 meters in the San Blas Bay. Our single specimen seems to be typical.

Occurrence.—Base of the bank, Moore House Beach.

Genus **LOXOSTOMUM** Ehrenberg, 1854

Loxostomum wilsoni McLean, n.sp. Pl. 45, figs. 5a-b

Test elongate, three times as long as broad, initial portion tapering, outline serrate; chambers fairly numerous, rapidly enlarging and increasing in height as added, the peripheral portion at base of each chamber developing as a small projection which gives test the serrate outline, sixteen chambers to holotype; sutures distinct, depressed, somewhat limbate in some specimens; wall smooth and quite coarsely perforate; aperture elongate, ellipsoidal, with a raised lip which extends as a small carina along apertural face, aperture terminal. Length of holotype, 0.65 mm.; breadth, 0.25 mm.; thickness, 0.09 mm.

Loxostomum wilsoni, n. sp. is close to *Bifarina vicksburgensis* (Cushman), from which it differs in a lesser development of the uniserial portion, in having higher chambers in the last portion, and in being broader in relation to length.

Named in honor of Mr. Druid Wilson, of the U. S. Geological Survey, who kindly identified the final collections of mollusks for reference in this paper.

Types.—Holotype, P.R.I., No. 22,301; paratypes, P.R.I., No. 22,300 and U.S.N.M., No. P3113.

Occurrence.—Beach below the Moore House, at the base of the bank and at four feet up the bank.

Genus **UVIGERINA** d'Orbigny, 1826

Uvigerina calvertensis Cushman Pl. 46, figs. 2a-b

Uvigerina calvertensis Cushman, 1948, Maryland Dept. Geol., Mines Water Res., Bull. 2, p. 22, pl. 15, figs. 9-10. ,

Uvigerina kernensis Clapp, Ann Dorsey, 1948, (not Barbat and Von Estorff). Maryland Dept. Geol., Mines Water Res., Bull. 2, p. 308, pl. 36, fig. 24.

Test elongate, slender, fusiform, initial end pointed, tending to become biserial in the later portion, periphery lobulate; chambers large, distinct, inflated in the later portion; sutures distinct, deeply incised; wall thin, ornamented by numerous high, thin costae, about twelve to fifeen on each chamber in the later portion, the costae usually appearing serrate, occasionally irregular in pattern and branching, those of each chamber independent, the greatest development of the costae on the initial part of the test, usually diminishing in strength on the last one or several chambers, often breaking down into aligned spines, occasional specimens being very finely hispid over the later half of the test; aperture terminal, at the end of a short, cylindrical neck, surrounded by a narrow phialine lip. Length, 0.45-0.70 mm.; diameter 0.17-0.23 mm. (Cushman, 1948.)

A few specimens answering the above description are in the Yorktown formation. The form was described from a subsurface Calvert (?) formation bed.

Occurrence.—Base of bank, beach below Moore House; Camp Wallace; Fort Eustis well at 37 to 101 feet deep.

Uvigerina cf. **carmeloensis** Cushman and Kleinpell Pl. 46, fig. 1

Ann Dorsey Clapp (Maryland Dept. Geol., Mines, and Water Resources, Bull. 2, p. 308, pl. 36, fig. 25, 1948) recorded a species from the Choptank formation as *Uvigerina carmeloensis* Cushman and Kleinpell. In the Moore House Beach material, there are two specimens which seem to be the same as Clapp's form.

Uvigerina cf. **tenuistriata** Cushman (not Reuss)

Pl. 45, figs. 9a-b; Pl. 46, figs. 3a-b

Four specimens from Carter's Grove are close to the *Uvigerina tenuistriata* figured by Cushman in U. S. Geological Survey, Bulletin 676 (Plate 12, fig. 1, 1918). Evidently, from the number of different forms ascribed to it, *Uvigerina tenuistriata* Reuss is another species whose original meaning has been destroyed by assignment of different forms to the species. Cushman's *U. tenuistriata* (and the present specimens) do not seem to match Reuss's figures well and are probably a different species.

Genus **SIPHOGENERINA** Schlumberger, 1883

Siphogenerina lamellata Cushman Pl. 46, fig. 4

Siphogenerina lamellata Cushman, 1918, U. S. Geol. Survey, Bull. 676 pp. 55-56, pl. 12, figs. 3a-b.; Cushman, 1930, Florida Geol. Survey Bull. 4, p. 49, pl. 9, fig. 10.; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p 28, pl. 9, fig. 4.; Clapp Ann Dorsey, 1948, Maryland Dept. Geol., Mines and Water Res., Bull. 2, p. 309, pl. 36, figs. 13a-b.; Bermudez, 1949, Cushman Lab. Foram. Res., Spec., Publ., No. 25, pp. 221-222, pl. 14, fig 9 (not 10).; Puri, 1953, Florida Geol. Survey, Bull. 36, p. 125, pl. 16, fig. 8.

Test elongate, tapering gradually from the initial end, broadly rounded at the apertural end, chambers comparatively few, indistinct, surface ornamentation consisting of several equidistant, longitudinal lamellae extending from the initial end to the apertural end, where they fuse; aperture with a tubular neck and phialine lip. Length 1 millimeter. (Cushman, 1918.)

Except for a single specimen here figured, from the inner sand of a shell from Camp Wallace, this species is restricted to the Calvert formation of Virginia and Maryland. In its natural position (Calvert formation), the species is abundant and seems to represent a special environmental assemblage. Its occurrence in the Camp Wallace shell can only be explained as a redepositional element. Bermudez recorded the species in the upper Oligocene of the Dominican Republic; all other records are for the Miocene. The type figure by Cushman is highly stylized and unsatisfactory for comparison purposes, and this figure may have caused a different form to be also placed in *Siphogenerina lamellata* as in the possible case of Bermudez's Oligocene report.

Occurrence.—A single specimen from Camp Wallace.

Genus **ANGULOGERINA** Cushman, 1927

Angulogerina occidentalis (Cushman) Pl. 46, fig. 5

Uvigerina angulosa, Cushman, 1922, (not Williamson), Carnegie Inst. Washington, Publ. 311, p. 34, pl. 5, figs. 3-4.

Uvigerina occidentalis Cushman, 1923, U. S. Nat. Mus., Bull. 104, pt. 4. p. 169.

Angulogerina occidentalis Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 50, pl. 9, figs. 8-9.; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 28, pl. 9, figs. 8a-b.; Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Publ. No. 25, p. 218, pl. 13, fig. 57.; Puri, 1953, Florida Geol. Survey, Bull. 36, p. 125, pl. 22, figs. 7-8.

Angulogerina angulosa occidentalis Boltovskoy, 1954, Revista del Inst. Nacional Invest. Ciencias Nat. y Mus. Argentino Ciencias Nat. "Bernadino Rivadavia," tomo 3, No. 3, p. 197, pl. 11, figs. 1a-b, 2a-b.; Boltovskoy, 1954, *idem,* tomo 3, No. 4, p. 283, pl. 26, fig. 7.

Test minute, elongate, triangular in transverse section, the periphery somewhat lobulate; chambers distinct, those of the last-formed portion becoming more distinct and remote; sutures distinct and depressed; wall ornamented with longitudinal costae on all but the last-formed chambers in the adult; apertural end drawn out into a short, tubular neck and slight, phialine lip. Length usually less than 0.50 mm.; diameter 0.15-0.20 mm. (Cushman and Cahill, 1933.)

Specimens from the Yorktown formation vary but seem to fit the description, considering that the species seems to vary considerably as reported by others. It is recorded from the present to the lower Miocene.

Occurrence.—Base of bank, lower part of beach at Carter's Grove.

Angulogerina sp. Pl. 46, fig. 6

The single specimen is from the Moore House Beach, four feet up the bank. It is a large form for the genus with basal projections on the chambers, and it bears no costae as in the case of *A. occidentalis.*

Family **ROTALIIDAE**

Genus **PLANISPIRILLINA** Bermudez, 1952

Planispirillina orbicularis (Bagg) Pl. 46, figs. 7-8

Spirillina orbicularis Bagg, 1898, Bull. Amer. Paleont., vol. 2, No. 10, p. 33, (327), pl. 2 (22). figs. 2a-c.; Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 58, pl. 14, fig. 1.; Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 51, pl. 9, figs. 12a-b.; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 29, pl. 9, figs. 10a-b.

Planispirillina orbicularis Puri, 1953, Florida Geol. Survey, Bull. 36, p. 130, pl. 20, figs. 1-2.

Test planispirally coiled, the coils increasing in diameter as added, periphery broadly rounded, ventral side with rows of beads more or less following the coils, dorsal side wih a row of pits along the sutures; aperture arched, comparatively narrow. Diameter about 0.50 mm. (Cushman and Cahill, 1933.)

Bagg described this species from the Yorktown formation, and it has been found in the Duplin and Choctawhatchee formations. Present specimens seem to be typical.

Occurrence.—Moore House Beach, at base of bank and six feet up the same bank.

Genus **DISCORBIS** Lamarck, 1804

Discorbis floridana Cushman Pl. 46, figs. 9-12, 15

Discorbis rosacea Cushman 1930, (not D'Orbigny), Florida Geol. Survey, Bull. 4, p. 51, pl. 9, figs. 13a-c.

Discorbis subaraucana Cushman, 1930, (not Cushman, 1922). Florida Geol. Survey, Bull. 4, p. 52, pl. 10, figs. 1a-c.

Rosalina floridana Parker, 1954, Bull. Mus. Comp. Zool., Harvard Univ., vol. 3, No. 10, pp. 524-525, pl. 8, figs. 19-20.

Discorbis floridana Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 39, pl. 5, figs. 11-12.; Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 21, pl. 4, figs. 7-8.; Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 88, pl. 13, figs. 2a-c; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 29, pl. 9, figs. 12-13.; Parker 1948, Bull. Mus. Comp. Zool., Harvard Univ, Vol. 100, No. 2, pl. 5, figs.

23a-b.; Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 238, pl. 15, figs. 16-18.; Puri, 1953, Florida Geol. Survey, Bull. 36, p. 131, pl. 24, figs. 7-9.; Phleger and Parker, 1954, Geol. Soc. Amer., Mem. 46, pt. 2, p. 20, pl. 10, figs. 4a-b

Discorbis floridanus Bandy, 1954, U. S. Geol. Survey, Prof. Paper 254-F, p. 136, pl. 31, figs. 1a-c.

Test rotaliform, periphery slightly, if at all lobulated, dorsal side rounded, much convex, ventral side concave, somewhat umbilicate; chambers comparatively few, five or six in the last-formed coil, on the dorsal side coarsely punctate, on the ventral side punctate near the periphery, but on the inner concave portion smooth, with very fine punctate, if any; sutures in the younger portion slightly limbate, those of the later portion not limbate, rather indistinct, very slightly depressed; aperture an elongate, arched opening at the base of the last-formed chamber, opening on the umbilicate area, often with a slight, thin lip; color of the early whorls brown, of the last whorl white. Diameter not exceeding 0.4 mm. (Cushman, 1931.)

This form is a shallow water species found in from 1 to 11 fathoms in the Dry Tortugas; in 50-100 feet in the Gulf of Mexico (by Bandy); and in 0 to 12 meters in the Gulf area by Phleger. It is a rare species even where reported most frequently, and if all references cited in synonymy above are correctly assigned to the species, the form is a variable one, as it seems to range from forms with an umbilical flap, to individuals with an open and excavated umbilicus. Yorktown specimens show just such variation. The species ranges from the present to the Calvert Miocene and despite records older than the Miocene, it seems not to extend beyond the Miocene.

Occurrence.—Powell's Lake; Carter's Grove; Bluffs at Yorktown; and the Moore House Beach. Rare at all localities.

Discorbis (?) sp. Pl. 47, figs. 1a-e

This peculiar form is represented by a single specimen from the middle part of the beach, six feet up the bank, at Carter's Grove. Dimensions are; diameter, 1.08 mm.; thickness about 0.22 mm. The singular development of the last chamber and the pronounced umbilical depression seem to set this specimen aside from all forms known to the writer, and it may be necessary to erect a new genus to accommodate the form. It has certain features related to *Discorbis*, however, and I am placing it in that genus pending the finding of additional specimens upon which study can be made.

Discorbis rehderi McLean, n.sp. Pl. 46, figs. 13-14

Discorbis rosacea Cushman, 1918, (not *Rotalia rosacea* d'Orbigny), U. S. Geol. Survey, Bull. 676, p. 59, pl. 14, figs. 4a-c.
Rotorbinella ? rosacea Puri, 1953, Florida Geol. Survey, Bull. 36, p. 136, pl. 24, figs. 1-3.

Test planoconvex, dorsal side convex, ventral side flattened or slightly concave, chambers numerous, much elongated in those last formed; sutures very oblique, five chambers in the last-formed coil; margins acute, carinate from below, umbilicate; aperture entirely ventral, umbilical cavity distinct. Diameter 0.50 milimeter. (Cushman, 1918).

By emending Cushman's description to include a perforate, thin wall and to note the definitely pointed dorsal spire, the description of this species is complete. Diameter of holotype, 0.65 mm.

D'Orbigny's original figure of *Rotalia rosacea* shows an umbilical plug and a different ventral chamber arrangement from the form Cushman named *Discorbis rosacea* from the Suffolk exposure of the Yorktown formation. Present specimens are identical to the Suffolk one and are better preserved.

Named in honor of Dr. Harald Rehder, of the Mollusk Division, U. S. National Museum, Washington, D.C., who has given the author assistance and consideration during the studies attendant to the writing of this paper.

Types.—Holotype, P.R.I., No. 22,325; paratypes, P.R.I., 22,326-22,330.

Occurrence.—Langley Field; Moore House Beach; Camp Wallace; and the Powell's Lake Spillway.

Discorbis turrita Cushman Pl. 47, figs. 2a-d

Discorbis turrita Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 59, pl. 14, figs. 2a-c.; Cushman and Cahill, 1933, U.S. Geol. Survey, Prof. Paper 175-A, p. 30, pl. 10, figs. 6a-c.

Test minute, the central portion closely coiled and conical, the later portion broader and more extended, ventral side nearly flat, five to six chambers in the last-formed coil, ventral peripheral margin with a definite keel, in side view subconical; wall smooth, punctate; aperture extending from the ventral edge to the umbilicus, narrow, with a definite raised margin. Diameter 0.4 millimeter. (Cushman, 1918.)

I have two specimens which can be ascribed to this species as they answer fully to the above description. The type described by Cushman came from the Suffolk, Virginia, exposures of the Yorktown formation.

Occurrences.—Rare, at the base of the bank at both the Moore House Beach and the lower part of the beach at Carter's Grove.

Genus **VALVULINERIA** Cushman, 1926

Valvulineria washingtoni McLean, n.sp. Pl. 47, figs. 3-4

Test biconvex, involute on ventral side, somewhat evolute on dorsal side, periphery angular and somewhat lobulate; chambers quite inflated, particularly on dorsal side, seven chambers in final whorl of holotype; sutures distinct, limbate, curved in early portion of dorsal side but straight in final portion, curved and less limbate on ventral side; wall glassy, coarsely perforate, thin; aperture a well-developed high arched opening extending from the ventral side of the periphery over into the dorsal coil. Diameter of holotype, 0.55 mm.; thickness, 0.22 mm.

This species is structurally similar to *Valvulineria floridana* Cushman but has limbate sutures and a more pronounced aperture which extends over the peripheral angle.

Named in honor of General George Washington, who won the American Revolution by accepting the surrender of the British forces in the historic York-James Peninsula.

Types.—Holotype, P.R.I., No. 22,335; paratypes, P.R.I., Nos. 22,334 and 22,336-22,337 and also U.S.N.M., No. P3106.

Occurrence.—Fort Eustis well at 37 to 101 feet deep, and at Powell's Lake Spillway.

Genus **BUCCELLA** Andersen, 1952

Buccella anderseni McLean, n.sp. Pl. 50, figs. 1a-c; Pl. 51, figs. 1, 4

Test medium to large size for the genus, unequally biconvex, dorsal side usually the highest one, periphery rounded to slightly angular, test distinctly trochoid with a relatively high spire; dorsal side hyaline and finely perforate, with somewhat limbate and oblique sutures; ventral side rather smooth, but largely coated with coarse pustules which cover a large part of the central portion of the test and extend outward along the sutural regions almost to the periphery, the ventral sutures are straight and radiating, deeply depressed and in a wide trough which is filled with pustules; eight to nine chambers to the final whorl, adult test contains

2½ to three coils. Diameter of microspheric holotype, 0.45 mm.; thickness about 0.21 mm.

Megalospheric A^1 form is much thicker and more highly trochoid and has notably larger proloculum than the microspheric form; sutures of dorsal side are the same in early portion but more oblique in final coil. Diameter of figured paratype, 0.50 mm.; thickness, 0.32 mm.

Megalospheric A^2 form is less thick than A^1 form and more closely resembles microspheric form in general outlines; proloculum is larger than that of A^1 form and there are only two coils rather than the usual three of the other forms. Diameter of figured paratype, 0.60 mm.; thickness about 0.24 mm.

All apertures are concealed by pustulose material.

Buccella anderseni is close to *B. frigida* (Cushman) and *B. depressa* Andersen, but it differs from these in degree and coverage of pustules, in the straight ventral sutures, more pointed spire, and in maximum size and chamber numbers, these last two features being the least significant.

Named in honor of Dr. Harold V. Andersen of Louisiana State University, who described the genus.

Types.—Holotype, P.R.I., No. 22,343; paratypes, P.R.I., Nos. 22,338-22,342 and 22,344-22,349.

Occurrence.—Powell's Lake Spillway; Carter's Grove; the bluffs at Yorktown, and 37-101 feet deep in the Fort Eustis well.

Buccella depressa Andersen Pl. 50, figs. 2-4

Eponides peruvianus Cushman and Parker, 1931, (not D'Orbigny), U. S. Nat. Mus., Proc, vol. 80, art. 3, p. 19 (not figured).

Buccella depressa Andersen, 1952, Washington Acad. Sci., Jour. vol. 42, No. 5, pp. 145-146, tf. 7a-c, 8.

Eponides peruvianus campsi Boltovskoy, 1954, Revista del Inst. Nacional Invest. Ciencias Nat. y Mus. Argentino Ciencias Nat. "Bernadino Rivadavia", tomo 3, No. 3, p. 204, pl. 17, figs. 6a-c, 7, 8.; Boltovskoy, 1954, *idem,* tomo 3, No. 4 p. 287 pl. 27, figs. 8a-b.

Test of medium size; trochoid; dorsal and ventral sides equally biconvex. Dorsal side with surface smooth, finely perforate and hyaline (in well-preserved specimens); and with slightly curved sutures oriented oblique to the peripheral margin. Ventral side with surface more coarsely perforate than the dorsal surface, sutures greatly depressed, nearly radial, and partly filled with opaque pustulose material; chambers inflated; and with depressed umbilicus and basal margin of last-formed chambers bearing a moderate coating of pustulose material. Periphery broadly acute to rounded and lobulate. The number of chambers in the last-formed whorl ranges from 7 to 9, the most common being 8. Adult tests have 2½ to 3 coils.

In well preserved specimens all apertures are concealed by pustulose material. Weathered specimens exhibit . . . . a low arched primary aperture at the basal margin of the last-formed chamber and slitlike supplementary apertures that extend along the outer postero-sutural margins of each chamber. (Andersen, 1952.)

Dimensions cited are diameter, 0.46-0.49 mm.; thickness, 0.20-0.22 mm.

Occurrences cited are from 4 to 10 fathoms or more, in present waters.

Occurrence.—Base of the bank at Carter's Grove beach.

Buccella hannai (Phleger and Parker) Pl. 51, figs. 3a-c

Eponides hannai Phleger and Parker, 1951, Geol. Soc. Amer., Mem. 46, p. 21, pl. 10, figs. 11-14.

Buccella hannai Andersen, 1952, Washington Acad. Sci., Jour. vol. 42, No. 5, p. 144, tf. 3a-c.

Test small; trochoid; biconvex, ranging from specimens with equal convexity on dorsal and ventral sides to specimens that are extremely convex on the dorsal side and nearly flat on the ventral side. Dorsal side with surface smooth, finely perforate and hyaline (in well-preserved specimens); and with curved and limbate sutures that form the peripheral margin of each chamber. Ventral side with surface more coarsely perforate than the dorsal surface; sutures depressed and radial; chambers slightly inflated; and with umbilicus, sutures, and anterior basal margin of last-formed chamber bearing a coating of pustulose material. Periphery distinctly lobulate; typically acute and limbate although an occasional specimen (not necessarily all young specimens) has a very rounded periphery. The number of chambers in the last-formed whorl range from 7 to 9, the most common being 8. Adult tests have from 3 to 3½ coils.

The only apertures are the supplementary apertures on the ventral side of the test. Each aperture is a low arched opening located at the postero-sutural margin of each chamber. In those specimens with an acute periphery, the supplementary apertures are in a slight depression at the outer margin of the suture near the periphery. In those specimens with a rounded periphery, the apertures are located about midway between the periphery and the umbilicus. (Andersen, 1952.)

Maximum diameter is 0.38 mm.; maximum thickness, 0.19 mm. according to Andersen.

Occurrence.—Bluffs at Yorktown, and 37-101 feet deep in the Fort Eustis well. Reported at less than 100 meters deep in Gulf of Mexico and from a mudlump island off the Mississippi River.

Buccella parkerae Andersen Pl. 51, figs. 2a-c

Eponides mansfieldi Cushman and Parker, 1931, (not Cushman, 1930), Contr. Cushman Lab. Foram. Res., vol. 7, pt. 1, pl. 2, fig. 10a-c.

Buccella parkerae Andersen, 1952, Washington Acad. Sci., Jour. vol. 42, No. 5, p. 149, tf. 9a--c.

> Test small; trochoid; biconvex, dorsal side nearly conoidal, ventral side with an umbilical flattening. Dorsal side with surface coarsely perforate; and with sutures of variable intensity; in the early coils concealed by a thin exogenous covering of shell material, in the last coil distinct, limbate, and in some specimens slightly raised above the surface of the test. Ventral side with surface coarsely perforate; depressed sutures radial near the umbilicus and abruptly curved backward at the peripheral margin; umbilicus depressed; and with umbilicus, sutures, and basal margin of the last-formed chamber bearing a coating of pustulose material, thickly deposited in the umbilicus, less densely deposited in the outer portion of the sutures. Periphery acute, limbate and slightly lobulate. The number of chambers in the last-formed whorl range from 9 to 11, 11 being the most common. Adult tests with 2½ to 3 coils.
>
> The primary aperture is concealed by pustules. Supplementary apertures on the ventral side of the test are located in the slight depression at the outer margin of the suture near the periphery. Each aperture is a long, slitlike opening barely visible under high magnification. (Andersen, 1952.)

Andersen reports dimensions as: diameter, 0.42 mm.; thickness, 0.17 mm.

The form came from the upper Temblor formation (Miocene) of San Joaquin Valley, California.

Occurrence.—Camp Wallace; Carter's Grove; Moore House Beach; Powell's Lake Spillway, and the Crisfield (Maryland) well at 248 to 287 feet deep. Special note: In citing Andersen's descriptions, I have omitted his discussions of internal features because present specimens are not broken to show them and are too few to section.

Genus **ROTALIA** Lamarck, 1804

Rotalia limbatobeccarii McLean, n.sp. Pl. 47, figs. 5-8

Test round, distinctly trochoid, high, slightly lobulate to nonlobulate, periphery slightly angular to entirely rounded, three coils visible on dorsal side, only one or occasionally two coils visible on ventral side; 10 or more chambers to the final whorl, the usual number being 11; sutures limbate, slightly to considerably raised above surface of test, usually glassy; wall smooth, glassy, thin; the sutures, the central part of the dorsal side, and the umbilical area are more or less heavily overlain with glassy shell material; the umbilicus either has one distinct plug quite highly raised, or a set of irregular umbilical beads, or is depressed slightly but still filled with the glassy material; ventrally, the chambers terminate in definite lobed projections which stop short of the umbilical plug; these lobes are emphasized by heavy interchamber furrows which merge into the limbate raised sutures about halfway toward the periphery; aperture an elongate slit at the base of the apertural face of the final chamber extending from close to the periphery into the umbilical area, slightly if at all lipped. Diameter of largest syntype, 0.70 mm.; thickness, 0.32 mm. Other specimens are generally somewhat smaller, the average being about 0.60 mm. or slightly larger.

Designation of a holotype for this variable form is highly inadvisable; specimens can be selected from among the graded series which would seem to be different species if compared with a holotype, yet the gradation from heavily raised sutures to the opposite form are too gradual to allow species separation of the forms. The species, in its extreme suturation resembles *R. beccarii ornata* Cushman dorsally but differs ventrally in the lobed chamber development and umbilical plugging.

Types.—Syntypes, P.R.I., Nos. 22,365-22,369; and U.S.N.M., No. P3105.

Occurrence.—Beach below the Moore House, mainly at the base of the bank, but also sparingly in the 4-foot elevation in the bank.

Genus **POROEPONIDES** Cushman, 1944

Poroeponides lateralis (Terquem) Pl. 47, figs. 9-11; Pl. 48, figs. 1-2

Rosalina lateralis Terquem, 1878, Soc. Geol. France, ser. 1, Mem. vol. 3, p. 25, pl. 2(7), figs., 11a-c.

Eponides lateralis Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 55, pl. 10, figs. 7a-c.; Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 92, pl. 13, figs. 8a-c.; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 31, pl. 11, figs. 1a-c.

Eponides (?) *lateralis* Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, pp. 47-48, pl. 10, figs. 5a-c.

Pulvinulina repanda Brady, 1884, Rept. Challenger Expedition, Zool., vol. 9, pp. 627, 684-685, pl. 104, figs. 18a-c.

Poroeponides repandus Miller, 1953. Contr. Cushman Fd. Foram. Res., vol. 4, pt. 2, p. 59, pl. 10, figs. 1a-c.

Poroeponides lateralis Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 34, pl. 4, fig.23.; Puri, 1953, Florida Geol. Survey, Bull. 36, p. 134, pl. 24, figs. 10-12.; Bandy, 1954, U. S. Geol. Survey, Prof. Paper 254-F, p. 137, pl. 30, figs. 1a-c, 3a-c.

Poroeponides cribrorepandus Asano and Uchio, 1951, in Stach, L. W., "Illustrated Cat. Japanese Tert. Smaller Foram." Pt. 14 Rotaliidae, p. 18, tfs. 134-135.

Test usually somewhat ovate, biconvex, periphery subacute and keeled; chambers distinct, later ones rapidly enlarging and flaring, inflated somewhat on the ventral side; sutures limbate dorsally, oblique, raised, ventrally depressed, nearly radial; wall smooth except for the raised sutures and on the ventral side the last-formed chamber with numerous large perforations; aperture at the base of the ventral edge of the chamber, low. Length up to 1.50 mm. (Cushman, 1930.)

Yorktown specimens vary from typical forms to those with closed umbilicus and few apertural pores. Some specimens show an umbilical flap. The species ranges from the Yorktown formation to the present and is a shallow water form.

Occurrence.—Carter's Grove; Langley Field; Moore House Beach; Camp Wallace.

Genus **CANCRIS** Montfort, 1808

Cancris sagra (d'Orbigny) Pl. 48, figs. 3-5, 7

Rotalina sagra d'Orbigny, 1839, in De La Sagra, Hist. Physique, Politique et Nat. de l'ile de Cuba, Foraminiferes, p. 77, pl. 5, figs. 13-15.

Pulvinulina sagra Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 65, pl. 22, fig. 3, pl. 23, fig. 1.

Pulvinulina semipunctata Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 51, pl. 8, figs. 5-6.

Cancris sagra Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 56, pl. 11, figs. 4a-c.; Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 74, pl. 15, figs. 2a-c.; Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 94, pl. 14, figs. 13a-c.; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 32, pl. 11, figs. 4-5.

Test longer than broad, biconvex, the ventral side more strongly convex than the dorsal, periphery acute; chambers few, 6 to 7 in the adult whorl, increasing rapidly in size as added; sutures slightly depressed on the dorsal side, strongly on the ventral, gently curved; wall smooth; an elliptical area of clearer, thinner wall near the aperture, which is below a slight lip on the ventral side. Length up to 0.75 mm.; breadth 0.55-0.70 mm.; thickness 0.20-0.30 mm. (Cushman and Cahill, 1933.)

The above description fails to note the distinctly perforate character of the test but is otherwise close to the forms from the Yorktown formation. The range of the species, as reflected in the above synonymy is from the present to the Oak Grove and Chipola Miocene of Florida. Many forms assigned to *C. sagra* are in error, although the species does exhibit some degree of variation and may be subject to broad interpretation.

Occurrence.—Carter's Grove; Langley Field, and the beach below the Moore House. All occurrences rare.

Family AMPHISTEGINIDAE

Genus AMPHISTEGINA d'Orbigny, 1826

Amphistegina sp. Pl. 49, figs. 15a-c

A single specimen of this form was found at the base of the bank in material collected at Carter's Grove by Dr. Denise Mongin. A list of the Foraminifera and mollusks collected by Dr. Mongin will be included as part of the paper on Ostracoda to follow this one. Since Dr. Mongin's collections were made from different levels and one different locality than those of the author, it is thought best to report her material in a different section. The Carter's Grove outcrop was much altered and at the time of Dr. Mongin's collection was more exposed than was the case when the material for this report was collected, due to a recent hurricane.

The species may be the same as the *Amphistegina lessoni* of Cushman and Cahill, but I believe it is not *A. lessoni.* One broken specimen does not suffice to establish the identity of this form, which may be new. The presence of an amphisteginid in the Yorktown formation is of enough interest to record and figure it for future reference.

Family GLOBIGERINIDAE

In handling the forms referred to this family, it is necessary to depart from normal taxonomic procedure. The reason for such departure is that it is virtually impossible to ascertain what constitutes a globigerinid species in the confusion existing in the family. Reference to the original description of a given species is useless; early descriptions and figures are incredibly poor and lacking in essential points of comparison.

Therefore, it is necessary to resort to a different method of reference; in this paper, the author has had special drawings made of the globigerinids found in the Yorktown formation. These drawings consist of a spiral view, an umbilical view, and an enlargement of the test wall. The drawings, plus accompanying notes will give a means of specimen comparison with Yorktown forms, and it is hoped that the results here noted will give some one the necessary impetus to review and revise this important family so as to provide some reasonable method of reference.

All of my forms (except *Orbulina*) are marked with a reticulate surface which differs in size of reticulation, in amount of inter-reticulate spaces, and in relationship of "pores" to the depressed areas. It at first seemed that the size of the pores relate to the development of the larger apertures, and that the relationship was that the pores enlarge as the major apertures decrease in size. This may still hold true in the case of *Globigerina*, but in the case of two forms which I assign to *Globigerinoides* pores seem to be lacking.

At this stage of the study, it is impossible to know whether the pore size and the relative reticulation of a given form is a function of species distinction or whether it reflects an environmental reaction of the individual, or even if the significance is to be found in the alternation of generations. I am not sure that the generation-alternation system of the globigerinids has been described or studied. Until this is known and can be discriminated on the basis of living material, it is unsafe to define species in fossil material.

As it was originally described, with reference to a figure by Carpenter, there is nothing which can be used to define *Globigerina sacculifera* of Brady. The subsequent figures and description by Brady (published in 1884) show a form quite different from the figure cited by Brady from Carpenter's *G. helicina* which must be considered the type figure of *G. sacculifera* by original designation. The senescent, pointed, pouchlike final chamber appears to me to be a feature which would appear on more than one species, and yet special stress is laid on this feature in the original description by Brady. Brady's 1884 emended description with figures is quite specific, although lacking in description of the test wall; whether this new description can be taken as the definitive one is not certain.

Carpenter's *G. helicina* figure (the designated type figure of *G. sacculifera*) shows a test whose only similarity to subsequently figured *G. sacculifera* specimens lies in the pointed senescent final chamber. The large umbilical opening of Carpenter's form and the quadrate chamber arrangement are unlike the later figures and bears close resemblance to the form I have designated below as form E (possibly Heron-Allen and Earland's *G. conglomerata*).

G. conglomerata Schwager, shows a similarity to Carpenter's form of *G. helicina*. Carpenter's *G. helicina* seems not to be that of D'Orbigny; with that I agree with Brady. I am not sure whether Schwager's form is the same as that of Heron-Allen and Earland's.

However, it must be remembered that these questions are unanswerable until the type specimens are figured and fully described so as to show all features, including the character of the test wall. A single view of a given form plus the usually meager description accompanying it, is not sufficient to discriminate globigerinid species. If the type specimens are lost, I would favor suspension of all species not fully described in this family.

Hofker (Micropaleontologist, vol. 8, No. 2, pp. 38-39, 1954) has been experimenting with the "pore-index" system as it relates to *Candorbulina* and *Orbulina* and has arrived at conclusions which my material cannot confirm or deny. He further stated that he has counted a number of speces which have been assigned in one species of *Globigerina*: I am inclined to agree that dissimilar forms have been too freely assigned to given species—it is for this reason that one cannot now define any given species with certainty.

It appears to me that one additional thought is pertinent to the subject of the Globigerinidae. These forms are pelagic and are distributed freely by oceanic currents, thus offering no problem in world-wide distribution. By contrast, the benthonic forms are relatively restricted. It would seem to this writer that the concept that the globigerinids are the more primitive forms from which benthonic forms are descended, would allow one to solve two problems; 1, that of distribution of benthonic populations (especially on Sea-mounts) and 2, the possibility that the globigerinids are the more plastic and variable forms which would allow a different approach to species differentiation.

Genus **GLOBIGERINA** d'Orbigny, 1826

Globigerina sp. form A Pl. 52, figs. 1a-c

Test small, four chambers visible on either side, chambers much enlarging as added, globular, arranged in a suggestion of a trochoid spire; wall coarsely reticulate, with wide interreticular spaces, the depressions polygonal and noncrowded, each depression having a large pore in the center; aperture if present is at the base of the chamber on the umbilical side. Diameter, 0.40 mm.

This form is rare and was found only at the base of the bank at the Moore House Beach. The *Globigerina* sp? of Cushman (U. S. Geol. Survey, Bull. 676, p. 57, pl. 12, figs. 5, 7, 1918) is the same form and came from the Yorktown formation at Suffolk, Va.

Globigerina sp. form B Pl. 52, figs. 2a-c

Test small, distinctly trochoid, seven chambers to spiral side, about four on umbilical side, early chambers enlarge gradually as added, but last three much accelerated in size as added; wall quite coarsely reticulate, with wide reticulae, depressions polygonal and not crowded, each depression containing a single, moderate-sized pore; aperture a large arched opening in the umbilical area at the base of the final chamber; additional supplementary apertures on the spiral coil. Diameter, 0.60 mm.

This form is possibly the *Globigerina sacculifera* of Cushman (U. S. Geol. Survey, Bull. 676, p. 57, pl. 13, figs. 2a-c, 1918) and of others. I think it is not Brady's form. It is present at Carter's Grove at the base of the bank, lower part of beach.

Globigerina sp. form C Pl. 52, figs. 3a-c

Test small, distinctly trochoid, 12 chambers to spiral side, four visible on umbilical side, early chambers enlarge gradually as added, the last three greatly accelerated in size as added, globular; wall with medium reticulations, thin reticulae, depressions polygonal and quite crowded, each depression with a single moderate-sized pore; aperture a broad flat arch at base of final chamber at the umbilical area; additional, well-developed supplementary apertures at the chamber bases on the spire. Diameter, 0.55 mm.

This form is also similar to those assigned to *Globigerina sacculifera*, but not as Brady originally figured the form. It is present at the base of the bank at the Moore House beach.

Globigerina sp. form D Pl. 52, figs. 4a-c

Test small, with a high spire, about 11 chambers visible on spiral side, three on umbilical side, early chambers enlarge gradually as added, last three chambers greatly accelerated in size as added. but not as much as in previous forms listed above; wall with medium reticulation, thin reticulae, depressions subrounded to polygonal, quite crowded, with a minute pore in some depressions but absent in others; aperture a rounded arch on umbilicus looking through a similar opening internally; supplemental apertures develop on later part of spire at base of final chamber. Diameter, 0.36 mm.

This may be a young form of form B above, but the wall structure seems to separate it from form B, and in its accelerated final chambers this seems to be an adult form. Found at the base of the bank, Moore House Beach.

Globigerina sp. form E Pl. 53, figs. 1a-c

Test small, trochoid coil, but low, 12 chambers visible on spiral side, only four on umbilical side, chambers enlarge regularly and quite rapidly in size as added, globular; wall finely reticulate, granular in texture at low powers, higher power shows polygonal, often triangulate small depressions separated by wide reticulae or intradepressional areas, each depression contains a well-defined but small pore; aperture a large arch which opens into the large umbilicus. Diameter, 0.55 mm.

This form lacks the supplementary spiral apertures of the previous three forms and differs from them in the distinctive appearance of four chambers of almost equal dimension on the umbilical side. It is a common form in the Moore House Beach bank base and seems identical with forms figured as *Globigerina conglomerata* by Heron-Allen and Earland (Discovery Rept., vol. IV, pl. 13, figs. 6-8, 1932).

Genus **GLOBIGERINOIDES** Cushman, 1927

Globigerinoides (?) sp. form F Pl. 53, figs. 4a-c

Test small, in a rather disorganized trochoid coil, with relatively numerous chambers; wall with medium-sized reticulation, thin reticulae, depressions polygonal or subround, no pores visible; apertures arched, at bases of projecting chambers, about two visible on each side. Diameter, 0. 35 mm.

This interesting form is represented by a single specimen from the Moore House Beach, four feet up the bank.

Globigerinoides sp. form G Pl. 53, figs. 2a-c

Test small, highly trochoid and with a high spire, 14 chambers visible on spiral side, five visible on umbilical side, chambers rather regularly enlarging in size as added, moderately globular; wall with medium reticulations, reticulae rather thick, depressions polygonal, not crowded, no pores visible in depressions; aperture probably obscured by foreign material, but none visible. Diameter, 0.30 mm.

This peculiar form was found as a single specimen in the 37 to 101 foot depth interval of the Fort Eustis well.

Genus **ORBULINA** d'Orbigny, 1839

Orbulina cornwallisi McLean, n.sp. Pl. 53, figs. 3a-b

Test small, almost a sphere; wall thin, glassy, perforate; with a few megapores and numerous micropores, each pore surrounded with a whitened area beveled inward toward the pore. Diameter of holotype, 0.50 mm.

This form differs from *Orbulina universa* d'Orbigny in having no visible spinosity or "knobs" as reported for *O. universa*.

Named for General Cornwallis who surrendered at Yorktown to end the War of the Revolution.

Types.—Holotype, P.R.I., No. 22,411; paratypes, P.R.I., No. 22,412 and U.S.N.M., No. P3107.

Occurrence.—The species occurs rarely at the base of the bank at the Moore House Beach.

Family **GLOBOROTALIIDAE**

Genus **GLOBOROTALIA** Cushman, 1927

Globorotalia sp. Pl. 48, figs. 6a-b

A single specimen of this genus which is here figured was found in the base of the bank at the Moore House Beach. Additional material should be studied to determine the species of the form found.

Family ANOMALINIDAE

Genus PLANULINA d'Orbigny, 1826

Planulina depressa (d'Orbigny) Pl. 48, figs. 8-11

Truncatulina depressa d'Orbigny, 1839, Voyage dans l'Amerique Meridionale, vol. 5, pt. 5, Foraminiferes, p. 39, pl. 6, figs. 4-6.

Planulina depressa Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 60, pl. 12, figs. 2a-c.; Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 34, pl. 12, figs. 6a-c.; Puri, 1953, Florida Geol. Survey. Bull. 36, pp. 141-142, pl. 27, figs. 1-3.

Test much compressed, not completely involute in the adult, earlier chambers showing on both sides of the test, periphery subacute; chambers numerous. later ones often somewhat irregular, eight to ten chambers in the final whorl; sutures distinct, somewhat limbate on the dorsal side, confluent with the keeled edge, on the ventral side depressed; wall very coarsely perforate; aperture at the peripheral margin. Diameter 0.75-0.60 mm.; thickness 0.10-0.15 mm. (Cushman and Cahill, 1933.)

Diameters of Yorktown formation specimens range from 0.80 mm. to 0.95 mm.

This species is from the Choptank Miocene to the present oceans and is reported from the Duplin marl of North Carolina and the Choctawhatchee formation of Florida.

Occurrence.—This form is common in the Carter's Grove outcrop beds and is apparently restricted to it in the Peninsula.

Genus CIBICIDES Montfort, 1808

Cibicides cf. **lobatulus** (Cushman) Pl. 48, figs. 12-13

Truncatulina lobatula Cushman, 1918, U. S. Geol. Survey, Bull. 676, pp. 60-61, pl. 17, figs. 1-3.

Cibicides lobulatulus Clapp, Ann Dorsey. 1948, Maryland Dept. Geol., Mines Water Res., Bull. 2, pp. 315-316, pl. 39, figs. 5a-c.

There are a number of irregular forms from the Yorktown formation which seem similar to the forms figured in the synonymy above. The specimens are thick and lobate with a tendency to coil inward over the dorsal side. The form is perforate but not coarsely so.

Unfortunately, so many different forms have been ascribed to Walker and Jacobs' species that assigning the name *lobatulus* to a *Cibicides* is tantamount to giving the form a status more truthfully described by the term "*incertae sedis*". The species should probably be suspended as being of no taxomic value—it was badly figured and inadequately described in the first place.

Cibicides sublobus (Cushman) Pl. 49, figs. 1-3

Truncatulina subloba Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 62, pl. 19, figs. 1a-c.

Test planoconvex, dorsal side flattened, ventral side slightly convex; chambers comparatively few, six or seven in the last-formed coil, peripheral margin carinate, lobular in face view; sutures distinct, depressed, especially on the ventral side, with an anteriorly projecting lobe on the dorsal side; wall coarsely punctate. Diameter, 0.6 millimeter. (Cushman, 1918.)

Cushman stated that this species is allied to *T. lobatula;* it is difficult to separate from *Cibicidella variabilis,* and it may be that species before it adds the distinctively irregular chambers. The species was first described from the Yorktown formation at Suffolk, Virginia, and is common in the present material.

Occurrence.—Langley Field, Carter's Grove Beach, beach below the Moore House, and Powell's Lake Spillway.

Genus **HANZAWAIA** Asano, 1944

Hanzawaia concentrica (Cushman) Pl. 49, figs. 4-6

Truncatulina concentrica Cushman, 1918, U. S. Geol. Survey, Bull. 676, pp. 64-65, pl. 21, figs. 3a-c.

Cibicides concentrica Cushman, 1930, Florida Geol. Survey, Bull. 4 pp. 61-62, pl. 12, figs. 4a-c.; Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, pp. 120-121, pl. 21, figs. 4-5, pl. 22, figs. 1-2.; Parker, 1948, Bull. Mus. Comp. Zool., Harvard Univ., vol. 100, No. 2, pl. 1, figs. 16a-b.

Cibicides concentricus Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 35, pl. 13, figs. 3a-c.; Cushman 1944, Cushman Lab. Foram. Res., Spec. Publ. No. 12, p. 37, pl. 4, figs. 29a-b.; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines Water Res., Bull. 2, p. 315, pl. 39, figs. 1-2.; Phleger and Parker, 1948, Geol. Soc. Amer., Mem. 46, pt. 2, p. 29, pl. 15, figs. 14-15.; Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Publ. No. 25, p. 296, pl. 26, figs 7-12,

Cibicidina concentricus Parker, 1954, Bull. Mus. Comp. Zool., Harvard Univ., vol. 3, No. 10, pl. 13, figs. 7, 10.

Hanzawaia concentrica Puri, 1953, Florida Geol. Survey, Bull. 36, p. 140, pl. 12, figs. 7-9.

Test nearly planoconvex, dorsal side nearly flat, ventral side convex, periphery subcarinate; chambers distinct, 7 to 9 in the adult whorl. the inner end of the dorsal side with a definite proximal portion, fusing with adjacent ones to form a concentric band about the middle, and more or less separated by a series of depressions; sutures deep on the ventral side, slightly limbate and flush on the dorsal side; wall smooth, finely perforate; aperture largely dorsal with a thin lip. Diameter up to 1.00 mm. (Cushman and Cahill, 1933.)

This species is considered a shallow water form and goes to a depth of 210 fathoms in present waters. Its geologic range is reported from the Oligocene to the present. The species is the most abundant single form found in the Yorktown formation, sometimes exceeding 60% of a given sample but is absent in the Powell's Lake Spillway locality.

Occurrence.—At all localities except the Powell's Lake Spillway.

Genus **DYOCIBICIDES** Cushman and Valentine, 1930

Dyocibicides biserialis Cushman and Valentine Pl. 49, figs. 7a-b

Dyocibicides biserialis Cushman and Valentine, 1930, Contr. Dept. Geol. Stanford Univ., vol. I, No. 1, p. 31, pl. 10, figs. 1, 2a-b.; Cushman, 1931, U. S. Nat. Mus., Bull 104, pt. 8, p. 126, pl. 24, fig. 2; Cushman and Parker, 1931, U. S. Nat. Mus., Proc., vol. 80, art. 3, p. 22, pl. 4, fig. 8. Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 62, pl. 12, figs. 6a-b.; Cushman and Todd, 1945, Cushman Lab. Foram. Res., Spec. Publ. No. 15, p. 72, pl. 12, fig. 10.; Cushman and Gray, 1946, Cushman Lab. Foram. Res., Spec. Publ. No. 19, p. 46, pl. 8, figs. 18-19.; Boltovskoy, 1954, Revista Inst. National Invest. Ciencias Nat. y Mus. Argentino Ciencias Nat. "Bernardino Rivadavia," tomo 3, No. 4, p. 292, pl. 29, figs. 8a-b.

Truncatulina variabilis Heron-Allen and Earland, 1932, Discovery Repts., vol. 4, pt. 1, pp. 420-421, pl. 14, figs. 36-39.

Test fairly large, the early portion close coiled, later in a spreading, biserial series of plano-convex chambers, the dorsal, attached side, flattened; 7-8 chambers in the last coil, chambers not inflated, but becoming much inflated in the biserial portion and greatly enlarging; sutures in the early coiled part limbate and not depressed, in the biserial portion continuing the limbate character on the dorsal side but becoming deeply depressed ventrally; wall coarsely perforate; aperture in the early coiled portion peripheral or slightly dorsal, in the uncoiled portion an elongate slit at the outer edge of the chamber at the line of attachment. Length of adult, 1.35 mm.; breadth, 0.80 mm.; diameter of coiled portion, 0.35 mm. (Cushman and Valentine, 1930.)

The species is reported from the Miocene to the present, Heron-Allen and Earland contended that the genera *Dyocibicides* and *Cibicidella* are invalid, as the chamber arrangements upon which they were erected are due to the protoplasm seeking the lines of least resistance rather than being due to generic differentation.

Occurrence.—Rare at Camp Wallace and Carter's Grove.

Dyocibicides perforatus Cushman and Valentine Pl. 49, figs. 8a-c

Dyocibicides perforata Cushman and Valentine, 1930, Contr. Dept. Geol. Stanford Univ., vol. 1, No. 1, pp. 31-32, pl. 10, figs. 3a-c.

Test very much compressed throughout, periphery subacute, the early portion close-coiled, trochoid, later chambers becoming biserial; chambers very slightly inflated, distinct, 7-8 in the last whorl of the coiled portion; sutures very distinct, on the dorsal side of the coiled portion limbate and flush with the surface, others depressed, not limbate as are all those of the ventral side; wall finely, evenly, and conspicuously perforate, otherwise smooth; aperture nearly peripheral in the early portion, becoming terminal in the biserial portion. Length, 0.90 mm.; breadth, 0.60 mm.; thickness 0.20 mm. (Cushman and Valentine, 1930.)

There is one occurrence of this form in the Yorktown formation, and it seems to answer the original description but differs from forms ascribed to the species in later works.

Occurrence.—Carter's Grove, midpart of beach, 10 feet up the bank.

Genus **CIBICIDELLA** Cushman, 1927

Cibicidella variabilis (d'Orbigny) Pl. 49, figs. 9-11, 14

Truncatulina variabilis d'Orbigny, 1839, in Barker, Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, "Foraminiferes" p. 135, pl. 2, fig. 29.; Bagg, 1912, U. S. Geol. Survey, Bull. 512, p. 84, pl. 24, figs. 1-4 (not pl. 25, figs 4-5).

Cibicidella variabilis Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 127, pl. 24, fig. 3.; Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 192, pl. 15, figs. 5-7.; Cushman and Todd, 1945, Cushman Lab. Foram. Res., Spec. Publ. No. 15, p. 72, pl. 12, fig. 11.; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines Water Res., Bull. 2, pp. 316-317, pl. 39, figs. 8a-b.; Puri, 1953, Florida Geol. Survey, Bull. 36, p. 140-141, pl. 8, figs. 4-6.

Descriptions of this species are generalized but include these points: a *Cibicides*-like early portion succeeded by irregular later chambers; the apertures are lipped and appear on the edges of later chambers; the form is perforate and has a flattened attached side, and a side showing some globulation with depressed sutures.

It is possible as claimed by Heron-Allen and Earland that this form is merely an individual irregularity of a form which has been often referred to *Cibicides lobatulus*, and which I have included as *Cibicides sublobus* (Cushman), for the addition of a series of irregular chambers to these species would produce a form indistinguishable from *Cibicidella*. Undoubtedly more than one species has been referred to *C. variabilis;* as figured in the present collection this form appears to range from the Oligocene to the present.

Occurrence.—This species is common to all localities studied for this paper and is the most common form developed at Powell's Lake Spillway.

Genus **RECTOCIBICIDELLA** McLean, new genus

Test attached on flattened dorsal side, elongate, early chambers arranged as in *Cibicides,* later chambers uniserially or irregularly arranged in an elongate process from the early coiled portion; wall calcareous, coarsely perforate; aperture as in *Cibicides* in early portion, in the adult form the aperture is on the last chamber with a produced neck, sometimes secondary apertures are on the earlier chambers. Type species: *Rectocibicidella robertsi* McLean, n. sp.

Rectocibicidella differs from *Cibicidella* in the elongate chamber processes and in the tubular projection of the aperture on the final chamber.

Rectocibicidella robertsi McLean, n.sp. Pl. 49, figs. 12-13

Test elongate, early portion in a *Cibicides*-like coil, followed by an irregularly uniserial or irregularly developed elongate chamber series; the dorsal side flattened, attached, ventral side somewhat more globose and with depressed sutures; wall calcareous, coarsely perforate; aperture in early stages as in *Cibicides,* in the adult a flattened opening on an elongate projection or tube from the final chamber, with secondary apertures appearing in earlier chambers as simple openings in the apertural face of the chambers. Length of holotype, 1.00 mm.; other dimensions variable.

Named in honor of Dr. Joseph Kent Roberts, Professor of Paleontology, University of Virginia, who has long encouraged the author in this study, and who has contributed much sound advice and information.

Types.—Holotype, P.R.I., No. 22,482; paratype, P.R.I., No. 22,483.

Occurrence.—Carter's Grove, base of bank, lower part of beach.

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PLATES

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5a-b.	**Textularia eustisensis** McLean, n. sp. Holotype, P.R.I., No. 22,055; 5a = apertural view, 5b = side view (25X).	318
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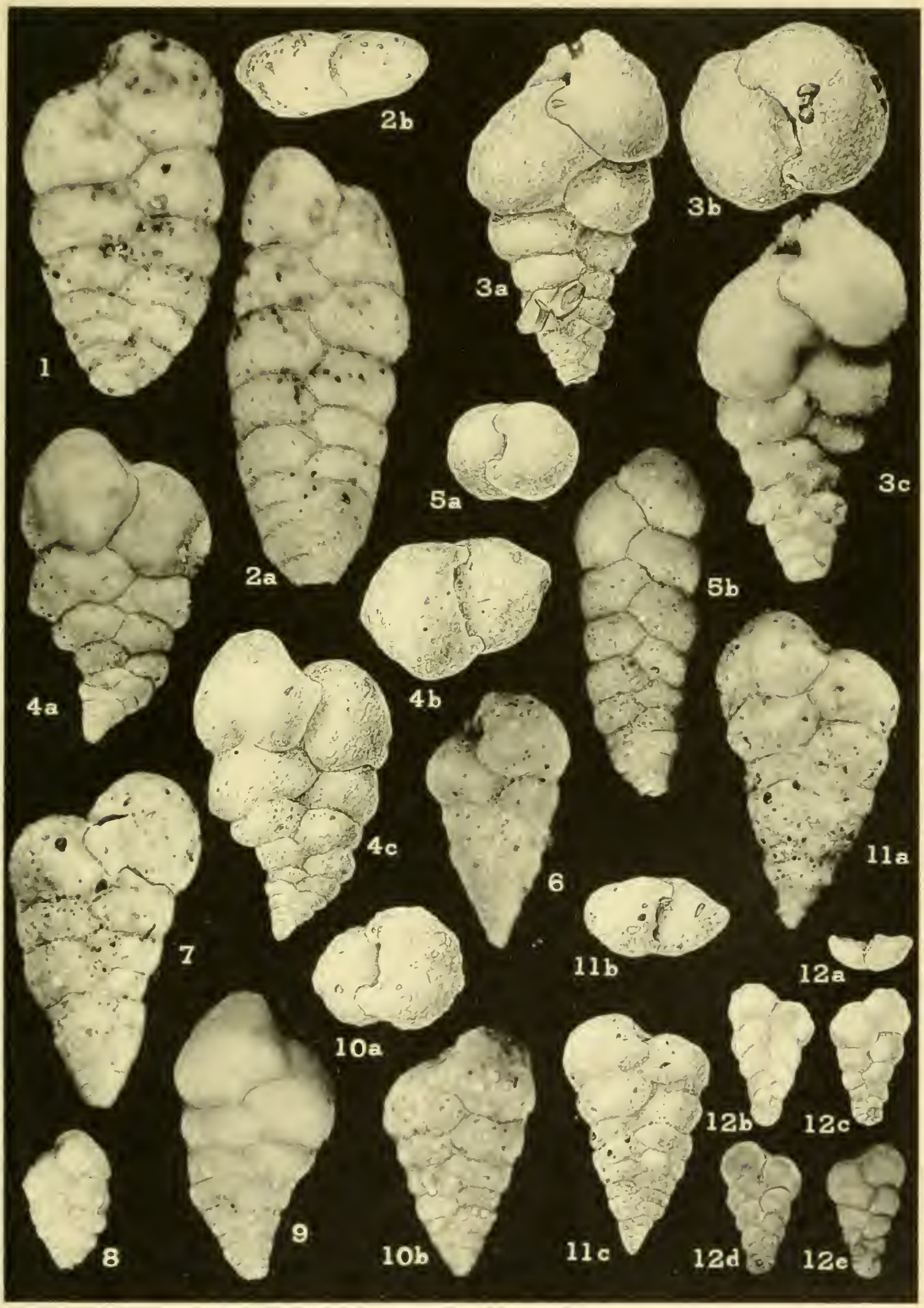
NOTE: the following figures are drawings; the rest are photographs; 2b, 3a, 3b, 4b, 4c, 5a, 10a, 11b, 11c, 12a, 12b, 12c. The photographs in the following plates have been retouched only to the extent that faint sutural lines have been strengthened where it was obvious that plate-making processes would fail to show such lines, which are in the photographs, but would be lost in reproduction of figures. Drawings have been used in two cases: 1. where depth of focus does not allow photographic rendition, and 2, where photographs will not show requisite structural or surface details. In creating these plates the author had only one thought in mind—to give an accurate rendition of the species figured. It was found in a number of cases that photographs and drawings were needed for some specimens. It is believed that these plates will serve to correctly delineate the Foraminiferal species for direct comparison with other specimens. All magnifications listed on these plates are approximate.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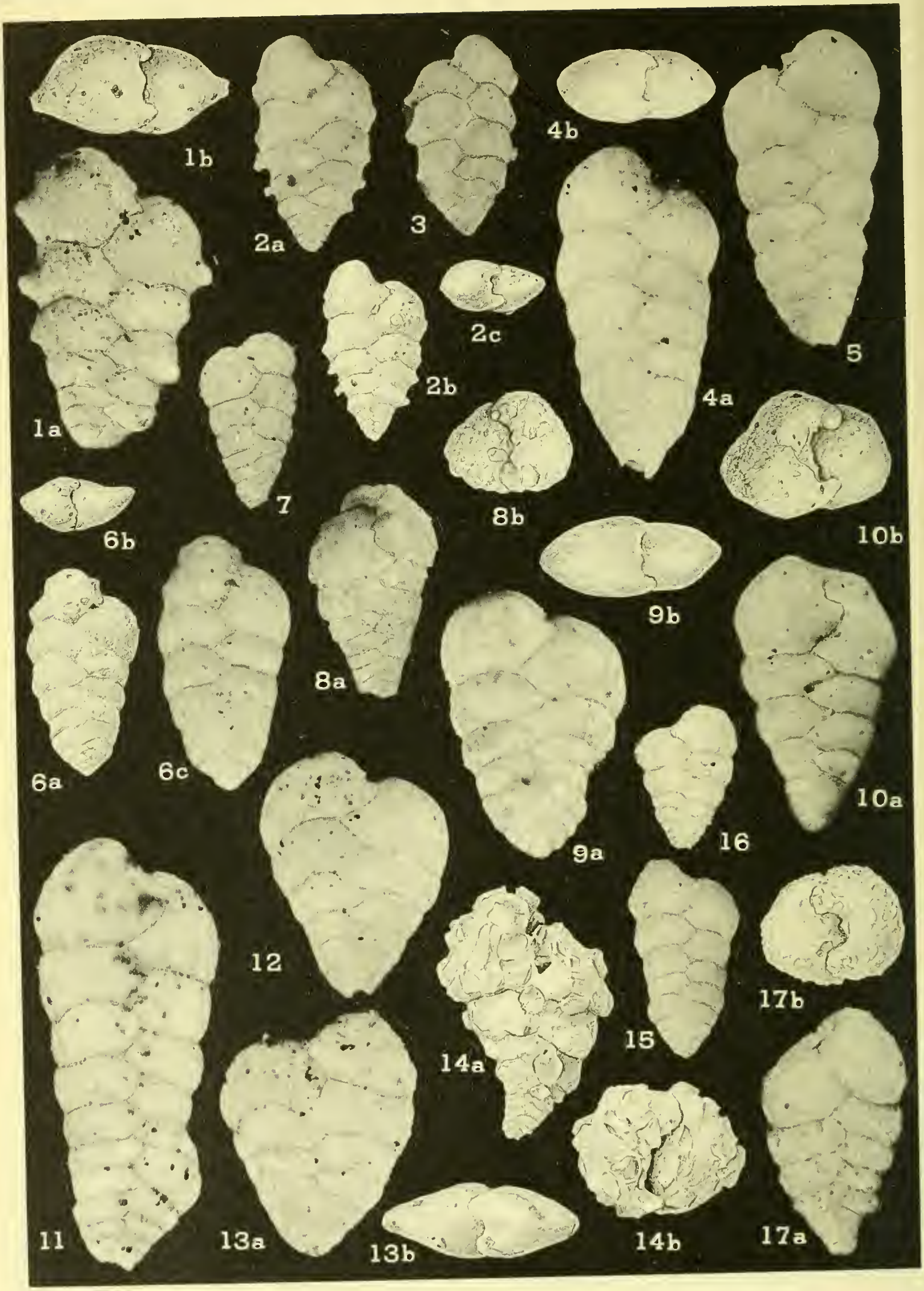
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Explanation of Plate 36

Figure		Page
1-3.	**Textularia mayori** Cushman 1 = P.R.I., No. 22,070 (60X); 2, 3 = P.R.I., No. 22,074 (30X); 1b, 2 c = apertural views, rest are side views.	320
4-6, 9. 11, 15. 16.	**Textularia articulata** d'Orbigny 4, 5 = P.R.I., No. 22,019 (50X); 6 = P.R.I., No. 22,023 (33X for photo); 9 = P.R.I., No. 22,003 (megalospheric form) (47X); 11 = P.R.I., No. 22,014 (50X); 15, 16 = P.R.I., No. 22,021 (20X); 4b, 6b, 9b = apertural views; rest are side views.	316
7, 12, 13.	**Textularia gramen** d'Orbigny 7 = P.R.I., No. 22,064 (30X); 12, 13 = P.R.I., No. 22,063 (46X); 13b = apertural view; rest are side views.	319
8, 14.	**Textularia pseudobliqua aspera** McLean, n. subsp. 8 = paratype, P.R.I., No. 22,080 (30X); 14 = holotype, P.R.I., No. 22,081 (30X); 8b, 14b = apertural views; rest are side views.	320
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17a-b.	**Textularia pseudobliqua** McLean, n. sp. Holotype, P.R.I., No. 22,078 (25X); 17a = side view; 17b = apertural view.	320

NOTE: the following figures are drawings, the rest are photographs: 1b, 2b, 2c, 4b, 6a, 6b, 8b, 9b 10b, 13b, 14a, 14b, 17b.

Explanation of Plate 37

Figure		Page
1, 4-5.	**Massilina mansfieldi** Cushman and Cahill 1 = P.R.I., No. 22,116; 4 = P.R.I., No. 22,126; 5 = P.R.I., No. 22,119; 1c, 4b, 5b = apertural views; rest are side views; (30X).	324
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8a-b.	**Quinqueloculina seminulangulata** McLean, n. sp. Holotype, P.R.I., No. 22,103 (25X); 8a = side view; 8b = apertural view.	322
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12a-b. 14a-b.	**Quinqueloculina seminula** (Linné) 12 = P.R.I., No. 22,092 (25X); 14 = P.R.I., No. 22,090 (25X); 12b = apertural view; rest are side views.	321
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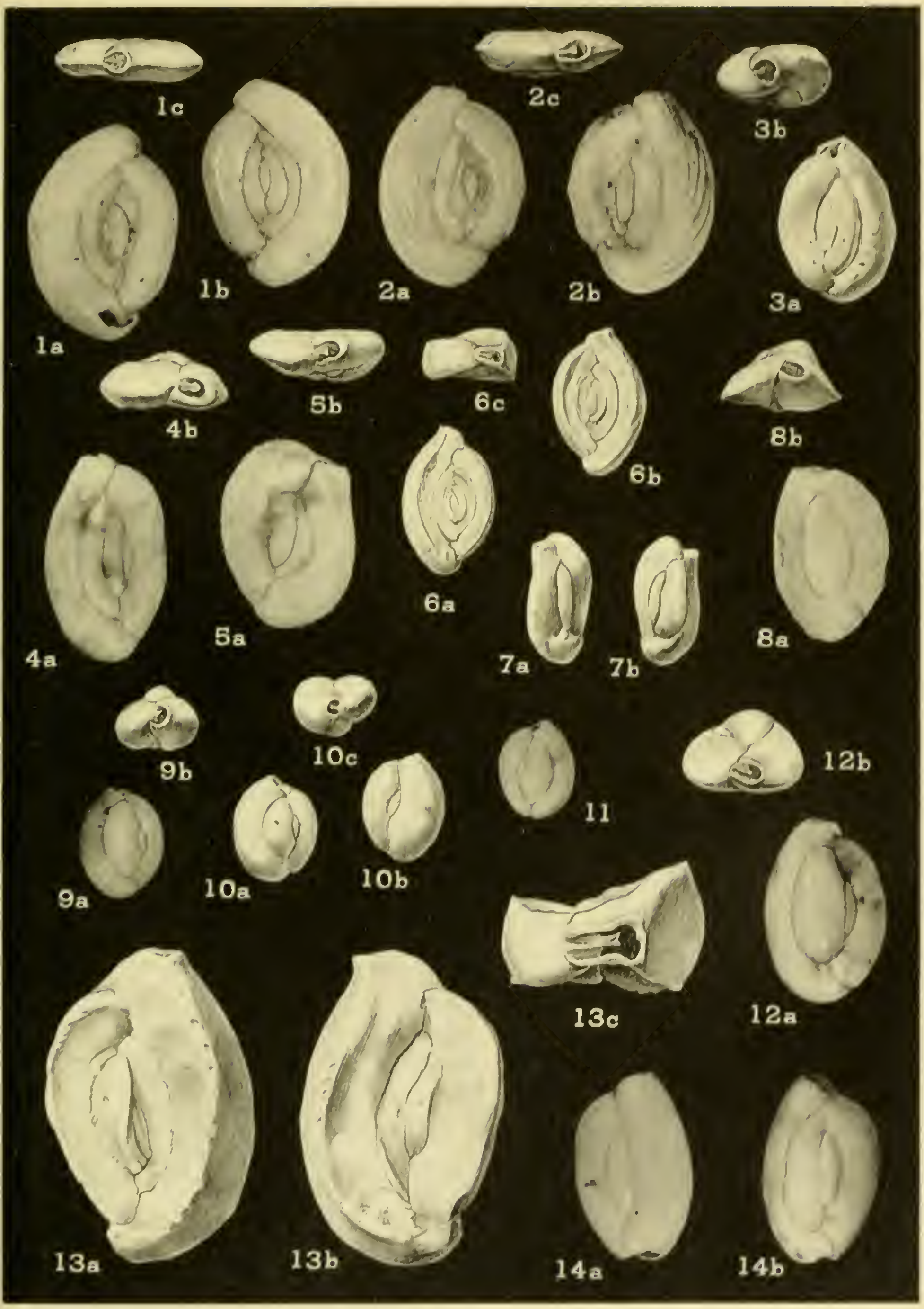
NOTE: The following figures are drawings; the rest are photographs; 1c, 2c, 3a, 3b, 4b, 5b, 6a, 6b, 6c, 7a, 7b, 8b, 9b, 10a, 10b, 10c, 12b, 13a, 13b, 13c.

Plate 37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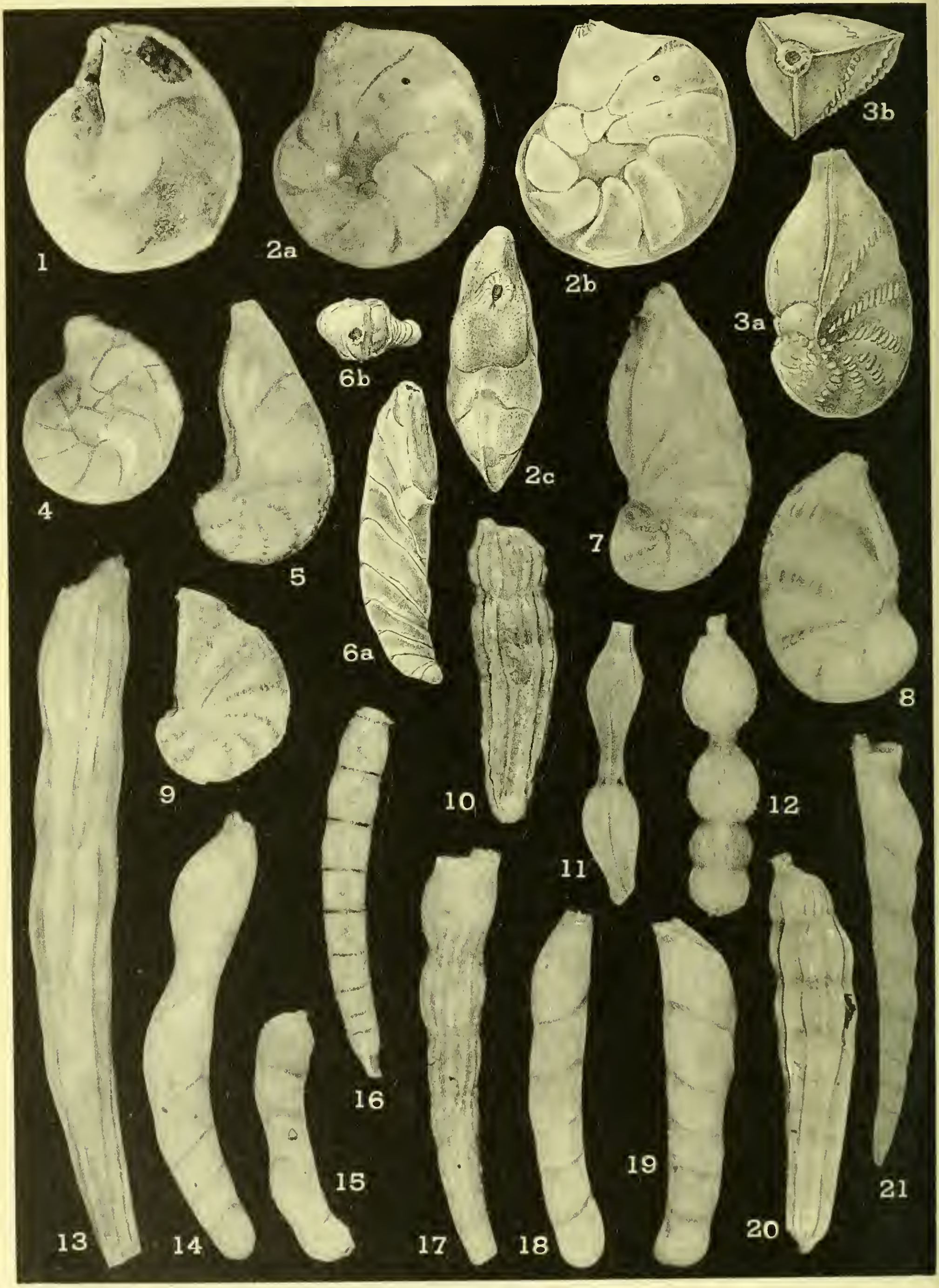
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Explanation of Plate 38

Figure		Page
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14, 15, 18, 19.	**Dentalina kaicherae** McLean, n. sp. 14 = paratype, P.R.I., No. 22,144; 15 = paratype, P.R.I., No. 22,145; 18 = holotype, P.R.I., No. 22,145; 19 = paratype, P.R.I., No. 22,146; specimens 15 and 18 on same slide; (all 43X).	328
16.	**Dentalina** cf. **intermedia** Hantken P.R.I., No. 22,143 (46X).	327
17.	**Dentalina** sp. B P.R.I., No. 22,149 (44X).	328
21.	**Dentalina** sp. C P.R.I., No. 22,150 (44X).	329

NOTE: The following figures are drawings; the rest are photographs; 2b, 2c, 3a, 3b, 6a, 6b.

Explanation of Plate 39

All figures approximately 64X.

Figure		Page
1-4.	**Nodosaria catesbyi** d'Orbigny P.R.I., No. 22,151.	329
5-6.	**Lagena palmerae** McLean, n. sp. 5 = holotype, P.R.I., No. 22,166; 6 = paratype, P.R.I., No. 22,165; 5a, 6b = apertural views; rest are side views.	332
7a-b.	**Lagena globulohispida** McLean, n. sp. Holotype, P.R.I., No. 22,161; 7a = side view; 7b = apertural view.	331
8a-b.	**Lagena dorseyae** McLean, n. sp. Holotype, P.R.I., No. 22,159; 8a = side view; 8b = apertural view.	330
9.	**Lagena (Entosolenia ?) carteri** forma **alpha** McLean n. forma Holotype, P.R.I., No. 22,158.	330
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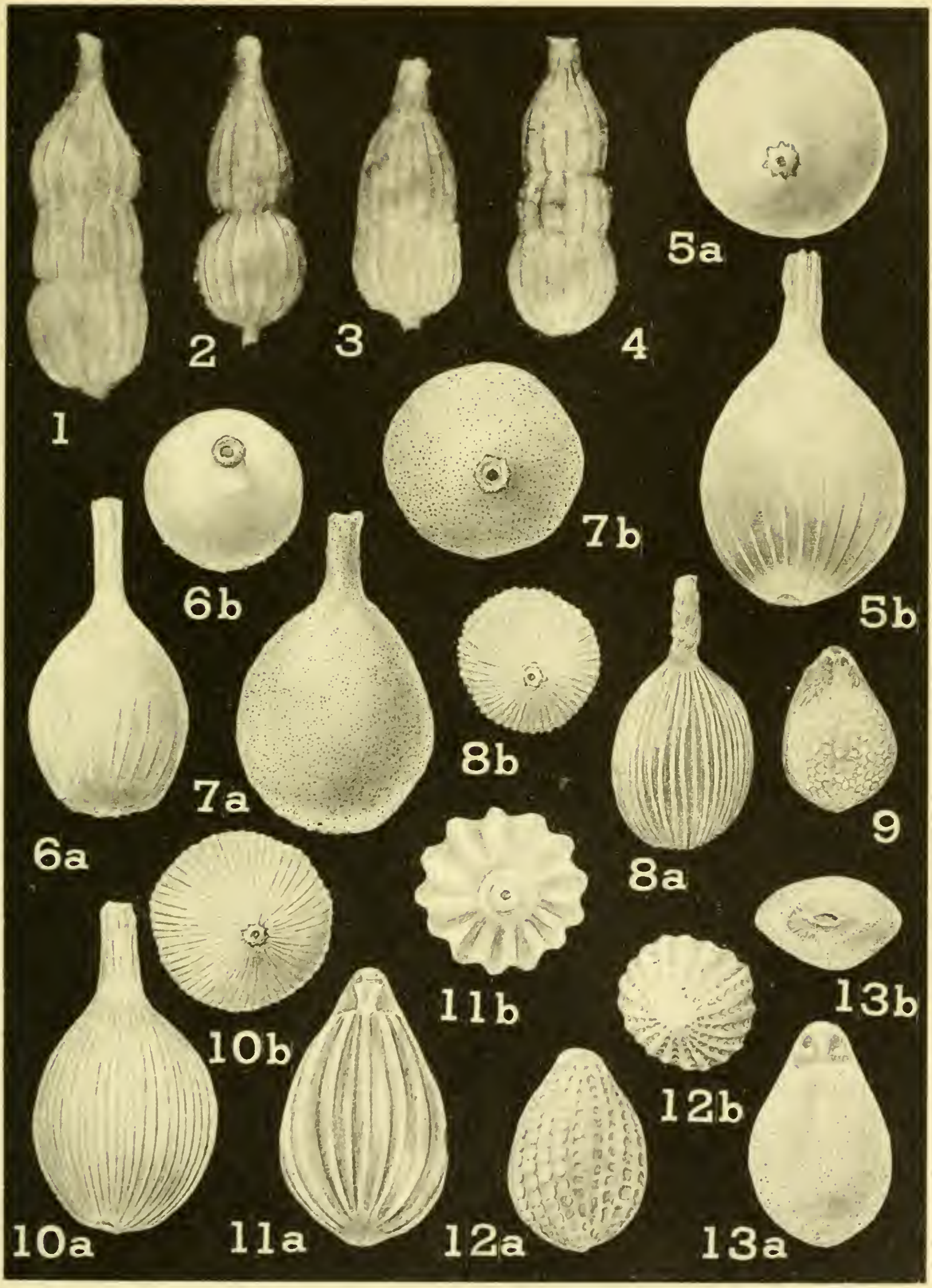
11a-b.	**Lagena pseudosulcata** McLean, n. sp. Holotype, P.R.I., No. 22,174; 11a = side view; 11b = apertural view.	332
12a-b.	**Lagena melo** (d'Orbigny) P.R.I., No. 22,164; 12a = side view; 12b = apertural view.	331
13a-b.	**Lagena (Entosolenia ?) carteri** McLean, n. sp. Holotype, P.R.I., No. 22,157; 13a = side view; 13b = apertural view.	330

NOTE: All figures except 1-4 are drawings; 1-4 are photographs.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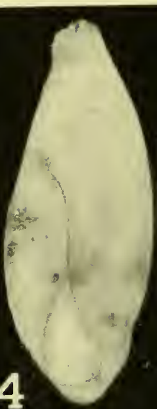
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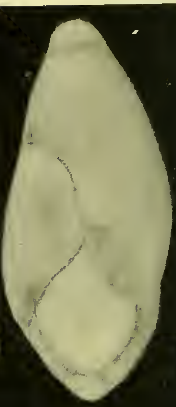
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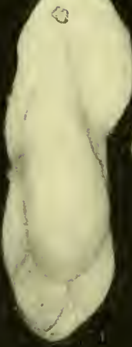
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Explanation of Plate 40

Figure		Page
1-3.	**Guttulina austriaca** d'Orbigny 1, 2 = P.R.I., No. 22,177 (55X); 3 = P.R.I., No. 22,180 (55X).	333
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8, 10-11.	**Guttulina pseudocostatula** McLean, n. sp. 8 = paratype, P.R.I., No. 22,190; 10 = paratype, P.R.I., No. 22,192; 11 = holotype, P.R.I., No. 22,193 (55X).	334
9.	**Guttulina** sp. A P.R.I., No. 22,197 (52X).	334
12.	**Guttulina** sp. B P.R.I., No. 22,198 (49X).	335
14.	**Pseudopolymorphina** cf. **novangliae** (Cushman) P.R.I., No. 22,199 (55X).	335

NOTE: Figure 2 is a drawing; others are all photographs.

Explanation of Plate 41

Figure		Page
1, 2.	**Pseudopolymorphina** sp. A 1 = P.R.I., No. 22,200; 2 = P.R.I., No. 22,201 (35X).	336
3-5, 11.	**Sigmomorphina nevifera** Clapp 3 = P.R.I., No. 22,226 (34X); 4 = P.R.I., No. 22,218 (37X); 5 = P.R.I., No. 22,222 (37X); 11 = P.R.I., No. 22,219 (35).	336
6-9, 16-17.	**Pseudopolymorphina rutila** (Cushman) 6, 7 = P.R.I., No. 22,209 (38X); 8 = P.R.I., No. 22,207 (33X); 9 = P.R.I., No. 22,208 (31X); 16 = P.R.I., No. 22,205 (39X); 17 = P.R.I., No. 22,204 (40X); 8b, 9b = apertural views; rest are side views.	335
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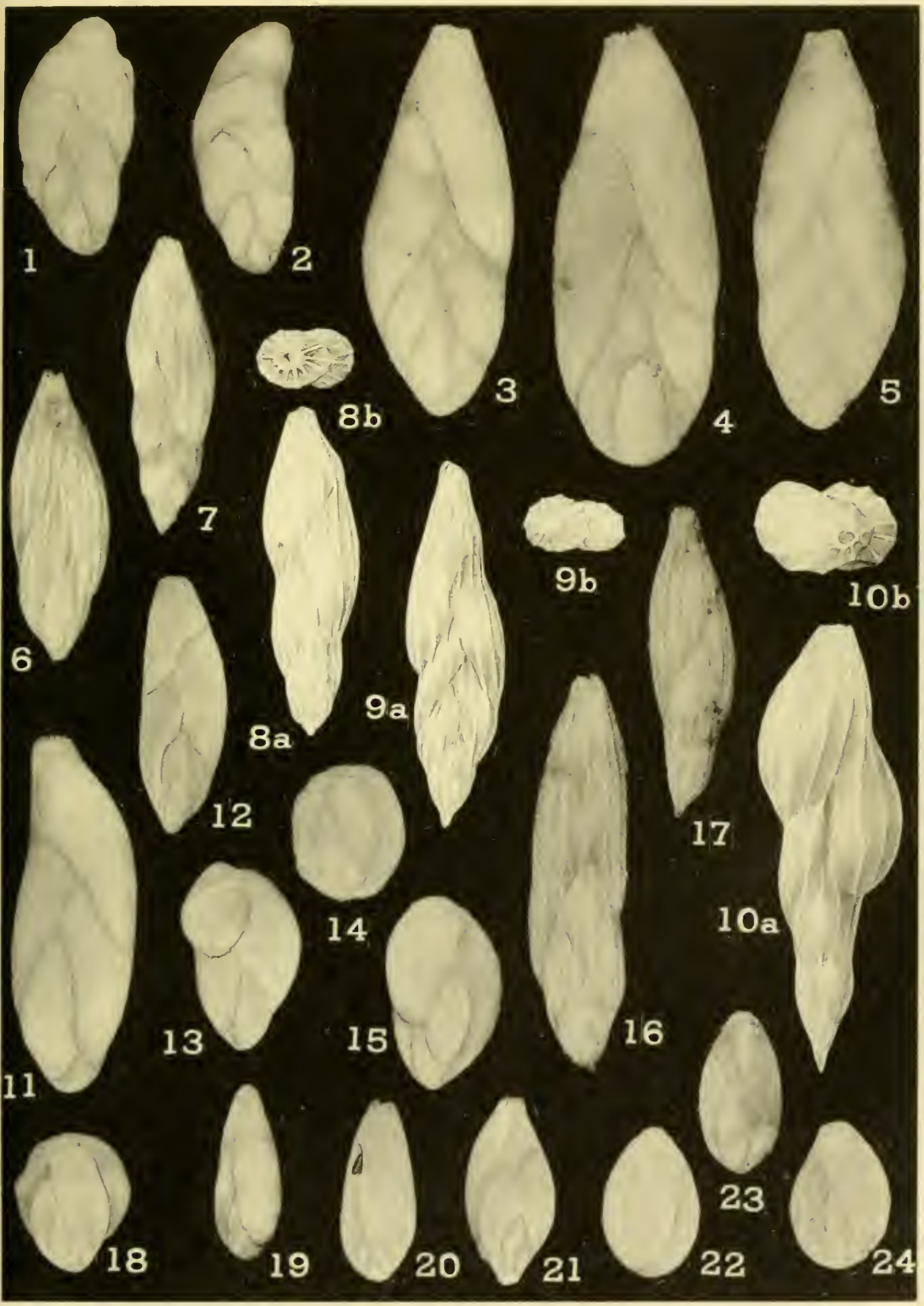
12, 19-24.	**Sigmomorphina semitecta** "var." **terquemiana** (Fornasini) 12 = P.R.I., No. 22,234 (38X); 19 = P.R.I., No. 22,231 (40X); 20, 21 = P.R.I., No. 22,233 (34X); 22, 23, 24 = P.R.I., No. 22,235 (37X).	337
13, 15.	**Sigmomorphina pearceyi** Cushman and Ozawa P.R.I., No. 22,228 (39X).	337
14, 18.	**Sigmomorphina concava** (Williamson) 14 = P.R.I., No. 22,217; 18 = P.R.I., No. 22,216; (33X).	336

NOTE: The following figures are drawings, the rest are photographs: 8a, 8b, 9a, 9b, 10a, 10b.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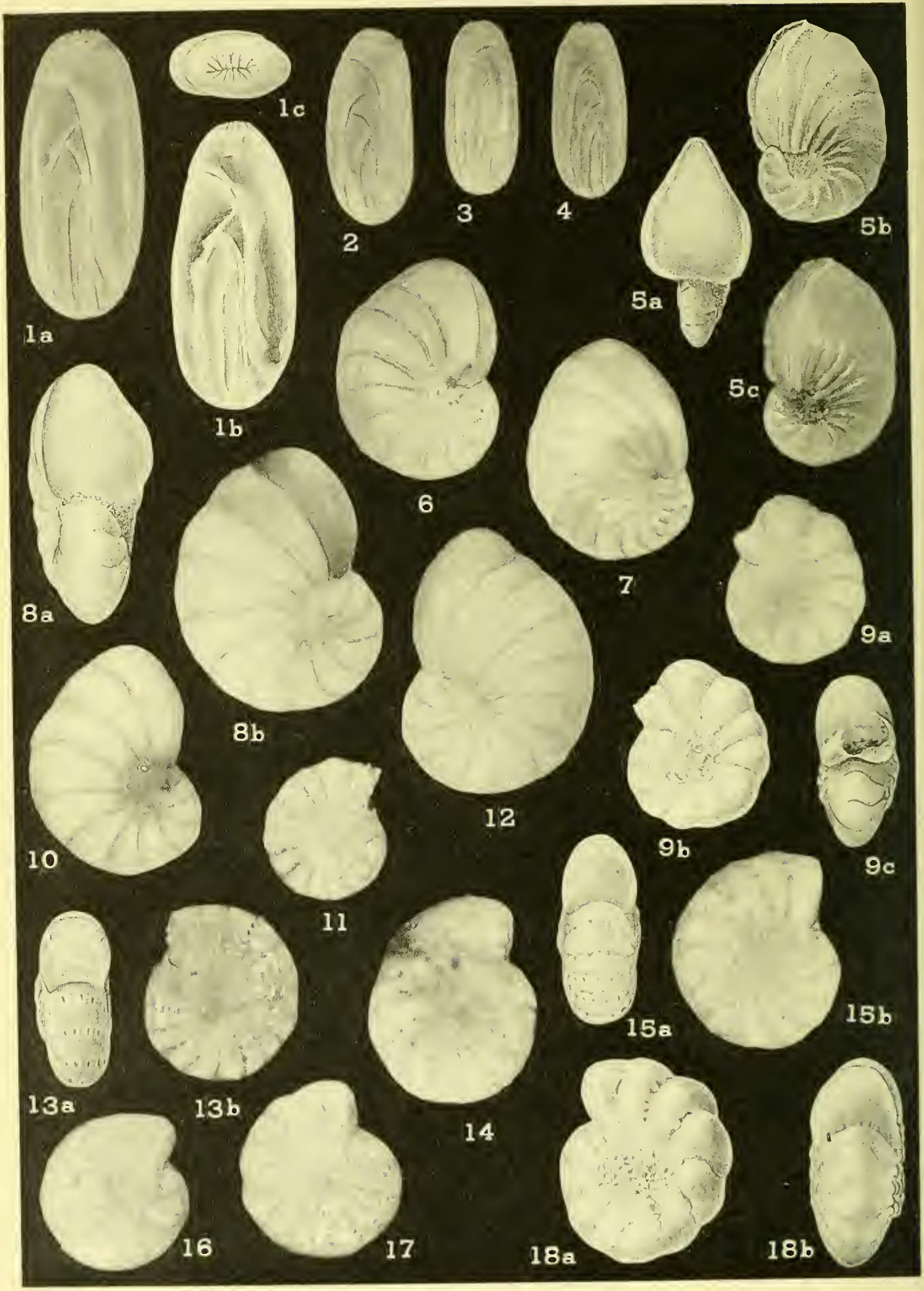
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Explanation of Plate 42

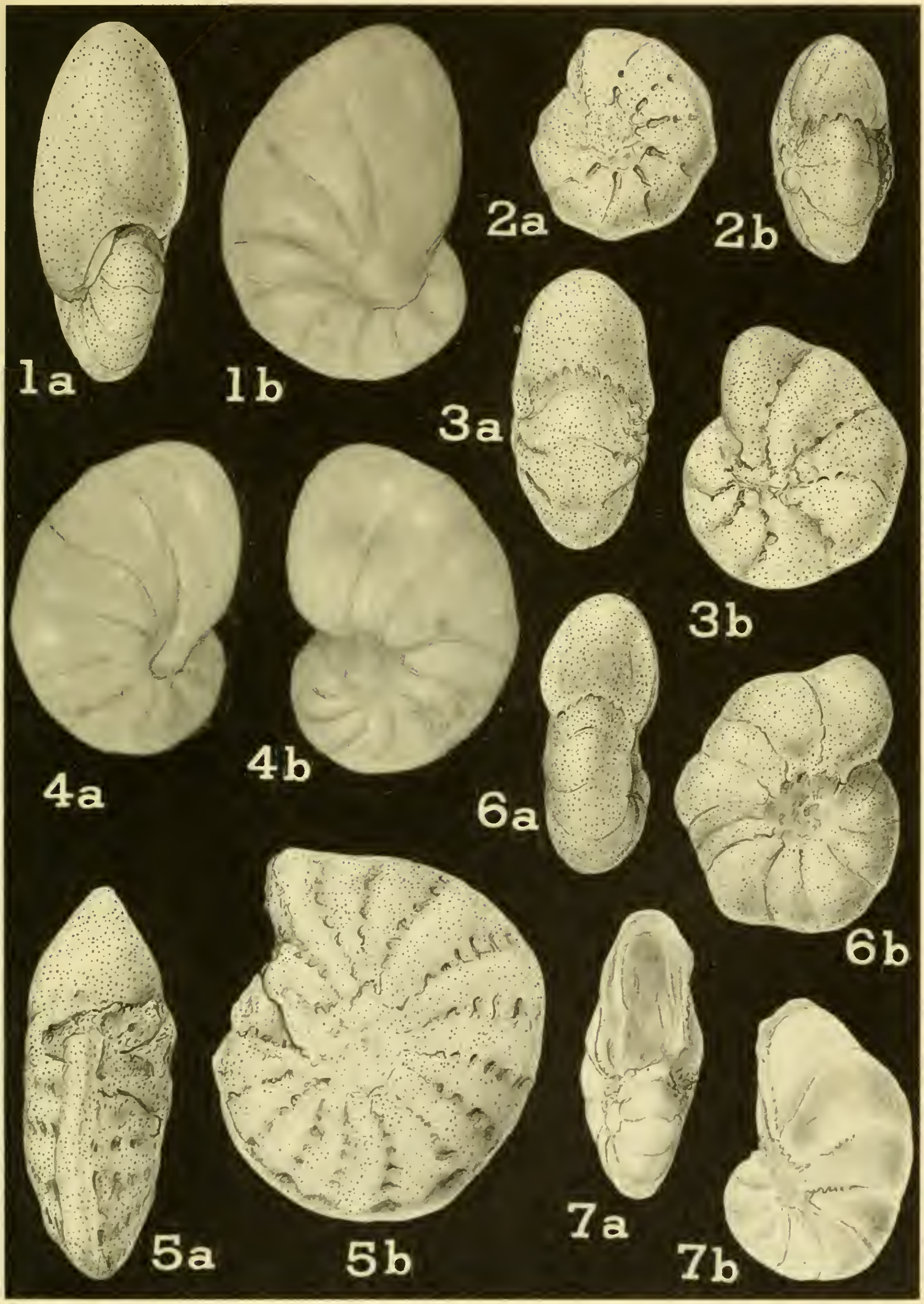
Figure		Page
1-4.	**Sigmomorphina williamsoni** (Terquem) .... 1a-c = P.R.I., No. 22,239 (44X); 2-4 = P.R.I., No. 22,240 (28X); 1c = apertural view, rest are sides.	338
5a-c, 7.	**Nonion mediocostatus** (Cushman) .... 5 = P.R.I., No. 22,242 (50X); 7 = P.R.I., No. 22,243 (48X); 5a = apertural view, rest are side views.	339
6, 8, 10, 12.	**Nonion pizarrensis** (Berry) .... 6 = P.R.I., No. 22,244 (44X); 8, 12 = P.R.I., No. 22,252 (41X); 10 = P.R.I., No. 22,261 (49X); 8a = apertural view, rest are side views.	340
9a-c, 18a-b.	**Elphidium johnstonae** McLean, n. sp. .... 9 = paratype, P.R.I., No. 22,276 (44X); 18 = holotype, P.R.I., No. 22,279 (45X); 9c, 18b = apertural views, rest are side views.	343
11, 13-17.	**Elphidium kaicherae** McLean, n. sp. .... 17 = holotype, P.R.I., No. 22,282 (44X); 11, 13, 16 = paratypes, P.R.I., No. 22,283 (44X); 14, 15 = paratypes, P.R.I., No. 22,284 (44X); 13a, 15a = apertural views, rest are side views.	343

NOTE: The following figures are drawings, all other figures on plate are photographs; 1b, 1c, 5a, 5b, 8a, 9b, 9c, 13a, 15a, 18a, 18b.

Explanation of Plate 43

Figure		Page
1a-b, 4a-b.	**Nonionella auris** (d'Orbigny) 1 = P.R.I., No. 22,268; 4 = P.R.I., No. 22,266; 1a = apertural view; 1b, 4a = ventral views; 4b = dorsal view; (90X).	341
2a-b, 3a-b.	**Elphidium incertum** (Williamson) 2= P.R.I., No. 22,274 (86X); 3 = P.R.I., No. 22,271 (103X); 2a, 3b = side views; 2b, 3a = apertural views.	342
5a-b.	**Elphidium advena** (Cushman) P.R.I., No. 22,269 (90X); 5a = apertural view; 5b = side view.	341
6a-b.	**Nonion?** sp. B P.R.I., No. 22,264 (91X); 6a = apertural view; 6b = side view.	341
7a-b.	**Nonion** cf. **grateloupi** (d'Orbigny) P.R.I., No. 22,241 (89X); 7a = apertural view; 7b = side view.	340

NOTE: All figures are drawings except 1b, 4a, 4b, which are photographs.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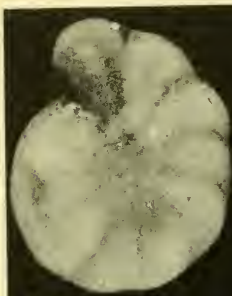
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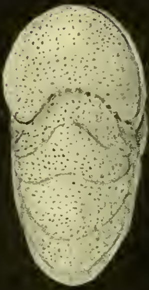
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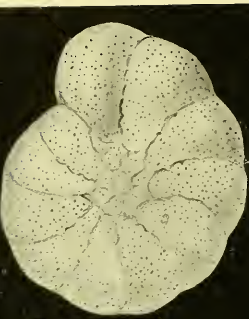
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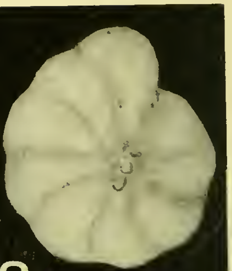
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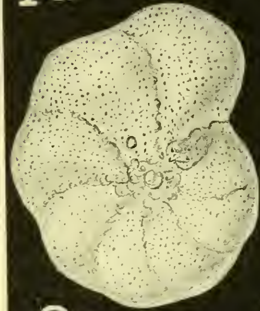
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Explanation of Plate 44

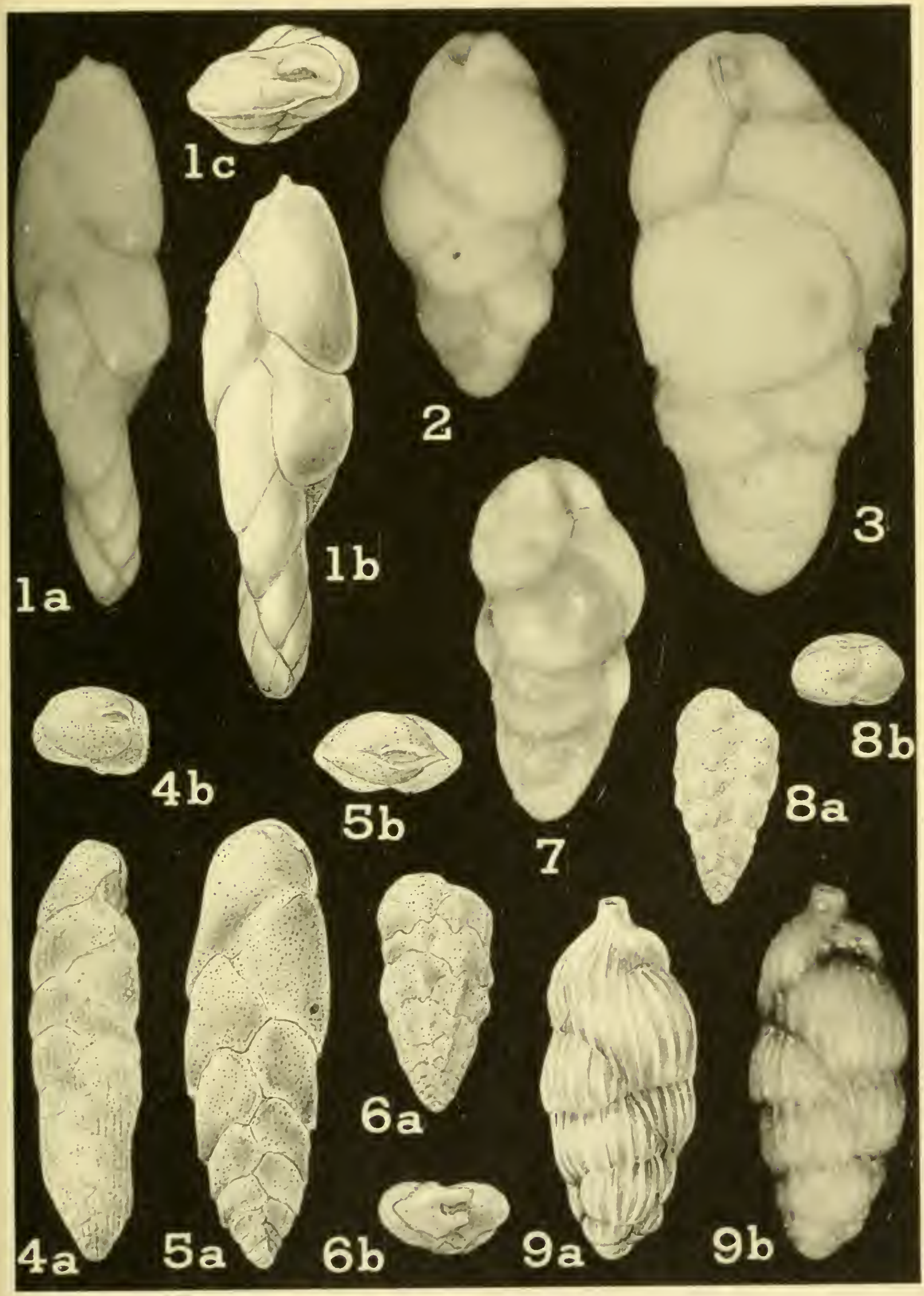
Figure		Page
1-2.	**Nonion** ? sp. A P.R.I., No. 22,263 (90X); 1b = apertural view, rest are side views.	341
3-5, 7.	**Elphidium johnstonae** McLean, n. sp. 3—paratype, P.R.I., No. 22,275 (110X); 4-5, 7—paratypes, P.R.I., No. 22,280 (100X); 3b apertural view, rest are side views.	343
6, 8-10.	**Bulimina gracilis** Cushman 6, 8 = P.R.I., No. 22,287 (53X); 9 = P.R.I., No. 22,286; 10 = P.R.I., No. 22,290.	344
11a-b.	**Bulminella** cf. **elegantissima** (d'Orbigny) P.R.I., No. 22,285; 11a = side view (95X); 11b = apertural view (much enlarged) (190X).	344
12a-b.	**Virgulina punctata** d'Orbigny (Juv. form) P.R.I., No. 22,296 (Specimen was lost after it was figured) (90X); 12a = side view; 12b = apertural view.	346

NOTE: The following figures are drawings, the rest are photographs: 1b, 1c, 3a, 3b, 11a, 11b, 12a, 12b.

Explanation of Plate 45

Figure		Page
1a-c.	**Virgulina punctata** d'Orbigny P.R.I., No. 22,295 (90X); 1a-b = side views; 1c = apertural view.	346
2, 3, 7.	**Bulimina preacanthia** McLean, n. sp. 2 = paratype, P.R.I., No. 22,294; 3 = holotype, P.R.I., No. 22,293; 7 = paratype, P.R.I., No. 22,292; (92X).	345
5a-b.	**Loxostomum wilsoni** McLean, n. sp. Holotype, P.R.I., No. 22,301; 5a = side view; 5b = apertural view; (95X).	348
4a-b.	**Bolivina striatula** Cushman P.R.I., No. 22,299 (91X); 4a = side view; 4b = apertural view.	347
6a-b, 8a-b.	**Bolivina lafayettei** McLean, n. sp. 6 = holotype, P.R.I., No. 22,298; 8 = paratype, P.R.I., No. 22,297; 6a, 8a = side views; 6b, 8b = apertural views; (85X).	346
9a-b.	**Uvigerina** cf. **tenuistriata** Cushman P.R.I., No. 22,307; (93X).	349

NOTE: The following figures are photographs, the rest are drawings: 1a, 2, 3, 7, 9b.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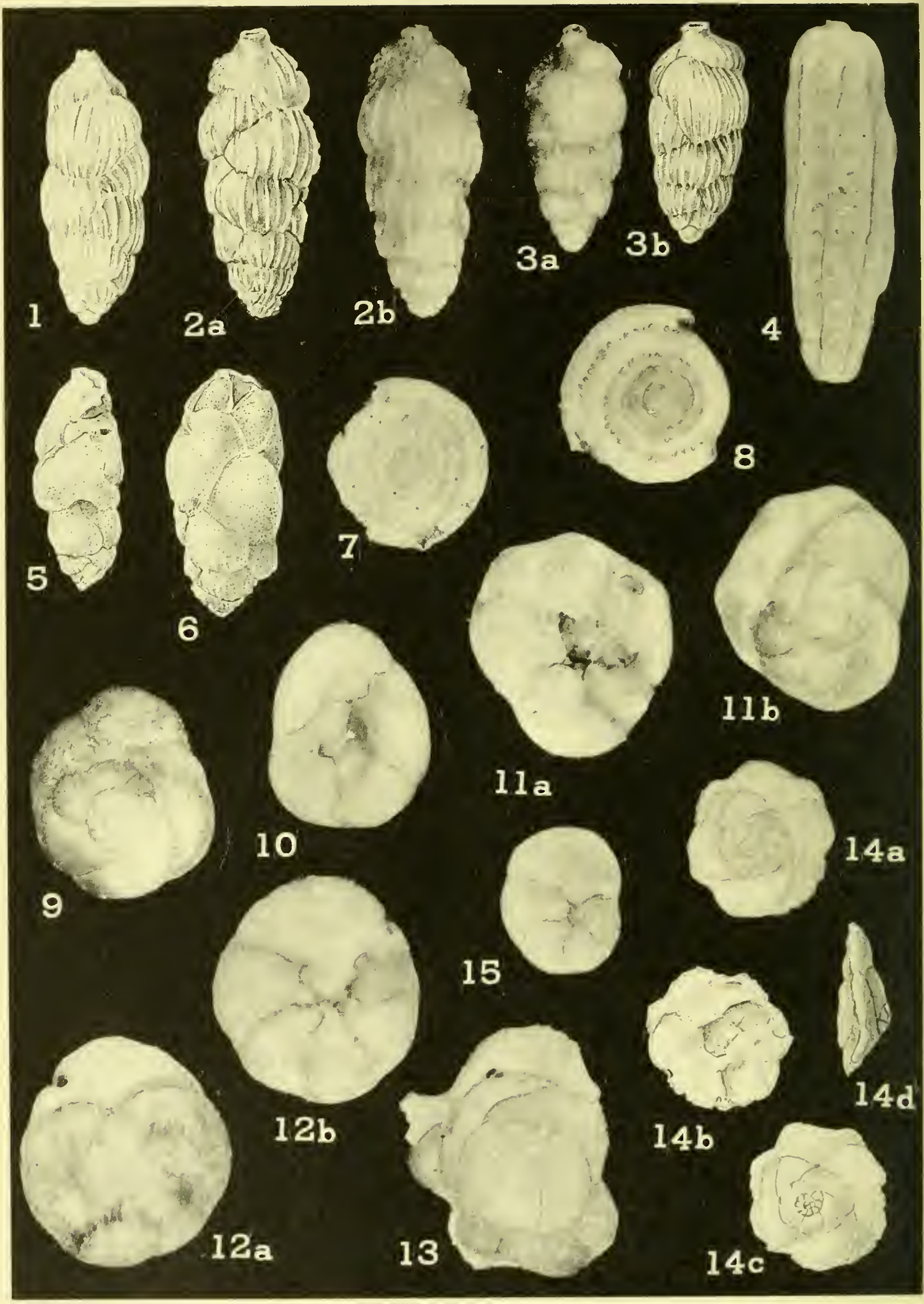
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Explanation of Plate 46

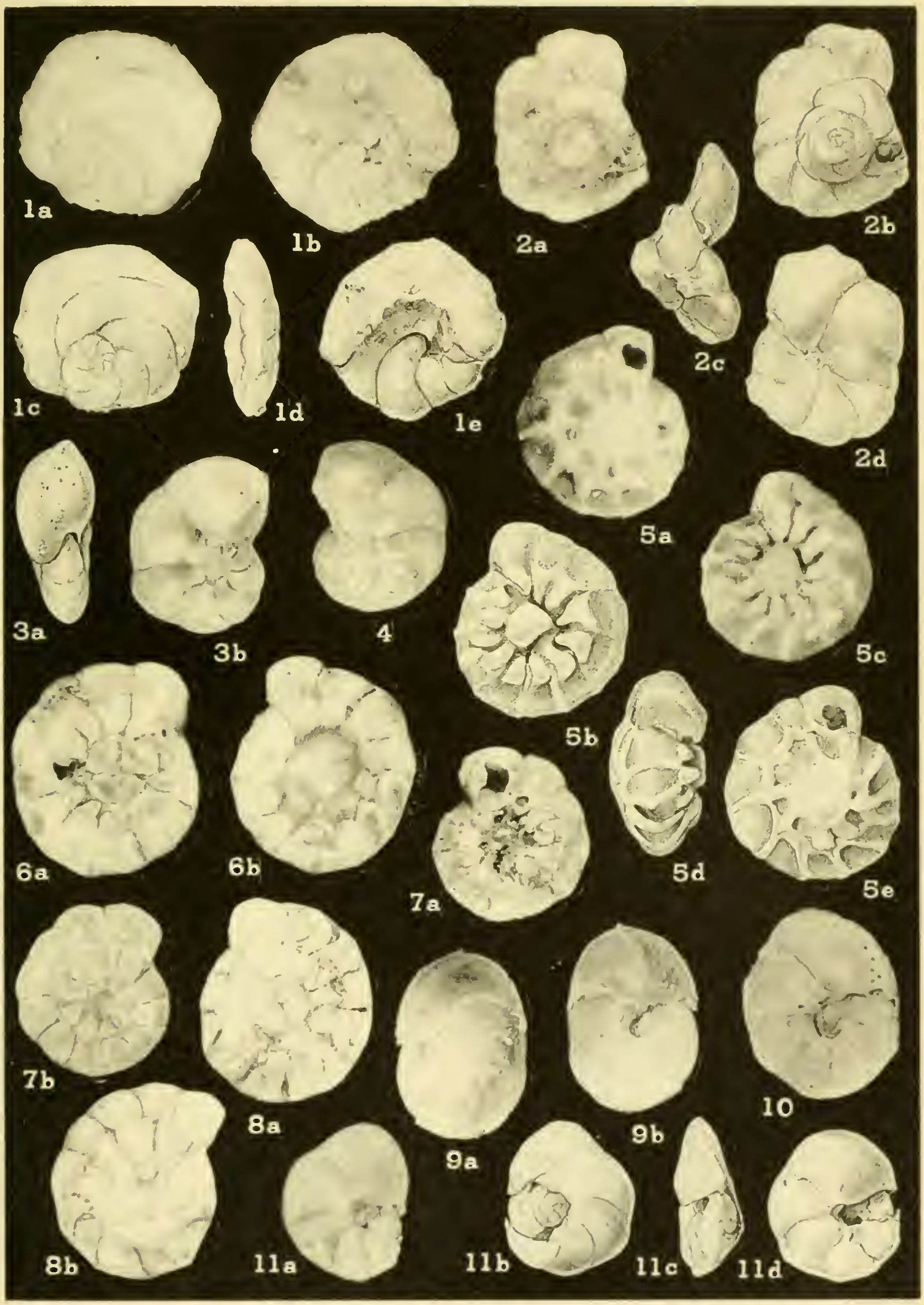
Figures		Page
1.	**Uvigerina** cf. **carmeloensis** Cushman and Kleinpell P.R.I., No. 22,306 (63X).	349
2a-b.	**Uvigerina calvertensis** Cushman P.R.I., No. 22,304 (62X).	348
3a-b.	**Uvigerina** cf. **tenuistriata** Cushman P.R.I., No. 22,308 (62X).	349
4.	**Siphogenerina lamellata** Cushman P.R.I., No. 22,309 (36X).	349
5.	**Angulogerina occidentalis** (Cushman) P.R.I., No. 22,310 (62X).	350
6.	**Angulogerina** sp. P.R.I., No. 22,311 (63X).	351
7-8.	**Planispirillina orbicularis** (Bagg) 7 = P.R.I., No. 22,312; 8 = P.R.I., No. 22,313; (56X).	351
9-10, 11-12, 15.	**Discorbis floridana** Cushman 9-10 = P.R.I., No. 22,320 (56X); 11a-b = P.R.I., No. 22,314 (56X); 12a-b = P.R.I., No. 22,321 (56X); 15 = P.R.I., No. 22,316 (59X); 9, 11b, 12a = dorsal views; 10, 11a, 12b, 15 = ventral views.	351
13, 14a-d.	**Discorbis rehderi** McLean, n. sp. 14 = holotype, P.R.I., No. 22,325 (32X); 13 = paratype, P.R.I., No. 22,329 (60X); 13, 14a, 14c = dorsal views; 14b = ventral view; 14d = side view.	353

NOTE: The following figures are drawings, the rest are photographs: 1, 2a, 3b, 5, 6, 14b, 14c, 14d.

Explanation of Plate 47

Figure		Page
1a-e.	**Discorbis** (?) sp. P.R.I., No. 22,311 (24X); 1a, 1c = dorsal views; 1b, 1e = ventral views; 1d = side view.	352
2a-d.	**Discorbis turrita** Cushman P.R.I., No. 22,332 (43X) 2a, 2b = dorsal views; 2c = side view; 2d = ventral view.	353
3-4.	**Valvulineria washingtoni** McLean, n. sp. Figs. 3a-b, P.R.I., No. 22,335, holotype; fig. 4, paratype, P.R.I., No. 22,336 (45X); 3a = side view; 3b = dorsal view; 4 = ventral view.	354
5-8.	**Rotalia limbatobeccarii** McLean, n. sp. Figs. 5a-e, syntype P.R.I., No. 22,368; figs. 6a-b, syntype P.R.I., No. 22,366; figs. 7a-b, syntype P.R.I., No. 22,369; figs. 8a-b, syntype P.R.I., No. 22,366 (all 43X); 5a, 5b, 6b, 7b, 8b = dorsal views; 5b, 5c, 6a, 7a, 8a = ventral views; 5d = side view. These four syntypes are figured to show the variations that this species is subject to.	357
9-11.	**Poroeponides lateralis** (Terquem) Figs. 9a-b, P.R.I., No. 22,374; figs. 10, P.R.I., No. 22,374; (30X) figs. 11a-e, P.R.I., No. 22,380 (26X); 9a, 11b = dorsal views; 9b, 10, 11a, 11d = ventral views; 11c = side view.	358

NOTE: The following figures are drawings, all other figures are photographs: 1c, 1d, 1e, 2b, 2c, 2d, 3a, 5b, 5d, 5e, 11b, 11c, 11d.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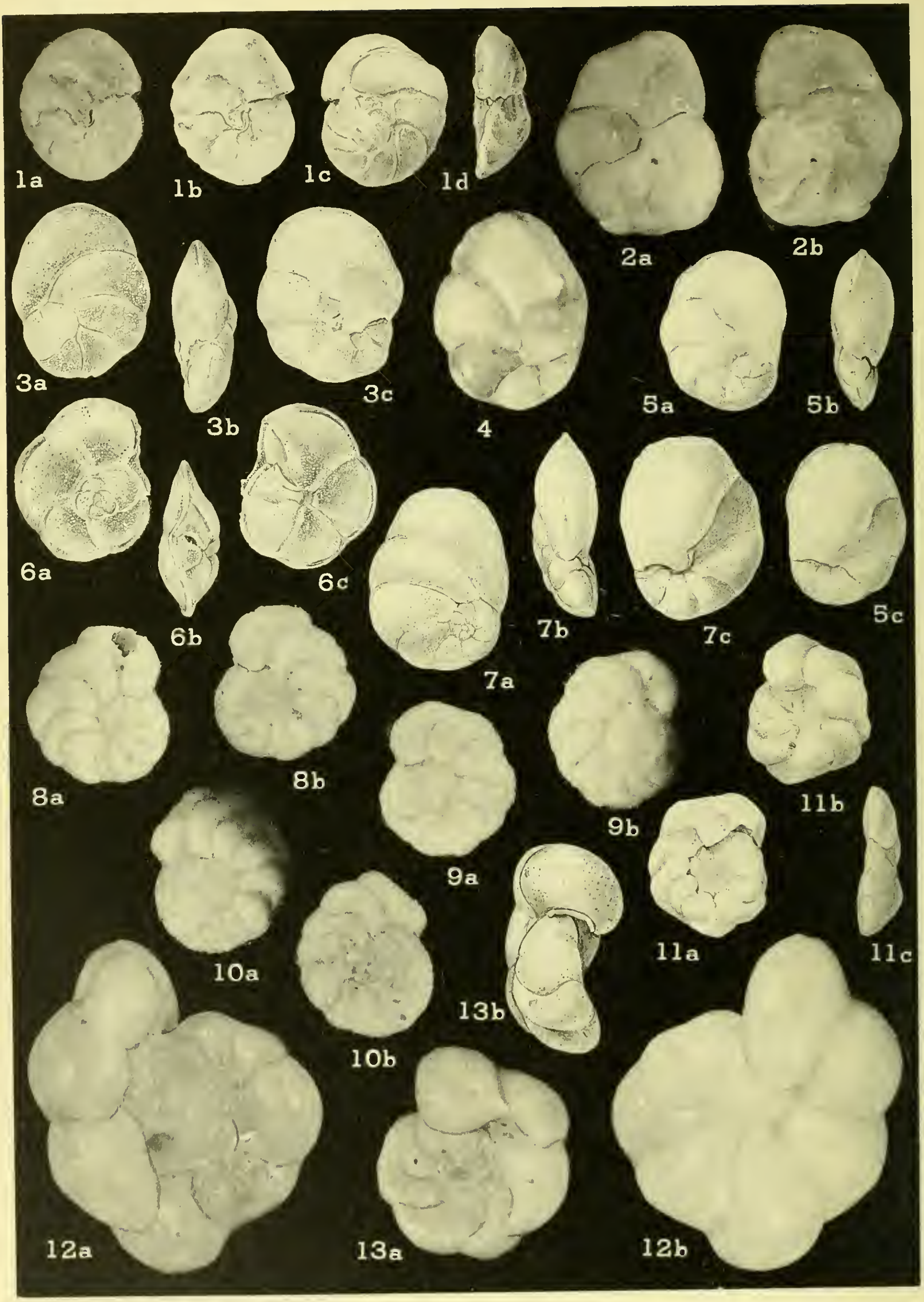
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Explanation of Plate 48

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1, 2. **Poroeponides lateralis** (Terquem) 358
Fig. 1, P.R.I., No. 22,372 (23X); fig. 2, P.R.I., No. 22,385 (25X); 1a, 1b, 2a = ventral views; 1c, 2b = dorsal views; 1d = side view.

3-5, 7. **Cancris sagra** (d'Orbigny) 359
Fig. 3, P.R.I., No. 22,394; fig. 4, P.R.I., No. 22,392; fig. 5, P.R.I., No. 22,395; fig. 7, P.R.I., No. 22,393 (all 44X); 3a, 5a, 7a = dorsal views; 4, 3c, 5c, 7c = ventral views; 3b, 5b, 7b = side views.

6a-b. **Globorotalia** sp. 365
P.R.I., No. 22,413 (46X); 6a = dorsal view; 6b = side view; 6c = ventral view.

8-11. **Planulina depressa** (d'Orbigny) 366
Figs. 8-10, P.R.I., No. 22,416; fig. 11, P.R.I., No. 22,420 (all 25X) 8b, 9a, 10b, 11a = dorsal views; 8a, 9b, 10a, 11b = ventral views; 11c = side view.

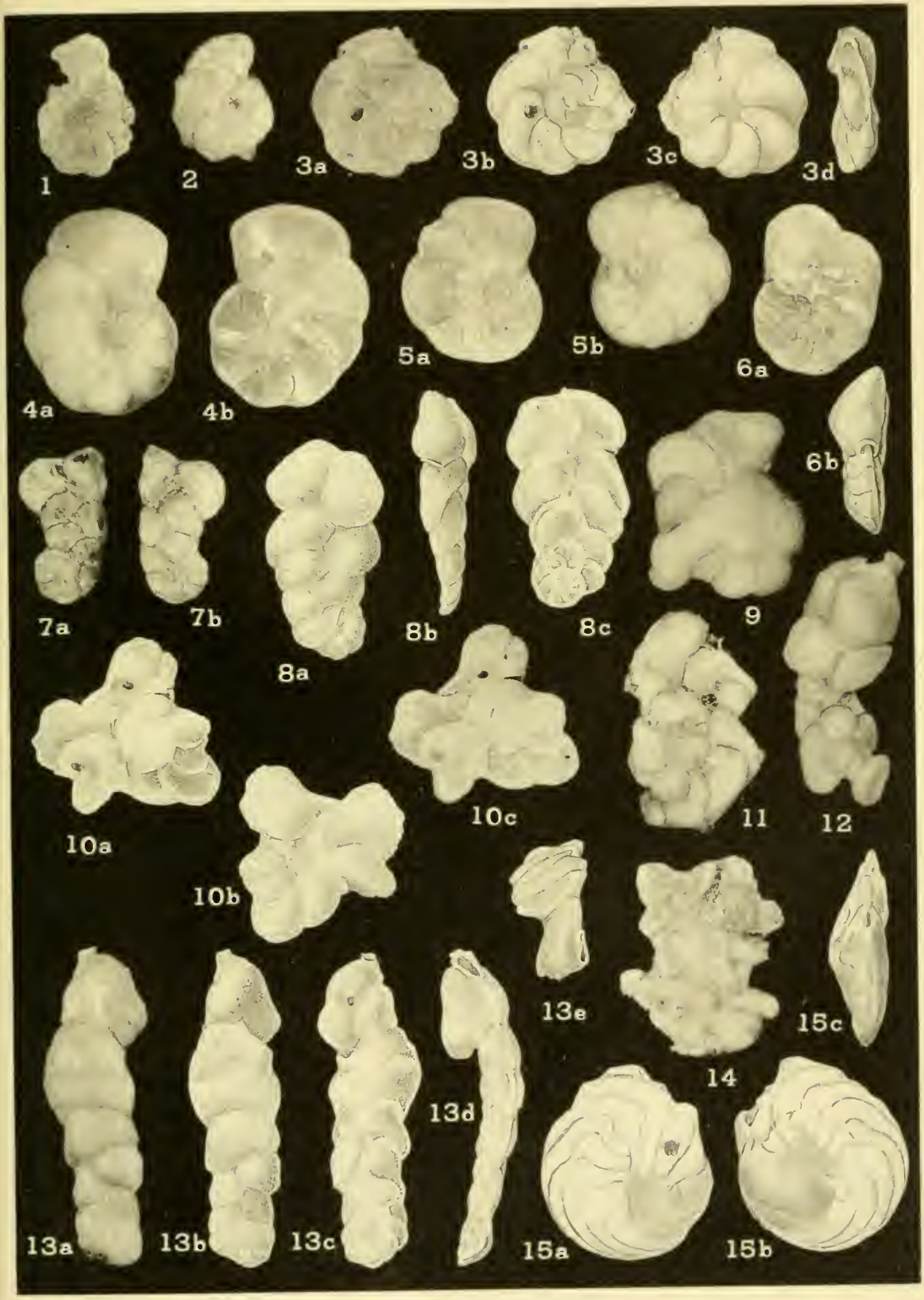
12, 13. **Cibicides** cf. **lobatulus** 366
Figs. 12a-b, P.R.I., No. 22,424 (46X); Figs. 13a-b, P.R.I., No. 22,428 (43X); 12a, 13a = dorsal views; 12b = ventral view; 13b = side view.

NOTE: The following figures are drawings, all other figures are photographs: 1b, 1c, 1d, 3a, 3b, 3c, 5a, 5b, 5c, 6a, 6b, 6c, 7a, 7b, 7c, 11a, 11b, 11c, 13b.

Explanation of Plate 49

Figure		Page
1-3.	**Cibicides sublobus** (Cushman) Figs. 1 and 2, P.R.I., No. 22,433; figs. 3a-d, P.R.I., No. 22,239 (all 25X); figs. 1, 3a, 3b = dorsal views; figs. 2, 3c = ventral views; fig. 3d = side view.	367
4-6.	**Hanzawaia concentrica** (Cushman) Figs. 4 and 5, P.R.I., No. 22,456; fig. 6, P.R.I., No. 22,443 (24X); figs. 4b, 5a, 6a = dorsal views; figs. 4a, 5b = ventral views; fig. 6b = side view.	367
7a-b.	**Dyocibicides biserialis** Cushman and Valentine P.R.I., No. 22,460 (28X); 7a = attached side; 7b = free side.	368
8a-c.	**Dyocibicides perforatus** Cushman and Valentine P.R.I., No. 22,464 (32X); 8a = free side; 8c = attached side; 8b = peripheral view.	368
9-11, 14.	**Cibicidella variabilis** (d'Orbigny) Figs. 9, 10, P.R.I., No. 22,469; (27X); figs. 11, 14, P.R.I., No. 22,474 (22X); 9, 10b, 11 = views of free sides; 10a, 10c, 14 = views of attached sides.	369
12, 13.	**Rectocibicidella robertsi** McLean, n. sp. Fig. 12, paratype P.R.I., No. 22,483; figs. 13a-e, holotype, P.R.I., No. 22,482 (all 45X); 12 = free side of paratype; 13a, 13b = free side of holotype; 13c = attached side of holotype; 13d = peripheral view of holotype; 13e = top (apertural) view of holotype.	370
15a-c.	**Amphistegina** sp. P.R.I., No. 22,484 (20X); 15a = dorsal view; 15b = ventral view; 15c = peripheral view.	360

NOTE: The following figures are drawings, all other figures are photographs: 3b, 3d, 6b, 8a, 8b, 8c, 10a, 10b, 13b, 13c. 13d, 13e, 15a, 15b, 15c.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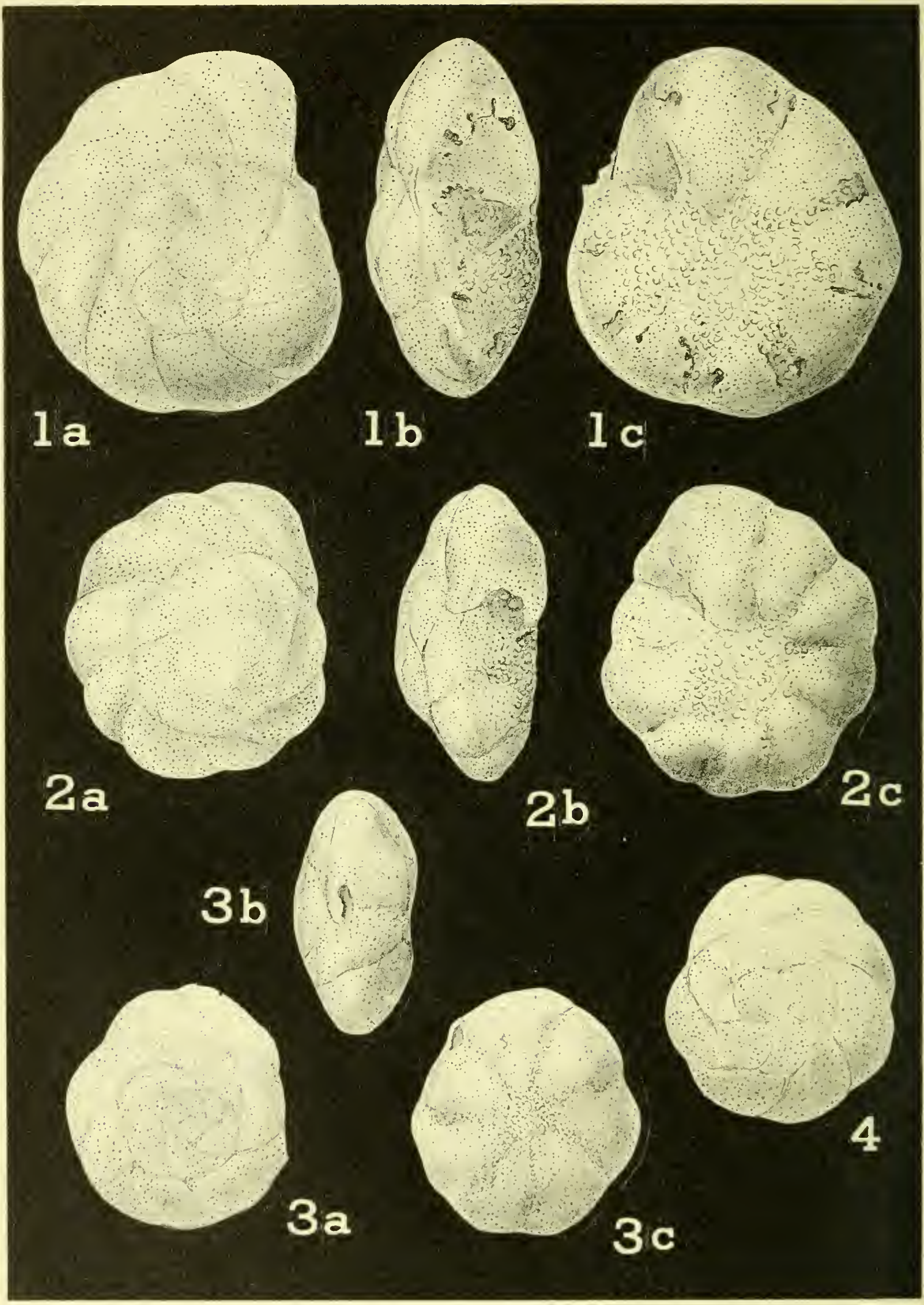
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Explanation of Plate 50

All figures on this plate are magnified 94X.

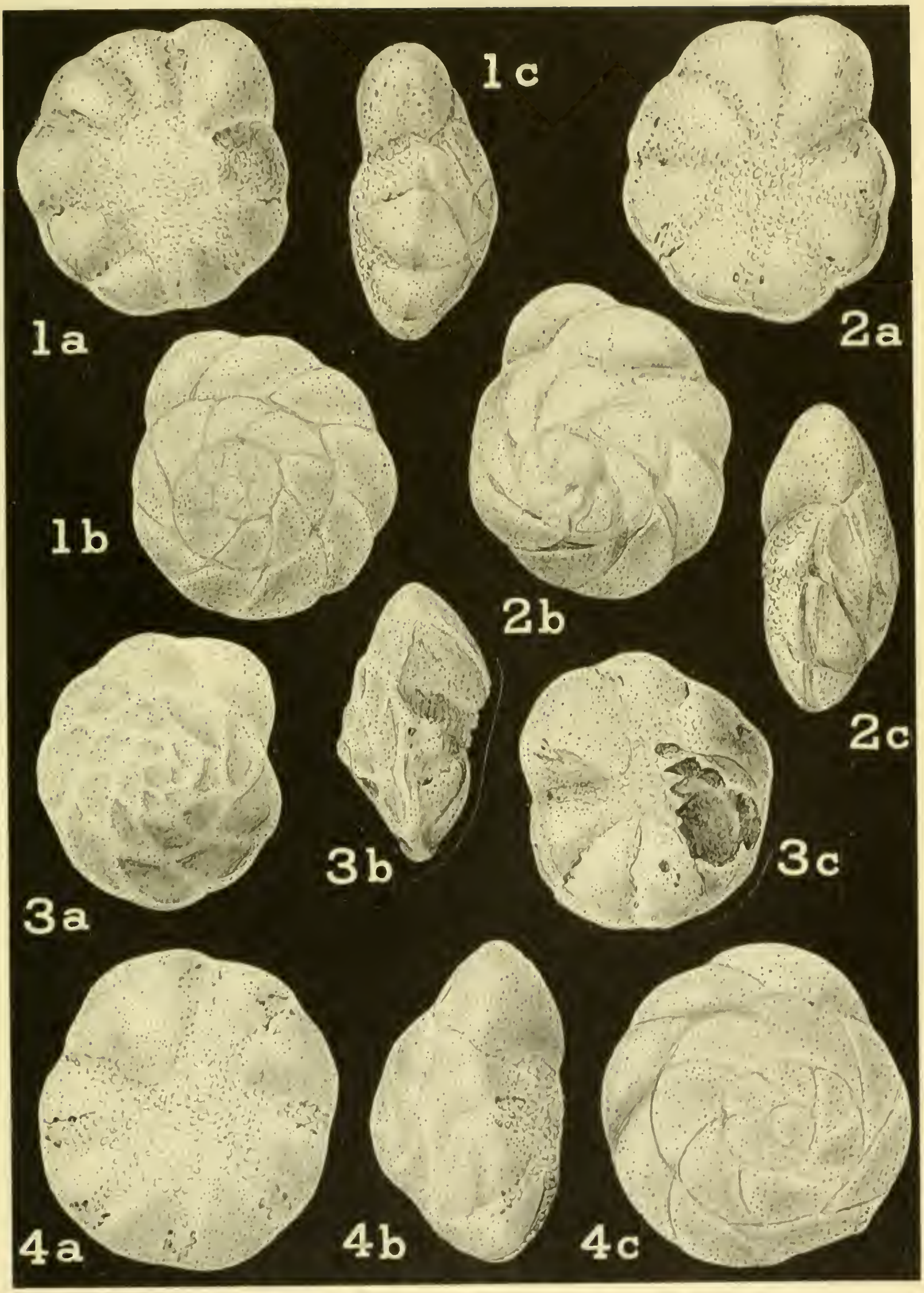
Figure		Page
1a-c.	**Buccella anderseni** McLean, n. sp. Paratype, P.R.I., No. 22,347; megalosphaeric A_2 form: a) dorsal view; b) edge view; c) ventral view.	354
2a-c.	**Buccella depressa** Andersen P.R.I., No. 22,350; microsphaeric form: a) dorsal view; b) edge view; c) ventral view.	355
3a-c.	**Buccella depressa** Andersen P.R.I.. No. 22,351; megalosphaeric A_1 form: a) dorsal view; b) edge view; c) ventral view.	355
4.	**Buccella depressa** Andersen P.R.I., No. 22,351; megalosphaeric A_2 form, dorsal view.	355

NOTE: All figures on plates 16 to 19 are drawings.

Explanation of Plate 51

All figures on this plate are magnified 94X.

Figure		Page
1a-c.	**Buccella anderseni** McLean, n. sp. Holotype, P.R.I., No. 22,343; microsphaeric form; a) ventral view; b) dorsal view; c) edge view.	354
2a-c.	**Buccella parkerae** Andersen P.R.I., No. 22,361; a) ventral view; b) dorsal view; c) edge view.	356
3a-c.	**Buccella hannai** (Phleger and Parker) P.R.I., No. 22,353; a) dorsal view; b) edge view; c) ventral view.	356
4a-c.	**Buccella anderseni** McLean, n. sp. Paratype, P.R.I., No. 22,339; megalosphaeric A_1 form; a) ventral view; b) edge view; c) dorsal view.	354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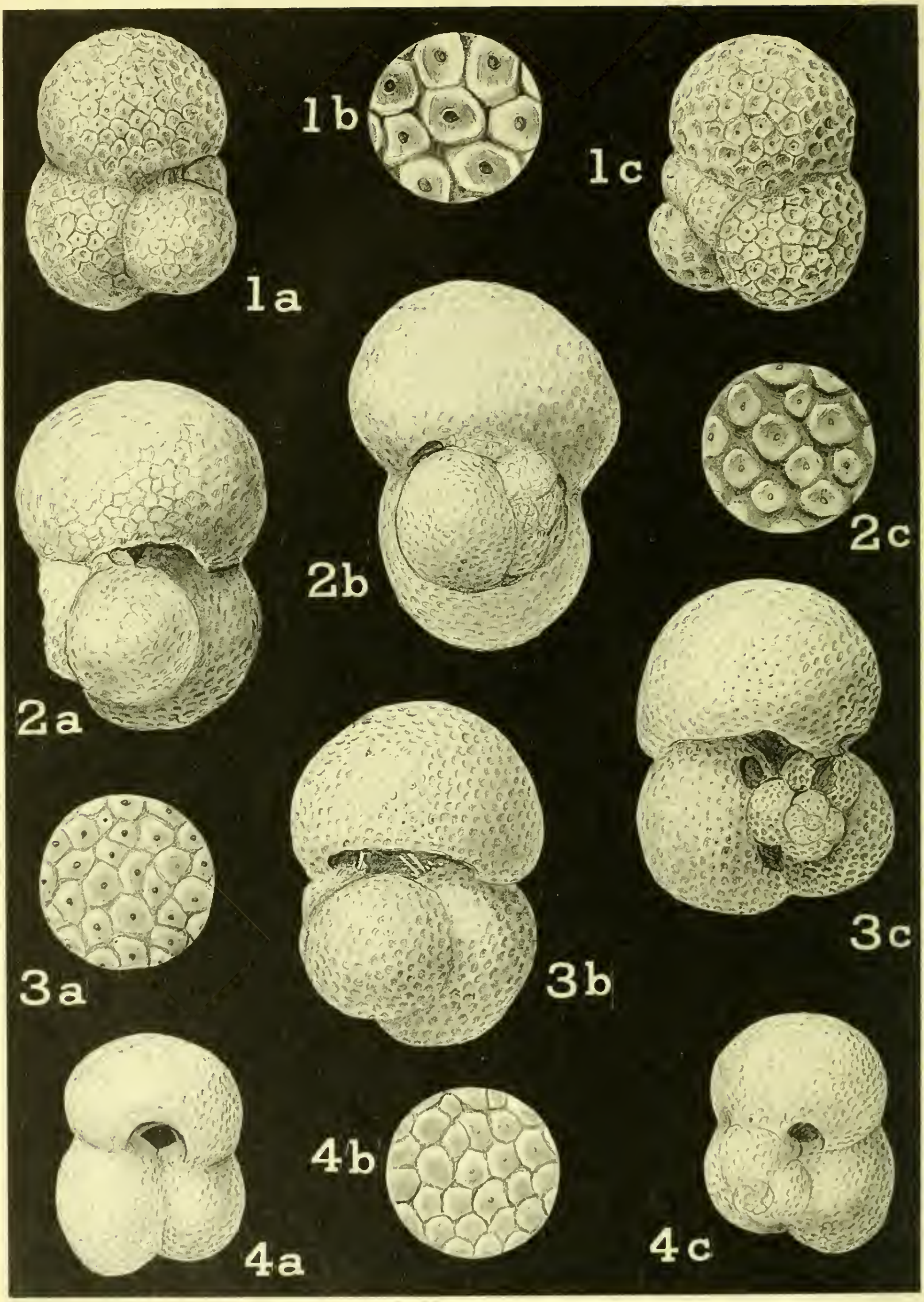
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Explanation of Plate 52

Figure		Page
1a-c.	**Globigerina** sp. form A P.R.I., No. 22.397; a) umbilical view 95X; b) detail on test wall 270X; c) spiral view 95X.	362
2a-c.	**Globigerina** sp. form B P.R.I., No. 22,402; a) umbilical view 95X; b) spiral view 95X; c) detail of test wall 270X.	363
3a-c.	**Globigerina** sp. form C P.R.I., No. 22,403; a) detail of test wall 270X; b) umbilical view 95X; c) spiral view 95X.	363
4a-c.	**Globigerina** sp. form D P.R.I., No. 22,404; a) umbilical view 95X; b) detail of test wall 270X; c) spiral view 95X.	364

Explanation of Plate 53

Figure		Page
1a-c.	**Globigerina** sp. form E P.R.I., No. 22,407; a) umbilical view 95X; b) detail of test wall 270X; c) spiral view 95X.	364
2a-c.	**Globigerinoides** sp. form G P.R.I., No. 22,410; a) umbilical view 95X; b) detail of test wall 270X; c) spiral view 95X.	365
3a-b.	**Orbulina cornwallisi** McLean, n. sp. Holotype, P.R.I., No. 22,412; a) general view 95X; b) detail of test wall showing pores 270X.	365
4a-c.	**Globigerinoides** (?) sp. form F P.R.I., No. 22,409; a) umbilical view 95X; b) detail of test wall 270X; c) spiral view 95X.	364


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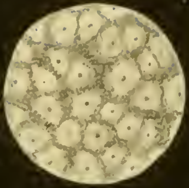
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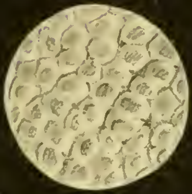
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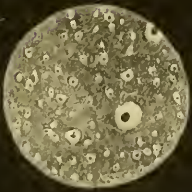
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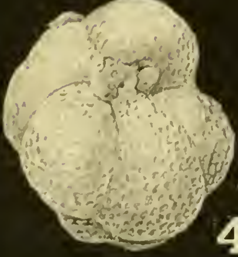
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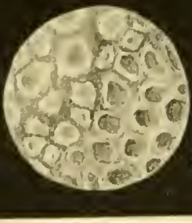
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