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NAMES OF AND VARIATION IN CERTAIN AMERICAN LARGER FORAMINIFERA, PARTICULARLY THE EOCENE PSEUDOPHRAGMINIDS - NO. 4

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W. Storrs Cole

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CONTENTS

NAMES OF AND VARIATION IN CERTAIN AMERICAN LARGER FORAMINIFERA, PARTICULARLY THE EOCENE PSEUDOPHRAGMINIDS – NO. 4

W. STORRS COLE*
Cornell University, Ithaca, New York

ABSTRACT

Eight species of American Paleocene and Eocene larger Foraminifera of the genus *Pseudophragmina*, family Discocyclinidae, are discussed and illustrated. Several of these species have been illustrated inadequately, and in consequence specimens from other localities were described as new species, many of which are considered to be synonyms. The associated foraminiferal and molluscan faunas, wherever possible, are analyzed to assist in defining the stratigraphic position of the species under consideration. The genus *Pseudophragmina* is subdivided into two subgenera, *Pseudophragmina s. s.* and *Athecocyclina*. The formerly recognized subgenus *Proporocyclina* is demonstrated to be a synonym of *Pseudophragmina s. s.*

INTRODUCTION

Vaughan (1945) discussed in detail and illustrated most of the known American Paleocene and Eocene species of larger Foraminifera of the family Discocyclinidae. Later, Cole (1958 *b;* 1959) reviewed selected species in an attempt to more adequately define and illustrate these particular species. This discourse, in which eight species of the genus *Pseudophragmina* are considered, is a long delayed continuation of the earlier studies.

Confusion in the recognition of species has resulted, in part, because the type description and illustrations of many species were substandard. The species *Discocyclina cloptoni* Vaughan (1929, p. 14, pl. 5, all figs.) may be cited as an example. Another problem is that many specific names were based upon the examination of too few specimens and thin sections so that variation between specimens was neither understood or recognized. Moreover, much of the earlier work on larger Foraminifera was based on the concept that these organisms were specialized and evolving rapidly, therefore species of necessity had to have a limited stratigraphic range.

Cole (1958 *b,* p. 420-423) presented data to demonstrate that species, such as *Pseudophragmina flintensis* (Cushman), not only had numerous synonyms, but also had a stratigraphic range from middle into the upper Eocene and a much wider geographic distribution than had been attributed it formerly. A study of that kind, however, was not possible without the examination of speci-

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*Professor emeritus, Department of Geological Sciences, Cornell University. Acknowledgment with thanks is made to the Department of Geological Sciences which supported this research and supplied the cost of the printed plates.

mens from a number of geographic and stratigraphic situations. Moreover, such studies must be based firmly on the work of others and a complete survey of the literature.

Recently much emphasis has been placed on zonation by planktonic Foraminifera. In the past, however, little attention has been given to the integration and correlation of the planktonic zones with faunas of larger Foraminifera. Studies of the kind undertaken by Bronnimann and Rigassi (1963, plate 1), in which zonation by planktonic Foraminifera and benthonic Foraminifera was contrasted, are essential before the stratigraphic relationships and geographic distribution of Foraminifera can be understood completely.

Although in many situations planktonic and larger Foraminifera are not encountered in the same sample, a number of occurrences are being reported so that tentative correlations can be suggested (Cole, 1967, p. 114). One difficulty which is encountered by one attempting such an integration is that authors do not report associations of larger and planktonic Foraminifera. Concentration is given only to one aspect of a composite fauna and associated elements are completely ignored. If more data were given even in a fragmentary manner, it should be possible to develop an integrated foraminiferal zonation rather than two distinct and separate zonations.

Concepts of the classification of Foraminifera have been evolving over many years as data accumulated. My viewpoint has changed markedly from rigid conformity and strict adherence to identification of species without regard to the fact that "The amount of variation in many species of orbitoids is bewildering" (Vaughan, 1933, p. 6) to an appreciation of the variation which does occur. Admittedly, any concept may be carried too far. Thus, postulates made in this article should be evaluated and accepted or rejected on the data presented.

LOCALITIES OF THE FIGURED SPECIMENS

CUBA

Loc. 1. At km. 74 on the railroad between Nuevitas and Pastelillo, Camaguey Province; Palmer sta. 1479 (Palmer, 1948, p. 86); upper Eocene.

2. Asphalt seep and quarry on Rancho Peñon, 7 kilometers

north of Martí (Hato Nuevo) and 850 meters northwest of the little settlement of Peñon, Matanzas Province (Cole and Gravell, 1952, p. 708); middle Eocene.

JAMAICA

3. About one mile northwest of Port Maria, St. Mary's Parish; E. Robinson, collector; middle Eocene (Cole and Applin, 1964, p. 28).

MEXICO

4. Arroyo Guadalupe, 50 miles N. 80° W. of La Paz, Baja California; type locality of *Discocyclina cloptoni* Vaughan (1929, p. 15); Tepetate Formation, middle Eocene.
5. About 2 miles south of Zaragosa, Nuevo Leon; type locality of *Discocyclina zaragosensis* Vaughan (1929, p. 14); lower Eocene Wilcox group (Vaughan, 1945, p. 100).
6. Twelve kms. west of Potrero del Llano, Vera Cruz; W. S. Cole, collector; Guayabal Formation, middle Eocene.

TRINIDAD

7. Kugler loc. K 3878, Soldado Rock; specimens supplied by H. G. Kugler. See: Vaughan and Cole, 1941, pl. 2, for exact location.

UNITED STATES

Alabama

8. ". . . foot of Salt Mountain, Clarke County, Alabama, out of a fresh rock cut at the Jackson fault, deposited in the U.S. National Museum. Collected by C. W. Cooke." (Vaughan, 1936, p. 257); Salt Mountain Limestone, lower Eocene.

California

9. Near base of silt member of the Las Llajas Formation about 800 feet north and 300 feet west of the southeast corner of sec. 30, T 3 N, R 17 W, Santa Susana Quadrangle (USGS 1951), Chivo Canyon, Ventura County; UCLA loc. 3832 (Cole, 1958 *b,* p. 412); Las Llajas Formation, Simi Valley, Penutian stage (Mallory, 1959, p. 275).

Florida

10. On the north bank of the Chipola River near the old wagon bridge east of Marianna, Jackson County; H. Gun-

ter and W. S. Cole, collectors; Ocala Limestone, upper Eocene.

11. St. Mary's River Oil Corporation Hilliard Turpentine Company well no. 1 (W-333) at a depth of 1745-1752 feet; well located in the NW corner of the NW ¼ of the SE ¼ of sec. 19, T 4 N, R 24 E, Nassau County (Cole, 1944, p. 18); Oldsmar Limestone, lower Eocene (Applin and Applin, 1944, p. 1745).

Louisiana

12. Near Provencal, Natchitoches Parish, USGS sta. 2914; T. W. Vaughan, collector; locality for syntypes of *Orthophragmina advena* Cushman (1921, p. 139); middle Eocene.
13. Victoria Mills, Natchitoches Parish; gift of the late Donald W. Gravell; middle Eocene.

SUBGENERA OF PSEUDOPHRAGMINA

In 1940 Vaughan and Cole (*in* Cushman, 1940, p. 329, 330) proposed that the genus *Pseudophragmina* H. Douvillé (1923, p. 106, the type of which is *Orthophragmina floridana* Cushman (1917, p. 116), should be subdivided into three subgenera, *Pseudophragmina* H. Douvillé, 1923, *Proporocyclina* Vaughan and Cole, 1940 (type: *Discocyclina perpusilla* Vaughan, 1929), and *Athecocyclina* Vaughan and Cole, 1940 (type: *Discocyclina cookei* Vaughan, 1936).

Although this subdivision was published in 1940, it was abstracted from a manuscript on larger Foraminifera on Trinidad which was published in 1941 as Special Paper 30 of the Geological Society of America.

At that time Vaughan and Cole (*in* Cushman, 1940, p. 329, 330; 1941, p. 57) considered that the annular stolons which interconnect adjacent equatorial chambers in an annulus were distally situated in the genus *Pseudophragmina*. The subgenera *Pseudophragmina* and *Athecocyclina* included species in which the radial chamber walls of the equatorial chambers were incomplete, whereas the subgenus *Proporocyclina* contained species in which the radial chamber walls were complete (Pl. 3, fig. 5).

Species assigned to the subgenus *Pseudophragmina s. s.* were assumed to have the distal part of the radial chamber walls ". . . degenerate in places represented by rows of granules" (Vaughan and Cole, 1941, p. 57) (Pl. 9, fig. 6). Species included in the subgenus *Athecocyclina* had radial chamber walls which were indistinct or not developed (Cole and Herrick, 1953, pl. 2, figs. 9-11; Vaughan, 1945, pl. 45, figs. 1-4; Sachs, 1957, pl. 17, figs. 7-10).

In 1945 Vaughan published an extensive review of American discocyclinids including a detailed discussion of the internal structure of these organisms and their classification. The classification which Vaughan (1945, p. 67) used was essentially that of Vaughan and Cole (*in* Cushman, 1940, pp. 327-330; 1941, pp. 55-57).

However, Vaughan (1945, p. 68) slightly revised the definition of the genus *Pseudophragmina* by the observation that ". . . the radial chamber walls in adjacent annuli are aligned. Some deviation from this arrangement because of the intercalation of additional chambers in distal annuli has already been noted but *the basic plan is strikingly constant"* (italics mine).

Moreover, Vaughan (1945, p. 68) wrote "The characterization of *Pseudophragmina* should be changed to read annular stolons not confined to the distal side of the chambers, but a distally situated stolon is usually present. Still another difference is that the equatorial layer in *Pseudophragmina* is thinner than in *Discocyclina.*"

This expanded definition of *Pseudophragmina* was accepted by Cole (*in* Cushman, 1948, p. 371) and incorporated in the final edition of Cushman's "Foraminifera: their classification and economic use".

Vaughan (1945, p. 68) recognized "The three subgenera of *Pseudophragmina* . . . intergrade as a series, although the type species are distinct enough." In addition he realized that certain species did not conform perfectly to the definitions which had been proposed for the subgenera of *Pseudophragmina*. Vaughan (1945, p. 68) wrote "There was indecision regarding the placing of four species-*Pseudophragmina advena, P. cloptoni, P. perkinsi* and *P. zaragosensis.* Structurally they are similar and should be placed in a group by themselves. I am referring them to the subgenus *Proporocyclina* after having placed them in *Athecocyclina*".

Cole (1958 *b*, pp. 413-417) analyzed the species of the subgenus *Proporocyclina* and suggested that the species assigned to this subgenus could be divided in three groups on the appearance of the equatorial chambers. On this basis he proposed three categories: Type I. — Species which have equatorial chambers with nearly straight radial chamber walls, and the chambers are radially elongate. This development is shown clearly in *Pseudophragmina flintensis* (Pl. 3, fig. 5; Pl. 7, figs. 3, 7; Cole, 1958 *b,* pl. 50, all figs.). Type II. — Species characterized by equatorial chambers with thin undulatory radial chamber walls, and the equatorial chambers are not radially elongate. *P. tobleri* (Pl. 5, fig. 1; Cole, 1959, pl. 32, figs. 9, 11) and *P. clarki* (Pl. 5, figs. 5, 6; Cole, 1958 *b,* pl. 52, fig. 10) were cited as examples. Type III. — Species which possessed narrow annuli throughout and more or less imperfect radial chamber walls. *P. advena* was given as an example (Pl. 8, figs. 1, 2; Pl. 3, fig. 4).

The attempt by Vaughan and Cole (*in* Cushman, 1940, p. 329, 330; 1941, p. 57) to subdivide the genus *Pseudophragmina* into three subgenera and by Vaughan (1945) to utilize this classification focused attention on certain imperfections. Thus, Vaughan (1945, p. 68) expanded the definition of the genus *Pseudophragmina* to include data which were not incorporated previously. Vaughan (1945, p. 68) clearly recognized and stated his indecision concerning the subgenus in which the species he (Vaughan, 1945, p. 97) assigned to the "Group of *Pseudophragmina advena* (Cushman)" should be placed.

Vaughan (1945, pp. 97, 98) wrote concerning *Pseudophragmina advena* and related species "Their annuli are much narrower than those of the subgenus *Pseudophragmina* . . . Because of this difference they can not be referred to the [subgenus] *Pseudophragmina.* The subgenus *Athecocyclina* has defective or no radial walls. Although the radial chamber walls in the group of species under consideration are incomplete between many chambers, they are better developed than in the subgenus *Athecocyclina.* In some species of the subgenus *Proporocyclina* the annuli are rather narrow *(P. tobleri),* and not infrequently the radial chamber walls are interrupted. *P. advena* and its allies are intermediate between *Proporocyclina* and *Athecocyclina* but seem closer to the former than to the latter and consequently are placed in that subgenus."

If the quotation is analyzed certain inconsistencies should be apparent at once. *P. advena* and its allies are excluded from the subgenus *Pseudophragmina* because these species have narrow annuli throughout. However, this limitation was not inserted in the definition of the subgenus nor should it be. The increase of the width of the annuli seemingly is a valid specific criterion in certain species, but in other species such expansion may occur in certain specimens and not in others. Moreover, specimens may have a progressive increase in the width of the annuli followed by a decrease in the width of the annuli (Pl. 7, fig. 7).

Vaughan (1945, p. 114) assigned only three species to the subgenus *Pseudophragmina, P. bainbridgensis, P. floridana,* and *P. novitasensis.* All of the specimens assigned to these species do have radially elongate equatorial chambers (Pl. 3, fig. 6; Pl. 9, figs. 4-7).

In the original definitions (Vaughan and Cole, *in* Cushman, 1940, pp. 329, 330; 1941, p. 75) which Vaughan (1945, p. 69) accepted with slight modification the subgenus *Pseudophragmina* was defined as possessing incomplete radial chamber walls with the distal part degenerate, in places represented by rows of granules, whereas the subgenus *Proporocyclina* was characterized by having complete radial chamber walls.

The chamber walls (Pl. 3, fig. 6; Pl. 9, figs. 4, 5, 7) of *P. bainbridgensis* assigned by Vaughan (1945, p. 86) to the subgenus *Pseudophragmina* are complete, and are entirely comparable to those of *P. flintensis* (synonym: *Discocyclina perpusilla* Vaughan, 1929) (Pl. 3, fig. 5; Cole, 1958 *b*, pl. 50, all figs.). Even the type of the subgenus *Pseudophragmina, P. floridana* (Cushman), has radial chamber walls (Pl. 9, fig. 6) which are complete in places. In fact, *P. tobleri* assigned by Vaughan and Cole (1941, p. 62) to the subgenus *Proporocyclina* has more irregularly developed and less complete radial chamber walls (Pl. 5, fig. 1) than does *P. floridana.*

In part the apparent incompleteness of the radial chamber walls of *P. floridana* is the result of the destruction of parts of these walls in preparing the thin sections. Many of the granules to which Vaughan and Cole referred are the result of irregular thickening of the radial chamber walls. However, there are some incomplete radial chamber walls, but these also occur in *Proporocyclina* (Pl. 3, fig. 5).

Vaughan (1945, pl. 38, figs. 1, 2) published excellent illustrations of the equatorial sections of specimens he identified as *Pseudophragmina (Proporocyclina) cushmani* (Vaughan). The arrangement of the radial chamber walls, particularly in the central area of figure 2, plate 38 (Vaughan, 1945) resembles those of *P. tobleri* (Pl. 5, fig. 1; Vaughan and Cole, 1941, pl. 22, figs. 3, 4; Cole, 1959, pl. 32, figs. 9, 10), but those in the peripheral zone (left side of Vaughan's fig 2) resemble the radial chamber walls of *P. floridana* (Pl. 9, fig. 6) and *P. bainbridgensis* (Pl. 3, fig. 6; Pl. 9, figs. 5, 7).

As the subgenera *Pseudophragmina* and *Proporocyclina* are defined, there is not any structure or combination of structures by which these two subgenera can be distinguished. The conclusion has been reached that these two subgenera should be combined.

Vaughan (1945, p. 55) in his discussion of stolons in the discocyclinids wrote "In *Pseudophragmina (Proporocyclina) perpusilla* (pl. 22, fig. 1) where the chambers are radially aligned, as is usually the case, there is on the proximal and distal side of each equatorial chamber a radial stolon which connects with a chamber in an adjacent annulus . . . It looks as if the presence of two stolons, one at each end of a chamber, were a generic character, but not enough chambers have been examined to be sure whether the feature is constant".

The development of the annuli and the incomplete radial chamber walls in specimens assigned to the subgenus *Athecocyclina* are different than in many of the species placed in the subgenera *Pseudophragmina* and *Proporocyclina*. Vaughan (1945, p. 101) observed in specimens of *Athecocyclina* "The annular walls are excellently preserved. They tend to be wavy . . . Along these there are in places thickenings, and there appear to be between the adjacent annuli passages for stolons.

The radial walls are completely absent or poorly developed. In places they are represented by thin lines (in the section) across the annuli; some of them seem to be connected with the thickening along the annular walls; but they are irregular in development."

Radial stolons in a species assigned to *Athecocyclina* have been illustrated by Vaughan (1945, pl. 17, figs. 7, 7*a*, 8) in vertical sections and in an equatorial section (pl. 18, fig. 1*a*). Comparable radial stolons have been illustrated by Cole (1956, pl. 29, figs. 8,

10) in a species placed in *Proporocyclina.* Study of these preparations demonstrate that the thickening of the annular wall and the development of the incomplete and irregular radial chamber walls is a reflection of the radial stolon system.

This relationship is shown also in the excellent illustration of an equatorial section published by Vaughan (1945, pl. 42, fig. 2) and to a lesser extent in figure 1 of this same plate. Illustrations which show the same phenomenon are given (Pl. 2, figs. 4, 5; Pl. 3, figs. 1-3; Pl. 8, figs. 1, 2, 8).

Cole (1959, p. 386) demonstrated that *Discocyclina cookei* Vaughan, 1936, the type of *Athecocyclina,* was a synonym of *Discocyclina stephensoni* Vaughan, 1929. Vaughan (1945, pl. 45, fig. 4) has illustrated an equatorial section of *Pseudophragmina (Athecocyclina) stephensoni* which in certain areas shows the radial stolon system. This system is similar to that of specimens formerly identified as *P. (Proporocyclina) cloptoni* (Vaughan).

The major difference between species assigned to *Athecocyclina* and those species Vaughan (1945, p. 97) placed in the "Group of *Pseudophragmina advena* (Cushman)" is that these specimens have a stronger development of irregular, "radial walls" in the annuli. To distinguish this kind they will be referred to as pseudoradial prolongations rather than incomplete radial walls. True radial walls may be complete (Pl. 3, figs. 5, 6; Pl. 5, figs. 5, 6; Pl. 7, figs. 3, 7) or they may be incomplete (Pl. 5, fig. 1; Pl. 7, figs. 1, 2). In all cases, however, these walls appear throughout equatorial sections so that a distinct and regular pattern is observed.

In specimens which will be assigned to *Athecocyclina* the annucli may be open (Vaughan, 1945, pl. 45, figs. 1-4; Sachs, 1957, pl. 17, figs. 7-9), may have short distally projecting pseudoradial prolongations (Vaughan, 1945, pl. 18, fig. 1*a*), or may have irregular, but distinct pseudoradial prolongations (Pl. 3, figs. 1-4).

Thus, the genus *Pseudophragmina* H. Douvillé, 1923, will contain two rather than three subgenera, *Pseudophragmina* (synonym: *Proporocyclina* Vaughan and Cole, 1940) and *Athecocyclina* Vaughan and Cole, 1940.

If this revision of the subgenera of *Pseudophragmina* is accepted, all of the species listed by Vaughan (1945, table 9) in the subgenus *Pseudophragmina* will remain in this subgenus. All of the species which he assigned to the subgenus *Proporocyclina* will be transferred to the subgenus *Pseudophragmina* with the following exceptions: *P. advena, P. cloptoni, P. perkinsi,* and *P. zaragosensis.* These four species will be assigned to *Athecocyclina.*

Additional observations on radial stolons are given under *Pseudophragmina zaragosensis* (Vaughan) in another section of this discourse.

DISCUSSION OF SPECIES

Family **DISCOCYCLINIDAE**

Genus **PSEUDOPHRAGMINA** H. Douvillé, 1923

Subgenus **PSEUDOPHRAGMINA** H. Douvillé, 1923

Pseudophragmina (Pseudophragmina) bainbridgensis (Vaughan)
Pl. 3, fig. 6; Pl. 9, figs. 1-5, 7

1928. *Discocyclina (Atkinocyclina) bainbridgensis* Vaughan, Florida Geol. Sur., 19th Ann. Rep., pp. 160, 161, pl. 1, fig. 5.
1945. *Pseudophragmina (Pseudophragmina) bainbridgensis* (Vaughan), Vaughan, Geol. Soc. Amer., Mem. 9, pp. 86, 87, pl. 33, figs. 1-4; pl. 34, figs. 1-3.
1945. *Pseudophragmina (Pseudophragmina) bainbridgensis* var. *angusta* Vaughan, Geol. Soc. Amer., Mem. 9, p. 87, pl. 34, figs. 5-7.
1945. *Pseudophragmina (Pseudophragmina) bainbridgensis* var. *obsoleta* Vaughan, Geol. Soc. Amer., Mem. 9, p. 87, pl. 33, fig. 5; pl. 34, fig. 4.
1945. *Pseudophragmina (Pseudophragmina) novitasensis* Vaughan, Geol. Soc. Amer., Mem. 9, p. 88, pl. 35, all figs.

Discussion. — This species was based (Vaughan, 1928, p. 160) upon two specimens from the upper Eocene Ocala Limestone on the Flint River above Bainbridge, Georgia, of which only the type was illustrated (Vaughan, 1928, pl. 1, fig. 1). The surface ornamentation of the type is distinctive consisting of a sequence of concentric, closely spaced ridges on which are superimposed a number of narrow, flat-topped, subequal costae which radiate from a centrally located knob.

Vaughan (1945, p. 86) later received specimens of this species from R. W. Barker from a locality 1.4 miles north of Monroeville, Alabama. Vaughan (1945, pl. 33, fig. 2) illustrated the exterior of two of these specimens and an equatorial section (pl. 34, fig. 1). This equatorial section was described in detail.

Additional specimens (Vaughan, pl. 33, figs. 3, 4; pl. 34, figs.

2, 3) assigned to this species were obtained from the upper Eocene near Nuevitas, Camaguey Province, Cuba (loc. 1 of this article). This material formed the basis for the first adequate description of the internal structure of this species.

As Vaughan (1945, p. 86) clearly indicated this additional material proved that this species should be transferred to the subgenus *Pseudophragmina* of the genus *Pseudophragmina,* and he correctly stated that the internal structure was similar in many respects to that of *P. floridana,* the type of the genus.

Apparently Vaughan (1945, pp. 87, 88) was impressed by slight differences in the development of surface ornamentation shown by the Cuban specimens as he described two varieties, *P. bainbridgensis angusta* and *P. bainbridgensis obsoleta.* He (Vaughan, 1945, p. 87) admitted, however, "The specimens seem to form an unbroken series from those with completely obsolete rays in var. *obsoleta* to those with narrower, longer rays in var. *angusta.*"

Although the illustrations of the variety *obsoleta* (Vaughan, 1945, pl. 33, fig. 5; pl. 34, fig. 4) are similar to other Cuban specimens (Vaughan, 1945, pl. 35, all figs.) from the same sample, except the concentric ridges are slightly more prominent in *obsoleta,* they are separated from the *P. bainbridgensis* series and described as *P. (P.) novitasensis.*

A number of specimens from the Nuevitas locality (Palmer 1479; loc. 1 of this article) were available. Several thin sections (Pl. 9, figs. 1-5, 7) made from these Cuban specimens are illustrated. The specimens were separated on surface ornamentation, and selected specimens were sectioned. The specimens form a complete intergradational series, thus, only one species is recognized.

P. bainbridgensis is a distinct and easily recognized species. Vaughan (1945, p. 88) recognized that *P. bainbridgensis* is similar in some aspects to *P. floridana* (Pl. 1, figs. 1-6), but differs in the development of the lateral chambers and the size of the embryonic chambers. In addition, the ring of periembryonic chambers is markedly different in the two species.

Although Vaughan (1945, p. 88) wrote concerning the radial chamber walls ". . . they are essentially the same as those of *P. floridana* (Cushman), he failed to observe they are also essentially the same as those of *Pseudophragmina flintensis* (=*Discocyclina perpusilla* Vaughan), the type of the subgenus *Proporocyclina* (compare fig. 6, Pl. 3 with fig. 5, Pl. 3).

Geographic distribution and stratigraphic position.—This species is known only from three localities, two in the United States and one in Cuba. The horizon is certainly upper Eocene.

Pseudophragmina (Pseudophragmina) cedarkeysensis Cole

Pl. 6, figs. 5, 9; Pl. 7, figs. 1, 2, 6

1942. *Pseudophragmina (Proporocyclina) zaragosensis* Cole, Florida Geol. Sur., Bull. 20, pp. 46-48, pl. 13, figs. 1-5; pl. 14, figs. 1-5 (not *Discocyclina zaragosensis* Vaughan, 1929).
1944. *Pseudophragmina (Proporocyclina) cedarkeysensis* Cole, Florida Geol. Sur., Bull. 26, pp. 81-83, pl. 2, fig. 13; pl. 18, fig. 9; pl. 26, figs. 1-4; pl. 27, figs 1, 2.
1944. *Pseudophragmina (Proporocyclina) hannai* Cole, Florida Geol. Sur., Bull. 26, pp. 84-87, pl. 1, fig. 12; pl. 8, figs. 7, 17; pl. 12, figs. 7-11; pl. 18, figs. 5, 6; pl. 26, fig. 5; pl. 27, fig. 3; pl. 28, figs. 1, 2.
1945. *Pseudophragmina (Proporocyclina) cedarkeysensis* Cole, Vaughan, Geol. Soc. Amer., Mem. 9, p. 95.
1945. *Pseudophragmina (Proporocyclina) hannai,* Cole, Vaughan, Geol. Soc. Amer., Mem. 9, p. 95.
1957. *Pseudophragmina (Proporocyclina) cedarkeysensis* Cole, Levin, Micropaleont., vol. 3, No. 2, p. 147, pl. 4, fig. 12.
1967. *Pseudophragmina (Proporocyclina) cedarkeysensis* Cole, Butterlin, Eclogae Geol. Helvetiae, vol. 60, No. 2, pp. 546-548, pl. 2, figs. 1-11; pl. 3, figs. 1-7.

Discussion.—The types of this species were identified originally by Cole (1942, p. 46) as *P. zaragosensis* (Vaughan) because of a superficial resemblance of the vertical sections. Although Cole (1944, p. 81) later named these specimens *P. (Proporocyclina) cedarkeysensis,* he had some doubt whether this was correct (Cole, 1958 *b,* p. 417, footnote). In part, this was caused by the fact that Vaughan (1945, p. 100), after studying a new equatorial section of a topotype of *Discocyclina zaragosensis,* assigned this species to the subgenus *Proporocyclina.* Inspection of the illustration given by Vaughan (1945, pl. 44, fig. 1) with a magnifying glass proves that *P. zaragosensis* should be placed in the subgenus *Athecocyclina.* This illustration shows that radial chamber walls are not developed and the small projections which do occur are pseudoradial projections. The annular walls are comparable to those developed in the specimens from a well in Mississippi referred to *P. zaragosensis* (Cole, 1960 *a,* pl. 4, fig. 4; 1963, pl. 7, fig. 1-4).

P. cedarkeysensis has well-developed, regular radial walls (Pl. 7, figs. 1, 2) and definitely belongs in the subgenus *Pseudophragmina* (synonym: *Proporocyclina)* as defined in this article.

Occurrence. — The types of this species are from the Suwannee Petroleum Corporation Sholtz No. 1 well, Levy County, Florida at a depth of 1470 feet (Cole, 1944, p. 82). *P. (Pseudophragmina) cedarkeysensis* also was found in the St. Mary's Oil Corporation, Hilliard Turpentine Company No. 1 well, Nassau County, Florida, at a depth of 1680-1690 feet (identified as *P. (Proporocyclina) hannai*) (Cole, 1944, p. 84), and at 1785-1795 feet correctly assigned to *P. cedarkeysensis* (Cole, 1944, p. 83). Levin (1957, p. 147) reported this species as moderately abundant in the interval between 1300 and 1310 feet in the Humble Oil & Refining Company's C. E. Robinson No. 1 well, Levy County, Florida. Butterlin (1967, p. 548) discussed and illustrated this species from the Corinto well No. 1, State of Campeche, Mexico, at a depth of 985-1175 meters, the only locality outside of Florida for this species.

Associated species. — In the Hilliard Turpentine No. 1 well, Nassau County, Florida, Cole (1944, p. 34) reported *P. (Athecocyclina) stephensoni* (identified as *P. (A.) cookei*) in association with *P. (Pseudophragmina) cedarkeysensis.* Butterlin (1967, p. 549) found *P. (A.) stephensoni* at a depth of 1000-1105 meters in the Corinto No. 1 well, State of Campeche, Mexico, within the zone (985-1175 meters) from which he recorded *P. (P.) cedarkeysensis.* Butterlin identified associated smaller Foraminifera as *Helicostegina dimorpha* Barker and Grimsdale and *Amphistegina parvula* (Cushman).

Applin and Jordan (1945, p. 131) listed among species of Foraminifera characteristic of the Oldsmar Limestone (lower Eocene) of Florida *Helicostegina gyralis* Barker and Grimsdale. Although Applin and Jordan (1945, p. 131) believed that *Amphistegina lopeztrigoi* D. K. Palmer was characteristic of the Lake City Limestone (early middle Eocene) of Florida, Levin (1957, p. 146) recorded these two species from the Oldsmar Limestone in the interval from which he obtained *Pseudophragmina cedarkeysensis* Cole.

Some nomenclatural and stratigraphic problems concerning *Amphistegina lopeztrigoi* D. K. Palmer and *Helicostegina gyralis* Barker and Grimsdale should be clarified. The late Mrs. D. K.

Palmer (1934, p. 255) named specimens from the Cuban Eocene (". . . probably Middle Eocene . . .") *A. lopeztrigoi*. Cole (1958, p. 201) decided that *A. lopeztrigoi* was a synonym of *"Nummulites" (=Amphistegina) parvula* Cushman (1919, p. 291), the type of which was obtained from the middle Eocene of St. Bartholomew. On this island *A. parvula* occurs at numerous localities in association with a number of middle Eocene species of Foraminifera (Cole, 1958 *a*, p. 190).

The name *Helicostegina gyralis* was given by Barker and Grimsdale (1936, p. 236) to specimens from the ". . . top of the lower or base of the middle Eocene . . ." of the Tampico Embayment Area of Mexico. Cole and Gravell (1952, p. 713) suggested that *Helicostegina dimorpha* Barker and Grimsdale (1936, p. 235) and *H. gyralis* represented only one species, a consolidation accepted by Cole (1960 *b*, p. 58). As *H. dimorpha* is not only the type of the genus *Helicostegina*, but also the first species described by Barker and Grimsdale, *H. gyralis* is a synonym of *H. dimorpha*. Although Cole and Applin (1964) used the name *H. gyralis*, this was an oversight occasioned by the fact that this name had been used previously in a number of articles on Floridian Foraminifera.

Amphistegina parvula (identified as *A. lopeztrigoi*) has been reported from the ". . . Lower middle Eocene" of the Tampico Embayment Area of Mexico (Barker and Grimsdale, 1936, p. 233) in association with *Eulinderina guayabalensis regularis* Barker and Grimsdale (1936, p. 238) and *E. semiradiata* Barker and Grimsdale (1936, p. 238), species which Cole (1960 *b*, p. 60) placed in the synonymy of *Lepidocyclina antillea* Cushman.

Cole (1942, p. 33; 1944, p. 55) and Applin and Jordan (1945, p. 131) recorded *A. parvula (=A. lopeztrigoi)* as a middle Eocene species of Florida. Cole and Gravell (1952, p. 714) reported this species (as *A. lopeztrigoi)* from the middle Eocene of Cuba, but Beckmann (1958, p. 417, fig. 2) gave the range in Cuba from Paleocene into the middle Eocene.

Levin (1957, p. 146) was the first to report *A. parvula (=A. lopeztrigoi)* from the Oldsmar Limestone (lower Eocene) of Florida in the same zone from which he obtained *Pseudophragmina cedarkeysensis* Cole. Butterlin (1967, p. 549) found *A. parvula* and *P. cedarkeysensis* in association in a Mexican well in sediments which he referred to the "éocène moyen (partie inferieure). Thus, *Amphistegina parvula* has a stratigraphic range, at least, from lower into middle Eocene in Florida and Mexico as *P. cedarkeysensis* is assumed at present to be confined to the lower Eocene.

The types of *Helicostegina dimorpha* Barker and Grimsdale (1936, p. 235) and *H. gyralis* Barker and Grimsdale (1936, p. 236) were obtained from the sediments in the Tampico Embayment Area of Mexico which were correlated with the lower middle Eocene (Barker and Grimsdale, 1937, p. 173). Cole (1942, p. 34) reported the occurrence of *H. dimorpha* (identified as *H. gyralis)* in two wells in Levy County, Florida, and referred this section of these wells to the middle Eocene.

H. dimorpha (=H. gyralis) occurred in Cuba (Cole and Gravell, 1952, p. 713) and in Jamaica (Cole, 1956, p. 209; table 4) in association with other middle Eocene larger Foraminifera. Levin (1957, p. 146) reported this species in a well in Levy County, Florida, as abundant at depths between 1250 and 1390 feet with the ". . . greatest concentration of specimens between 1360 and 1370 feet." In this same well *Pseudophragmina cedarkeysensis* was ". . . only moderately abundant in the interval between 1300 and 1310 feet."

The Applins (1944, p. 1699) defined the Oldsmar Limestone (lower Eocene) ". . . to include the interval that is marked at the top by the presence of abundant specimens of *Helicostegina gyralis* Barker and Grimsdale . . ." Cole and Applin (1964, p. 15) wrote "As *H. gyralis* [=*H. dimorpha*] has not been reported elsewhere in the Caribbean Region below the base of the middle Eocene, the suggestion is made that the *Helicostegina gyralis* [=*H. dimorpha*] zone be included in the basal part of the Lake City limestone."

The occurrence of *Amphistegina parvula* (Cushman) in middle Eocene sediments of St. Bartholomew (Cole, 1958 *a*, p. 190), Mexico (Barker and Grimsdale, 1936, p. 233), Cuba (Cole and Gravell, 1952, p. 714), and Florida (Cole, 1942, p. 33; Applin and Jordan, 1945, p. 131) is firmly established. As summarized above, the occurrence of *Helicostegina dimorpha* in the middle Eocene at several Caribbean localities can be accepted.

Levin (1957, p. 146) and Butterlin (1967, p. 549) demonstrated that these two species occur in Florida and Mexico in association with *Pseudophragmina cedarkeysensis* Cole in the lower Eocene. Thus, the stratigraphic range of these two species is more extensive than was postulated originally.

Finally, it should be noted that Cushman (1919, pl. 4, figs. 3-6) illustrated two different species as *"Nummulites" parvula*. The type (pl. 4, fig. 3) and figure 6, plate 4 are interpreted as *Amphistegina lopeztrigoi* D. K. Palmer; figure 6, plate 4 is probably this species, but figure 5, plate 4 is another species, a true *Amphistegina*.

Studies in progress suggest that *Amphistegina parvula (=A. lopeztrigoi)* may be in reality the same as Cuban specimens which were named *Eoconuloides wellsi* Cole and Bermudez. The structural similarity between these specimens is shown by a comparison of specimens of undoubted *Amphistegina lopeztrigoi* (compare figs. 7, 8, pl. 91, Cole and Gravell, 1952) with specimens of *Eoconuloides wellsi* (pl. 92, figs. 6-8, Cole and Gravell, 1952).

Amphistegina senni Cushman *(in* Vaughan, 1945, p. 49), the type of *Tremastegina* Bronnimann, 1951) is undoubtedly a synonym of *Amphistegina parvula* (Cushman) *(=Amphistegina lopeztrigoi* D. K. Palmer). Therefore, *Tremastegina* is a synonym of *Eoconuloides,* 1944, which in turn may prove to be a synonym of *Helicostegina* Barker and Grimsdale, 1936. The apertures are the same [see: Barker and Grimsdale, 1936, pl. 34, fig. 1 *("Amphistegina lopeztrigoi"*); plate 34, fig. 7 *(Helicostegina dimorpha)*; and Cole and Gravell, pl. 92, fig. 7 *(Eoconuloides wellsi)*]. All of these specimens also develop supplemental chamberlets in the final volutions.

Pseudophragmina (Pseudophragmina) clarki (Cushman)
Pl. 5, figs. 5, 6; Pl. 6, figs. 3, 4, 6

1920. *Orthophragmina clarki* Cushman, U. S. Geol. Sur., Prof. Paper 125, pp. 41, 42, pl. 7, figs. 4, 5.
1958. *Pseudophragmina (Proporocyclina) clarki* (Cushman), Cole, Bull. Amer. Paleont., vol. 38, No. 176, pp. 419, 420, pl. 52, figs. 3-11 (additional references and synonyms).
1964. *Pseudophragmina (Proporocyclina) clarki* (Cushman), Cole and Applin, Bull. Amer. Paleont., vol. 47, No. 212, pp. 32, 33, pl. 9, figs. 1-4.

Discussion.—Cole (1958 *b*, pl. 52, figs. 3, 7) published two vertical sections of specimens identified as *P. clarki* from this

California locality (loc. 9). Three additional vertical sections (Pl. 6, figs. 3, 4, 6) and two equatorial sections (Pl. 5, figs. 5, 6) made from specimens from this locality are illustrated.

Cushman and McMasters (1936, p. 516, pl. 77, figs. 6-9) illustrated specimens from the middle Eocene Llajas Formation of the Simi Valley of California identified by H. G. Schenck as *Discocyclina cloptoni* Vaughan. Three of the specimens are illustrated by surface views. The internal structure of the equatorial plane is illustrated by a view taken by reflected light of a "natural" section, X30.

As this illustration (Cushman and McMasters, 1936, pl. 77, fig. 9) shows an equatorial plane similar to that of *P. clarki* rather than to *Discocyclina cloptoni,* one of the equatorial thin sections of *P. clarki* was photographed by reflected light (Pl. 5, fig. 6). Careful comparison of these illustrations demonstrates that the specimens identified by Schenck as *Discocyclina cloptoni* are indeed *P. clarki.*

This observation is substantiated by the surface aspect of these specimens. Definite pustules are developed on the surface, whereas the surface of *Discocyclina cloptoni* is smooth.

Butterlin (1967, p. 545) expressed the opinion that the specimens illustrated by Cushman and McMasters did not conform to *Discocyclina cloptoni.* Although he did not attempt to reassign these specimens, he correctly observed that these specimens had equatorial sections which conform to ". . . à une espèce du groupe 1 de Cole (1958)".

Vaughan (1945, p. 99) stated that he had received specimens of *P. (P.) cloptoni* from the Simi Valley, and he apparently accepted the identification by H. G. Schenck *(in* Cushman and McMasters, 1936, p. 516) as he wrote "This species had been reported from essentially the same locality and bed by Cushman and McMasters . . . ."

Butterlin (1967, pl. 1, figs. 1-3, 6) illustrated specimens from the "Eocène moyen, Formation Las Llajas, Californie (U.S.A.)" identified as *Pseudophragmina (Pseudophragmina) cloptoni* (Vaughan). These specimens do represent this species and appear to be identical with the types from Baja California.

Although I have examined a number of samples from the Simi

Valley, I have not found specimens which resemble *P. cloptoni* (=*P. advena*). Mallory (1959, p. 275) reported from this area *Pseudophragmina (Proporocyclina)* cf. *P. cloptoni* (Vaughan) (?) and stated "A questionable identification."

From these data it seems that the actual occurrence of *P. cloptoni* (=*P. advena*) in California must be questioned.

Geographic distribution and stratigraphic position. — *P. clarki* has been reported from several localities in California (Vaughan, 1945, p. 106). Cole (1958 *b*, p. 419) considered that *Orthophragmina peruviana* Cushman (*in* Bosworth, 1922, p. 138) was a synonym. If this assumption is correct, the geographic distribution of this species would be from Peru to California. Recently, Cole and Applin (1964, p. 32) identified specimens from a well in Walton County, Florida, as *P. clarki*, the first record of this species in the Gulf Coast area of the United States.

Vaughan (1945, pp. 104, 114) recorded *P. clarki* as a middle Eocene species. Mallory (1959, p. 275) placed it in "basal Llajas, Simi Valley, Ulatisian; and upper Lodo Domengine Creek, Ulatisian." The Ulatisian stage is middle Eocene (Mallory, 1959, p. 40).

Pseudophragmina (Pseudophragmina) flintensis (Cushman)
Pl. 3, fig. 5; Pl. 7, figs. 3-5, 7

1917. *Orthophragmina flintensis* Cushman, U. S. Geol. Sur., Prof. Paper 108-G, pp. 115, 116, pl. 40, figs. 1, 2.
1958. *Pseudophragmina (Proporocyclina) flintensis* (Cushman), Cole, Bull. Amer. Paleont., vol. 38, No. 176, pp. 420-423, pl. 50; pl. 51; pl. 52, figs 1, 2 (references and synonyms).

Discussion. — Additional illustrations (Pl. 7, figs. 3-5, 7) of Cuban specimens are illustrated to supplement those published by Vaughan (1945, pl. 36, figs. 3-6; pl. 37, fig. 1), and an equatorial section (Pl. 3, fig. 5) of a specimen from Mexico, originally identified as *Discocyclina perpusilla* Vaughan (=*P. flintensis*), is introduced for comparison (see: Cole, 1958 *b*, pp. 420-423 for an enlarged discussion of this species).

Pseudophragmina (Pseudophragmina) floridana (Cushman)
Pl. 1, figs. 1-6; Pl. 9, fig. 6

1917. *Orthophragmina floridana* Cushman, U. S. Geol. Sur., Prof. Paper 108-G, p. 116, pl. 40, fig. 3.
1920. *Orthophragmina floridana* Cushman, U. S. Geol. Sur., Prof. Paper 125-D, p. 44, pl. 9, fig. 7.
1924. *Pseudophragmina floridana* (Cushman), H. Douvillé, Soc. Géol. France Bull., ser. 4, vol. 23, p. 373, pl. 13, figs. 1-3.

1936. *Pseudophragmina floridana* (Cushman), Vaughan, Jour. Paleont., vol. 10, No. 4, pp. 258, 259, pl. 43, figs. 3-7.

Discussion. — This species, the type of the genus *Pseudophragmina* H. Douvillé (1923, p. 106), was described by Cushman (1917, p. 116) from USGS loc. 6768 ". . . soft white Ocala limestone (upper Eocene) on Chipola River at wagon bridge half a mile east of Marianna, Florida . . ." The type description adequately delineated the external appearance of this species, and the illustration (Cushman, 1917, pl. 40, fig. 3) of this aspect is excellent. The only mention of the internal structure in the type description (Cushman, 1917, p. 116) is: "Equatorial chambers in horizontal section very narrowly rectangular."

H. Douvillé (1924, pl. 13, figs. 1-3) gave the first illustrations of the equatorial chambers. Cushman (1920, p. 44) briefly described without illustration some of the salient features of vertical sections. Vaughan (1936, pl. 43, figs. 5-7) illustrated parts of vertical sections and gave (pl. 43, figs. 3, 4) additional views of the equatorial chambers.

In 1928 Vaughan (p. 159) recorded ". . . *Discocyclina floridana* has typically reniform embryonic chambers . . ." and in 1936 he (p. 258) described with measurements the embryonic chambers. The first illustration, however, of the embryonic apparatus of *P. floridana* was given by Cole (1964, fig. 588, 1 *a*), and at the same time a complete vertical section (Cole, 1964, fig. 588, 1 *c*) was published. Illustrations of these two thin sections are given as figures 1, 6, Plate 1.

The embryonic apparatus of two other megalospheric specimens (Pl. 1, figs. 4, 5) and a microspheric specimen (Pl. 1, fig. 3) are shown, and an additional vertical section of megalospheric specimen (Pl. 1, fig. 2) is given. Details of the equatorial chambers (Pl. 9, fig. 6) are illustrated.

Occurrence. — Cushman (1920, p. 44) reported that in addition to the type locality (USGS sta. 6768, bed. 1) on the Chipola River at the wagon bridge half a mile east of Marianna, Jackson County, Florida, *P. floridana* occurred in bed 3 (USGS sta. 7192) at this same locality and at another locality (USGS sta. 8259) northwest of Marianna. He doubtfully recorded a single specimen from a locality on the Flint River in Baker County, Georgia.

Puri (1957, p. 139) recorded this species at three localities, all of which are in Jackson County, Florida. Thus, all the localities at which *P. floridana* has been reported occur within a limited geographical area if the single specimen from the Georgia locality is disregarded.

Associated species.—The types of *Pseudophragmina floridana* (Cushman) were obtained from USGS sta. 6768 which is also the type locality for *Asterocyclina mariannensis* (Cushman) (1917, p. 116) and its microspheric form which Cushman (1917, p. 116) named *A. americana*, *Asterocyclina chipolensis* Vaughan (1928, p. 158), and *Camerina mariannensis* (Vaughan) (1928, p. 158).

Cole (1958 *a*, pl. 18, figs. 2, 7-10; pl. 19, figs. 8, 13; pl. 21, fig. 7) illustrated specimens of *Camerina* which occurred in association with *Pseudophragmina floridana* at locality 10 (approximately the same locality as USGS sta. 6768) which he identified as *"Operculinoides" floridensis* (Heilprin). In addition Cole (1958 *b*, pl. 50, figs. 1, 5; pl. 51, figs. 2, 14, 15) illustrated specimens from locality 10 identified as *Pseudophragmina flintensis* (Cushman) (1917, p. 115) (synonym: *Discocyclina citrensis* Vaughan, 1928, p. 159). Other associated species at locality 10 in addition to those recorded at USGS sta. 6768 are: *Heterostegina ocalana* Cushman, *Lepidocyclina ocalana* Cushman, *Lingula ocalana* Puri, and *Asterocyclina nassauensis* Cole.

Comparison with P. flintensis.—*P. floridana* and *P. flintensis* occur in association at certain localities, such as, locality 10 (Florida). These species are similar in external aspect [compare fig. 3, pl. 9, *(P. flintensis)* with fig. 7, pl. 9 *(P. floridana)*, Cushman, 1920]. The vertical sections of these two species are also similar as the lateral chambers have the same arrangement and shape. The only noticeable difference in most vertical sections is the size of the embryonic chambers.

Comparison should be made first with specimens from the middle Eocene Guayabal Formation of the Tampico Embayment Area (Cole, 1958 *b*, pl. 51, figs. 9, 10) originally identified as *Discocyclina perpusilla* Vaughan. These vertical sections, except for the size of the embryonic chambers, are identical to the specimen of *P. floridana* from the upper Eocene of Florida (Pl. 1, fig. 2). Figures 2, 14, 15, plate 51 (Cole, 1958 *b*) represent specimens from upper Eocene of Florida identified as *P. flintensis*. These specimens have the same convex roofs and floors of the lateral chambers as *P. floridana* (Pl. 1, figs. 1, 2) has, except the cavities of the lateral chambers are not so large in these sections of *P. flintensis*.

The major difference between *P. floridana* and *P. flintensis* occurs in the development of the embryonic apparatus. The embryonic chambers of *P. floridana* (Pl. 1, figs. 4-6) are large and are completely surrounded by a ring of large, distinct periembryonic chambers. The embryonic chambers of *P. flintensis* (Pl. 7, figs. 3, 7; Vaughan, 1945, pl. 36, fig. 2; Cole, 1958 *b*, pl. 50, all figs.) are small in comparison and the periembryonic chambers are small and numerous.

Unless accurately oriented equatorial sections are available, it is doubtful if *P. floridana* could be distinguished from *P. flintensis*. This may account for the fact that *P. floridana* has been identified only from a small geographic area and at essentially one stratigraphic horizon in Florida.

Subgenus **ATHECOCYCLINA** Vaughan and Cole, 1940

Pseudophragmina (Athecocyclina) advena (Cushman)
Pl. 2, figs. 1-6; Pl. 3, figs. 1-4; Pl. 4, figs. 1-7; Pl. 5, figs. 2-4; Pl. 8, figs. 1-8

1921. *Orthophragmina advena* Cushman, U.S. Geol. Sur., Prof. Paper 128-E, p. 139, pl. 22, figs. 1-5.
1928. *Discocyclina perkinsi* Vaughan, Jour. Paleont., vol. 1, No. 4, p. 277, pl. 46, figs. 4,5.
1929. *Discocyclina cloptoni* Vaughan, U.S. Nat. Mus., Proc., vol. 76, Art. 3, pp. 14, 15, pl. 15, figs 1-6
1938. *Discocyclina advena* (Cushman), Gravell and Hanna, Amer. Assoc. Petrol. Geol., Bull., vol. 22, pp. 1008-1010, pl. 6, fig. 8; pl. 7, figs. 4, 8.
1945. *Pseudophragmina (Proporocyclina) advena* (Cushman), Vaughan, Geol. Soc. Amer., Mem. 9, p. 98, pl. 42, fig. 1.
1945. *Pseudophragmina (Proporocyclina) cloptoni* (Vaughan), Vaughan, Geol. Soc. Amer., Mem. 9, pp. 98, 99, pl. 42, fig. 2.
1945. *Pseudophragmina (Proporocyclina) perkinsi* (Vaughan), Vaughan, Geol. Soc. Amer., Mem. 9, pp. 99, 100, pl. 43, all figs.
1952. *Pseudophragmina (Proporocyclina) compacta* Cole and Gravell, Jour. Paleont., vol. 26, No. 5, pp. 720, 721, pl. 95, fig. 6; pl. 99, figs. 6-8; pl. 100, figs. 1, 2, 5, 6, 13.
1952. *Pseudophragmina (Proporocyclina) advena* (Cushman), Cole and Gravell, Jour. Paleont., vol. 26, No. 5, p. 721, pl. 100, figs. 4, 9.
1952. *Pseudophragmina (Proporocyclina) cloptoni* (Vaughan), Cole and Gravell, Jour. Paleont., vol. 26, No. 5, p. 721, pl. 100, fig. 8.
1952. *Pseudophragmina (Proporocyclina) perkinsi* (Vaughan), Cole and Gravell, Jour. Paleont., vol. 26, No. 5, p. 721, pl. 100, fig. 7.

1956. *Pseudophragmina (Proporocyclina) advena* (Cushman), Cole, Bull. Amer. Paleont., vol. 36, No. 158, pp. 222, 223, pl. 29, figs. 6-10.

1967. *Pseudophragmina (Pseudophragmina) cloptoni* (Vaughan), Butterlin, Eclogae Geol. Helvetiae, vol. 60, No. 2, pp. 544-546, pl. 3, fig. 1-3.

Discussion. — Cole (1958 *b*, pp. 413-417) proposed a classification based on the development of the radial chamber walls to distinguish species of *Pseudophragmina* which were assigned to the subgenus *Proporocyclina*. In this revision certain of the species which were included in the Type III group (species with narrow annuli throughout and more or less imperfect radial chamber walls) are transferred to the subgenus *Athecocyclina*, whereas others are assigned to the subgenus *Pseudophragmina* of which *Proporocyclina* is a synonym. *Pseudophragmina advena* (Cushman) is an example of a species, formerly assigned to *Proporocyclina*, which is reclassified under *Athecocyclina*, whereas *Pseudophragmina cedarkeysensis* Cole represents a species belonging to the subgenus *Pseudophragmina*.

In 1958*b* Cole (p. 415) expressed the opinion that "It is impossible to separate *P. (P.) perkinsi* from *P. (P.) cloptoni* and *P. (P.) compacta*." At that time (Cole, 1958 *b*, p. 416) *Pseudophragmina advena* was maintained as a valid species. Although specimens assigned to *P. perkinsi*, *P. cloptoni*, and *P. compacta* are still considered to represent only one species, an additional consolidation is suggested with the inclusion of *Pseudophragmina advena* (Cushman). In this case *P. advena* has priority and the other species become synonyms of *P. advena* (Cushman), 1921.

The rationale for the consolidation of *P. perkinsi*, *P. cloptoni*, and *P. compacta* is demonstrated by comparison of the internal structures which are identical in specimens formerly assigned to three species. Detailed study of numerous thin sections proves that there are not any recognizable differences. A number of illustrations are given, all of which are of the same magnification for ease in making comparisons.

Parts of equatorial sections of topotypes of *P. cloptoni* are illustrated as figures 3, 4, Plate 2 and figure 8, Plate 8. Similar illustrations of specimens identified by Vaughan (1945, p. 99) as *P. perkinsi* are given as figures 5, 6, Plate 2. The equatorial section of *P. compacta* illustrated by Cole and Gravell (1952, pl. 99, fig. 8) is satisfactory and is not reproduced.

In addition parts of equatorial sections of specimens from Jamaica identified by Cole (1958*a*, p. 191) first as *P. compacta* and later (Cole, *in* Cole and Applin, 1964, p. 28) as *P. perkinsi* are illustrated as figure 4, Plate 5 and figure 7, Plate 8.

Illustrations of small areas of certain equatorial sections to show the annular walls and pseudoradial prolongations are given as figures 1-3, Plate 3.

The critical central parts of vertical sections of the specimens identified by Vaughan (1945, p. 99) as *P. perkinsi* are illustrated as figures 1, 2, Plate 4 (thin specimens) and figures 2, 3, Plate 5 (thick specimens). Three topotype specimens of *P. cloptoni* are illustrated as figures 3-5, Plate 4. One of the vertical sections of *P. compacta* used by Cole and Gravell (1952, pl. 100, fig. 6) in the type description is reproduced as figure 7, Plate 4. Jamaican specimens first identified as *P. compacta* and later as *P. perkinsi* are shown as figure 6, Plate 4 and figure 7, Plate 8.

Study of these sections and others which are not reproduced are convincing proof that it is impossible to separate these specimens into three species. However, it does not follow that these three species should be synonyms of *Pseudophragmina advena* (Cushman) as specimens assigned to that species do show more variation than exhibited by the others.

Illustrations (Pl. 2, fig. 1; Pl. 3, fig. 4; Pl. 4, fig. 8; Pl. 8, figs. 3-6) of eight topotype specimens of *P. advena* are given. These specimens vary from individuals which have a deep umbonal depression (Pl. 8, figs. 3, 4) to others which are compressed, lenticular (Pl. 4, fig. 8; Pl. 8, fig. 6; Cole and Gravell, 1952, pl. 100, fig. 4). Shape is obviously an unsatisfactory specific criterion, not only because in the topotype population specimens are extremely variable, but also specimens in other populations (Cole, 1956, pl. 29, figs. 6-10) do not exhibit this variability in shape.

The embryonic chambers of a topotype specimen (Pl. 2, fig. 1) of *P. advena* are "nephrolepidine," but Cushman (1921, pl. 22, fig. 3) illustrated an embryonic apparatus of the "eulepidine" kind. Gravell and Hanna (1938, pl. 7, fig. 4) published an illustration of *P. advena* with "eulepidine" embryonic chambers. The "eulepidine" kind of embryonic chambers was observed in making sections of topotypes of *P. advena,* but unfortunately these preparations were not good enough to photograph.

The embryonic chambers of *P. advena* vary from "nephrolepidine" to "eulepidine." However, this same variation occurs in topotypes of *Discocyclina cloptoni* (Pl. 2, fig. 3, 4; Pl. 8, fig. 8; Vaughan, 1945, pl. 42, fig. 2) and in specimens (Pl. 2, fig. 2; Pl. 8, fig. 1) from Jamaica (loc. 3).

The annuli of *P. advena* (Pl. 3, fig. 4; Vaughan, 1945, pl. 42, fig. 1) are similar to those of Jamaican specimens (Pl. 3, figs. 1, 2) and *Discocyclina cloptoni* (Pl. 3, fig. 3; Vaughan, 1945, pl. 42, fig. 2). All of these specimens have similar pseudoradial prolongations of the *Athecocyclina* kind.

P. advena can not be distinguished from the other specimens with which comparison has been made by the structures of the equatorial section. Thus, the only practical means of distinguishing *P. advena* from these other specimens would be by the structures of the vertical section.

Topotype specimens of *P. advena* have the cavities of the lateral chambers slitlike (Pl. 8, figs. 3-5) between thick roofs and floors in some specimens, whereas others (Pl. 4, fig. 8; Pl. 8, fig. 6) have similar thick roofs and floors with low, open, elongate cavities particularly toward the periphery of the test. The arrangement and shape of the lateral chambers is the same in all of these specimens even though certain specimens have distinct rather than slitlike cavities. This development is not of specific importance.

Although specimens referred to *P. advena* are more variable in shape and in the development of the cavities of the lateral chambers, the overall similarities are such that *P. advena* is consolidated with *P. cloptoni, P. compacta* and *P. perkinsi.*

Geographic and stratigraphic position.—P. advena (as *P. advena)* has been recognized widely in the middle Eocene of the Gulf Coast (Gravell and Hanna, 1938, pp. 1008, 1009) of the United States and in Jamaica (Cole, 1956, p. 222); in the middle Eocene of Cuba as *P. compacta* Cole and Gravell (1952, p. 720); in the middle Eocene Tepetate Formation of Baja California as *P. cloptoni;* and in the upper Eocene of Jamaica and Cuba as *P. perkinsi.* The occurrence of this species as *P. cloptoni* in the Llajas

Formation of California (Cushman and McMasters, 1936, p. 516) can not be verified (see under *P. clarki,* this article).

P. advena as recognized in this article has an extensive geographic distribution and a stratigraphic range from middle into upper Eocene. The geographic distribution and stratigraphic range of *P. advena* is similar to that of *Pseudophragmina (Pseudophragmina) flintensis* (Cushman) (Cole, 1958*b,* pp. 420-423).

As early as 1952 Cole and Gravell (p. 715) postulated that specimens in the middle Eocene of California which Schenck (1929) named *Discocyclina californica* were identical to specimens from Cuba which they assigned to *Discocyclina (Discocyclina) marginata* (Cushman) (1919, p. 56). Therefore, the recognition that *P. cloptoni* from Baja California is a synonym of *P. advena* of the Gulf Coast of the United States tends to confirm the fact that middle Eocene species are common in both areas.

Associated species. — No other species of larger Foraminifera have been reported in association with *P. advena* at its type locality or at other localities on the Gulf Coast of the United States. In Jamaica (Cole, 1956, Table 4) the same situation was encountered at one locality. However, at another locality (Cole, 1958*a,* p. 191; Cole and Applin, 1964, p. 28) *P. advena* (identified first as *P. compacta,* later as *P. perkinsi)* was associated with *Asterocyclina monticellensis* Cole and Ponton, *Camerina floridensis* (Heilprin), *C. striatoreticulata* (L. Rutten), *Dictyoconus walnutensis* (Carsey), *Fabiania cassis* (Oppenheim), *Helicolepidina spiralis* Tobler, *Lepidocyclina (Polylepidina) antillea* Cushman, and *Pseudophragmina (Proporocyclina) flintensis* (Cushman). Although this fauna contained several species which are assumed to be restricted to the middle Eocene, others range into the upper Eocene.

In Cuba (Cole and Gravell, 1952, p. 720) *P. advena* (identified as *P. compacta)* was associated with several species which are believed to mark the middle Eocene, such as *Gunteria floridana* Cushman and Ponton, *Discocyclina (Discocyclina) marginata* (Cushman), and *Asterocyclina monticellensis* Cole and Ponton. However, in this Cuban fauna other species were reported, such as *Pseudophragmina flintensis* (identified as *P. cushmani* and *P. convexi-*

camerata) which apparently range from middle into the upper Eocene.

P. advena (identified as *P. perkinsi)* occurs also in Cuba in sediments which are definitely upper Eocene (loc. 1). Vaughan (1945) identified at this locality *Asterocyclina mariannensis* (p. 80), *A. minima* Cushman (identified as *Discocyclina rutteni)* (p. 82), *Pseudophragmina bainbridgensis* (p. 86), and *P. flintensis* (p. 89). In addition *Camerina floridensis* (Heilprin) occurs abundantly at this locality with less abundant specimens of *Lepidocyclina ocalana* Cushman.

Pseudophragmina (Athecocyclina) stephensoni (Vaughan)

Pl. 6, figs. 1, 2

1929. *Discocyclina stephensoni* Vaughan, U.S. Nat. Mus., Proc., vol. 76, art. 3, p. 16, pl. 6, figs. 1-4.
1959. *Pseudophragmina (Athecocyclina) stephensoni* (Vaughan), Cole, Bull. Amer. Paleont., vol. 39, No. 182, pp. 386-387, pl. 32, figs. 1-4 (references and synonyms).
1967. *Pseudophragmina (Athecocyclina) stephensoni* (Vaughan), Butterlin, Eclogae Geol. Helvetiae, vol. 60, No. 2, pp. 549, 550, pl. 1, figs. 4, 5, 7-10.

Discussion. — The type illustrations of this species were not satisfactory. Vaughan (1945, p. 101, pl. 45, figs. 3,4) described and illustrated two new equatorial sections of topotypes which showed excellently the structures of the median plane. At my suggestion Lloyd Henbest of the U. S. Geological Survey rephotographed the type vertical sections. The best one of these was published (Cole and Herrick, 1953, pl. 2, fig. 8).

Later, Cole (1959, p. 386) decided that *Discocyclina cookei* Vaughan (1936, p. 256) was a synonym of *P. stephensoni.* Vaughan (1945, pl. 45, figs. 1,2) illustrated two satisfactory median sections of *Discocyclina cookei,* but the illustrations of the vertical sections (Vaughan, 1936, pl. 42, figs. 4,5) were not sufficiently enlarged to be entirely satisfactory. New illustrations are given as figures 1, 2, Plate 6.

Geographic distribution. — This species under various specific names has been reported from a number of localities. It has been found in surface outcrops in Mexico *(Discocyclina stephensoni* Vaughan, 1929); in Alabama [*Discocyclina cookei* Vaughan, 1936, and *Pseudophragmina (Athecocyclina) macglameriae* Vaughan, 1945]; in Trinidad [*P. (A.) soldadensis* Vaughan and Cole, 1941];

in Barbados [*P. (A.) soldadensis calebardensis* Vaughan, 1945]; in Venezuela [*P. (A.) cookei* (Vaughan) Caudri, 1944; Cizancourt, 1951]; and in Cuba [*P. (A.) stephensoni* (Vaughan) Sachs, 1957]. Cole and Herrick (1953, p. 54) reported *P. (A.) stephensoni* from several wells in Georgia, and Butterlin (1967, p. 549) recovered this species from a well in the State of Campeche, Mexico.

Associated species. – Cole (1959, Table 1) summarized the species of larger Foraminifera which have been found in association with *P. (A.) stephensoni. Camerina catenula* (Cushman and Jarvis) (synonyms: *Pellatispirella antillea* Hanzawa, *Operculina bermudezi* D. K. Palmer, *Camerina pellatispiroides* Barker, and *Operculinoides georgianus* Cole and Herrick) was the species most commonly reported with *P. (A.) stephensoni. Discocyclina (Discocyclina) barkeri* Vaughan and Cole and *D. (D.) weaveri* Vaughan [synonyms: *D. (D.) blanpiedi* Vaughan, *D. (D.) grimsdalei* Vaughan and Cole, *D. (D.) fonslacertensis* Vaughan, *D. (D.) mestieri* Vaughan, and *D. (D.) aguerreverei* Caudri] occurred at a number of these localities. Other species are listed by Cole (1959, Table 1).

Butterlin (1967, p. 549) found the following species associated with *P. (A.) stephensoni: P. (Proporocyclina) cedarkeysensis* Cole, *Helicostegina dimorpha* Barker and Grimsdale, and *Amphistegina parvula* (Cushman). In addition, he listed *P. (Pseudophragmina)* sp. cf. *P. (P.) palenquensis* Vaughan.

Stratigraphic position. – Vaughan (1945, p. 101) reported that *P. (A.) stephensoni* occurred in Mexico in association with *Ostrea thirsae* Gabb. "According to Dr. Julia Gardner the stratigraphic horizon is high Midway (Paleocene), which would be the equivalent of the basal lower Chicontepec".

P. (A.) stephensoni (identified as *Discocyclina cookei* Vaughan, 1936) was obtained from the Salt Mountain Limestone of Alabama. Toulmin (1940, p. 113) wrote "In spite of some faunal differences between the two formations the Salt Mountain Limestone is believed to be equivalent to the *Ostrea thirsae* beds of the Nanafalia". In 1955 Toulmin (p. 219) stated "The most important downdip lithic change is the replacement of some beds of the Nanafalia formation by the Salt Mountain Limestone, a white chalky fossiliferous massive biohermal limestone of irregular thickness and sporadic occurrence". These relationships are shown diagramatically (Toulmin, 1955, fig. 5).

Loeblich and Tappan (1957, pp. 174, 177, fig. 28) discussed the smaller Foraminifera of the Salt Mountain Limestone and assigned it to the *Globorotalia velascoensis-acuta-spiralis* subzone of the *G. angulata* zone of the Paleocene. The Nanafalia formation is placed above the Salt Mountain Limestone in the Wilcox group.

Vaughan (1945, pp. 102,103) described *P. (A.) macglameriae,* a species which Cole (1959, p. 386) placed in the synonymy of *P. (A.) stephensoni,* from ". . . the glauconite zone that immediately overlies the Coal Bluff lignite. Where the specimens were collected, the bed containing them lies directly on the Naheola shale, the lignite being absent and is approximately 120 feet above the Matthews Landing [Naheola] marl. *Ostrea thirsae* lies some 40 feet higher . . . " Vaughan (1945, p. 103) stated that an associated molluscan species, *Venericardia wilcoxensis tripla* Dall, according to the late Julia Gardner" . . . is restricted in recorded occurrence to the upper Midway horizon. There are no species in the collection which strongly suggest a Wilcox age".

Thus, Vaughan (1945, p. 103) placed *P. (A.) stephensoni* and *P. (A.) macglameriae* in the Paleocene, Midway group, and *P. (A.) cookei* in the lower Eocene, Wilcox group.

Muir (1936, p. 101) stated that *Discocyclina (Discocyclina) weaveri* Vaughan, 1929, occurs at its type locality in Mexico in association with *Ostrea thirsae* Gabb and *Turritella* aff. *humerosa* Conrad. The late Dr. Julia Gardner (1945, p. 7) wrote concerning the lower Tertiary of northeast Mexico "No faunal break between the Midway and the Wilcox has been determined . . . the faunas characterized by an abundance of *Ostrea thirsae* and of *Turritella sanjuanensis* of the *T. humerosa* group have been referred to the upper Midway, although *Ostrea thirsae* is a characteristic fossil of the Nanafalia formation of Alabama and *Turritella humerosa* of the Aquia formation of Maryland. A similar assemblage, together with *Discocyclina weaveri* Vaughan was collected . . . from the Tanlájas formation in the Plaza in San Antonio, San Luis Potosí."

P. (A.) stephensoni (=*Discocyclina cookei* Vaughan, 1936) and *D. (D.) weaveri* (=*Discocyclina blanpiedi* Vaughan, 1936) occur in the Salt Mountain Limestone of Alabama in association with

Ostrea thirsae. Although these two species do not occur together at their type localities in Mexico, both species are accompanied by *Ostrea thirsae.* Muir (1936, p. 104) stated "The evidence at present available indicates that *D. stephensoni* occurs at a lower stratigraphic level than *Discocyclina weaveri* Vaughan".

In Trinidad, Cuba, Barbados, and Venezuela species of *Pseudophragmina (Athecocyclina),* all of which Cole (1959, Table 1) assigned to *P. (A.) stephensoni* occur with species of *Discocyclina (Discocyclina)* which Cole (1959, Table 1) considered were synonyms of *D. (D.) weaveri.*

On the evidence available in 1959 Cole (p. 380) wrote " . . . *P. (A.) stephensoni* is a high Paleocene species". This postulate was strongly influenced by the assignment of the sediments in Mexico in which *P. (A.) stephensoni* and *D. (D.) weaveri* occurred by Vaughan (1945, p. 103) to the Paleocene and the placement of the Salt Mountain Limestone in the Paleocene by Loeblich and Tappan (1957, p. 177, fig. 28).

However, Cole (1944, p. 34) had found *P. (A.) stephensoni* (identified as *P. (A.) cookei*) in association with *Pseudophragmina (Pseudophragmina) cookei* in a well in Nassau County, Florida, in sediments which he correlated with the Salt Mountain Limestone. The Applins (1944, p. 1699, 1744) assigned this part of the section in this well to the Oldsmar Limestone (lower Eocene). Recently, Butterlin (1967, p. 549) recovered these two species in association in samples from a Mexican well in sediments which he placed in the lower part of the middle Eocene.

As recorded in the literature *P. (A.) stephensoni* seemingly has a stratigraphic range from Paleocene (Vaughan, 1945, p. 103) into the lower part of the middle Eocene (Butterlin, 1967, p. 549). If identifications have been made correctly, *P. (A.) stephensoni* occurs at its type locality in Mexico in association with *Ostrea thirsae. P. (A.) stephensoni* (=*P. (A.) cookei*) in Alabama was found in the Salt Mountain Limestone from which *Ostrea thirsae* has been reported (Blanpied, 1938, p. 30). These associations would suggest a correlation with the Nanafalia Formation (Wilcox group).

This correlation is strengthened by the association of *P. (A.) stephensoni* (=*P. (A.) cookei*) and *P. (P.) cedarkeysensis* in association in the well in Nassau County, Florida, in the Oldsmar Limestone which has been accepted generally to be the equivalent of the Wilcox group.

However, there is the distinct possibility that *P. (A.) stephensoni* may range from high Paleocene into the lower Eocene, Wilcox. Cole and Herrick (1953, p. 50, footnote 2) reported the occurrence of this species with *Camerina catenula* (Cushman and Jarvis) (identified as *Operculinoides georgianus nom. nov.* = *Miscellanea soldadensis* Vaughan and Cole, 1941) in wells in Georgia in sediments which they believed to be Midway (Paleocene).

The type locality of *Camerina catenula* (Cushman and Jarvis) (1932, p. 42) is in the Lizard Springs Formation of Trinidad from ". . . pit at Lizard Springs near Guayaguayare, southeastern Trinidad, British West Indies". Bolli (1957, p. 61) divided the Lizard Springs Formation on planktonic Foraminifera into eight zones, ". . . five of which are regarded as of Paleocene age (lower Lizard Springs) and three as of lower Eocene age (upper Lizard Springs).

Although it has been impossible to discover from which of the planktonic zones of the Lizard Springs Formation *Camerina catenula* was obtained, Bolli (1957, p. 65) reexamined " . . . the type sample (K. 2950) of 'Bed 3' from Soldado Rock of Trinidad" and assigned it to ". . . the *Globorotalia velascoensis* zone which is the highest zone of the lower Lizard Springs."

Sample K. 2950 (Soldado Rock) is the type locality for *Discocyclina (Discocyclina) barkeri* Vaughan and Cole (1941, p. 58). This species occurred at locality K. 2951 (upper part of "Bed 3", Vaughan and Cole, 1941, p. 9) in association with *D. (D.) weaveri* (identified as *D. (D.) grimsdalei* Vaughan and Cole) and *Camerina catenula* (identified as *Miscellanea soldadensis* Vaughan and Cole = *Operculinoides georgianus* Cole and Herrick).

P. (A.) stephensoni (identified as *P. (A.) soldadensis* Vaughan and Cole) was described from locality K. 2851, a rubble block in "Bed 4" (Kugler, *in* Vaughan and Cole, 1941, p. 9). The exact stratigraphic position of this block was not known (Kugler, *in* Vaughan and Cole, 1941, p. 63).

However, Cushman and Renz (1946, p. 10) imply that *P. (A.) soldadensis* Vaughan and Cole (=*P. (A.) stephensoni*) as well as other species of larger Foraminifera were associated with *Camerina catenula* at its type locality.

If the type locality of *C. catenula* in Trinidad is the stratigraphic equivalent of "Bed 3" of Soldado Rock, it would fall in the *Globorotalia velascoensis* planktonic zone which Bolli (1957, p. 63) placed in the high Paleocene. As *P. (A.) stephensoni* (identified as *P. (A.) soldadensis)* has been reported in association with *C. catenula* (Cushman and Renz, 1946, p. 11) not only at the type locality of *C. catenula,* but also at other localities (Cole and Herrick, 1953, p. 50, footnote 2; Sachs, 1957, p. 106), it may be assumed that *P. (A.) stephensoni* ranges from the Paleocene into the lower Eocene Oldsmar Limestone of Florida.

Bronnimann and Rigassi (1963, p. 292) wrote " . . . Apolo outcrops contain *'Operculina' catenula* Cushman and Jarvis, *'Amphistegina' lopeztrigoi, Discocyclina barkeri* Vaughan and Cole, *Discocyclina anconensis* Barker and usually other discocyclinas, pseudophragminas and proporocyclinas. This association is closely related with that of the younger Alkázar formation".

The Apolo Formation is assigned to the lower Eocene *Globorotalia angulata* zone (Bronnimann and Rigassi, 1963, p. 293) and the overlying Alkázar sediments are referred to the *Globorotalia velascoensis - Globorotalia pseudomenardii* zone (p. 309) of the lower Eocene. These two planktonic zones are included in a larger foraminiferal zone, the *"Operculina" catenula* biostratigraphic zone (Bronnimann and Rigassi, 1963, plate 1).

The assignment of Cuban specimens identified as *"Operculina" catenula* and certain other species of larger Foraminifera which are known elsewhere to be associated with *P. (A.) stephensoni* to these planktonic zones suggests a definite placement of these benthonic species, at least, so far as the lower stratigraphic limit of this benthonic fauna is concerned.

The *Globorotalia angulata* and *G. velascoensis - G. pseudo menardii* zones of Bronnimann and Rigassi (1963, p. 293 and plate 1) are the stratigraphic equivalent of three zones *(Globorotalia pusilla* to *G. velascoensis* recognized by Bolli, 1957, p. 63) in the upper part of the lower Lizard Springs Formation of Trinidad. Bolli assigned these zones to the Paleocene, whereas Bronnimann and Rigassi placed them in the lower Eocene.

As early as 1938 Cole (p. 23) recognized in a well drilled in Jackson County, Florida at a depth of 1761-1768 feet " . . . an excellent fauna of undoubted Midway age". In this same well at depths between 1390-1412 feet Cole (1938, p. 31) identified *Discocyclina cookei Vaughan (=P. (A.) stephensoni)* and correlated this part of the well with the Salt Mountain Limestone.

Recently, Mrs. E. A. Applin (1964, p. 51) has given an excellent account of the Paleocene biofacies of western Florida with a detailed discussion (p. 52) of the occurrence of *Globorotalia velascoensis* in this and other areas. So far as I know, *G. velascoensis* in Mexico, Trinidad, and Florida does not range above the Paleocene.

Mrs. Applin (1964, p. 54) wrote "It is, therefore, difficult to understand the assignment of the Salt Mountain Limestone to the '*G. velascoensis* Zone' . . ." by Loeblich and Tappan (1957, p. 177). In the well in Jackson County, Florida (Cole, 1938, pp. 23, 31), the Salt Mountain Limestone occurs stratigraphically well above the first appearance of a typical Midway fauna.

Butterlin (1967, p. 14) and Butterlin and Bonet (1960, p. 5) found in Yucatan *Camerina catenula* and other species of Foraminifera in sediments which they correlate with the lower Eocene. Among the associated species are *Borelis floridanus* Cole, a supposed marker for the Cedar Keys Limestone (Paleocene) and *Coskinolina elongata* Cole, diagnostic of a zone in the Oldsmar Limestone (lower Eocene). All of these species may have a longer stratigraphic range, similar to that of *P. (A.) stephensoni,* than has heretofore been suspected so that in terms of the Gulf Coast stratigraphic section these sediments could be either high Paleocene or low lower Eocene. More data are needed, especially correlation with the planktonic zones which have been established.

In summary, *Camerina catenula* and *P. (A.) stephensoni* have been reported in association at a number of localities in the Caribbean region, and several of these localities seem to represent the *Globorotalia velascoensis* planktonic zone. This zone, moreover, has been accepted generally as one of the zones of the Paleocene. However, in Florida (Cole, 1944, p. 34) and Mexico (Butterlin, 1967, p. 549) *P. (A.) stephensoni* occurs with *P. (Pseudophragmina) cedarkeysensis,* a species which has been assumed to characterize the Oldsmar Limestone (lower Eocene) of Florida.

Although the data available suggest that *C. catenula* is confined to the upper Paleocene, and that *P. (A.) stephensoni* ranges from upper Paleocene into the lower Eocene, Wilcox, there is a distinct possibility that *C. catenula* also ranges upward into the lower Eocene.

However, that may be, the important fact is that there is a zone of larger Foraminifera characterized by several species of larger Foraminifera which Cole (1959, p. 378) referred to as the "*Operculina catenula* fauna" which can be recognized over a wide geographic area. Although the species composition of this fauna may vary from locality to locality because of ecological conditions, the zone can be recognized. Data available suggest that this zone seems to occupy a stratigraphic position from high Paleocene into the lower part of the lower Eocene as these terms are commonly accepted in the Americas.

Pseudophragmina (Athecocyclina) zaragosensis (Vaughan) Pl. 6, figs. 7, 8

1929. *Discocyclina zaragosensis* Vaughan, U.S. Nat. Mus., Proc., vol. 76, Art. 3, pp. 13, 14, pl. 4, figs. 1-3.
1945. *Pseudophragmina (Proporocyclina) zaragosensis* (Vaughan), Vaughan, Geol. Soc. Amer., Mem. 9, p. 100, pl. 44, fig. 1.
1960. *Pseudophragmina (Proporocyclina) zaragosensis* (Vaughan), Cole, Micropaleont., vol. 6, No. 2, p. 134, pl. 4, figs. 4, 5.
1963. *Pseudophragmina (Proporocyclina) zaragosensis* (Vaughan), Cole, Bull. Amer. Paleont., vol. 46, No. 205, p. 15, pl. 7, figs. 1-4.

Discussion.—Vaughan's (1929, pl. 4, figs. 1-3) original illustrations of this species are poor. In 1945 Vaughan (p. 100, pl. 44, fig. 1) illustrated a part of an equatorial section which he described in some detail. This section demonstrates that this species should be referred to the subgenus *Athecocyclina* as defined in this article.

At my request Lloyd Henbest of the U. S. Geological Survey photographed the vertical section (Pl. 6, fig. 8) which Vaughan (1929, pl. 4, fig. 3) published and another topotype (Pl. 6, fig. 7). Certainly additional preparations are necessary, but these demonstrate that *Pseudophragmina (Athecocyclina) zaragosensis* is a different species than *P. (Pseudophragmina) cedarkeysensis* Cole (see discussion under that species).

Specimens from the Weston Library well No. 2, Sun Oil Company, Hancock County, Mississippi, at a depth of 4510-4540 feet which Cole (1960 *a,* p. 134, pl. 4, figs. 4, 5) identified as *P. (Pro-*

porocyclina) zaragosensis are definitely this species, but should be assigned to the subgenus *Athecocyclina.*

These interesting specimens with multiple sets of bilocular embryonic chambers have the same type of open annuli without radial chamber walls (Cole, 1960 *a,* pl. 4, fig. 4) similar to the topotype illustrated by Vaughan (1945, pl. 44, fig. 1). The vertical section (Cole, 1960 *a,* pl. 4, fig. 5) has the same strong pillars, lateral chambers, and equatorial layer which characterize the types of *P. zaragosensis* (Pl. 6, figs. 7, 8).

The specimens from Mississippi were preserved in such a manner that by placing a knife on the equatorial plane at the periphery, it was possible to split the specimens along the equatorial plane. Illustrations (Cole, 1963, pl. 7, figs. 1-4) of several specimens prepared in this manner have been published.

These specimens do not have any radial chamber walls. The annular walls in most cases when observed in three dimensions in these preparations consist of a series of small, upward projections between which are depressions. This arrangement shows clearly in some of the illustrations (see, fig. 1, and parts of figs. 2, 4, pl. 7, Cole, 1963). The depressions between the projections are about the same size as the projections and seem to be closely spaced radial stolons.

So far as I can ascertain this is the only locality in addition to the type locality from which this species has been recognized.

Stratigraphic position.—Vaughan (1945, p. 100) wrote that *P. zaragosensis* at its type locality in Nuevo Léon, Mexico, was associated with *Venericardia (Venericor) diga* Gardner and Bowles. Vaughan stated that the late Dr. Julia Gardner considered the horizon to be equivalent to the Tuscahoma Formation (lower Eocene, Wilcox Group) of the eastern Gulf Coast of the United States). If this is correct, *P. zaragosensis* occurs at a higher stratigraphic horizon than *P. (Pseudophragmina) cedarkeysensis* Cole and *P. (Athecocyclina) stephensoni* (Vaughan).

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PLATES

Explanation of Plate 1

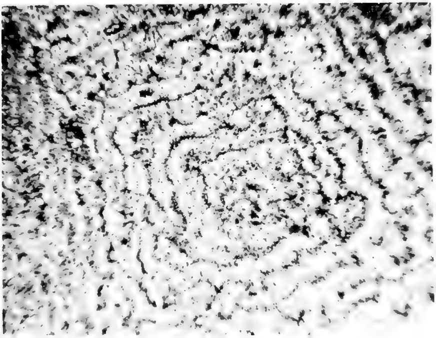
Figure Page

All figures, × 40.

1-6. **Pseudophragmina (Pseudophragmina) floridana** (Cushman) 22, 23, 25

1. Central part of a vertical section of a well-developed megalospheric specimen (entire specimen illustrated as fig. 588, 1*c*, Treatise on Invertebrate Paleont., Part C, Protista 2, vol. 2, 1964). 2. Vertical section of a small megalospheric specimen. 3. Central part of an equatorial section of a microspheric specimen. 4-6. Central parts of equatorial sections of megalospheric specimens. 6. Same specimen as fig. 588, 1*a*, Treatise on Invertebrate Paleont., Part C, Protista 2, vol. 2, 1964.

1-6. Locality 10, Florida, Ocala Limestone, upper Eocene. See text for locality descriptions.



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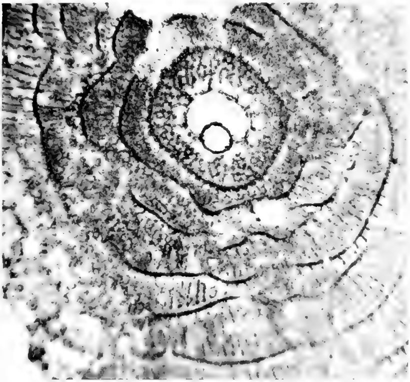

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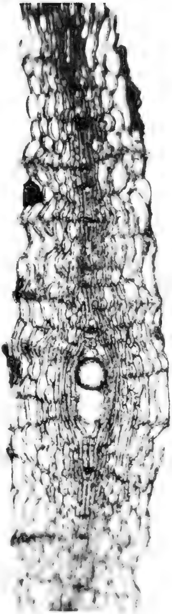

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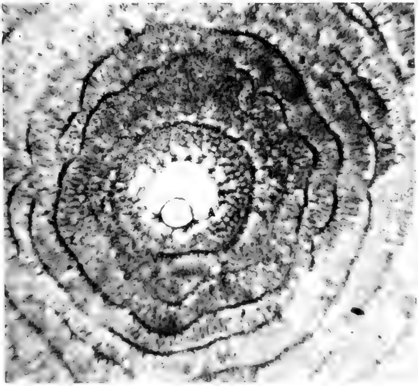

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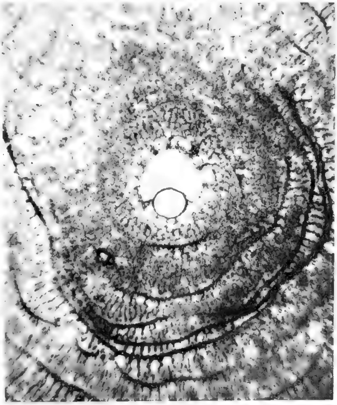

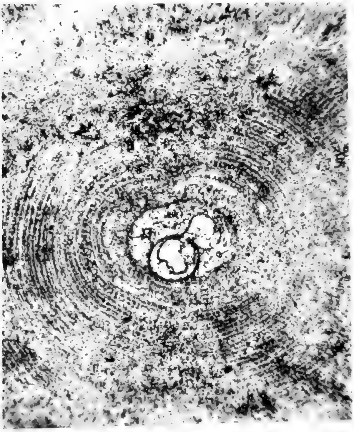
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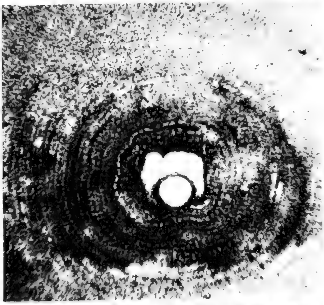
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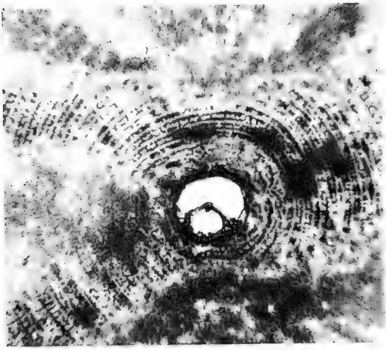
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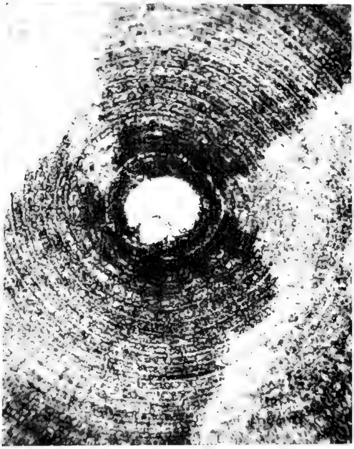
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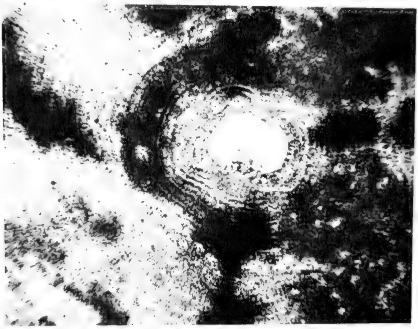
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Explanation of Plate 2

Figure		Page
	Central parts of equatorial sections of megalospheric specimens, × 40.	
1-6.	**Pseudophragmina (Athecocyclina) advena** (Cushman)	13, 25, 26, 27, 28

1. Topotype of *Orthophragmina advena* Cushman. 2. Specimen identified as *Pseudophragmina (Proporocyclina) perkinsi* (Vaughan) by Cole (*in* Cole and Applin, 1964, p. 28). 3,4. Topotypes in *Discocyclina cloptoni* Vaughan. 5,6. Specimens identified by Vaughan (1945, p. 99) as *Pseudophragmina (Proporocyclina) perkinsi* (Vaughan).

1. Loc. 12, Louisiana, middle Eocene.
2. Loc. 3, Jamaica, middle Eocene.
3,4. Loc. 4, Baja California, middle Eocene.
5,6. Loc. 1, Cuba, upper Eocene.
See text for locality descriptions.

Explanation of Plate 3

Figure		Page
	Parts of equatorial sections, × 210, to illustrate annuli and equatorial chambers.	
1-4.	**Pseudophragmina (Athecocyclina) advena** (Cushman)	10, 13, 25, 27, 28

1. Specimen identified as *Pseudophragmina (Proporocyclina) perkinsi* (Vaughan) by Cole (*in* Cole and Applin, 1964, p. 28); embryonic chambers of this specimen illustrated as fig. 1, Pl. 8. 2. Specimen identified by Vaughan (1945, p. 99) as *P. (Proporocyclina) perkinsi* (Vaughan). 3. Topotype of *Discocyclina cloptoni* (Vaughan); embryonic chambers of this specimen illustrated as fig. 3, Pl. 2. 4. Topotype of *Orthophragmina advena* Cushman; embryonic chambers of this specimen illustrated as fig. 1, Pl. 2.

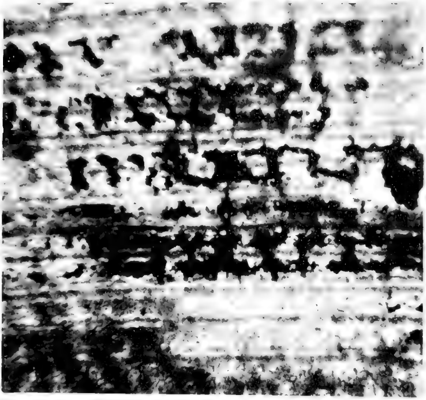
Figure		Page
5.	**Pseudophragmina (Pseudophragmina) flintensis** (Cushman)	8, 10, 11, 13, 22

Specimen originally named *Discocyclina perpusilla* (Vaughan); equatorial section of this specimen illustrated as fig. 7, Pl. 7.

Figure		Page
6.	**Pseudophragmina (Pseudophragmina) bainbridgensis** (Vaughan)	11, 12, 13, 14

Specimen identified as *P. (P.) bainbridgensis* var. *angusta* Vaughan (1945, p. 87); equatorial section of this specimen illustrated as fig. 7, Pl. 9.

1. Loc. 3 — Jamaica, middle Eocene.
2,6. Loc. 1 — Cuba, upper Eocene.
3. Loc. 4 — Baja California, middle Eocene.
4. Loc. 12 — Louisiana, middle Eocene.
5. Loc. 6 — Mexico, middle Eocene.
See text for locality descriptions.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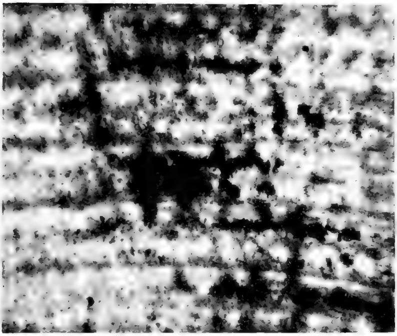
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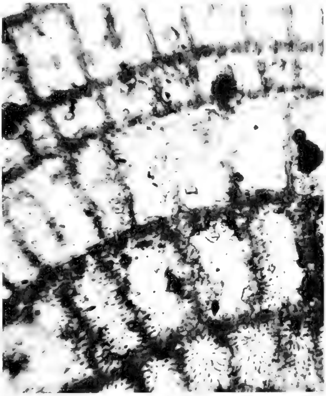
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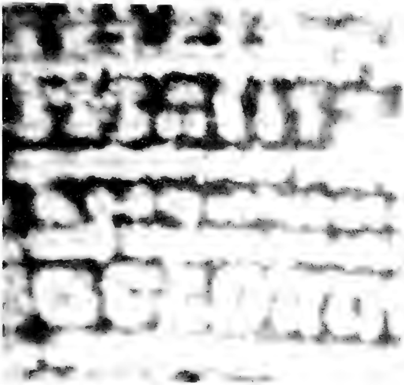
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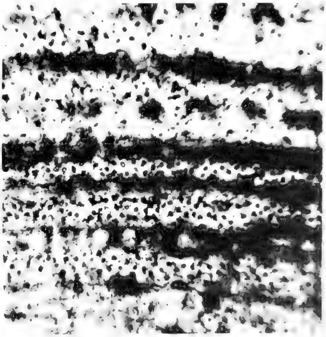
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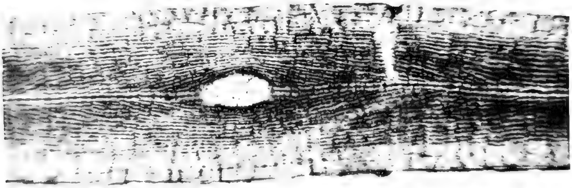

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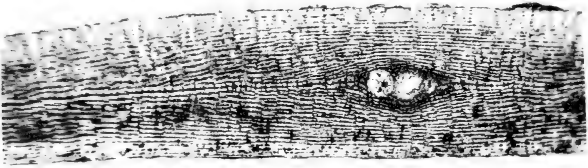

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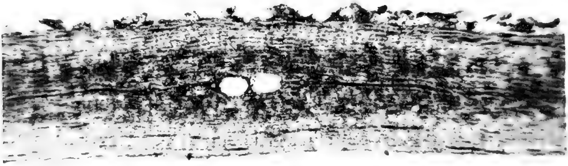

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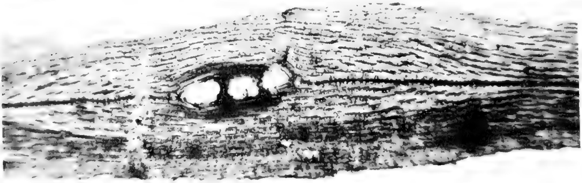

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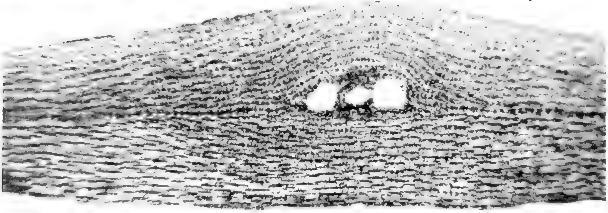

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Explanation of Plate 4

Figure Page

Central parts of vertical sections of megalospheric specimens, ×40.

1-8. **Pseudophragmina (Athecocyclina) advena** (Cushman) 25, 27, 28

1,2. Specimens identified by Vaughan (1945, p. 99) as *Pseudophragmina (Proporocyclina) perkinsi* (Vaughan). 3-5. Topotypes of *Discocyclina cloptoni* Vaughan. 6. Specimens identified as *P. (Proporocyclina) perkinsi* (Vaughan) by Cole (*in* Cole and Applin, 1964, p. 28). 7. Syntype of *P. (Proporocyclina) compacta* Cole and Gravell (after Cole and Gravell, 1952, pl. 100, fig. 6). 8. Topotype of *Orthophragmina advena* Cushman.

1,2. Loc. 1 — Cuba, upper Eocene.
3-5. Loc. 4 — Baja California, middle Eocene.
6. Loc. 3 — Jamaica, middle Eocene.
7. Loc. 2 — Cuba, middle Eocene.
8. Loc. 12 — Louisiana, middle Eocene.
See text for locality descriptions.

Explanation of Plate 5

Figure Page

1. **Pseudophragmina (Pseudophragmina) tobleri** Vaughan and Cole 10, 11, 12, 13
   Equatorial chambers, × 210, of a topotype; specimen illustrated as fig. 11, pl. 32, Cole, 1959.

2-4. **Pseudophragmina (Athecocyclina) advena** (Cushman) 25, 27
   2,3. Central parts of vertical sections, × 40, of specimens identified by Vaughan (1945, p. 99) as *Pseudophragmina* (*Proporocyclina*) *perkinsi* (Vaughan). 4. Part of an equatorial section, ×40, of a specimen identified as *P.* (*Proporocyclina*) *perkinsi* (Vaughan) by Cole (*in* Cole and Applin, 1964, p. 28).

5,6. **Pseudophragmina (Pseudophragmina) clarki** (Cushman) 10, 13, 20
   5. Part of an equatorial section, ×40, by transmitted light. 6. Part of an equatorial section, ×20, by reflected light; compare with the specimen fig. 9, pl. 77 identified by H. G. Schenck (*in* Cushman and McMasters, 1936, p. 516) as *Discocyclina cloptoni* Vaughan.

1. Loc. 7 — Trinidad, lower Eocene.
2,3. Loc. 1 — Cuba, upper Eocene.
4. Loc. 3 — Jamaica, middle Eocene.
5,6. Loc. 9 — California, middle Eocene.
See text for locality descriptions.

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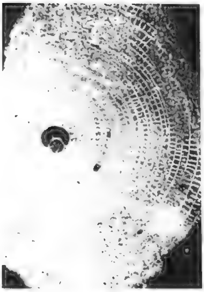

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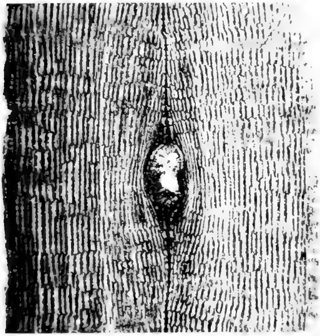

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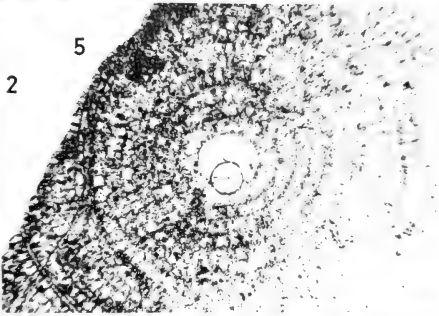

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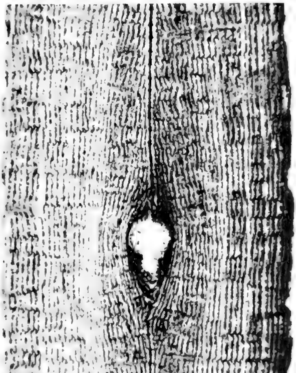

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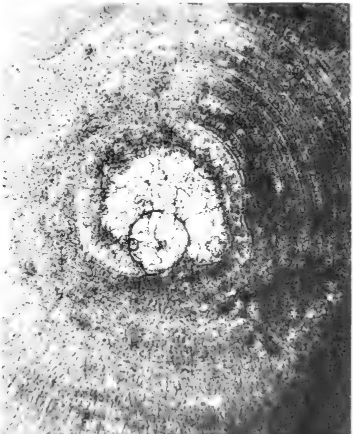

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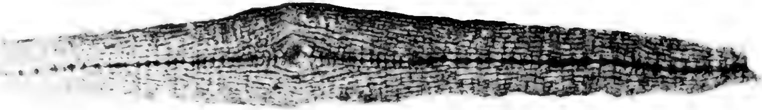
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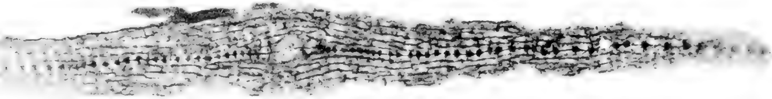
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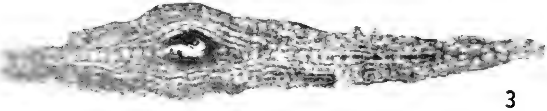
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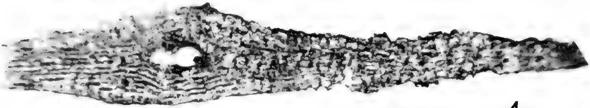
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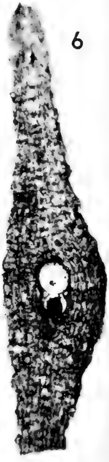
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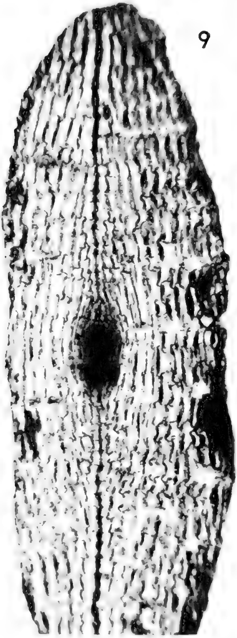
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Vertical sections, × 40, except 5, × 20.

1,2. **Pseudophragmina (Athecocyclina) stephensoni** (Vaughan) . 30
New illustrations of two of the syntypes of *Discocyclina cookei* Vaughan (1936, pl. 42, figs. 4,5), a synonym of *P. stephensoni*.

3,4,6. **Pseudophragmina (Pseudophragmina) clarki** (Cushman) . 20
Vertical sections.

5,9. **Pseudophragmina (Pseudophragmina) cedarkeysensis** Cole 16
Vertical sections of topotypes of *Pseudophragmina hannai* Cole, a synonym of *P. cedarkeysensis*.

7,8. **Pseudophragmina (Athecocyclina) zaragosensis** (Vaughan) . 37
New illustrations of *Discocyclina zaragosensis* Vaughan. 7. Vertical section, not centered, of a topotype. 8. Syntype illustrated by Vaughan (1929, pl. 4, fig. 3).

1,2. Loc. 8 — Alabama, lower Eocene.
3,4,6. Loc. 9 — California, middle Eocene.
5,9. Loc. 11 — Florida, lower Eocene.
7,8. Loc. 5 — Mexico, lower Eocene.
See text for locality descriptions.

Explanation of Plate 7

Figure Page

All figures, × 40, except 4, × 20.

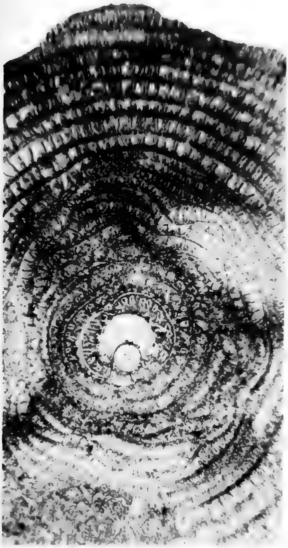
1,2,6. **Pseudophragmina (Pseudophragmina) cedarkeysensis** Cole 10, 13, 16

1,2. Parts of equatorial sections of megalospheric specimens, topotypes of *Pseudophragmina (Proporocyclina) hannai* Cole. 6. Vertical section of a megalospheric specimen, topotype of *P. (Proporocyclina) hannai* Cole.

3-5,7. **Pseudophragmina (Pseudophragmina) flintensis** (Cushman) 10, 11, 22, 25, 27

3. Part of an equatorial section of a Cuban specimen identified by Vaughan (1945, p. 89) as *P. (Proporocyclina) flintensis* (Cushman). 4,5. Vertical sections of Cuban specimens identified by Vaughan (1945, p. 89) as *P. (Proporocyclina) flintensis* (Cushman). 7. Equatorial section of a Mexican specimen originally identified as *Discocyclina perpusilla* Vaughan.

1,2,6. Loc. 11 — Florida, lower Eocene.
3-5. Loc. 1 — Cuba, upper Eocene.
7. Loc. 6 — Mexico, middle Eocene.
See text for locality descriptions.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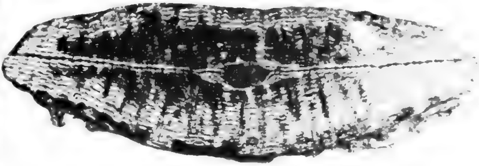
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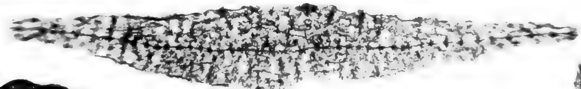
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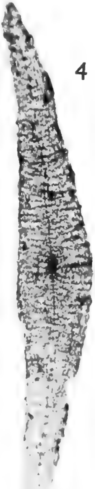
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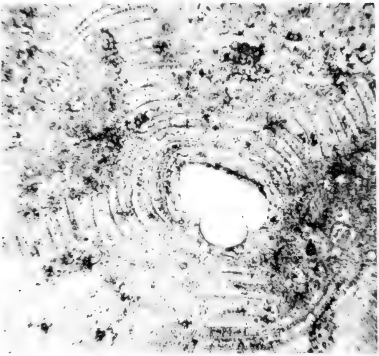

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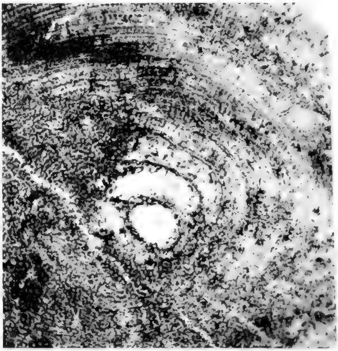

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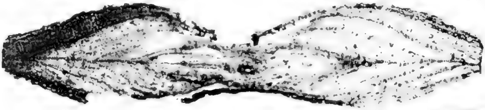

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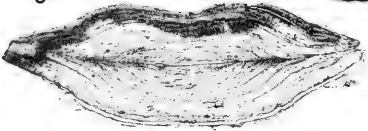

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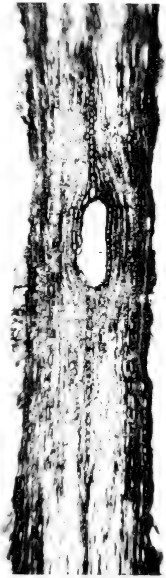

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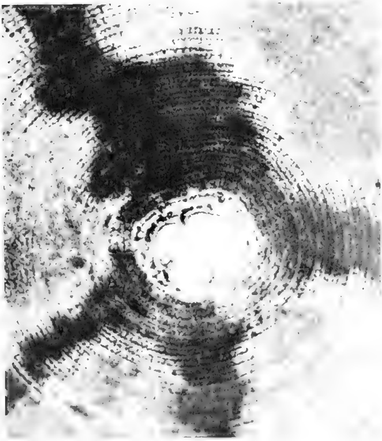

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1-8.	**Pseudophragmina (Athecocyclina) advena** (Cushman)	10, 13, 25, 26, 27, 28

1,2,8. Parts of equatorial sections. 1. Specimen identified as *Pseudophragmina (Proporocyclina) perkinsi* (Vaughan) by Cole (*in* Cole and Applin, 1964, p. 28). 2. Specimen identified by the late D. W. Gravell as this species. 8. Topotype of *Discocyclina cloptoni* Vaughan. 3-5. Vertical sections of topotypes with slitlike cavities of the lateral chambers. 3,4. Megalospheric specimens. 5. Microspheric specimen. 6. Part of a vertical section of a megalospheric specimen with open cavities of the lateral chambers, particularly in the peripheral zone. 7. Specimen identified as *P. (Proporocyclina) perkinsi* by Cole (*in* Cole and Applin, 1964, p. 28).

1,7. Loc. 3 — Jamaica, middle Eocene.
2. Loc. 13 — Louisiana, middle Eocene.
3-6. Loc. 12 — Louisiana, middle Eocene.
8. Loc. 4 — Baja California, middle Eocene.
See text for locality descriptions.

Explanation of Plate 9

Figure		Page
	All figures × 40
1-5,7.	**Pseudophragmina (Pseudophragmina) bainbridgensis** (Vaughan)	11, 12, 14

1,3. Vertical sections of topotypes of *Pseudophragmina (Pseudophragmina) novitasensis* Vaughan. 1. Evenly lenticular specimen, section not exactly centered. 3. Umbonate specimen. 2. Vertical section of a topotype of *P. (Pseudophragmina) bainbridgensis* "var." *angusta* Vaughan. 4,5. Parts of equatorial sections of topotypes of *P. (P.) novitasensis* Vaughan. 7. Part of an equatorial section of a topotype of *P. (P.) bainbridgensis* "var." *angusta* Vaughan; for enlarged equatorial chambers of this specimen, see fig. 6, Pl. 3.

| | |
---|---|---
6. | **Pseudophragmina (Pseudophragmina) floridana** (Cushman) | 8, 11, 12, 22, 23

Peripheral equatorial chambers.

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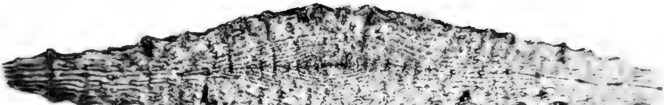
6. Loc. 10 — Florida, upper Eocene.
See text for locality descriptions.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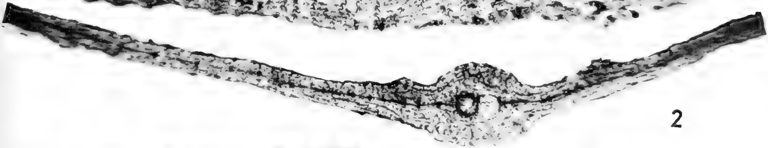
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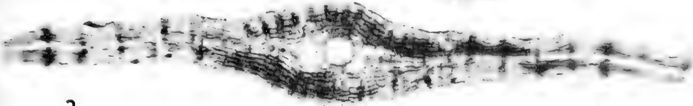
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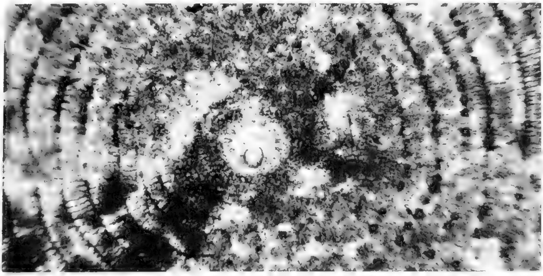

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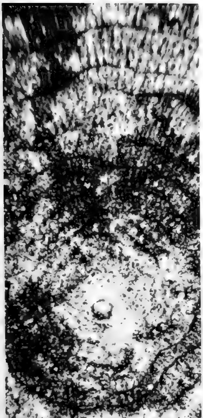

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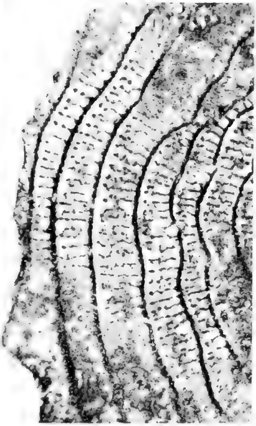

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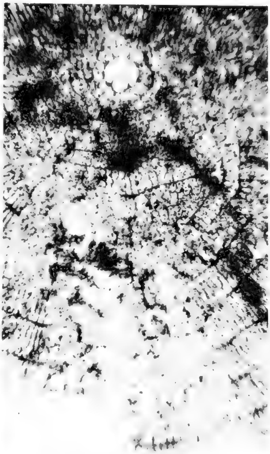

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No. 248

BULLETINS
OF
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(Founded 1895)

Vol. 56

No. 249

REPRINT in PART

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of the
NORTH CAROLINA GEOLOGICAL SURVEY
AGRICULTURE OF THE EASTERN COUNTIES;
together with
DESCRIPTIONS OF THE FOSSILS OF THE MARL BEDS

By

Ebenezer Emmons

1858

1969

Paleontological Research Institution
Ithaca, New York 14850, U.S.A.

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1968 - 1969

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Printed in the United States of America

Preface to the Reprint

The "Report of the North Carolina Geological Survey; Agriculture of the Eastern Counties," by Ebenezer Emmons, published in 1858, has been out of print for many years. Over one third of the report is given over to the description and illustration of fossils, both vertebrate and invertebrate, many of which were new. The vertebrates range from Cretaceous reptiles to Tertiary sharks and Pleistocene mammals, but the invertebrates furnished the greater part of the new taxa. These are mostly Miocene mollusks, but a few Eocene echinoids and Bryozoa are also described. The fossils came from locally available marls which were then widely dug and used as a fertilizer. Later publications have superseded the parts concerned with agriculture, but the pages devoted to the description and illustration of the fossils and to the description of the marl deposits and the localities from which the fossils came are a part of the basic geologic data of the Atlantic Coastal Plain and are reprinted here. The reprint to which an index has been added consists of pages [i-ii], ix-x, 78-111, 193-314, or about one half of the original xvi plus 314 pages of the report.

We gratefully acknowledge the contribution of James E. Allen of Alexandria, Louisiana, who furnished the negatives for the publication and to Druid Wilson, United States Geological Survey, for making the extensive Index of the original work.

Dr. Jasper L. Stuckey, State Geologist of North Carolina, graciously permitted the Paleontological Research Institution to publish this reprint of the early North Carolina Geological Survey.

Katherine V. W. Palmer
Director

REPORT

OF THE

NORTH-CAROLINA GEOLOGICAL SURVEY

AGRICULTURE OF THE EASTERN COUNTIES:

TOGETHER WITH

DESCRIPTIONS OF THE FOSSILS OF THE MARL BEDS.

Illustrated by Engravings.

BY

EBENEZER EMMONS.

RALEIGH:
HENRY D. TURNER.
1858.

To His Excellency, Thomas Bragg,

Governor of North-Carolina:

Sir:

I am gratified that another opportunity is furnished me to express my obligations to your Excellency for the interest you still entertain for the Geological Survey of North-Carolina. This fact, while it has been extremely gratifying, serves at the same time to impress me with the importance of the work, and to excite a fear, also, that it may fall short of your expectations, and thus disappoint, not only yourself, but many others who feel and manifest an interest in its success. No one, however, could feel a greater disappointment at such a result than myself; and fearing that my labors, together with the labors of those who assist me, might fail to be satisfactory, I have certainly lost no time, nor spared any work, which I deemed necessary to secure the wished-for result.

With the consciousness, then, of having done this much for its success, I submit with cheerfulness this second report to your Excellency's consideration.

I am, Sir,

Your obedient servant,

EBENEZER EMMONS.

Raleigh, *March* 1, 1858.

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ses, however, that the ash is variable in the proportions of its elements.

The tobacco which obtains the highest price in the Paris market contains a much larger proportion of potash and less lime. This specimen had the fine yellow brown color which is regarded as indicative of the best quality. As it is, however, it is a lime plant, nearly one-half being composed of carbonate of lime.

CHAPTER VI.

FERTILIZERS—CONTINUED.

Marl beds, or Marl formations.—The different periods to which they belong, or their relation to each other.

§ 52. There are three distinct formations from which marl is obtained. Enumerating them in the ascending order, or according to age, they lie relatively to each other as follows: 1. *Green Sand;* 2. *Eocene Marl;* 3. *Miocene Marl.*

The first, or green sand, is the formation which is so favorably known in New Jersey as a fertilizer, having been employed for that purpose for more than half a century. It derived its name partly from its green color, and partly from its granular consistence. The beds thus named are known not only in this country but also in many parts of Europe by the same name, and where, to a certain extent, they are also used as a fertilizer.

In the geological systems its beds are subordinate to the cretaceous system, and in Europe form subordinate beds beneath the chalk—the white chalk in common use for marking.

In this country this part of the cretaceous system is wanting, or has not yet been recognized. From its wide extent, both in this country and Europe, it is, geologically speaking, an important formation; so also in an economical point of view it is equally important, for it has been a source of revenue to the agricultural community, not second even to guano. For permanent improvements in the soil it is superior to this far famed substance, its effects lasting from ten to fifteen years. In New Jersey it first attracted attention from an accident: some green sand being thrown out of a ditch upon a bank, an exceeding fine growth of clover was the consequence. It was immediately inferred that the substance upon the ditch bank was the cause of this fine growth; and hence a trial was made of it.

From many subsequent experiments and observations its claim as a good fertilizer became established. This happened more than fifty years ago, and ample experience in the mean time has fully satisfied the agricultural community at large that it is worthy the confidence which has been reposed in it.

§ 53. In the subsequent pages I propose to give a full statement of the grounds upon which its reputation rests, and also to furnish numerous analyses of the best and poorest varieties of this substance. In the first place I deem it proper to show its geological relations, and its relative position to other beds of marl, inasmuch as it will aid in determinining in any given case whether the substance or beds in question really belong to those which have received the common name referred to. In all cases this is an economical question, or may be thus used, inasmuch as the beds formed during this geological era have a composition which fits them for the purpose for which they have been so largely employed. Beds, therefore, occupying their position may be supposed without trial and without analysis to contain the active fertilizing matter. It, however, cannot be determined by these external observations, how much they contain, for it is found that they are variable in composition, so far as quantity is concerned. For the purpose of determining their commercial value, or to ascertain the amount which may be profitably employed and how far they may be transported has to be ascertained by analysis.

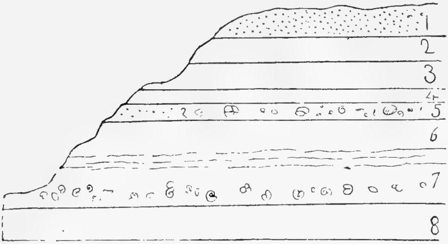
There are several localities at which the green sand occurs. The strongest marl beds occur at Black Rock on the Cape Fear river, about twenty-five miles above Wilmington. It forms low bluffs at several other points, but it appears to terminate from two to five miles below Brown's landing.

Striking across the county to the eastward it again appears prominently at Rocky Point, twenty miles above Wilmington. The green sand, unlike the shell marl, forms continuous beds, but as its beds are undulating, they rise at certain points to the surface, and then sink beneath it.

In this State I have been unable to determine its thickness, or the number of beds which properly belong to it. For this reason I propose to describe them now, as they are known to exist in New Jersey, inasmuch as such a description may aid others where it exists, to determine with accuracy both their thickness and the number of beds which compose the green sand formation in North-Carolina. The difficulty in the way of solving this question is the slight elevation of the banks of rivers and ravines above the adjacent country. We find at Black Rock, for example, a strong bluff of this deposit, but the water is never low enough to disclose the bottom beds, or the masses upon which it rests.

In order to state all that is known of the green sand and marl, and their relations to each other, I have prepared several sections which show how they are situated with respect to each other. From these sections it will be seen that the marl beds vary much in thickness, and in their relations at different places where they are exposed to the best advantage. Thus, section I, fig. 1, exhibits all the beds as they exist at Black Rock:

FIG. 1.



1. The upper bed is the common marine sand spread widely over the county. 2. Beneath it there is a mass of brown soil, or earth, which is probably more widely spread than any other in the eastern part of the State. It is sometimes pebbly towards the upper part, and at many places the pebbles are cemented by oxide of iron. A pudding stone is thereby formed, which is very firm, and has been employed as a rough building material. In the vicinity of Fayetteville it is not unfrequently used for the more ordinary kinds of construction. From the vicinity of Raleigh eastward it may be seen by the road-side where a cut has been extended through the superincumbent sand. This bed, which is at least twelve feet thick at Fayetteville, originated in the decomposition of primary rocks, the debris of which becomes red, or reddish brown, by exposure to the atmosphere. If any thing, it is more persistent towards the belt where these rocks formed the surface materials. How this stratum has been spread out so evenly and widely through the whole width of the State from south to north is not satisfactorily accounted for. Along the western margin referred to it rests on the rocks from which it is derived. Eastward, however, where recent beds of different kinds take their proper places, this brown earth formation is found near the surface, but with several marine strata beneath and upon which it reposes. It always maintains the position I have given it, or its relations are never altered; and hence, though it may be regarded as a soil, still it must

have been spread out by some general cause, and at one specific period.

This bed, however, is not confined to this State. It extends over a part of Maryland, Virginia, South Carolina, Georgia, and Alabama.

It is, therefore, a wide spread stratum, having its origin through the influence of general causes. That this cause or force operated with considerable violence is indicated by the losses which one at least of the inferior formations has sustained. The shell marl, for example, is never a continuous deposit, and some of the beds are frequently furrowed and channelled, apparently by a rush of water over them, removing not only the upper layers, but cutting frequently deep into the beds. An erosion of this kind is illustrated by fig. 5. The brown earth fills these eroded channels without mixing at all with the marl.

The next stratum beneath is a brick clay, which is also general, but it is absent occasionally, in which case the brown bed occupies its place. This clay varies considerably in composition; it is sometimes charged with sand, in others it is very fine and compact, and makes the best of brick. It passes also into potter's clay. It is bluish white, gray and reddish at different places. It never exceeds five feet in thickness.

4. The fourth stratum is sand, usually gray, and loose in texture, not unlike quick sand.

5. The shell marl occupies the fifth place in the descending order. It will be fully described hereafter.

6. The beds of green sand occupy the sixth place, and at Blackrock it may be divided into two beds; the upper contains a large amount of clay, and the lower is sandy with more lime; it is also indurated, or partially consolidated.

The lower mass forms a shelving projection from the upper, some eight or ten feet wide, when it falls off perpendicularly to a depth of fifteen feet. The lower part is always under water, and I know of no locality at which this part of the formation is exposed. I regard this as an unfortunate circumstance, inasmuch as I have reason to believe that the quality of the marl is better towards the bottom, or lower in the bank, than where it is exposed. At certain points in New Jersey it has a sandy base, but several feet above it becomes a rich marl.

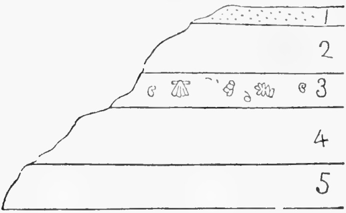
The color of this kind of marl is green or dark green. It is always rather sandy, but still it is rich even then in fertilizing matter. The Blackrock beds here have a dark green, or greenish gray, and may be divided into two parts: the *upper* which has a darker color, and is much like clay to the feel; and the *lower*, which is consolidated and of a greenish gray, and rather gritty to the touch. There is no dividing line which is so clearly marked that we can fix upon the termination of the lower, and the beginning of the upper division, but still the difference observable is sufficiently strong to admit of the division I have proposed; though, geologically, it may be regarded as one mass. The division is more important in an economical point of view, inasmuch as the composition of the upper is quite dissimilar to the lower bed.

§ 54. In New Jersey the green sand formation is composed of six distinct beds; three of which are known as green sand proper, in consequence of the peculiar composition; and three which are composed of a common marine sand, and which separates each of the respective beds from the other. In North-Carolina it is probable that equivalent beds exist, but it has been impossible up to this time to recognize but two. At Blackrock the lowest is known by its fossils: the Exogyra costata, Ostrea falcata, Belemintes Americana, and casts of the cucullea vulgaris. This mass terminates in one which is quite argilaceous, and in this part of it no fossils have been observed.

The third or upper bed may be probably recognized at Tawboro', on the Tar river, at the marl beds of Col. Clark. It is only about four feet thick, but is underlaid by sand, in which much sulphuret of iron is disseminated.

The annexed section, fig. 2, shows the relations of the beds referred to upon the Tar river:

FIG. 2.



Soil. 1. Ten feet of yellow sand. 2. Four feet of greenish clay. 3. Six feet of shell marl. 4. Four feet of upper shell marl, containing lignite and pyrites. 5. Light gray sand, the thickness of which is undetermined, as it extends below the water of the Tar river, and does not become visible at any other place in the vicinity. It is probably one of the sand beds which seperate two of the adjacent beds of green sand. But as it has not furnished fossils it cannot be confidently maintained. It is, however, mineralogically, a green sand.

As all the beds of green sand are never exhibited at one place, and as those which have been spoken of, except the upper, on the Tar river, the thickness of this formation remains undetermined.

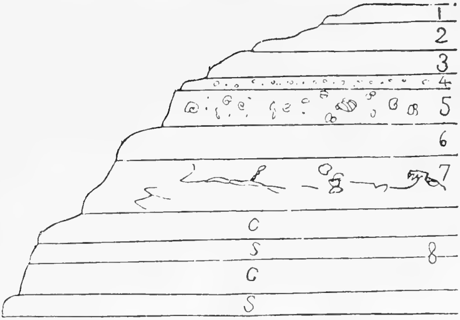
Wherever it occurs the country is comparatively low, and at no point yet discovered has the base of the Blackrock mass or lowest been sufficiently elevated to disclose, even approximately, its thickness.

§ 55. The bluffs which exhibit the tertiary and secondary formations of the eastern counties are mostly upon the south-side of the rivers and ravines. Some of these bluffs are high and commanding, but they are never continuous for long distances. The green sand does not appear in any bluff above Brown's landing. Indeed it disappears about three miles below, and though this landing is high and bold, yet I am unable to recognize a bed which can be referred to the upper part of the secondary formation.

At Brown's landing there are numerous distinct beds. In arrangement they belong to two distinct dates: 1st, the upper which is Miocene, and the lower which is probably Eocene.

These beds are exhibited in the following section:

FIG. 3.



1. Sand. 2. Brown earth. 3. Clay, four or five feet thick. 4. Sand and pebbles. 5. Shell marl. 6. Sand, with consolidated beds which becomes a gray sandstone, with fossils and lignite. 7. Blue clay. 8. Sand, blue clay, succeeded again by sand. The formation below is here concealed under water.

The most interesting points at Brown's landing are the thick beds of sand and clay beneath the shell marl, the latter of which is identical with that at Black Rock, where, it will be recollected, this marl rests upon the upper bed of green sand. At the landing we find interposed at least sixty feet of material which does not occur at Black Rock at all. These intervening beds I regard as Eocene. It may, however, prove to be Miocene, and as a part of the lignite formation equivalent to that which is spread over large tracts of country in Nebraska and Kansas. It has consolidated beds, cemented by carbonate of lime, in which lignite is very common. Another fact of interest is the presence of green sand in the shell marl, while it is almost entirely absent in the inferior beds. The marl contains, also, Exogyra, Belemnites and coprolites which belong to the green sand which were washed from these beds. The change in passing from the Eocene to the Miocene was attended with considerable violence, as the latter have abundance of pebbles, rolled coprolites as hard as quartz, teeth, etc. The bottom is truly a pebbly bed.

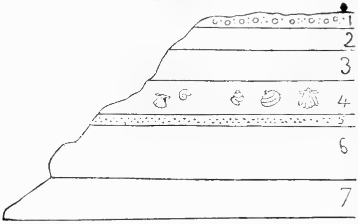
§ 56. The sand beds beneath the shell marl extend nearly to Fayetteville. They may be examined at the bridge over Rockfish creek, seven miles from Fayetteville, and at Mrs. Purdy's marl bed, ten miles above Elizabethtown, and, also, at Elizabethtown, in the high banks below the village.

The sand of this formation, when it is unconsolidated, is loose and caves from its banks continually. In addition to lignite and a few shells it contains an abundance of iron pyrites. Its whole thickness on the Cape Fear is about seventy feet.

It is possible the beds may be recognized on the Neuse and Tar rivers, especially at the Sarpony hills, fourteen miles below Goldsboro'.

§ 57. The bluff below Elizabethtown presents the following strata, as exhibited in fig. 4:

FIG. 4.

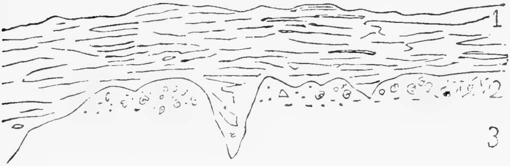


1. Sand with pebbles. 2. Brown earths. 3. Sand. 4. Shell marl three feet thick. 5. Sand containing lignite and consolidated layers, with numerous fossils.

The beds of sand with lignite or charred wood are similar to those of Brown's landing and Walker's bluff. But there are no particles of green sand or fossils from this formation in the shell marl bed. It appears that the shell marl beds in which are intermingled the organic remains from the secondary, are confined to a narrow belt which may be traced along the eastern border of the formation.

Section No. 5 is designed to show the relations of the shell marl to the white Eocene beds of the Neuse, which do not extend south-westward to the Cape Fear.

Fig. 5.



1. Soil, consisting of red earth penetrating into an excavation in the bed of Eocene marl. 2. Position of the ordinary shell marl. 3. Upper part of the bed in which most of the fossils occur. 4. Body of white, or light drab colored marl. The section shows the marl beds of Mr. Wadsworth, of Craven county.

It will be observed that the shell marl is in contact with the drab colored marl, the entire mass of the lignite formation of the Cape Fear being absent. At this place, the brown earth is present filling the ancient fissures of denudation. The shell marl is not present at this point, but appears in the same relative position three or four hundred yards west from this bed.

§ 58. The foregoing sections show the diverse nature of the beds composing many of the bluffs of the Cape Fear, Neuse and Tar rivers. The same facts would be also shown by sections at many points upon the Roanoke and Meherrin rivers farther north. The position of the shell marl seems to change, as in one case it rests upon the green sand, in the second upon a lignite formation some sixty or seventy feet thick, and then again upon a whitish marl which is well known to belong to the Eocene period.

The formation above the shell marl is mostly a marine sand. Its thickness is variable, and it is sufficiently great to prove that a long interval had elapsed before the present was fully ushered in.

§ 59. The series of beds, from the green sand upwards, which hold a definite place in the geological scale, have been exhibited in the sections alluded to, do not take in the most recent. Upon the coast or near it I have observed limited patches of peaty deposits resting upon a marine sand, and upon the former beds of shells composed mainly, if not entirely, of those which now live upon the coast. These beds of shells are rarely more than ten or fifteen feet above high tide. The peaty beds, however, lie at the water's edge, and at many points are rapidly disappearing by the action of tides and waves.

The mode in which the shells are collected appears to have been similar to that which was instrumental in the accumulation of the common shell marl; they appear to be heaps of dead shells thrown up by the waves,—still they are perfect, or are but slightly worn by attrition. Those which are changed the most have become simply chalky from the action of the weather upon them since they were deposited. The beds which are now forming have received the name of *Eolian* by Lieut. Nelson. The sands of the entire coast come under this denomination, and may be regarded as deposits overlying the accumulation of beds of shells already alluded to.

§ 60. The formations then upon the coast and interior of N. Carolina may be subdivided into: 1. *Green Sand*, an important part of the secondary; 2. *Eocene*, consisting of white marl which is made up of comminuted corals and shells, and the lignite beds which consist of gray sand and pebbles, embracing consolidated beds and a few beds of clay; 3. *Miocene* or *Shell Marl*, which is composed of fragments and entire shells accumulated in banks; 4. *Pliocene* and *Postpliocene*, which are made up of peaty beds, banks of shells, and finally, moveable sands, (Eolian sands,) which are constantly moving beyond the present coast line. It should be observed, however, that the third or Miocene division is regarded by Prof. Holmes and the late Prof. Tuomey as Pliocene.

In this State I have obtained the same fossils in equal numbers as those in Virginia, where the beds still retain the designation, *Miocene*. Not only, however, do they contain the Virginia fossils, but those which in South-Carolina have served to change the name from Meiocene to Pliocene. It appears that many of the Virginia species belong to a warm climate, that they became extinct at an earlier period than at points farther south, and that the same species which were once common on the coast of Virginia and Maryland, and which are now extinct so far as that part of our coast is concerned, still live farther south where the climate is congenial to the species.

CHAPTER VII.

FERTILIZERS—CONTINUED.

Stone Marl, its economical value.—Composition of the Green Sand of the Cape Fear River.

§ 61. The marls of North-Carolina do not rank so high as the strong marls of other States. This is in consequence of the large proportion of sand with which they are intermixed. It appears that the coast has been from time immemorial the great depository of sand. The rivers from the interior carry sand or matter in which silex greatly predominates. The rocks in the interior belong to the silicious class. Limestones are absent. But the great amount of sand of the coast has been probably derived from more distant sources, and hence it is probable we must look to the regular currents of the ocean which flow in, more or less, upon it, for the determation of the source from which its sands have been derived. When the Atlantic tide reached inland as far as the last of the series of falls of the rivers of the State, as the Roanoke, Cape Fear and Neuse, it acted upon a granite rock which readily decomposed, and which must have furnished an immense quantity of silicious debris. This rock may, therefore, have been one of the sources of the sand alluded to. Some beds of marl are consolidated into rock, and where this consolidation was effected through the agency of soluble silica, it has become a durable mass, and fit for being used in building. It has received the name of *stone marl*, which I propose to speak of in the first place.

§ 62. *Stone Marl.* There are two varieties of stone marl, both of which deserve a special notice. The first consists of shells cemented strongly together, and which are usually from one to one and a half inches across, and very uniform as to size. They are very firmly cemented by silica, which seems to have penetrated the shells more or less. This rock has been employed for a long period for small mill stones. Its valuable qualities consist in being easily wrought when first removed from the quarry, but subsequently becomes very hard and strong. Being made up of shells, it has a rough appearance, even when cut evenly; but this feature constitutes its recommendation. For certain structures it is admirably adapted. The enclosure of the cemetery in Newbern is made of this rock, and the noble arches have an imposing effect. The rock is very durable, as appears to be well sustained by the rock itself, where it is exposed, or has been exposed for ages. For rough work it may be used without dressing, but for ornamental, if dressed properly, it is far superior to granite for all structures, where the material should be indestructible. It is adapted to the construction of dwellings, as the walls will continue dry in wet weather.

This rock underlies Newbern and the adjacent county. It extends fifteen or twenty miles in a northeast and southwest direction. In some places it reaches the surface; in others it is forty to fifty feet below. I regard it as one of the best building materials in the State.

The second variety is a granular cream colored rock, and rather destitute of shells. It might be mistaken for an oolite. The grain is uniform, and like the preceding is soft, when first taken from the quarry, but becomes hard as any rock after an exposure to the air for a few months. This rock is not disposed to disintegrate, and hence in this respect is superior to granite.

This granular variety occurs in Wayne county. The rocks or consolidated parts of it are abundant on the plantation of Maj. Collier.

At a few places it is sufficiently pure to be burnt for lime; as a general rule it contains too much silex to make a strong lime.

The rock on Maj. Collier's plantation contains:

Silica,	59.400
Peroxide of iron in combination with alumina and phosphoric acid,	4.120
Carbonate of lime and a trace of magnesia,	36.480
	100.000

The amount of carbonate of lime is variable, and ranges in the consolidated varieties from 30 to 75 per cent. The silex in the rock exists in grains as sand, which are visible, but a soluble silica is no doubt the cementing material, which of course once existed in solution, or in a state of minute subdivision. This marl may be used in building, or if sufficiently pure and free from sand and silica, it may be burnt for lime, which will be adapted to agricultural purposes. Its composition fits it for this purpose as it contains a small proportion of phosphoric acid.

§ 63. The green sand is frequently partially consolidated. but never forms a building material. For agriculture, when the amount of potash is considered, it is the most important of the marls. In North-Carolina I have found no locality where its potash equals that of New Jersey. This I attribute in part to our inability to reach strata which are upon the same geological level, though it is probable that the amount of sand will be greater, and hence diminish proportionally the amount of available fertilizing matter.

The lowest mass accessible at Blackrock I found by analysis, has the following composition:

Silex and sand,	37.000
Peroxide of iron and alumina,	6.400
Carbonate of lime,	33.400
Phosphates of peroxide of iron,	1.600
Soluble silica,	1.460

Magnesia,	13.600
Potash,	1.431
Soda,	2.123
Organic matter,	1.600
Water,	1.800
	100.614

The sand is frequently in quite large angular grains. That part of the bed which is green, or properly green sand, is not so distinct as in New Jersey, and it would be impossible to separate the grains mechanically, while in New Jersey they may be separated from the other materials. These grains have been analyzed by Prof. Cook, who has found them composed of

Silica,	45.510
Protoxide of iron,	21.134
Alumina,	7.960
Magnesia,	2.400
Potash,	6.748
Lime,	3.842
Phosphoric acid,	0.990
Sulphuric acid,	1.129
Carbonic acid,	0.563
Sand,	0.850
Water,	9.110
	100.209

It has been found that the green grains in the green sand possess a very uniform composition, and that taking the average analysis of several specimens the grains contain silica, protoxide of iron, alumina, magnesia, potash and water in nearly equal proportions, while the other constituents are variable. The absence of the green grains in the marl of black rock may account for the small percentage of potash which is the principal element relied upon in the New Jersey marl. The lime and magnesia of the Blackrock marl is much greater than any of the New Jersey beds, and the sand and silica are not in great excess. It really has as much fertilizing matter as the New Jersey marl, but it is deficient in the most valuable part, potash. This element, however, seems to be replaced by soda, which no doubt takes the place of potash in many vegetables where ash is rich in the alkalies.

§ 65. The sand of the marl beds of New Jersey varies from 39 to 70 per cent.; the remainder of which is more or less valuable in agriculture.

The phosphate of lime is probably the most variable in its quantity of all the valuable elements, and it is regarded as a mixture, and not forming a chemical union with either of its elements. Indeed it may in many specimens be seen and distinguished by its greenish gray color.

But it is never evenly distributed through the bed, as it has been ascertained by analysis, that it has occasionally accumulated in the inside of shells. It is, however, always present in the marl, and it no doubt exerts a favorable influence upon vegetables.

The upper bed at Blackrock differs in composition from the lower. It is less gritty to the touch, is of a darker green, more compact, and resembles a dark green clay. The sand in it is greater in quantity than in the lower, but is much finer.

On submitting it to analysis I found:

Sand or silex,	70.43
Peroxide of iron and alumina,	9.00
Carbonate of lime,	11.40
Magnesia,	0.20
Potash,	0.38
Soda,	0.42
Organic matter,	4.80
Water,	3.80
	100.43

The specimen submitted to analysis was taken near the upper part of the bed, about four feet above the line, along which the exogyra are the most numerous.

The results which I have finally obtained by the analysis of the green sand at Blackrock have disappointed me. I expected at least twice as much potash as I have been able to obtain; still when the green sand is carefully examined under the microscope it shows such a large intermixture of sand, and such imperfect green grains of the silicates, that would lead any one to expect on analysis unfavorable results.

The upper bed has, however, been tested as a fertilizer, and very excellent results have been obtained by its use.

The field immediately adjoining the bed of green sand had become so much exhausted that it produceed but three barrels of corn to the acre. Its employment the first year doubled the product of the field. The quantity employed was about two hundred bushels to the acre. The stalks of corn previous to its use were but little larger than the finger, and about half as long as the common growth in this latitude.

Previous to my last analysis of the marl of this locality I had hopes that it was sufficiently rich and valuable for transportation to the county of Chatham. If, however, on farther examination, beds can be found which contain from four to six per cent. of potash, there is no doubt it may be freighted in return boats to several points along the Deep river.

§ 66. The value of this species of marl is estimated from the amount of potash and phosphoric acid which it contains.

The price of marl in New Jersey is about eight cents per bushel. A bushel weighs, when it is wet from the bed, one hundred pounds. It loses, on drying in the atmosphere, twenty pounds.

The New Jersey fertilizer company deliver marl on board of vessels at their wharf for nine cents per bushel, and the white horse marl is delivered on the line of railroad, not exceeding ten miles from the beds or pits, for ninety cents. per ton. The potash in the different beds of New Jersey varies from two to seven per cent., very rarely as high as the last figure. At the pits individuals pay for marl from twenty-five to seventy-five cents per ton provided they perform the labor. The value of the potash in marl has been estimated at four cents per pound. Soluble phosphoric acid is estimated at five cents per pound, and the insoluble at two. But this distinction is uncalled for, inasmuch as all the phosphoric acid becomes available in time. The soluble, it is true, is more rapid in its effects, and produces more immediate results: it is no better for permanent improvements. Prof. Way, chemist to the royal agricultural society of England, has estimated the soluble phosphoric acid at eight and a half cents per pound, and the insoluble at three.

It must be recollected that in order to bring phosphoric acid to a soluble condition it requires considerable expense. It is better to purchase what is called the insoluble or tribasic phosphates than the soluble ones which are found in our markets and sold as superphosphate of lime.

The actual value of the mineral fertilizers to farmers is a question quite different from that which considers the value of bone dust, or potash by the pound. Immense benefits have been secured by the use of marl, which, considered in a commercial point of view, was worth nothing. The phosphoric acid in a bushel of shell marl is not worth, in commerce, a penny; but for use on worn out lands the farmer is enriched more than one-fourth of a dollar after paying for the labor of raising and applying it.

We are not, however, to confine our estimates of the value of a marl from its phosphoric acid and potash. Excluding the sand and insoluble silica, all the soluble matters are valuable to the farmer as fertilizers, and hence the determination of how much is soluble, and how much insoluble, is a more correct mode of getting at the value of marl than by confining our estimates to the two elements referred to.

These remarks apply only to the value of a marl for the private use of an individual owner, who employs his own hands in raising it when there is the least to do and economises his expenses to the best advantage.

Marl, however, in its crude state, as it exists in the pits, has a value which admits of estimation. The common shell marl may be hauled very frequently from two to four miles, and give profitable returns. This is often done. The shell marl, however, will not bear transportation as far as the green sand of Blackrock.

§ 67. I have alluded already to the difficulty of recognising certain marl beds in consequence in part of the absence of characters upon which geologists can rely. Among the beds of which there are doubts respecting their epoch, I find a green sandy deposit, which, if mineralogical characters may be relied upon, would be referred to the green sand which is now under consideration. They contain the green sand grains, but the characteristic fossils are absent except in one or two localities. The formation in question exists beneath the white or brownish shell marl at Mr. Flowers, Bladen county, Kingston, Lenoir county, on the Neuse, and at Tawboro', on the Tar river, and at many intermediate points on the banks of the creeks and ravines. It always occupies a position inferior to the shell marl, but as the latter are frequently absent, beds of sand and clay immediately succeed it. The green sandy beds at Mr. Flowers, beneath his shell marl, contain a few specimens of the Ostrea falcata, and at one or two of the bluffs above Mr. Flowers, on the Cape Fear, I found the vertebra of a large saurian, which I am confident belongs to the green sand, but in both of these cases their occurrence in these beds may have been accidental. I am inclined, however, in view of the few facts which bear upon the question of age, to refer these green sandy beds to the cretaceous system, occupying probably a position above these beds which have been described at Blackrock.

The predominent element of these beds is sand: if a sample is washed, a coarse sand remains, which amounts to two-thirds or three-fourths of the whole quantity employed. The quantity, in a few instances, may not exceed 60 per cent. Notwithstanding the large percentage of sand, it has been successfully employed as a fertilizer. I have, therefore, submitted several specimens to analysis, taken from different beds extending from the waters of the Cape Fear to the Tar.

A representation of the composition of this formation, as it exists at Mr. Flowers, in Bladen, and at Kinston, on the Neuse, is given in the following analysis.

§ 68. The Kinston green sand marl is of a dark green color in the bed, but becomes lighter when dry. Imperfect specimens of an Ostrea occur in it, but too much broken to be determined. It contains:

Sand,	91.000
Peroxide of iron and alumina,	4.700
Lime,	1.000
Magnesia,	0.700
Potash,	0.230
Soda,	0.260
Water,	1.500
Soluble silica,	0.204
	99.634

The marl, or this variety of green sand at Kingston, is one of the most sandy varieties known. It was regarded as too sandy to require the analysis to which it was submitted; but as the marl bed only one mile above had been successfully employed as a fertilizer, and appears to be equally charged with this useless element, I was desirous of knowing how this fact could be explained. It will be seen that the nine per cent. of fertilizing matter is really rich in potash, soda and lime, and, therefore, where a heavy dressing is applied, quite a large amount of this matter is added to the soil, and which contains a small quantity of potash. The sulphuric acid was not determined, but all of these beds contain it, which is no doubt derived from the sulphuret of iron or pyrites, which is always present.

An unfinished analysis of a parcel taken from a bed which occupies a similar geological position on the plantation of Col. Green, of Craven county, gave:

Silex or sand,	83.20
Peroxide of iron and alumina,	9.00
Lime,	2.31
Magnesia,	0.50
Water,	2.60

It lies beneath a white eocene marl, has a deep green color in the bed, but becomes brown after being exposed to the atmosphere. It has not been used as a fertilizer, but is undoubtedly richer than the Kingston marl which produces good effects upon corn.

A similar composition obtained in the same beds upon the

Tar river. A marl, for example, which has been used as a fertilizer by Hon. R. R. Bridges, contains:

Sand or silica,	89.700
Peroxide of iron and alumina,	5.000
Lime,	1.500
Magnesia,	0.200
Potash and soda,	0.250
Water,	3.510
	100.151

It is evident this variety of marl cannot be transported far because of its excess of sand, and in the instances in which it has been employed it has been transported only a short distance. These marls, however weak as they may appear, frequently destroy the existing vegetation. It is due to the existence of decomposing sulphuret of iron, which forms an astringent salt, copperas, or a mixture of sulphate of iron and alumina. This injurious salt is not formed where there is a sufficient quantity of lime to neutralize the salt, in which case gypsum will be formed. It should be remarked that the astringent salts may exert a beneficial influence where they are formed only in small quantities.

Another similar outcrop of this sand appears in the bed of a creek adjacent to the dwelling of Col. Clark, in Tawboro' On submitting this marl to analysis I found it composed of

Sand,	91.300
Peroxide of iron and alumina,	5.800
Carbonate of lime,	0.190
Magnesia,	0.130
Potash,	0.150
Soda,	0.130
Sulphuric acid,	0.300
Water,	1.200
	99.200

A thin bed of the supposed upper part of the green sand formation appears in the series of beds on the banks of the Tar river, three miles from Tawboro'. At this bank the shell marl occurs in place, and has been used as a fertilizer by Col.

Clark with good success for many years; the relative position of this upper bed of green sand is represented in a section already described. It lies, as will be seen, immediately beneath the shell marl; and beneath the green sand a gray sand crops out, which is quite consolidated, and to the eye appears much like a limestone formation, but, as will appear in the sequel, is a bed of sand of unknown thickness.

The upper mass of green sand, which does not exceed four feet, has a similar composition to those already noticed. It is composed of

Sand,	79.[illegible]
Peroxide of iron and alumina,	[illegible]
Carbonate of lime,	2.752
Magnesia,	1.6[illegible]
Potash,	1.739
Soda,	0.30[illegible]
Soluble silica,	0.60[illegible]
Sulphuric acid,	0.2[illegible]
Organic matter,	2.0[illegible]
Water,	[illegible]
	[illegible]9.321

§ 69. Although the proportion of sand is large in this marl, yet I believe it is a more valuable fertilizer than the shell marl above it.

It contains more potash than the green sand of Black rock on the Cape Fear. It contains, it is true, less lime, but if the composition of the ash of the cotton stalk is consulted it will be perceived that magnesia is also required—this marl contains a large percentage of this substance.

It may be regarded as containing seventeen or eighteen per cent. of fertilizing matter. No trial has been made of this stratum, and of course nothing can be said upon the ground of trial.

§ 70. A very useless bed of gray sand occupies the bank at the water's edge, which has been alluded to. Nevertheless, I submitted a specimen of it to analysis. It is one of those beds which is charged with sulphuret of iron, and forms astringent salts, on decomposition, of the sulphuret of iron which is diffused through it. Beds of this description may be known by pouring muriatic acid over the material when a large quantity of sulphuretted hydrogen is liberated, which has the odor of rotten eggs—the smell of which is not usually forgotten.

This bed is composed of

Fine Sand,	93.500
Peroxide of iron and alumina,	2.000
Lime,	trace,
Magnesia,	trace,
Sulphuric acid,	1.000
Water,	3.200
Potash and soda, (undetermined,)	
	99.700

The bed is partially consolidated. It is, without doubt, entirely worthless as a fertilizer. As a geological formation it may probably be regarded as one of the beds of sand which separate the different beds composing the green sand proper: still, no opportunity has as yet been furnished me to see what lies beneath it.

The foregoing analyses of the green sand furnish all the necessary information respecting its composition. These beds in North-Carolina are deficient in potash, an element which, in New Jersey and Delaware, give to this fertilizer its importance. It is possible that exposures of other parts of this formation may come to light, which will be richer in potash. We do not obtain access to the best parts, which may be richer in this element. Other analyses, therefore, of new beds may result in better success, and finally furnish a fertilizer equally rich with those of New Jersey.

CHAPTER VIII.

Eocene or white marl.—Quantity or per centage of lime variable, but greater usually than in the other varieties.—The Wadsworth beds.—His letter and remarks.—Beds upon the Neuse.—Haughton's marl.—Composition, etc.

§ 71. In the ascending order, the next series of marls belong to that division of the formation which is known as tertiary, and that part of it which is called the eocene. This part is the oldest section of the division, and hence, reposes upon some part of the cretaceous system; either the green sand, which has been already considered, or else upon the chalk, as is the case in Europe.

Considered as a marl, it is readily distinguished from the green sand, even where its relations are concealed. The color is white, or else a light drab, or cream colored, and is very frequently made up of grains, which, when examined under the microscope, are found to be fragments of organic remains, such as corals, shells and echinoderms. Some beds, ten feet or more thick, are a mass of small fragments of fossils, mixed with sand. Some have a chalky whiteness, others take a brownish tinge. These beds are frequently soft, and may be loaded into a cart like dirt. In other cases, consolidation has taken place in part, and the mass is known as stone marl. This variety of marl is more calcareous than the green sand below, or the shell marl above, and when the mass is consolidated it makes a tolerable lime for agricultural purposes. But sand, which is a constant part of all formations in the eastern counties, exists in large proportions in some beds, and usually exceeds fifty per cent. But some beds have seventy or eighty per cent of lime, and when thus charged, the lime is well fitted for mortar, or whitewashing, as well as for agriculture.

§ 72. The eocene marl occupies a narrow but an ill-defined zone, stretching across several of the eastern counties, from the lower waters of the Cape Fear, in Hanover county, through a part of Onslow, Jones and Craven counties, crossing the Neuse twenty miles above Newbern, where it is either lost in the low grounds, or may be discontinued before it reaches Beaufort county, as the only marls of the lower waters of the Tar belong to the shell marl, or miocene beds; where the next bed below is visible, it is known to belong to the upper part of the green sand, which has been described.

The eocene is known to exist at Wilmington, at Pollocksville, in Jones county, and underlies the whole country in the vicinity of Newbern, upon the Neuse. In this formation I include the consolidated beds which have been employed for mill stones, and which consists of a mass of the casts of shells, the most common of which is a small species of clam. Recently, this variety has become an important building stone, and has been employed for enclosing the cemetery at Newbern, for which it is more suitable than any other rock which could have been procured.

§ 73. It will be seen from the foregoing remarks, that it occupies a less area than the green sand, and it will also prove to be more limited than the shell marl, though the latter never forms a continuous deposit over a large area. When in rocks, or consolidated, it is also broken up or traversed by fissures, and forms, if at the top of the ground, a very irregular surface.

§ 74. The white eocene marl has been used as a fertilizer, and probably with results as striking as the common shell marl. It would seem to possess some advantage over other marls, except the green sand, especially as it is fine and earthy. It is also richer in lime. For analysis I have selected several specimens from the central part of the region where it is underlaid with it.

The marl of Wm. Wadsworth, Esq., of Craven, furnishes a kind which represents its characteristics in as much perfection as any of the beds of the county. I found it composed of

Sand,	26.60
Water,	1.70
Magnesia,	0.10

Carbonate of lime,	71.22
	99.62

The sand is in the form of white grains, often coarse. It is a soft, earthy marl, and is made up of fragments of corals, shells, crinoid's or pentacrinites, with sand mechanically mixed.

The influence of this marl upon vegetation has always been favorable, and the testimony of Mr. Wadsworth, whose ample experience qualifies him to advance an opinion, fully sustains the foregoing statement.

I subjoin an interesting letter from Mr. Wadsworth upon the subject of marl and marling. His observations, I have no doubt, will be concurred in by his neighbors. I am the more desirous of making his letter public on account of his experiment with marl upon his premises for the purpose of counteracting the tendency to fever and ague during the autumnal months. If farther trial should confirm the opinion expressed in favor of the use of marl as a preventive of fever, the importance of the discovery cannot be over-estimated:

CORE CREEK, CRAVEN COUNTY,
May 7th, 1857.

PROF. E. EMMONS—*Sir:*—The marl, (a specimen of which is sent,) I have been applying since 1852. I have now marled 220 acres. I have, until this year and a portion of the last, applied 100 bushels to the acre. I am now using 75. The weaker parts of my land were burned with the former quantity. My land varies from a very stiff clay to a soil quite light. Presuming you will be willing to be troubled with it, I will give you my mode of using it, and the results: My carts are made to hold just five bushels. I have the land checked off with the plough into as many squares to the acre as I design putting on bushels of marl. One bushel is put into each square. The first four bushels is pulled out with a hoe from the tail of the cart, and the last one is dumped.

By this method I am enabled to have the material much more equally spread, which I think is a full equivalent for the extra trouble. I usually begin to haul after my crop is "laid by," and it remains in the heaps until about the following February, when it is spread and ploughed in. I have spread some and let it lay on the surface twelve months before it was turned under, but I never saw any advantage from it. I have a small piece of very poor land that has been lying in that condition since the first of the year 1854. It was designed as an experiment. The growth on it when it was marled was altogether broom straw; there is now mixed with that growth some briars, dog fennel, and other weeds. I have consequently inferred there was some improvement, but whether it is as great as on land that was marled and cultivated I shall not know until I cultivate it.

The land I have marled and cultivated has very considerably improved. My whole crop has very nearly doubled, notwithstanding one-fifth of the land I crop on is yet unmarled.

I cultivated the land every other year in corn, and it rested the other, and not pastured. Last year I sowed peas on a portion of the rested land; what will be the result I am now unable to say. I have used plaster on the marled land, and have not seen any beneficial effect.

I fear I am trespassing too much on your time; I will, however, say a few words on my experience of the effects of liming on the health of the place. Before marl was used on this plantation it was uncommonly sickly, so much so that I was compelled, to carry my family away every fall. Scarcely a person, white or black, escaped the ague and fever, if he had no more. All the land around the house has been marled, and the yard, under the houses, under and around the negro houses, I keep *freshly* marled every summer. Last summer I made my servants use it, as our grand mothers used to use sand, inside of the houses. Whether it is owing to this, or to a ditch I have had cut through the yard, or whether it is an accidental occurrence I can't say, but fall before last there was not a chill on the premises, and last fall there was but one case.

I will trouble you with one more *result:* These premises were infested with ants and fleas, now such animals are hardly known here.

W. B. WADSWORTH.

§ 75. In a subsequent letter Mr. Wadsworth's remarks go to confirm his previously expressed opinions, but that the reader may be benefitted by Mr. W.'s experience, I subjoin his remarks in his own language:

CRAVEN COUNTY, N. C., (NEAR NEWBERNE,
October 12*th*, 1857.

PROF. E. EMMONS—*Dear Sir:*—The fever for marling is spreading in this part of our county and a good deal of land will be limed this winter. I have given some of mine an over dose with only one hundered bushels. Last fall and winter I used only seventy five and now I am putting on fifty. My experence so far has taught me to begin with a very limited quantity and to add to it as the land improves. Where I have not burned my land the improvement is very satisfactory.

I mentioned in my last letter to you the effect that marling, or ditching, or both combined, had had upon the health of this place. I told you that this plantation was remarkably sickly previous to the fall of 1855—so much so that it was strange for even one to escape billious, or ague and fever. I mentioned that in 1855 there was not a case of either, in 1856 but one, and now I will add that so far this fall, in a family of forty persons, there has been but two cases. (I happened to have been one of the subjects.) These three falls have been dry. I don't know how a wet one would act upon us. I have kept marl plentifully used in my yard, and around and in my negro houses.

I shall be under many obligations to you for analysis of my marl.

Yours, &c.,
W. B. WADSWORTH.

§ 76. A marl belonging to the same epoch, (eocene) furnished by J. H. Haughton, from his plantation in Jones county, gave me 56.06 per cent of carbonate of lime. Another specimen gave:

Silex or sand,	13.00
Phosphate of peroxide of iron and alumina,	1.10
Carbonate of lime,	85.20
Carbonate of magnesia,	1.02
Potash,	0.02
	100.34

I have found in these white marls a small per centage of potash. It is evidently less than in the other varieties. This is made up like the Wadsworth marl, of fragments of fossils, in which certain species of corals and a crinoid abound.

A variety is met with which is derived from the disintegration of a large species of oyster. It occurs upon the plantation now owned by L. Haughton, Esq., and is known as the Pollock place, in Jones county. It contains:

Carbonate of lime,	34.54
Sand,	63.46
Peroxide of iron and alumina,	1.30
	99.30

Large grains of sand are distributed through the marl. It follows necessarily, from the manner in which these marls have accumulated, that they should vary in composition, and that the substance which reduces the quantity of carbonate of lime, should be sand.

A ready method by which its quantity may be estimated is by washing a given quantity. It will be seen, that by agitating it in a vessel of water, there is a considerable quantity of fine, inpalpable white powder. Wash it until the water pours off clear, and the sand with the coarse fragments of fossils remain. The existence of much sand is not suspected at first, but as washing progresses, it will be found to prevail, in some cases, over the carbonate of lime.

§ 77. Upon the Neuse, about twenty miles above Newbern, heavy banks of the marl under notice occur, which extend continuously for more than a mile. This exposure of marl is upon the plantations of Samuel Biddle and Benjamin Biddle. It is accessible, and forms steep escarpments on the south side of the river. On account of the accessibility of this outcrop of marl, it will hereafter become an important deposit from the lime which it is capable of furnishing. It is consolidated, and may be quarried for the kiln, but it also furnishes an abundance of marl in a fine state of subdivision.

It has been tried imperfectly as a fertilizer, but while the result was disastrous, we may infer from it, that it possesses as valuable properties as the kind used by Mr. Wadsworth, which has been described already. The quantity used by Mr. Biddle, in his first experiment, was 600 bushels to the acre; consequently, most of the vegetation was killed, and very little has grown upon the land, thus excessively marled, for six years. It is just recovering from the dose. The consolidated part of this outcrop of marl contains:

Sand,	20.00
Carbonate of lime,	78.60
Oxide of iron and allumina,	1.70
	100.30

Another specimen of consolidated marl from Benjamin Biddle's plantation (Egypt) gave me:

Sand,	9.60
Peroxide of iron snd alumina, containing phosphoric acid,	4.40
Carbonate of lime,	85.00
Magnesia,	trace,
	99.00

A few grains of coarse sand were visible in the rock. This mass is evidently sufficiently pure for burning into lime. It would be adapted for the various purposes for which lime is required, as mortar, whitewashing, or for agriculture.

CHAPTER IX.

FERTILIZERS—CONTINUED.

Shell marl.—Heterogeneous in its composition, and arrangement of its materials.—Chemical constitution.—Application of marl.—Poisonous marl.—How corrected.—Theories respecting the operation of marl.

§ 78. The third bed of marl in the ascending order has been appropriately called *shell marl*, from the great abundance of undecomposed marine shells, of which it is mainly composed. The mass, taken as a whole, is formed of perfect shells, and those which have become fragments, and sand. There is no order in their arrangement in the bed. They lie as if they had been washed up on a beach; hence, they are mixed confusedly together. The relative position of the shell marl is exhibited in the sections already given. It is not present, however, even where all the other members of the sections in a bluff or outcrop exists. Whether its absence is due to denudation, or whether the beds were formed only at certain points, has not been determined. Denudation, however, has taken place at some of the beds, as they still preserve the gullies which were cut through them, and which were subsequently filled with brown earth.

Although it is not possible to detect an orderly arrangement of materials, still, certain parts occupy usually a common position; for instance, the large pebbles, coprolites, and certain bones and teeth lie at the bottom of the stratum. The inference which may be deduced from this fact is, that during the first stage of its formation, there was considerable violence in the movement of the waters in which the stratum was accumulating; and that probably, prior to, and during the early part of its accumulation, there were shiftings of the strata; some being more elevated, others depressed; or there was a change of level of the sea coast, which set in motion the waters, and led to the violence which collected at the bottom the large and less destructible fragments to which I have alluded.

But in the first place, I propose to speak of the use of this marl stratum as a fertilizer; and as it has a more general distribution, it has been employed more extensively than either of the foregoing which I have described.

The beds of shell marl are not composed uniformly of the same elements in the same proportions. It is as heterogeneous as possible in this respect. Some beds contain ninety per cent of sand; in others it is reduced to twenty-five per cent, and the remainder is mostly carbonate of lime.

§ 79. The most important subdivision which can be founded upon composition, is that into a gray or whitish marl in the mass, the color of which is due to the great abundance of marine shells, and that of a dark bluish green marl, which contains grains of green sand. In the latter there is a notable amount of potash, while in the former it exists only in very small proportions. Some recognize a red or brown marl. This color, however, is due merely to exposure to the atmosphere, in consequence of which the protoxide of iron has changed, or is changing, by the absorption of oxygen into the peroxide. This change is indicative of a valuable marl, but it is no better subsequent to this change than before it. If in the greenish marl green grains can be distinguished, it may be inferred that the marl contains potash. The presence of carbonate of lime, as is usually known, is indicated by effervescence when acids are poured over it, and a judgment may be formed by its continuance and violence, whether it is rich in this substance. If it is prolonged, there is a large quantity of carbonate of lime in the specimen under examination. So the presence of sand may be detected and its quantity proximately determined by simple washing.

§ 80. The shell marl upon the Cape Fear river belongs usually to the former. A bed, however, in the bluff at Brown's landing, contains the green grains alluded to, but still it is readily distinguished from that upon the Tar river, which is usually bluish green, and belongs to the latter variety. I do not, however, attach much importance to the subdivision.

There are several beds of shell marl immediately upon the banks of the Cape Fear, or within a mile of them; and when marine shells are closely packed in the strata their several compositions are alike. As a representation of the composition of this marl, I shall select Mr. Cromarty's marl bed. near Elizabethtown. It consists mainly of:

Sand,	52.50
Carbonate of lime,	40.25
Peroxide of iron and alumina,	7.20
Magnesia,	0.75
Potash and soda,	traces.

I have always found phosphoric acid when the peroxide of iron and alumina are tested with molybdate of ammonia. It is very rare for the carbonate of lime to amount to seventy-five per cent. I found seventy-one per cent in Mr. McDaniel's marl, in Nash county. The bluish green marl of Tar river is quite sandy, and yet may be regarded as a rich marl. As an illustration of this fact, I subjoin an analysis of the marl bed owned by Col. Clark, three miles above Tawboro', on the Tar river. It consists of:

Peroxide of iron and alumina,	6.80
Carbonate of lime,	16.10
Magnesia,	0.436
Potash,	0.616
Soda,	1.988
Sulphuric acid,	0.200
Soluble silica,	0.440
Chlorine,	0.030
Phosphoric acid,	0.200
Sand,	72.600

Of one hundred parts, only about twenty-six can be regarded as available matter, and yet good results have attended its use.

Immediately above the shell marl of the Tar there is a bed of clay some four feet thick. This clay I have submitted to analysis for the purpose of ascertaining the quantity of potash it contains. The results show, however, that as a fertilizer, it is of no importance. It gave me:

Sand,	84.00
Peroxide of iron and alumina,	4.40
Lime,	0.35
Magnesia,	0.10
Potash,	0.05
Soda,	0.02
Soluble silica,	0.20
Organic matter and water,	10.50
	99.62

All the beds except the upper beds of sand were submitted to analysis. Only two in this bank are valuable fertilizers, the shell marl and the upper bed of green sand; both contain potash, soda and phosphoric acid; and there is no necessity for rejecting the latter when hauling marl for the plantation. If some method could be devised by which the sand could be cheaply separated from the mass, the remainder would form a marl superior to the richest green sand; the sand being coarse, presents a favorable condition for effecting a separation.

§ 81. The green shell marl of Mr. Bridger's plantation, upon Fishing creek, I found to possess a composition similar to Col. Clark's. There is a greater proportion of sand, but the available part is almost identical with the Tar river marl.

§ 82. The application of marl is an important matter, and requires a brief discussion. Notwithstanding marl has been used for many years, still there is much disagreement among planters of experience as to the best mode of applying it, and the quantity to be applied in any given case. Its effects are frequently deleterious if a large quantity is spread upon a poor soil, and yet it has not been ascertained how its injurious effects may be obviated. It is no doubt desirable in many instances to use a larger quantity of marl than the soil will admit of when it is in its natural state.

The quantity of marl which is usually spread upon an acre of ground is from 150 to 200 bushels. Three hundred bushels is often used. But certain worn out lands would be exceedingly injured for several years by even two hundred bushels The question, I have no doubt, has been often put: Why is marl ever injurious? The natural conclusion is that it contains some substance unfriendly to vegetation. This substance is no doubt in certain cases an astringent salt, formed in those marls which contain iron pyrites which is prone to decompose on exposure to those bodies which contain oxygen, the sulphur thereby is oxidated, and slowly acts upon the iron and forms copperas, or upon alumina, which is present in the marl. In small doses copperas will not fatally injure vegetation, but operates beneficially. The term in common use for expressing the effect of injurious marls is, *burning*. Those which are decidedly burning marls have the distinct taste of copperas, sometimes it appears upon the surface of those marls in dry weather, when it has a whitish appearance. But gypsum sometimes appears also. This may be distinguished from copperas by being tasteless.

the sugar parsnips yields about eight hundred bushels to the acre.

One of the incidental advantages of soiling is the production of a large amount of valuable manure which may be saved under cover, and to which may be added the refuse of the kitchen and garden, whereby its quantity may be indefinitely increased.

In the foregoing observations upon soiling, I have been disposed merely to allude to the subject, believing that those planters who wish to keep good stock, either of horses or cattle, will be inclined to try this as a part of their system of husbandry; a system, which, if carried out, will not fail to give them a good stock of cattle and cows as well as horses, all of which may be kept cheaper and better than in the mode now pursued in this State.

CHAPTER XV.

PALAEONTOLOGY.

Fossils of the Green Sand and Tertiary—Mammals—Horse—Hog—Mastodon and Elephant—Deer—Whales, or Cetaceans.

The distinguishing features or characteristics of any age or epoch, can be known only from the history of the men who were then living. The characteristics of the age when the Romans were gaining an ascendancy in the world, can only be known from the individual or collective memories of Roman citizens. A history competent to give us a knowledge of those times, would blend together the personal appearance of men, their habits, dress, food, etc., from which we should also obtain facts or inferences respecting the country, its animals and plants, its climate, topography and grand divisions. So of Greece, Egypt and Palestine. The memories of the actions of these nations in their generations, would furnish us the leading facts respecting the characteristics of the period in which the respective nations lived.

So, also, the characteristics of the fossils furnish at least a clue to the features of the epoch during which they lived. To determine these features, demands an intimate knowledge of the present; for, we are under the necessity of comparing the past with the present. The present is the standard, and no comparison can be made of any value which neglects the present. We find in the present certain structures and forms which we know have certain relations to climate, or to the conditions in which they exist. If, then, similar structures or forms are found attached to an extinct being of any epoch, it is a fair inference that that structure or form bore a similar relation to the external conditions which surrounded it. Its full description, then, would be a memoir of the animal, its habits would be indicated, its relation to surrounding circumstances would be known; many inferences would follow from each,—some would bear only upon its instincts, its food, its means of defence from the medium in which it lived, etc.

If, for example, an oval shaped bag filled with coloring matter, in connection with a fossil known as the Belemnite, it would be inferred that this bag contained a fluid designed to conceal it from its enemies; that it would deeply discolor the water into which it was cast, and thereby, under its cloud of dye-stuff, make its escape. Such a phenomenon is familiar now to the sailor. The cuttle-fish is thus supplied with dye-stuff, and he employs it for escaping from a pursuing enemy; and as this is so, so it is inferred, the animal did which was supplied with a similar apparatus in the period of the Lias and Chalk.

We might go on and note hundreds of analogous examples, but one must suffice. This view is borne out by one great and leading fact, that all extinct animals are constructed upon one of the four leading types which now prevail. Of the millions of individual fossils which have been seen, not one is known which does not belong to, and may be referred with certainty, to one of the great leading types of the present. It is the plan then, which really tells all this, or makes it possible to compare and infer with certainty. Observation is the way, but the plan of creation makes it possible to deduce a connected history of the past from the dead races, and thereby see at a glance how any former epoch differed from the present, or from those ancient ones with which it was more intimately connected.

My object, however, is not so much to direct the student in this chain of reasoning, or so to apply knowledge as to make him acquainted with the external forms of the fossils of the marl beds. The figures and descriptions will enable him to know the objects from their forms, and thereby to distinguish the marl beds which contain them from each other. It is, therefore, a practical subject, and may be studied as such. But the knowledge thus acquired prepares the way for further advances in science.

The fossils described in this part of the Report, belong to four or five periods, inasmuch as some of them are found in two or more successive ones. These periods have been distinguished by the following names which are expressive of certain ideas. Thus, the oldest is the cretaceous or chalk formation. It is, however, only a small part of it, and that part is the inferior or oldest part of the cretaceous system. This part is widely known as the Green Sand, and has been employed extensively as a fertilizer. The 2d, in the ascending order, is the Eocene, which means the dawn of the present, as a few species survive, which were created in this epoch or period. Only about four per cent., however, have lived on through all the vicissitudes of the times. The third, is the Miocene. Of the animals created during this period, more than half have perished, and we know them only through their remains. The fourth is the Pliocene, the animals of which less than half have perished. The fifth, the post-Pliocene, is known by its fossils being similar to those which now live, excepting five or six per cent. Hence, it may happen that one of the four species of animals which survive, and which was created in the Eocene period, may be found in all the succeeding beds, but it is evident it will be associated in each case with races or species quite different from those among whom it was first connected or who were its cotemporaries.

The cause of the extinction of so many species, is a mystery. The fact is well established, but it is only in certain cases that we can account for their disappearance. It appears to have been sometimes due to a sudden catastrophe, the ejection of mud, or poisonous matter into the medium in which they live. This happens now, and probably has happened before, but in a majority of instances, it is impossible to perceive any external cause which destroyed them; and hence, we are left to speculate on probabilities, without being able to arrive at satisfactory conclusions.

MAMMALIA.—EQUUS CABALLUS.

There is scarcely a question so interesting to the naturalist and historian as that which relates to fossil remains of the horse. The testimony of historians is, that the horse was not living upon this continent at the time of its discovery by Columbus. The testimony of the naturalist is, that the horse lived upon this continent at a period prior to its discovery, its remains having been found first in the miocene, and lastly in the pliocene, in which period it may have become extinct. Its earliest appearance is in the former; and it appears from the discovery of Prof. Holmes, of Charleston, S. C., that its remains are not uncommon in the latter.

FIG. 18.

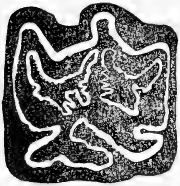


Figure 18 represents the crown of the third or fourth molar of the left side of the upper jaw. It has complicated enamel plates, or columns, and is somewhat worn, but by no means an old tooth, as its roots are undeveloped. It is two inches long and an inch thick. It is undistinguishable from the corresponding tooth of the recent domestic horse. It is a deep brown color, and looks like a fossil.

Figure 19 represents the crown of a tooth of the third or fourth molar, probably the third, of the left upper side. It has not been worn. It resembles a recent tooth, as it is whitish, and only stained brown on one side. The enamel plates, it will be perceived differ from the preceding, and they differ also from those of the corresponding tooth of the domestic horse. This difference, however, may arise from its unworn condition, as the enamel plates differ somewhat in configuration as they wear down. This tooth is three inches long and one thick.

FIG. 19.

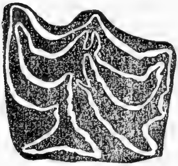
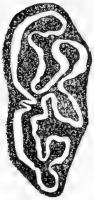


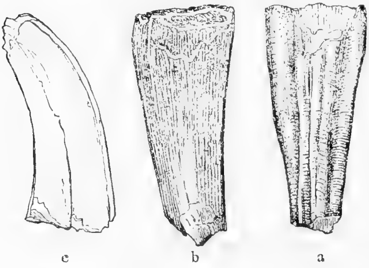
FIG. 20.



This figure (20) represents the back molar of the left side of the lower jaw of the horse. It differs only slightly from the corresponding tooth of the domestic horse. It is worn, but belonged to a young individual, and its roots are undeveloped. It is three inches long, one-half an inch thick, and one and a quarter wide.

Figure 21 represents one of the incisors of the horse; a, front side; b, inner side; c, lateral view. This scarcely differs from the corresponding incisors of the domestic horse.

FIG. 21.



The foregoing teeth are from the miocene of North-Carolina, and were discovered at an early period of the survey. No. 18 was found in a bed at Elizabethtown, Bladen county, and was accompanied with a tooth from the lower jaw. No. 19 and 20 are teeth washed up on the beach at Plymouth, N. C., and

No. 21 from the miocene of Pitt county. I found, also, molars, in Pitt county. They occur in a sandy bed, which may be ten or twelve feet above the shell marl. Although there is a close correspondence between the fossil teeth above described and those of the domestic horse, which was introduced into this country since its discovery, still, it is probable that it is a different species. If it is maintained that the fossil and introduced species are identical and the same, it follows that the same species was created about the same epoch, in two very different quarters of the globe, viz: Asia and America, and in climates which differed materially from each other. Farther discoveries must be made before this interesting question can be satisfactorily settled.

SUS SCROFA.—HOG.—(Fig. 22.)


(FIG. 22.)

The only relic of the hog which has been obtained during the survey, is the last inferior molar, scarcely differing from its fellow in the domestic hog. I obtained it at Washington, Beaufort county, from the miocene. It is brown, and is partially mineralized by sulphuret of iron. It has the same claim to genuineness as a fossil, as the teeth of the horse already described.

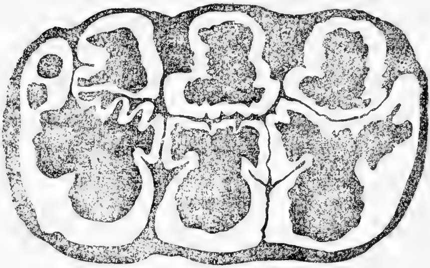
The hog was introduced into this country at the time of its settlement, but as in the case of the horse, it was peopled by this interesting animal a long time prior to its discovery. It also became extinct, and at its settlement was supplied again from a foreign country.

PROBOSCEDIANS.—MASTODON GIGANTEUS.—(Fig. 23.)

The bones of this large pachyderm are not uncommon in the miocene marl of North-Carolina.

Fragments of ribs and bones of the extremities are the most common. The figure of the superior part of the crown in the margin was taken from a tooth found in Halifax county. Its enamel is jet black and highly polished. It is the first or small molar of the right side of the under jaw. It is an old tooth with the lubercles worn down, and was probably

FIG. 23.



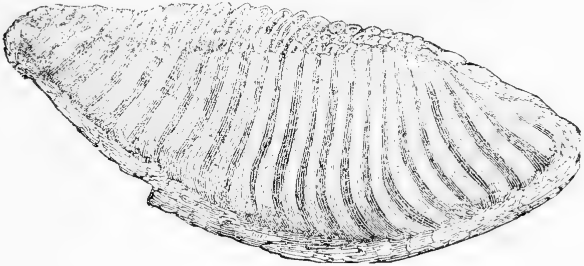
lost or shed while the animal was living. The figure is designed to show the arrangement of the enamel plates.

Bones of this immense quadruped have been found at numerous places. A large number were found in a marl pit near Goldsboro', and a large back molar in another marl pit in Nash. These bones are usually broken, and the pieces are rarely more than from three to six inches long. A cuneiform bone of the foot was found in a marl bed upon the Cape Fear. From the number of bones which have been found it is evident this large species of land quadruped, the largest known, must have been very numerous at one time. Its bones are associated with fossils, many of which are now extinct, and some or even many still survive. The oldest deposit in which the bones of the mastodon are known to occur is probably the miocene. They continued to occur in the subsequent formations until the latest, which just precede the advent of man; and, indeed, it is not at all improbable that man witnessed the final extinction of the race. The long bones which I have examined always contain animal matter, an evidence of their recent death.

The elephant was also a cotemporary with the mastodon. No teeth, however, have yet been found in North-Carolina which may have enabled me to identify its remains. But to those who have marl beds to identify its remains, a tooth (Fig. 24) of this interesting animal is given in the margin. It is a reduced figure of one found in the superficial deposits of New

York. A tooth belonging to the elephant was taken from the beach upon Seneca lake New York, and portions of a skeleton were found near the surface in Monroe county. All these bones contain also animal matter, and they are usually associated with moluscous animals which are living at the present time.

FIG. 24.



It is probable the mastodon lived in a period prior to that of the elephant, but it appears that both became extinct at or about the same time.

That the mastodon and elephant roamed in herds over a large part of this continent, seems to be indicated by the fact that their bones are found from the Atlantic to the base of the Rocky mountains. The bones of the mastodon, however, are more numerous and more widely extended than those of the elephant.

RUMINANTIA.—CERVUS VIRGINIANA

The discovery of the remains of the C. Virginiana deer, is an interesting fact. It appears to have been cotemporary with the Mastodon and Elephant, which have become extinct. So, also, it is cotemporary with the great Irish Elk, which has become extinct in Europe.

The base of the horn which I found in the Miocene bed about 10 miles above Elizabeth, on the Cape Fear, is about six inches long. In this horn, the first branch goes off from the axis nearer the head than usual, but this occurs occasionally in individuals of this species.

It appears from this discovery that the common red deer of America began its existence at or about the same period as the American horse; but while the horse became extinct, the deer has survived. In a fresh water marl bed, in Orange county, in New York, I found a horn of an extinct deer which was associated with the remains of the mastodon. The deer of the miocene marl survives, while a more recent species has become extinct, or such is the evidence of facts as they now stand.

REMAINS OF THE PORPOISE.

Several vertebræ which appear to have belonged to the porpoise, have been obtained from the marl beds near Rocky Mount. They appear to belong to a species which differs from the common one of the coast. The figure shows the end of the vertebræ to which the intervertebral substance is strongly attached; the other extremity is smooth. The body is encircled in part with a deep channel or groove, which is connected with the holes which transmit the vessels, and nerves at the base of the spinal arch.

In addition to the foregoing remains of the order, cetacea, I may mention the occurrence of the Zeuglodon cetoides. (Owen,) a fossil of the eocene, which was first found in Alabama, and described by the late Dr. Harlan, of Philadelphia. The teeth are entirely unlike those of the common cetaceans, and belong to a type not very unlike those of the seal. No teeth, however, have as yet been discovered in this State.—The remains of this cetacean consist of vertebra which were obtained from Washington, near the line of the Wilmington Rail Road.

One of the largest candal vertebræ of a whale, (fig. 25,) has broad flat transverse processes, standing at right angles to the body of the bone, the articular ends are unequal, the anterior being 5½ and the posterior 4¾ inches in diameter, and circular, with a length of 6 inches. Of this length the base of the transverse processes occupies 4 inches, and terminate behind in a rounded notch; their length is 2½ inches.

FIG. 25.

LOWER JAW OF A BALAENA OR WHALE.

On the Meherrin, near Murfreesborough, I found portions of three lower jaw-bones belonging to the genus Balaena, together with many vertebræ, all of which appear to belong to one species.

These jaws are imperfect,—the anterior part the left lower jaw is smooth, gently covex, and curved on the outside, but rather flat inside. The wide upper margin is perforated with three holes penetrating the jaw in a slightly descending course, and terminating anteriorly in an edge produced by a champering of the inside extremity, and rounded from the base up to the upper edge, which is grooved for six inches. They are $3\frac{1}{4}$ inches wide and 2 inches thick, and nearly straight. All the posterior parts of the jaw had been lost, and only two feet obtained. It is impossible to refer these fragments of jaws to either species which furnished the ear bones, as neither of these specimens were obtained at this locality. But the vertebræ and jaws belonged to one species, and it is possible hereafter to determine to which ear-bone belonged to the Murfreesborough species. It is evident that neither of these belonged to Prof. Leidy's Orycterocetus, because this belonged to a different family of the cetaceans.

OTOLITES, OR THE EAR BONES OF WHALES.

The remains of the cetacea may be said to be numerous in the miocene of North-Carolina. Vertebra and ribs are more commonly found than other parts for the reason that the individual parts exceed in number the other parts of the skeleton. The ear bones are the least common. Of this part I have those which I regard as having belonged to at least three different species. I base this conclusion on the established fact that these bones possess for each species a peculiar configuration; that though the bone in question has a general resemblance in all the species of which the family is composed, yet in the minute details of construction and form, each species has its own, which may be determined by close and careful comparisons. Thus, in the true whales, the thick posterior part is simple, while in the cachalot it is bilobed. and that this thickened and convex part in the simple kinds, while it is variable in form and extent in the different species of the true whales, and which is also joined to certain other differences, which may be observed in the thin overarching and expanded part.

For convenience of description, these bones may be divided, longitudinally, into two principal parts: 1. The thick involuted convex part which occupies the posterior segment of the bone, and which extends back to a rough longitudinal surface; and, 2d. The thinner and expanded part which begins where the former ends, and arches over the first in different degrees, forming, posteriorily, a convex surface, and interiorly towards the first part a concavity differing both in degree and extent in different species. The anterior or eustachian portion is formed wholly of the thinner expanded part. There is in the form of the expanded part some resemblance to the rim of the human ear.

The ear bones, in consequence of the thick convex part being simple, are all referred to the genus balaena. Other parts of the skeleton of this genus have been formed, as the vertebrae, ribs, lower jaw, &c.

The first of the bones (Fig. 26) which I propose to describe is the largest, and resembles in form the same bone belonging to the right whale, (the balaena mysticetus.)

Fig. 26.

In this specimen the thick involuted part is thickest at its extreme posterior end, and gradually diminishes to within three fourths of an inch of the flatish. expanded or eustachian part of the tube.

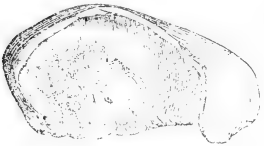
Its surface, as it passes backward, and corresponding to the span between the lobes in the cachalot, becomes slightly concave, and the whole surface to the boundary backwards and forwards to the channel, which separates it from the concave expanded portion, is irregularly wrinkled; these wrinkles increase in strength to its junction, with the latter part, where the line of division is distinctly defined. At the posterior part, there is a strong indentation, somewhat in the form of the letter U, surrounding the part where the expanded part springs. The thinner expanded part forms an arch, concave within, and quite regularly convex without; at the extremities it forms expanded hooks. The concave surface widens from the posterior to the anterior end, and is widest just within the margin. This bone differs from the same in the right whale, in its convex portion being lower and not above the level of the concave cavity beneath the arch; and being, also, perfectly separated by a change in the appearance of the part, and also by the perfect smoothness of the concave surface of the overarching wall, which, in this B mysticetus, is very rugged.

Its length is $3\frac{3}{4}$ inches, and width $2\frac{1}{4}$, and belonged to a large whale, though probably not the largest. It is, however, very bulky. Cuvier remarks, that the ear bones of the Balaeonoptera are very small in proportion to the size of the species; so that it does not follow that where the bone is small the spieces must be small also.

I propose the name *Balaena Mystictoides* for their species.

The thick, the posterior end, is nearly equally bisected by the thin expanded part, and around it there is a deep sinuous indentation which, on the inside, is continuous with the channel between the thick and thin parts.

FIG. 27.

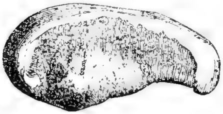


The otololite, next in size to the B mistiectoides, differs much from it in form and proportion of parts. The thick convex part is well defined, but rough, short and prominent. It rises higher than the base of the thin involuted part to which it slopes all round. It is marked with two or three strong folds, one of which is at or near its termination forward, and another beneath, which gives a slight emargination to the bone. It is separated fromthe anterior end by a flattened plane about half an inch wide, where their expanded part turns and forms a rather open hook, unlike that of the former, which is bent much more inwards. The posterior end is somewhat obliquely truncate, and at the root of the thin part there is a rough indentation disconnected with the wide channel within. The anterior border of the thin part forms an arch much less extended than the former, and the posterior and basal part is flattened and angular. Length 3½ inches; widest part 1⅛.

Another specimen measuring four inches long preserves the essential characters of the foregoing. It is very rugose around the thick convex part, and the middle fold creates a slight twolobed character to the interior part and its base.

The smallest (Fig. 28) has a well-defined convex part, which is smooth though somewhat wrinkled, but rough within, and the border rises almost immediately from it, especially posteriorly. The space between the border and convex part widens anteriorly where it is only gently

FIG. 28.



curved, scarcely forming a hook. Behind the convex part it is very regular, but the beginning of the thinner expanded part is formed by a rounded ridge which may be traced from one extremity to the other. It is far less angular, and more regular than the preceding. It is $2\frac{3}{4}$ inches long; greatest width $1\frac{1}{2}$ inches.

This ototite is one of the most common in the miocene beds. Unfortunately, in all these specimens, the thin expanded over-arching part is broken off, but it is evident that in this case this part was very limited.

The two smallest are perforated by boring moluscks, a fact which shows that instinct is sometimes at fault.

It is probably impossible in the present state of our knowledge of the anatomy of those extinct whales, to refer them to the species to which they belonged. That the foregoing ear-bones I have described belonged to different species of the whale, there can be no doubt.

Few extinct species of balaena are known to belong to the miocene period besides the orycterocetus of Leidy.

SUMMARY

of the characteristics of the three foregoing species, derived from a comparison with each other, and with the three which have been described, by PROF. OWEN.

The B. mysticetoides differs from B. affinis Owen, in the much greater extent of the overarching wall and the well defined limits, and greater prominence of the involuted part;—this part also bears a much greater proportion to the whole of the organ than it does in the affinis.

The B. definita Owen is very strikingly truncated at its posterior end, and has also its thick involuted part much less in proportion than in the B. mysticetoides, and its thin overarching border is also much less in extent.

It differs from the B. gibbosa, Owen, in most of the characters just stated; particularly the extent of the overarching wall, its thick convex part is much less prominent; but it resembles the B. gibbosa somewhat in its configuration at the posterior end, where the rim is continued around it, as it were, but in the gibbosa, it rises from near the base, while in the *mysticetoides* it rises higher and is surrounded by deep sinuous indentations. It resembles also the B. *emarginata* in the existence of a concavity on the inferior border of the thick convex part, but is much less; the overarching wall exceeds very much in extent that of the *emarginata*.

The figure 27 differs from the affinis in its prominent and distinctly defined convex involution. It resembles the B. definita somewhat, in its posterior truncation; but the involuted part is more prominent, and has a strong ridge or prominence on the border near its slope to the concavity; but it resembles still more closely the B. gibbosa, in the form of the convex part, but the thinner overarching wall is more extensive and broader at the eustachian termination, and the shape of the posterior end differs from it materially, particularly in the strong angle of the extreme of the overarching wall.

It differs from the B. emarginata, in having a prominence at the base of the involuted thick part instead of an emargination.

The figure 28 differs from the B. affinis in its prominent involuted part, and distinct form or separation from the concave overarching part; from the B. definita by its prolonged posterior part, in which respect it differs also from the gibbosa and from emarginata by its absence of this particular character, and by the presence of strong sugar upon the part next the concavity.

CHARACTERISTICS OF THE EAR-BONE OF THE COMMON WHALE OF THE COAST.

The ear-bone of the Balena Mystictus, the common whale of the coast, in my possession, measured, rather diagonally over the thick convoluted part, is 5½ inches long; the greatest thickness is 3 inches and 3 tenths; the depth or height of the convoluted part is 3 inches; greatest height measured to the top of the thin convolution 4 inches and 4 tenths. The thin involuted expansive is arched so as to have a distance of only half an inch from the thick involuted part. This may be divided into three principal lobes; two of them make up two-thirds of thin part, and these are divided externally by a deep sulcus, and internally by a thick rounded ridge which extends nearly to the base; the lobe of the thickest end is short. A deep sulcated cavity is formed by the thick and thin involuted parts of the bone. This cavity is 3 inches and six-tenths long and 2 inches and one-tenth, and the height nearly 3 inches.

An ear bone having the form and proportions of the Balaena Mysticetus, in many particulars, I have obtained from Craven county. The most important difference is in the height of the thick involuted part, the thin expanded part is broken off but there are so many points of resemblance, that it is highly probable it belonged to this species of whale. The fossil ear-bone is smaller. Its greatest length is only 4 inches and 2 tenths, and the height of the thick involuted part is only 2 inches and 2 tenths. Still, it is not at all improbable that we may regard it as having belonged to the young of the B. mysticetus, and if so this species commenced its existence in the Miocene period. This conclusion is founded upon the probability, that this ear-bone and certain thick heavy ribs of a whale, often found in the miocene deposits, belonged to this species. It is probable, too, that ear-bones vary somewhat in form and thickness in the same species; this is certainly true in the case of the ear-bone of fishes, of which I have many specimens, among which there are several varieties of form and size.

Other forms of cetacean ear-bones occur abundantly in the miocene of Tar River. Figure 28 belongs to one of the rarer forms of ear-bones. It has a distinct involuted portion. It is figured of the natural size.

Fig. 28. (A.)

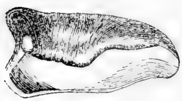


Figure 29 is another form of ear bone which is the most common of all, except the following. It has no distinct invo-

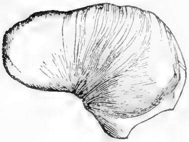


FIG. 29.

voluted part, though it is thickened at one end of it. It is more or less wrinkled transversely. In other respects it is rather discoidal.

Figure 30, it differs in form from all the preceeding. It is conical, and acute at one extremity and obtuse at the other. From the obtuse extremity, it sends off a short process at right angles, and is probably the point by which it is attached to the interior of the tympanic cavity.

FIG. 30.

But one of the most extraordinary of the ear-bones of this formation, is represented by figure 31. It consists of two parts, a short obtuse conical portion, and a long process extending at right angles from it. It is over seven inches long. The process referred to is four, measured from the base of the heavy conical part, and it extends half way across it, so that its whole length is about 5½ inches. The height of the conical part is 3½ inches. This is flattened, and its greater circumference is 8 inches. The arm or process is irregularly triangular, being hollowed out on two sides and flattened on the other. The whole form, however, is difficult to represent by means of a single figure. The figure is one-half the size of the original.

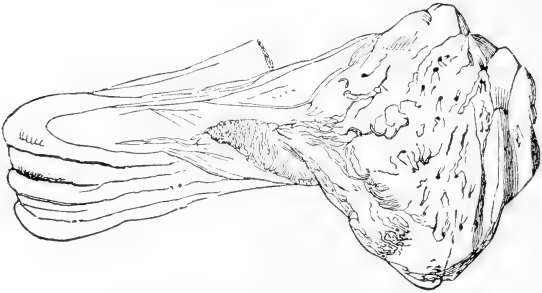
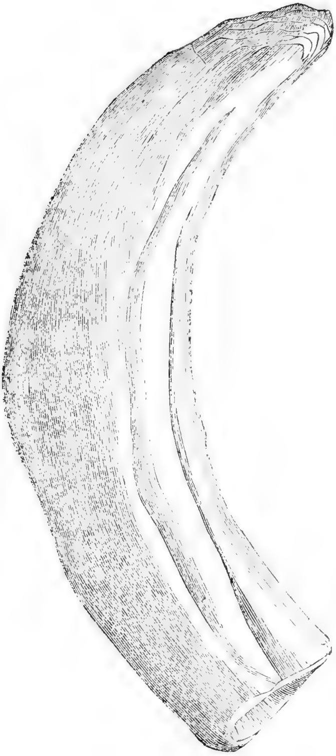


FIG. 31.

ORYCTEROCETUS QUADRATIDENS.—LEIDY. PROC. ACAD. NAT. SCI. VII, 378.

FIG. 32.



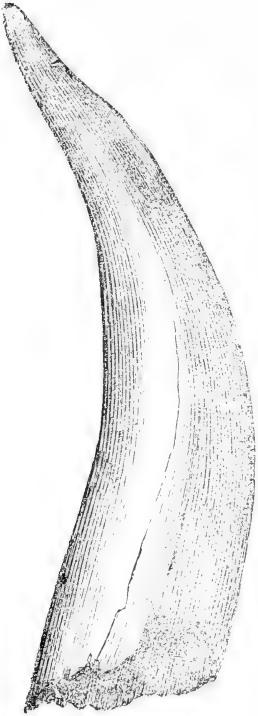
A single tooth belonging to this cetacean was found in Pitt county by Thos. Sparrow, Esq., to whom I am indebted for an opportunity for describing this interesting relic.

The tooth is remarkably curved for a cetacean. It is rather rough, and is somewhat quadrate or angular. This character, according to Prof. Leidy, is not constant. Its transverse section is rather ovate, with the anterior part flattened. It was pointed, but by exposure the apex is injured. Its base has a short conical pulp cavity, less than one inch in depth. Its surface is marked by longitudinal cracks.—The tooth belongs to the right lower jaw, and is drawn the natural size.

It is supposed to belong to the miocene, but the locality contains a few small fossils, derived from the eocene, and hence this may be of that age.

ORYCTEROCETUS CORNUTIDENS.—LEIDY.

FIG. 33.



The genus *Orycterocetus* was originally proposed on the fragment of a jaw, and several teeth from the miocene deposit of Virginia. In my collection I have a tooth like those just mentioned, except that it is not quadrate, which it is suspected, however, to be an unimportant character.—The specimen was discovered in the miocene deposit of North-Carolina. It is remarkable for its resemblance in form to a small ox-horn, being elongated, conical and curved. The base is excavated as in the teeth of the spermaceti whale, to which the extinct cetacean was probably allied. In structure, the tooth appears to be wholly composed of dentine. The length of the specimen in the curve is 4½ inches, but it appears when entire, to have been half an inch longer. The section of the base is oval, and is 14 lines in one diameter and 12 lines in the other.

FIG 34.

The oldest specimen of fossil belonging to the whale or cetacean family, belongs to the genus Physeter, and is regarded as the P. antiquus, (fig. 34.) It occurs in the eocene of Craven county. The size of the teeth prove that they belonged to the largest of the class. The largest tooth measures six inches in circumference, and is five and a half inches long, though a portion has been broken from the base. Its form is quadrangular, and presents a curve in front, but is rather straight behind. It shows no conical cavity, but is solid throughout. It shows a tendency to exfoliate concentrically. Many fragments more or less rolled and otherwise defaced, have been seen in the miocene beds upon the Tar River.—It is probable they may have been removed from a lower to an upper formation.

CHAPTER XVI.

REPTILIA.

Description of Reptilian remains of the marl beds of North-Carolina.—Reptiles of the Green sand.

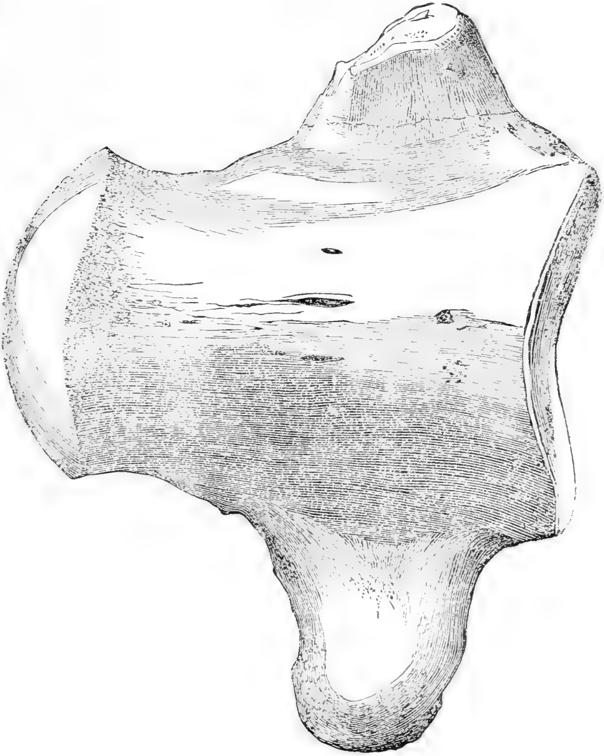
I was fortunate in discovering a vertebra of a large size on the lower Cape Fear, which, at the time, I supposed to be new. As the discovery was confined to this single piece of the skeleton, I deemed it insufficient to draw from it special conclusions respecting the family of saurians to which it belonged.

Since this discovery, Prof. H. D. Rodgers has presented to Prof. Owen, of London, a collection of vertebrae from the green sand of New Jersey, among which I find the saurian described, to which my North-Carolina fossil must belong.

Figure 34 (A.) represents the vertebra from the upper part of the green sand of North-Carolina. It belongs to the lumber region. Its type is procelian, that is, it is concave before and convex behind, like the crocodiles of the present day. The body is long, and from the anterior half it sends off strong processes at nearly right angles, which are thin and strong. The articulating extremities are less concave and convex than those of the alligators of the Southern States. In this character I find it agrees essentially with those of New Jersey.

The abdominal face is smooth, and marked by two, or a pair of elongated holes, situated rather nearer the concave than the convex end. The body is cylindrical, especially posteriorly. Prof. Owen refers the New Jersey saurian to the lizards and to the mososaurian type. The name which has been conferred upon this remarkable saurian is *Macrosaurus*. If my determination is right with respect to the identity of the New Jersey and North-Carolina specimens, it will be known by the same name. This vertebra is three and three quarter inches long, including convexity, which equals half an inch, and six inches from the end of one parapophysis to the other; across the concave articulation nearly two and a half inches; across the convex, two inches; length of the lateral process, nearly two inches.

Fig. 34 (a.)

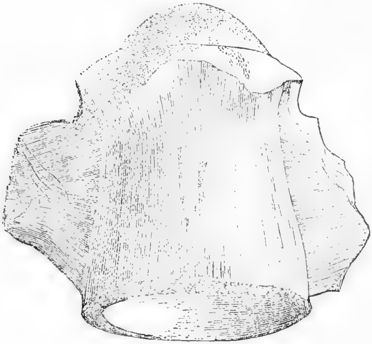


The entire length of this saurian cannot have been less than twenty-five feet, and it is a fact worthy of notice, that saurians of this description inhabited a region as far north as New-York, while at the present day their limits are confined to the central parts of North-Carolina. This fact, no doubt, indicates a milder climate in New-York and New-Jersey than is known at the present day. All the large land reptiles are confined to the warmer regions of the globe.

CROCODILUS ANTIQUUS.—LEIDY.

Another extinct saurian (fig. 35, A.,) is indicated in the discovery of vertebræ, which belong to, or are found in, the miocene marls. The most perfect one which I have obtained, is the 2d caudal, which as it is possible to identify it, may be compared with the Alligator lucius, the common large reptile of the Southern States, inasmuch, too as it belongs to the same type of vertebræ.

FIG. 35. (A.)

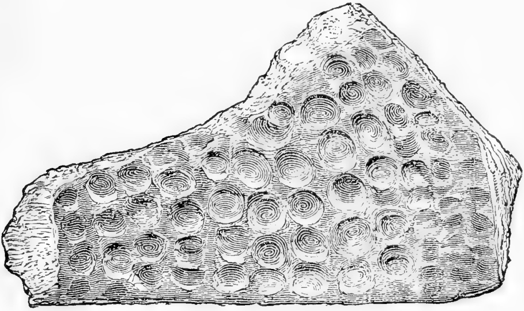


This vertebra differs from the corresponding one to which I have referred it; it is rather larger and thicker, and the proportion of its parts differ also. Its length is one quarter of an inch greater, but its diameter at the concave end is three-eighths greater, and the size or diameter of the body is still greater. The fossil is thick through its whole length, and varies but little at the ends; or it is much less compressed laterally than the vertebra of the living Alligator, and what is equally worthy of note, is, that the transverse processes come out more immediately from the body of the vertebra than the other. One more point may be made; a ridge of bone begins near the middle at the concave end, and runs a little downwards, until it reaches a slightly constricted part just before the border which surrounds the convex extremity; this gives the appearance of breadth to the bone when we look upon the abdominal face. There is a slender sharp ridge occupying the same relative position in the Alligator, but it seems to originate at the convex extremity. A slight groove runs longitudinally upon this face. Length, one and eight-tenths; width, over the concave end, one and five-tenths inches.

From all that I have been able to glean from the discoveries of others in this country, these vertebra appear to belong to a species which has been discovered in the miocene marls of New Jersey and Virginia. The species is now extinct.*

The cranial plates, one of which is illustrated by figure 36, belongs to a large unknown saurian. These were taken from the miocene upon the Neuse, fifteen miles below Goldsboro'. They are over half an inch thick, and ornamented with deep sculpturings, and from their massiveness might be referred to the *Macrosaurus*. But this reptile belongs to an older formation. I have, however a laniary tooth of the proper dimensions to correspond in size with the saurian, which may have been provided with this impenetrable armour, and also the middle

FIG. 36.



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* Proceeding of the Academy of Nat. Sciences, Phil., Vol. V, p. 307.

part of a femur to match both the plates and tooth, and all from the miocene or shell marl. The materials, however, for drawing up a proper description of this saurian, do not exist at present.

MOSSOSAURUS.

Tooth sharp pointed, pyramidal and curved backwards; enamel moderately and finely wrinkled; surface divided into two unequal parts by well defined and finely serrate carinae, the anterior of which is considerably curved on the last half inch, which forms the apex. Base of the outer surface smooth, and forming the segment of a large circle; this smooth band is usually covered with a thin enamel, and is a little over a line wide. The rest of the outer surface is divided by three ridges, the middle is strong, and extends to the point; the anterior dies out about half an inch from the apex; the posterior is inconsiderable, and extends a little more than half way to the apex; these ridges divide the surface towards the base into three slightly concave surfaces. The inferior has eight distinct ridges none of which reach the apex; these divide this strongly convex face into nine slightly concave facets, of which those adjacent to the carinae are the widest, (Fig. 36, A.) side view, natural size, (Fig. 37,) viewed from the point, showing the division into parts and its polygonal form.

Fig. 36. (A.)

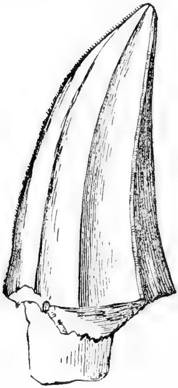
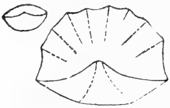


Fig. 37.



It is possible this tooth may differ from others which have been described. It differs from the one described by Dr. DeKay* in being finely rugose, and distinctly serrate, neither does he speak of angularities, though they are faintly indi-

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* Annals of the Lyceum of N. Y., vol. 3, p. 136.

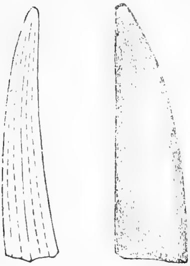
cated as existing upon the outer face in his transverse section, but that those faces are concave has not been stated by any writer.

The transverse section of the tooth, Mossosaurus Hoffmani, given by Prof. Owen, has no angularities at all on either face—the figure of the M. Maximiliani exhibits them upon the anterior face, but none upon the inner.

The tooth which I have just described is perfect, and not worn; the figures are good illustrations of its characters, and it appears, therefore, that the characters are either not uniform or else there are two species belonging to the green sand. It is evident that the tooth in question belongs to the species, Maximiliani, rather than the Hoffmani or gracilis.

POLYGONODON RECTUS,—LEIDY. MOSSOSAURUS RECTUS.

Fig. 37. (A)



Tooth long, pointed, compressed; nearly equally divided on the outer and inner faces; the faces are formed by five equal and similar planes, bounded by angular ridges, only two of which, on each face, can be said to approach the apex; these are the two anterior and two posterior ridges curved backwards; bicarinate; but the posterior edge is nearly straight, while it has a convexity before which gives an apparent curvature which does not exist; edges smooth; enamel is probably thin or removed, leaving a dense dentine, with fine longitudinal cracks which appear at first like fine striae. The tooth is broken at the base of the crown, showing a shallow pulp cavity.

This tooth differs from any of the preceding in its form and surface. It is particularly noticeable, that the part near the base is distinctly angular, and is divided into ten nearly equal planes, and is bounded by well defined angles. All these angles extend a little above the middle of the tooth. It differs from either of the three species of Mossosausus in its proportions. It also differs from the teeth of the Leiodon, by being much more compressed. The teeth of the Polyptichodon are circular, and the teeth also of the Pliogonodon, which I found upon the Cape Fear, are also quite circular and conical. It is possible it may be a palatine tooth of the M. Maximiliani. It differs, however, in form from those teeth. It appears to have had that kind of attachment to the jaw, which has been called acrodont. Length, one and three-quarter inches: width, at base, seven-sixteenths.

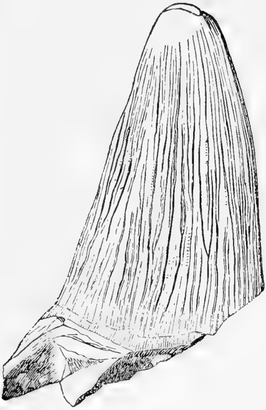
POLYPTYCHODON—OWEN. POLYPTOCHODON RUGOSUS.—E.

The teeth (Figs. 38 and 39) which are represented in the margin were discovered in a bed of miocene marl at Elizabethtown, Bladen county, in 1852–'3. They were regarded at the time as having belonged to an extinct undescribed species. I have had hopes that other parts of this saurian would be discovered which would throw some light upon its organization and form, but as yet no bones which can be referred to the genus, or species to which the teeth belonged, have come to light. Saurian bones of a large size are not wanting which may have belonged to the teeth under consideration, but more than one species have been discovered. In one instance the middle of a large femur; in others cranial plates, the sculpturing of which are quite different, are among the bones which have been discovered. These, however, are disconnected fragments, and hence are insufficient to settle the question of ownership. The epoch to which the bones referred to belong is not at all established. Large saurian vertebra have been found in the green sand, and teeth resembling those found at Elizabethtown in the eocene marl upon the Neuse. Hence it is probable that the

FIG. 38.

epoch of these reptiles is earlier than that of the miocene beds. They are found in those beds for the same reason that the exogyra costata of the green sand is also found in the miocene. While it is clear enough that fossils have been washed out of the green sand into the miocene. I have no evidence that they have been transported into the eocene, the next series above. The deposits seem to have quietly succeeded the green sand; but when the miocene period arrived, there was a breaking up of the older series, and their contents carried immediately up to this period, and under favorable circumstances fossils of both periods were intermingled together, and hence I regard the animals under consideration to have lived before the miocene beds were deposited.

FIG. 39.



The teeth which I have figured I have referred to a genus of crocodilian reptiles established by Prof. Owen, and which, in England, belonged to the chalk or cretaceous system.

The following description is drawn from the teeth before me: Teeth thick and conical, and slightly curved; transverse section circular or round; enamel traversed longitudinally by numerous transversely rugose cracks, the strongest of which reach the apex; no trenchant edges or carinae proper.

The teeth are only gently curved; they are very strong and robust, and the enamel is traversed by rather irregular rugose ridges, which appear like cracks. The inside ridge is stronger than the others, and are formed of two confluent ones, and takes the place of a carina, and extends to the point in the young tooth; but in old and worn teeth most of the ridges terminate considerably below the apex. The surface of the young tooth (Fig. 39) is very rough, and the edges of the rugosities are realy, irregularly serrate, and run into each other. The section is round at all places, from the base to the apex. Its crown is hollow, and its pulp cavity presents a conical hollow which extends about one-third of the length of the crown. On exposure to the weather, the crown exfoliates in conical layers. Below the crown, that part known as the root is hollow, but has a thick strong shell, which on the concave side has three wide shallow furrows; the middle one is exactly in the concavity; they occupy about one-third of the cylinder; the remainder is perfectly circular.

Prof. Owen's description of the polyptychodon* is as follows: "Teeth thick and conical; transverse section of the crown circular, without larger or trenchant ridges; enamel ridged longitudinally, but only a few reaching the apex. The crowns, when weathered, exfoliate in a conical manner by detached layers, like *a cone in cone;* base having a conical pulp cavity which opens into the crown in distinct sockets."

The foregoing description of Prof. Owen, of the genus Polyptychodon, applies so well to our teeth, that there can remain scarcely a doubt as to their generic identity. It is, however, only a generic similarity; the species appears to be quite different from both of the species described by Prof. Owen, and from its remarkable rugose enamel, I propose as its specific name, *rugosus.*

It differs from the Alligator in the absence of a deep constriction at the base of the crown, from the Pliogonodon of Leidy, by its robustness and rugosities, and from the Elliptonodon, by its circular section, this having a circular section only at the base of the crown, while in the former the crown has a circular section from base to apex.

Sculptured Cranial Plate, (Fig. 40.)—These plates are separated from each in the line of suture, and are generally broken. They are thick and strong, and were no doubt sufficiently

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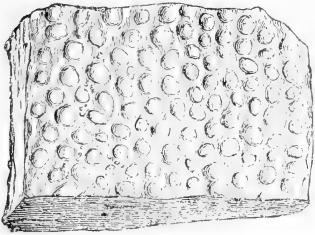
* Palaeontographical Society's transrction, p. 46, vol. for 1851. (Description of the P. interuptus and continuus.)

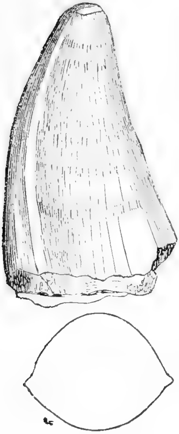
Fig. 40.



so to resist the entrance of a musket ball. The same remarks as it regards ownership have already been made. respecting other bones of this class, so common in these deposits. That there were two, at least, powerful reptiles, is evident from their bones and teeth, but in no instance have two been found attached, and in such relations that it would be safe to affirm that they belonged to the same individual.

ELLIPTONODON COMPRESSUS.—EMMONS.

Figs. 41 & 42.



Tooth curved, robust, sub-conical and pointed; crown circular at base, becoming elliptical, and finally sub-elliptical, or with the inside more flattened or less convex than the other; bicarinate; the anterior ridge becoming obsolete near the base of the crown, and without serratures or rugosities; enamel rather finely wrinkled longitudinally, or faintly rugose, and none of the rugosities extend to the apex; dentine is concentric; pulp cavity open, conical, carinate. Figures natural size. Figure 42, transverse section.

This tooth is broken at the base of the crown, and has lost a small part of its apex.

It differs very clearly from the Polyptychodon, Pliogonodon, Mossosaurus or Pleiosaurus. The clear and distinct marks of difference are shown in the figures of each referred to except the Pleiosaurus. This tooth was found in the miocene near the Cape

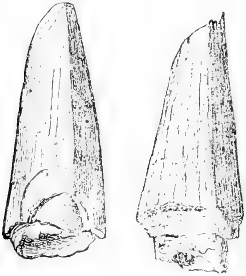
Fear River, in Bladen county. As the bones which have been found in these beds indicate the existence at a prior period of two large and formidable saurians, so the teeth confirm this view, and I have placed in this connexion a sculptured cranial plate, (fig. 40,) which may have belonged to this species.

Additional discoveries, however, are required before it is possible to determine to which of these plates the teeth respectively belong. All the bones which are found in the miocene beds, are broken, though they are mixed with perfect delicate shells. This fact proves that the bones were subjected to violence before they were imbedded in the miocene and hence belong, probably, either to the eocene or green sand.

PLIOGONODON NOBILIS. LEIDY.—(Figs. 43 & 44.[*])

In the collection of Prof. Emmons there are two, much mutilated teeth of a saurian discovered in a miocene deposit of Cape Fear, North-Carolina. These teeth, which have lost their fang and summit, are elongated conical, nearly straight or only slightly curved inwardly. Their section is circular with an inner pair of opposed carinae: and their surface is subdivided into numerous narrow planes and provided with a few vertical interrupted plicae, which are more numerous internally. The base of the crown is conically hollow: the dentine is concentric; and the enamel is finely wrinkled. The specimens measure three-fourths of an inch in diameter at base, and are about one and a half inches long, but when perfect their crown has been a half inch longer.

Figs. 43 & 44.



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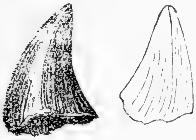
[*] These teeth appear to differ, one has a coarser aspect, and the striar are coarser. and it is more curved, and proportion differs. Description by Prof. Leidy.

From the teeth of *Mososaurus* those of *Pliogonodon* differ in their narrower proportion, their straightness, their circular transverse section, their relatively narrower planes, and in their possession of plicae. From the teeth of *Polyptychodon* they differ in the possession of dissimilar planes and carinae. and in their less degree of robustness; and from those of *Pleiosaurus* in the existence of divisional planes and the circular section.

DREPANODON IMPAR. LEIDY.—(Figs. 45 & 46.[*])

This genus and species are proposed on the crown of a tooth resembling the corresponding portion of the inferior canine of a bear, except that it has but a single carina, and that on the concave border internally. The specimen was discovered by Prof. Emmons, at Elizabethtown, Cape Fear. North-Carolina. It is black in color. curved, conical, most convex externally, and is oval in transverse section. The base is hollowed conically, and the enamel is smooth. The length of the specimen is three-quarters of an inch; the antero posterior diameter of its base is seven lines, and its transverse diameter five lines.

FIGS. 45 & 46



The tooth I suspect to have belonged to a crocodilian reptile, though it may possibly even prove to be a mammalian relic.

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[*] Described by Prof. Leidy.

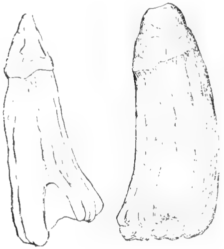
CHAPTER XVII.

PISCES.

Description of the remains of Fish in the North-Carolina Marl beds.

ISCHYRHIZA ANTIQUA.—LEIDY.

FIGS. 47 & 48.



The curious genus Ischyrhiza, was first brought to my notice by the discovery of a tooth in the Green Sand of New Jersey, by Prof. Leidy. My collection contains several teeth discovered on the Neuse River. In most specimens the crown has lost its apex, but the fang is entire. In the perfect condition, the crown has been laterally compressed, conical and inverted with smooth, shining enamel. The fang expands from the crown in a pyramidal manner; is quadrilateral, curved backward, and divided at base antero-posteriorly; the division becoming deeper posteriorly. The larger specimen, in the figure, which is of a red color, when perfect, was nearly, or perhaps quite two inches in length. Its fang is an inch long, eight lines antero-perteriorly at base, and six lines transversely. The base of the crown is oval in section, and measures six lines antero-perteriorly, and five lines transversely.

The smaller specimen is black in color, and was about half an inch shorter than the other. Its fang is about ten lines long, and at base is about six lines square. It belongs to miocene of North-Carolina.

FOSSIL SQUALIDAE OF THE TERTIARY OF THE EASTERN COUNTIES.

The fossil squalidae, or sharks, are known only by their teeth, as these are the only parts which are usually preserved.

Their vertebrae are sometimes preserved, but they must be exceedingly rare in beds which are as loose as the clays and sands of the tertiary deposits. But the teeth, being protected by a very dense enamel, and having a firm strong core, resist change for ages; it is in these organs, therefore, that memorials of this highly interesting order of fish have been preserved.

The teeth being attached loosely to a cartilaginous jaw, are almost always separated and detached; and hence, they occur singly. Of the mode in which they are connected, we are informed by the living species which inhabit the adjacent seas. From this source of information, we may be assured that these single teeth were arranged in several rows in both jaws; that only a single one, those of the front, stood upright, while the remainder lay flat with the points directed backwards, or obliquely so. When the front teeth drop out, its place is supplied at once by the uprising of that one which is opposite the vacant space. The teeth, though very numerous, differ but little in form, though they differ more in size. The most remarkable difference may be observed on comparing the symphysal teeth, or middle row with those on each side. Thus, Fig. 49, shows a front section of the lower jaw of the *galeocerdo arcticus;* the outer row standing upright those behind lying flat, and the middle teeth consisting of a series of small ones. This figure, therefore, is a type by which the reader may compare the prevailing arrangements in the existing, as well as in this extinct family of fishes.

FIG. 49.

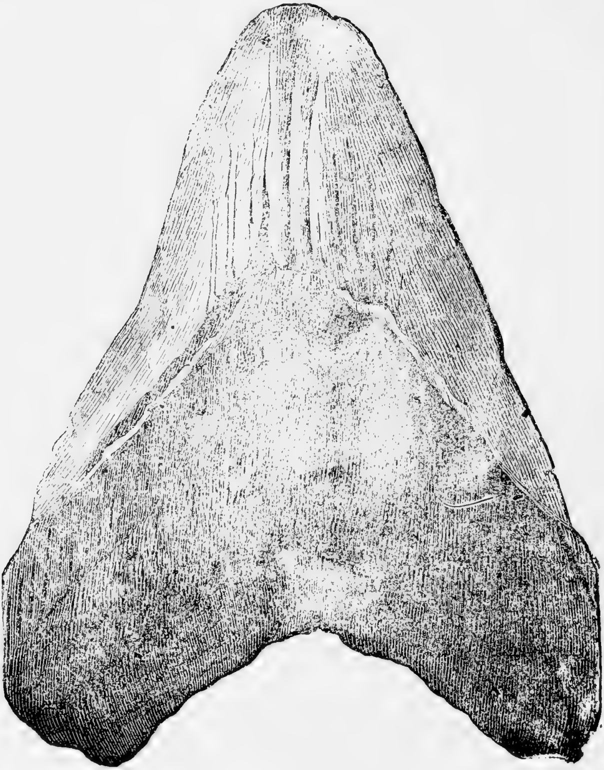
GENUS CARCHARODON.—SMITH.

Teeth very large, broad, triangular and rather uniformly dentated in both jaws. The enamel is usually cracked longitudinally; roots massive and divergent; inside nearly flat; surfaces smooth, and scarcely ever striated.

CARCHARODON MEGALODON.—AGASS. (Fig. 50.)

This species has the form of an equilateral triangle, thoug

FIG. 50.



it admits of slight variations; teeth somewhat oblique, or inclined to the posterior end; upper, or outer side, nearly flat; under side prominently convex in the middle; enamel cracked longitudinally on both sides, particularly along the middle; serratures rather indistinct from the use of the tooth; core coarsely striated. It is usually found in the miocene beds, and is the most common upon the Cape Fear.

If the size of the teeth furnish an indication of the strength, size and ferocity of this species of shark, then it must have been one of the largest and most formidable animals of the ocean, combining, as Prof. Owen remarks, with the organization of the shark, its bold and insatiable character, they must have constituted the most terriffic and irresistable of the predaceous monsters of the ancient deep. The largest of the teeth measure sometimes six inches in length, and from four to five wide at base.

The jaws of the largest species of shark known in modern times measure about four feet around the upper, and three feet eight inches around the lower jaw. The length of the largest tooth is two inches, and the total length of the shark, when living, was thirty-seven feet. If the proportions of the extinct shark bore the same as those of the living, their length must have been over one hundred feet, equaling in this respect, the largest of the whales.

FIG. 51.

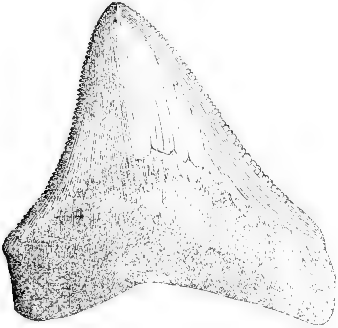
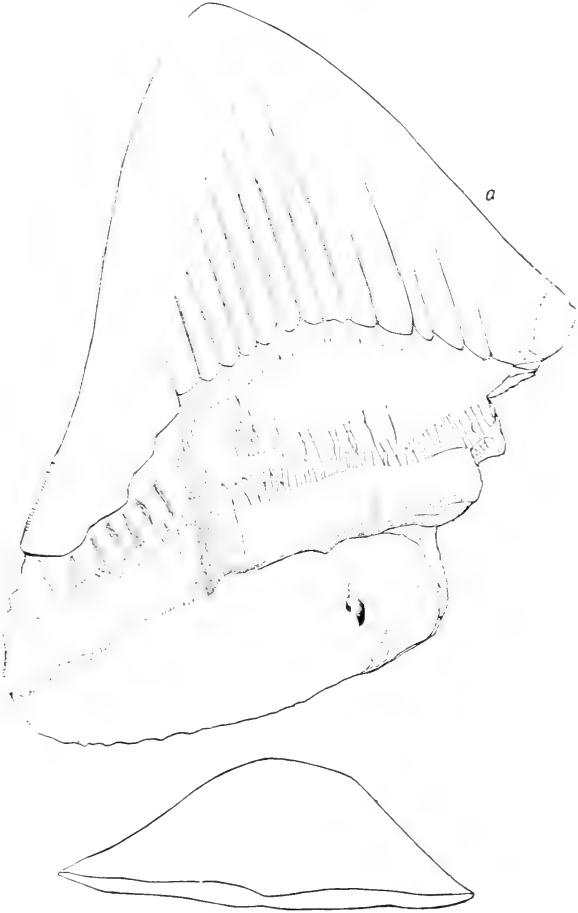


Figure 51 shows a smaller tooth of the carcharodon megalodon.

CHARCHARODON FEROX.—N. S. (Figs. 52, 53, 54.)

Form nearly an equilateral triangle, thick; inner face very

Figs. 52 & 53.



convex, outer nearly flat, and slightly champered towards the edges, and also slightly convex near the middle; seratures small, root thick, stout and straight across the base, and sloping on the inner face. The form of this tooth differs materially from the megalodon, especially in the relations of its height and breadth; height, four inches and a half, breadth at base, five inches; thickness of the root, one inch and a half, measured over the slope; length from the apex to the base of the root, five inches, measured along the edge; thickness at the middle, one inch. Found in the eocene of Craven county, N. C. The dimension of this species of shark equals that of the carcharodon megalodon. The tooth is thicker and stouter than this species, and more convex posteriorly, straighter across the base, and proportionally wider. Fig. 52 shows the outline of the tooth, fig. 54 is an edge view, and figure 53 a transverse section, showing convexity of the inferior face, and the flatness of the superior.

FIG. 54.

CARCHARODON SULCIDENS.—AGASS. (Figs. 55 & 56.)

Teeth large, thin and pointed; their forms correspond very closely to that of an isosceles triangle. They are flat on one side; the enamel extends to the root on both sides; it is more regularly sulcated upon the convex than upon the other side; fig. 55 young of the sulcidens.

FIG. 55.

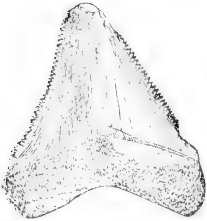
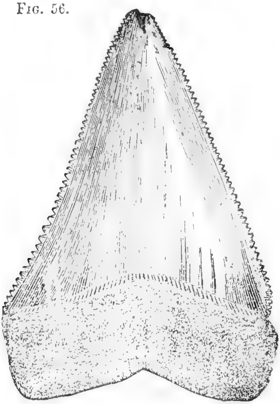
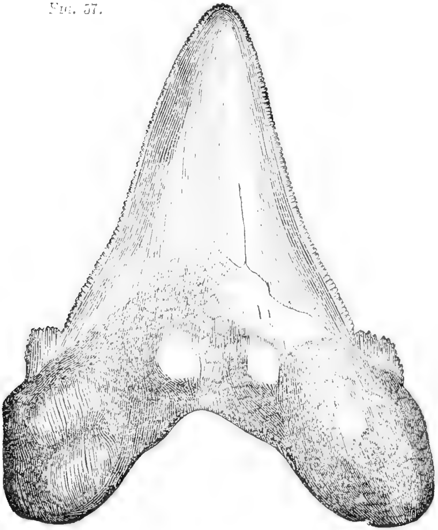


FIG. 56.



CARCHARODON ANGUSTIDENS. (Figs. 57 & 58.

FIG. 57.



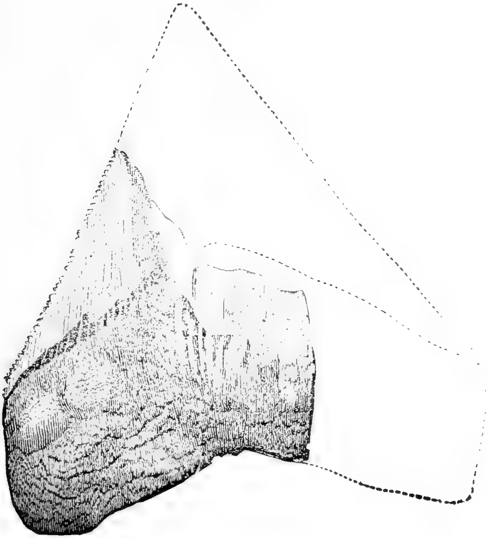
Crown only slightly oblique, rather thick, but comparatively narrow, but wide at base, and armed with serrated winglets, pointing upwards and outwards; the serratures are stronger than those upon the crown; roots massive, and separated by a distinct arch. Figure 58, a tooth which should probably referred to this species, though the arch of the root is flatter.

Prof. Gibbs, on the authority of Prof. Agassiz, has merged in the carcharodon angustidens, the following species: C. lanceolatus, C. heterodon, C. megalotis, C. semi-serratus, C. auriculatus, C. turgidus, C. semi-serratus, and C. toliapicus, on the ground that they are insufficiently characterized and not clearly distinguishable from each other.

CARCHARODON TRIANGULARIS, N. S. (Fig. 59.)

Crown of the tooth rather thin; the posterior faces of the crown meeting in the central line at an obtuse angle, but upon

FIG. 59.



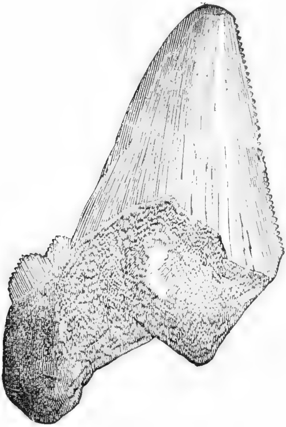
each side of this line they are quite flat; enamel thin, serratures small, root thick, striated and heavy, with a very low arch.

This tooth scarcely exhibits the usual convexities of either face; the faces being bounded by plane surfaces, the meeting of which give an obtuse angle when obtained by a central section through the crown. It belongs to the eocene, and was obtained from a bed near Newbern.

C. CRASIDENS, N. S. (Fig. 59, a.)

Tooth sub-conical, thick, slightly oblique; inner face very convex, outer flat at base, evenly but flatly convex near the apex, with an inconsiderable ridge extending from the base to a point near the apex, and somewhat ridged across the whole of the base of the outer face; serrae, sub-equal, and armed with serrate wings at base; root thick and prominent on the inside; enamel extends on the outer face to the root, and is extended continuously over the wings. This tooth belongs to the eocene at Wilmington. It is distinguishable from other teeth belonging to this order of fishes, by its very uniform degree of thickness from the base of the root, near its termination, at the apex.

FIG. 59, a.



CARCHARODON CONTORTIDENS.—N. S.—(Fig. 60.)

Tooth an irregular cone, with the crown twisted near the summit; base of the root nearly plane, with the branches projecting upwards, rather than downwards, so much so as to stand upright when placed upon its base; inside the base projects enormously inward; enamel thin; serratures small, subequal; inner face very convex; outer nearly flat at base, but traversed longitudinally by an inconsiderable prominence.

FIG. 58.

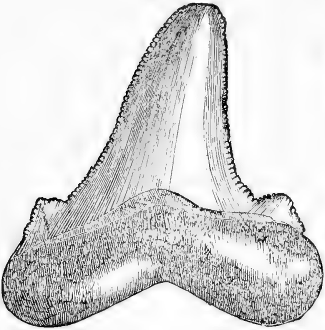
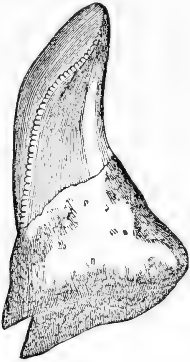


FIG. 60.



Only one tooth of this description has been obtained from the eocene at Wilmington. The form of the tooth is very peculiar, and may be readily distinguished by the great thickness of its root and projection inward. This projection is on a level with the branches of the root. The twist also, at the extremity, is also, a prominent feature in this tooth. It is probable, this tooth indicates the existence of a genus, which should be separated from the carcharodon, but the existence of a single tooth does not furnish all the characteristics which probably belong to it.

SPHENODUS RECTIDENS.—N. S.—(Figs. 61 & 62.)

FIGS. 61 & 62.

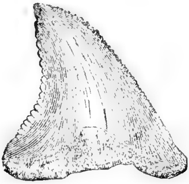
Tooth very long; comparatively slender; both faces convex; internal more so than the external; becoming narrower towards the edges; the base in some of the teeth trenchant, then nearly parallel two-thirds the length; enamel rather thick grooved on the inside, and cracked longitudinally on both, with a texture coarser than in the lamna; root unknown. Figure 62, transverse section. Green sand of North-Carolina.

GENUS HEMIPRISTIS.

Apex simple and smooth; margins of the tooth denticulated to a point near the apex.

HEMIPRISTIS SERRA.—AGASS.—(Fig. 63.)

FIG. 63.



The H. serra is characterized by teeth which are serrated to a point near the apex, where the serratures cease, and the margins are left smooth.

HEMIPRISTIS CRENULATUS.—N. S.

Form similar to the H. serra; sides convex, long at base, and rather thick; enamel smooth, and marked with only a few cracks; edges at base faintly crenate; entire towards the apex.

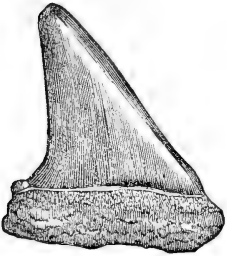
GENUS OXYRHINA.

Tooth flat, broad, oblique, lanceolate and smooth, widening at base rapidly; root thin and nearly straight, and destitute of spreading branches or forks.

OXYRHINA XYPHODON.—AGASS.—(Fig. 64.)

Lanceolate; base of the flat side marked with shallow furrows; enamel extends a little lower on the inner than outer side.

FIG. 64.



OXYRHINA HASTILIS.—AGASS.—(Figs. 65 & 66.)

Tooth rather elongated; lanceolate; nearly equilateral; bone of the enamel more arched than that of the oxyrhina xyphodon, and the root seems to be less developed. It closely resembles the xyphodon.

FIG. 65.

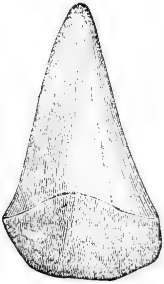
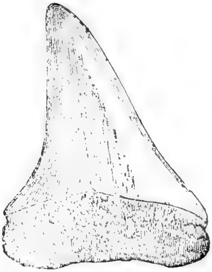


FIG. 66.



OXYRHINA DESORII.—GIBBS.—(Fig. 67.)

Tooth thick and strong; roots well developed and forked; enamel similar in texture to the carcharodon, and also cracked longitudinally.

It differs from the former in the character of the enamel, curvatures, the absence of serratures, and the form and development of its root.

FIG. 67.

GENUS GALEOCERDO.—AGASS.

This genus is an inhabitant of our present seas, and the species arcticus (Fig. 49) very closely resembles the galeocerdo aduncus, whose teeth are abundant in the miocene marl beds of North-Carolina. In both jaws the teeth are similar and equal. They form five rows, which contain twenty-three teeth each, an odd small tooth occupying a middle position over the symphysis. The back teeth become small and are relatively shorter than the side teeth, presenting in this respect an approach to the form of the teeth described as the galeocerdo latidens. In two species of galeocerdo which differ in size, the serratures are constant and preserve a great uniformity; and the common character of the serratures seems to be, that which might be called compound, by which I mean, that each notch is itself notched, and it is possible that many of the species possessed this character more or less, but have lost it by wear in their usage.

Figure 49 shows the arrangement of the front teeth of the lower jaw in the galeocedo arcticus, and the position of a small series of teeth immediately above the simphysis.

GALEOCERDO ADUNCUS.—AGASS.

Tooth oblique angulated, and winged on one side, or with the sides unequal. Anterior face convex, posterior rather flat. Serrate, serratures unequal, the first upon the wing the largest; upon the arched edge the serratures are largest upon the lower half of the crown.

GLLEOCERDO EGARTONI.

Tooth small, rather flat, lanceolate, slightly oblique, convex on both faces of the crown, but concave at the base on the outer face; root spreading widely, and obscurely wrinkled; serratures sub-equal, serrate or finely lobed; the enamel extends lower on the outer than the inner side. The latter character I am disposed to regard as its most distinguishable, for though the size of the teeth of this species may vary considerably, the character of the serratures will be preserved.

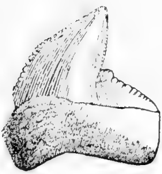
GALEOCERDO SUB-CRENATUS, N. S.

Tooth nearly upright, or with only a slight obliquity posteriorly; anterior edge formed by an arch belonging to the lower half, while the apical extremity or half the edge is straight, posterior edge is also straight for two-thirds the distance from the apex to the base, below which, the edge is drawn inwards; there is a constriction also on the opposite edge at the base of the crown; edges rather obsoletely crenate than serrate, smooth near the apex, and the smoother wing of the posterior edge stands at right angles to the axis of the crown; upper face rather flat, and marked by a faint rounded ridge extending from the base to the apex, and the surface slopes only from this ridge to the margins. The characteristics of this species will be gathered from the preceding description. The absence of distinct serratures, the form of the crown, its constriction at base, are the most important points, in which respects it differs from any which I have seen.

GALEOCERDO PRISTODONTUS.—AGASS.—(Fig. 68.)

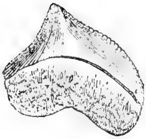
Crown large, oblique; anterior edge irregularly arched. and extending much farther upon the base than the opposite edge; upon the flat, or nearly flat face, or outer one, the enamel extends below that on the convex side; seratures unuequal. Rare in North-Carolina, but I have several specimens, and from Dr. Gibbs's account of it, it seems to be still more rare in South-Carolina.

Fig. 68.



G. LATIDENS.—(Fig. 69.)

FIG. 69.



Differs from the preceding in its proportional length of base, being considerably greater.

The crown is low, and the enamel extends lower upon the outer face; the senatures subequal; apex pointed.

It is much more common than the G. pristodontus.

GENUS LAMNA.

Teeth rather flat, narrow and elongated; smooth, and usually furnished with appendages at base.

LAMNA ELEGANS.—AGASS.—(Figs. 70, 71 & 71 A.)

Tooth narrow, lanceolate; inner face quite convex, outer rather flat and smooth; the former regularly striate at base, but towards the middle the striae degenerate into wrinkles: the outer ones are short, and but reach the edge of the tooth at base. The L. elegans is very common in the miocene beds of North-Carolina. Fig. 71 A, side view.

FIG. 70.

FIG. 71.

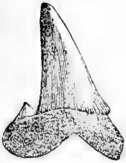
FIG. 71 A.

L. (ODONTASPIS) CONTORTIDENS.

Specimens which answer to the figures of this species, given by Prof. Gibbs, especially in the irregular form and absence of denticulations at base. In other characters there is only a slight difference between this and the L. elegans. They are found in the same beds.

L. COMPRESSA.

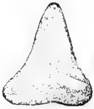
FIG. 72.



Compressed or flat, both faces convex and sub-equal, base irregularly denticulated; root wide and spreading. It differs widely from L. elegans and contortedens, but resembles the otodus; but Prof. Gibbs remarks that they are more lanciform, and the core more slender than the otodus.

FIG. 73.

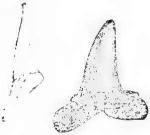
FIG. 74.



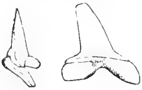
Figures 73 and 74 appear to belong to the lamna. They are rather thick and stout, and resembles very closely an oxyrhina. Miocene.

Figures 75, 76, 77, 78, 79, 80, and 81, belong to the eocene.

FIGS. 75 & 76.



FIGS. 77 & 78.



FIGS. 79 & 80.

FIG. 81.

L. CRASIDENS.

Tooth thick and comparatively short; not very thick and projecting inwardly; inner face striate as in the preceding species.

GENUS OTODUS.

Tooth rather broad and flat, and armed with equal sharp denticles at base; root rather thick, projecting inward.

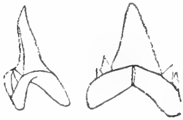
OTODUS APPENDICULATUS.—AGASS.

Tooth oblique, sharp or pointed, faces unequally convex;

denticles rather prominent and strong; line of base nearly horizontal; roots spreading widely, forming a very obtuse angle with each other.

I have referred also the following figures of teeth to the genus otodus: 82, 83, 84, 85, 86, 87, 88. They all belong to the eocene formation, and occur in a layer near the top. They are from the plantation of Mr. Wadsworth, of Craven county.

Figs. 82 & 83.



Figs. 84 & 85.

Figs. 86 & 87.

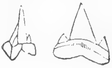


Fig. 88.

GENUS CORAX.

The following figures of teeth found in the eocene of Craven county. I am unable to refer them to species already described, viz: 82, 83, 84, 85.

Fig. 82a.

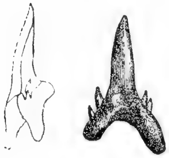
Fig. 83a.

Fig. 84a.

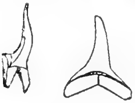
Fig. 85a.

GENUS ODONTASPIS.—(Figs. 86a, 87a, 88a, 89a.)

Figs. 86a & 87a.



Figs. 88a & 89a.



This genus should have followed lamna; I now introduce it for the purpose of referring to odontaspis, (figs. 86 and 87,) which appear to belong to this genus rather than lamna. So, also, figs. 88 and 89, which are destitute of basal denticles; but the cutting edge of the crown extends over the fangs and is slightly expanded on this part of the tooth; it preserves also its cutting edge. Eocene of Craven county.

I have no facilities at hand which enable me to make a correct reference of the eocene odontolites, and have to trust to my memory in making the references to the genera to which they belong.

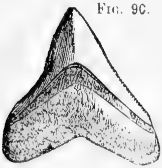


FIG. 90.

CARCHARODON.—(Fig. 90.)

NOTE.—The annexed figure of a tooth, which may probably be referred to this genus, is confined to the eocene of Craven county. I have been unable to refer it to a species already made known.

SUB ORDER.—THE RAYS.

The rays are distinguished from sharks proper, by the flatness of their bodies. There are several species in the sea bordering the coast of North-Carolina, one of which is known by the name of *sting ray.* The rays form three families: 1. the pristides, familiarly known as the saw fishes, whose muzzles are elongated into a flat long extension, armed on each margin by pointed teeth; 2, rajides, or rays, whose muzzle is simple, but whose tails are not armed with a sting; 3, the mylliobatides, comprehending those rays whose tails are armed with a sting. The remains of the latter family are known in the tertiary and cretaceous of North-Carolina. Their teeth differ in form from those of the sharks, and would scarcely be regarded as teeth at all, were it not for their occurrence in the living species upon the coast. They are placed in the mouth in the form of a pavement, and occupy the areas within the mouth of both jaws. They differ in form from the pycnodonts in being angular. They are employed in crushing hard bodies, as the shells of the molusca. Their mouths are placed below, and well situated for seizing the animals upon which they feed.

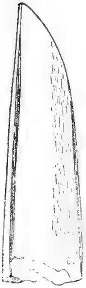
FAMILY PRISTIDES.

Fish which have a prolonged, bony muzzle, armed with a plain horizontal series of teeth upon each margin.

GENUS PRISTIS.—(Fig. 93.)

Single teeth broken from the flat plate near its junction have been found in the superior layer of the eocene in Craven county. One margin is grooved the whole length, and straight, the other is curved and grooved only at base. Figure the natural size. I have also found smaller ones, which belong apparently to the same species.

Fig. 93.



FAMILY MILIOBATIDES.

Rays whose tails are provided with serratine stings.

GENUS MILIOBATIS.

Sting dentated upon one margin. No stings of this kind have as yet been met with.

GENUS TRYGON.

Sting with both margins dentated.

TRYGON CAROLINENSIS.—N. S. (Figs. 91 & 92.)

Teeth in mosaic, the ends angular, they being bounded by six lateral planes.

Fig. 91.

Fig. 92.

Sting serrate, (Figs. 94 & 95,) grooved longitudinally, rounded on one side. Fig. 95 shows the form of a tranverse section.

Fig. 94.

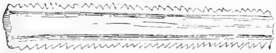


Fig. 95.

These specimens were found in the upper part of the eocene marl in Craven county, and as the teeth and stings were found in proximity, it is inferred that they belonged to one specie.

CLASS GANOIDEA.—FAMILY PYCNODONTIDAE.

This family possess teeth of a cylindrical form, and which are arranged upon both planes of the jaws in the form of a pavement. The longer axis lies across the mouth from side to side, but set in rows arranged from before backwards. The middle rows contain the longest teeth, and they diminish in length towards the sides of the mouth. An idea of this arrangement may be obtained by an inspection of the mouth of the mylliobates, the common sting ray of the coast. In this fish the teeth are set also in pavement, but they are not angular. But the teeth in the Pycnodonts are not placed with so much regularity as in the Myliobatides.

FIG. 96.

Fig. 96 is figure of a tooth belonging to the back part of one of the middle rows of the pavement, or mosaic. It may be called Pycnodus Carolinensis.

The teeth of this species of fish occur in the miocene associated with those belonging to the genera galeocerdo and lamna. The family of pycnodonts began their career in the Permian, but were the most numerous in the Jurassic period.

FIG. 97.

Another species of pycnodont is represented by its tooth in fig. 97, which appears to be much less common than the preceding.

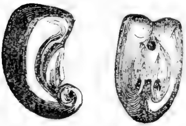
SCALE OF A GANOID.—(Fig. 98.)

A single scale (fig. 98,) was found in the miocene upon the Cape Fear. The fish was closely related to the gar-pike, (lepidosteus,) of most of the American rivers. The scale occupied a position in the first row of scales back of the head. The fish of this class had already become rare at the commencement of this epoch. The gar-pike is the only surviving one of this family in the American waters.

FIG. 98.

CLASS CYCLOIDEA.—(Figs. 99, 100.)

FIGS. 99 & 100.



The annexed figures represent a peculiar form of fish teeth, which are quite common in some of the marl beds in Edgecombe county. They were attached by ligament, and probably occupied a position in the throat.

CHAPTER XVIII.

MOLLUSCA. CLASS—CEPHALOPODA.

This class embraces those mollusca, whose locomotive organs are attached to the head. They have the form of muscular arms or tentacles. Besides the arms surrounding the head, they have fins and an apparatus by which they can propel themselves through the water by its ejection in a stream.

Some are covered by a shell, coiled in a vertical plane, as the nautilus; others are naked or destitute of an external shell, but have an internal one, which varies much in form in the different families.

Their eyes are well developed and their mouths are provided with jaws somewhat similar to the mandibles of a bird. They are predatory and live on fish, crabs and shell fish.

The most remarkable part of the apparatus by which they seize their prey, are the circular discs arranged on the under side of their arms, by which they are enabled to produce instantaneously a vacuum when applied to the surface of a fish or a slightly yielding body. By this arrangement they are able to seize and hold most securely their captives, and devour them at leisure. As a means of escape from enemies more powerful than themselves, they are provided with a bag or sac filled with a dark fluid which they can eject at will, and thereby discolor the surrounding water and escape unseen.

This sac is called the ink-bag, and the liquid is employed for the manufacture of the India ink. Even the consolidated fluid in the fossil ink-bags is used for this purpose.

This class is a large one, and the species which compose it are found in all seas. They were also extremely numerous in ancient times, and their hard parts as external and internal shells are preserved as relics of extinct races. One of the most common fossils of the green sand is the Belemnite,* which is an internal shell, though its form is quite unlike one.

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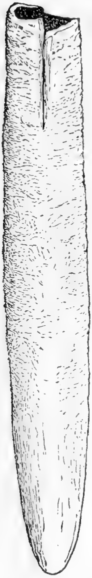
* From *belemnon*, a dart.

BELEMNITELLA AMERICANA.—(Fig. 101.)

The belemnitella is sub-cylindrical and tapering to a point from its base. The sides are marked by numerous ramose furrows, though they are arranged without much order, and being crowded they give the surface a granulated appearance. The base has a fissure which extends through the wall to a conical chamber. On the back, there is an elevated convex surface, narrow toward the base, but widens towards the apex, where it is lost.

FIG. 101.



This genus presents a great variety in form and size; but the foregoing characters are its constant characteristics. It occurs at Black Rock and Rocky Point, and is one of the characteristic fossils of the green sand. It is found also in the miocene beds, but is there by accident.

FIG. 103.

FIG. 102.

BELEMNITELLA COMHRESSA.—N. s. (Fig. 102.)

Shell slender, transverse section elliptical at base, and it becomes gradually more flattened to its apex; the fissure of the base is short; surface uneven and somewhat irregular. This species is entirely destitute of the granulations, or the convex surface of the preceding species.

The green sand of North-Carolina is poor in cephalopods. I have not yet observed either an ammonite or nautilus, though they occur sparingly in the eocene.

FIG. 105.

FIG. 104.

In the eocene of Craven county I found numerous specimens of the bony or horny cores of the jaws of cephalopods. I have not been able to determine the family to which they belong. Fig. 104 represents their form and size. They occur only in the upper part of the formation associated with sharks' teeth, and teeth and stings of one or two species of ray.

CLASS GASTEROPODA.—FAMILY MURICIDAE.

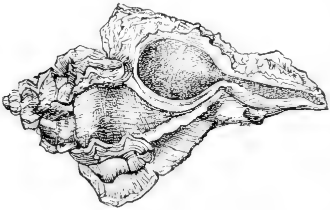
The muricidae are generally readily distinguished by their roughness occasioned by the periodical expansion of its lip. These being permanent, the shell is strongly marked by the rough shelly expansions along the lines of growth, as in the murex. The shell preserves its spiral form; the outer lip is entire behind, and the front prolonged in a straight canal. The eyes of this family are sessile and seated on tentacles: the animal has a broad foot.

GENUS MUREX.—LINN. ROCK SHELL.

The shell is roughened, or winged with the periodical expansions of its lip, which are permanent after it has advanced to a mature state.

MUREX UMBRIFER—CON.—CERASTOMA UMBRIFER—TOUMEY AND HOLMES—FOSSILS SOUTH-CAROLINA FROM CON. MSS.—(Fig. 104a.)

FIG. 104a.



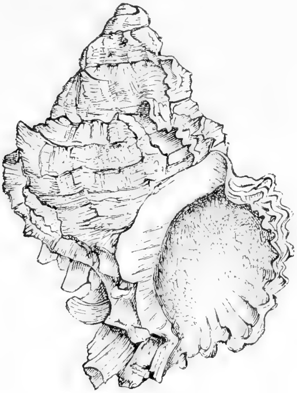
Shell fusiform; whirls subcarinated, or angulated and provided with six foliated and rather broad reflexed lamina, spirally arranged. Miocene Cape Fear River.

MUREX GLOBOSA.—(Fig. 105 A.)

Shell rather globose, or obtusely fusiform, and with four principal varices; intermediate ones irregular and spirally, traversed by many angular ridges, body whirl inflated, aperture oval, peristome continuous, and extended posteriorly on the body whirl, forming an angulated canal; outer lip ridged within and crenulated on the margin; collumela lip ridged.

and one ridge at the posterior angle; beak reflexed. Miocene of the Cape Fear River; half the natural size.

FIG. 105 A.



MUREX SEXCOSTATA.—(Fig. 106.)

Shell fusiform, with three spinous varices, and traversed spirally by angular ridges. Canal closed beak slightly reflexed. The body whirl has six ridges or ribs, with an intermediate lesser ridge. Shell imperfect.

FIG. 106.

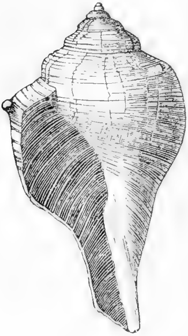
BUSICON CARICA, CON—PYRULA CARICA, GOULD, FULGUR CARICA, CON.

This shell is pyriform, swollen, thick and heavy. The outside is ornamented by transverse striae, and also with compressed tubercles, which stand upon the most prominent part of the body whirl. The outer lip is simple and sharp, pillar lip flexuous and concave above.

The suture of this species is not channelled, neither has it a turrited spire. It is one of the most common fossils of certain marl beds upon the Cape Fear river, but is less common upon the Neuse. It is one of the common living species upon the Atlantic coast.

BUSICON PERVERSUM, CON—PYRULA PERVERSA, REEVE.—(Fig. 107.)

FIG. 107.



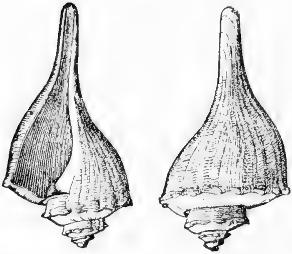
This shell is also pear-shaped and swollen. The prominent part of the whirl is ornamented with tubercles, and is also coronated; the whirls are turned to the left.

It is common upon the coast. It is very abundant in a post pliocene deposit at Beaufort, but is also often met with upon the Cape Fear.

BUSICON CANICULATUM, CON.—PYRULA CANICULATA, GOULD.—FULGUR CANICULATUM, CON.—(Fig. 108.)

Shell somewhat pear-shaped, spire depressed, and ornamented with revolving lines; body whirl swollen; canal long and straight; suture channelled. Common on the coast, and rather common, also, in the miocene.

FIG. 108.



PYRULA CAROLINEUSIS—TUOMEY AND HOLMEL,—H. TERTIARY FOSSILS OF SOUTH-CAROLINA.

Description: "Shell, pear-shaped; spire short, depressed; suture profoundly canaliculated, margined by the obtuse carina at the angle of the whirl; body whirl truncated above; angular whirls of the spire angulated in the middle, and in-

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* Fossils of South-Carolina,—Tuomey and Holmes, p. 145-'6.

clined slightly to the summit, having fine revolving lines indistinct, but prominent and waved on the base of the body-whirl; canal long and tapering." Miocene marl, Cape Fear.

PYRULA SPIRATA, LAM.—FULGUR PYRULOIDES. SAY.—FULGUR PYRUM, CON.

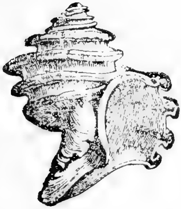
Shell pyriform; spire depressed obtuse; whirls flattened, and traversed by numerous revolving lines; suture caniculated. It still lives upon the coast, and is common in the post pleiocene of North-Carolina.

FIG. 109.

PYRULA RETICULATA—LAM—SYCOTYPUS RETICULATUS. (Fig. 109.)

Shell thin, cancellated; spire very short; surface marked by revolving lines, which are intersected by longitudinal ones, giving the shell its reticulated appearance or character. Occurs both in the miocene and post pleiocene beds, particularly at Beaufort. It is often much larger than the figure.

FIG. 110.



FUSUS LAM.

The genus Fusus is distinguished by its straight open canal and the absence of plaits upon the columella.

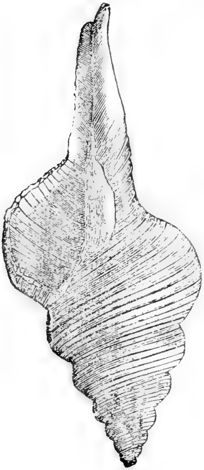
FUSUS QUADRICOSTATUS.—(Fig. 110.)

Shell thick, spire depressed, body whirl, inflated and ornamented by four elevated equidistant spiral belts, umbilicus large.—Newbern.

FUSUS EQUALIS.—N. S.—(Fig. 111.)

Shell thick, spire rather short, conical; whirls eight rounded and somewhat ventricose, and ornamented by numerous spiral subequal lines, coarser and more distant upon the back and rostrum; aperture and rostrum rather less than twice the length of the spire; outer lip ridged internally; pillar lip spirally ridged. Miocene of Cape Fear River.

FIG. 111.



FUSUS EXILIS.—(Fig. 111 A.)

FIG. 111 A.

Shell fusiform, spire elongated, composed of seven whirls, ornamented by revolving striae and longitudinal ribs; aperture one half the length of the shell.

FUSUS LAMELLOSUS.—N. S.—(Fig 112.)

FIG. 112.

Shell small, fusiform; spire composed of five or six whirls, ornamented with ten strong scalariform ribs, each rib on the body is composed of three sharp crenulated plates, the one in the middle being the largest.

FUSUS MONILIFORMIS.—N. S.—(Fig. 123.)

Shell small; whirls four, ornamented with raised beaded spiral lines, between which there are lines nearly simple; spire rather shorter than the aperture; aperture oval; canal short; the two upper whirls are smooth. Miocene of Cape Fear. Rare.

FASCIOLARIA.

This genus is characterized by its elongated fusiform shape, its round or angular whirls, open canal, and its folds upon columellar lip, which is more or less tortuous. The folds upon the lip are quite oblique, and two or three in number.

FASCIOLARIA DISTANS.—LAM. (Fig. 113.)

FIG. 113.

This shell at first sight appears smooth, but a careful inspection shows that it is finely striated longitudinally; its spire is composed of six or seven convex or prominent whirls, and its pillar has but one plait.

It is a common shell upon the coast, and in the post pleiocene at Beaufort, but not uncommon in the miocene of Cape Fear.

FASCIOLARIA ELEGANS.—N. S. (Fig. 114.)

FIG. 114.

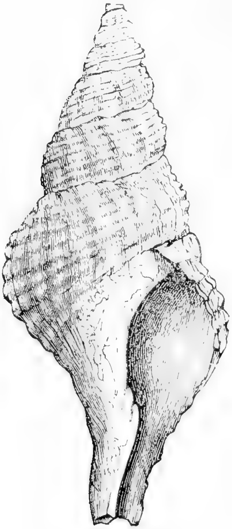
Shell elongated, acute; whirls eight rounded, ornamented with wide, and finely striated ribs; striae transverse to the ribs, or longitudinal; ribs of the body whirl, about fifteen, the middle of the body-whirl upon the outer lip, the four widest ribs alternate with three narrow ones; plaits three, concealed within the pillar lip; spire longer than the aperture.

This shell is rare in the miocene of North-Carolina. It would pass for fusus if the pillar lip was not examined just within the aperture, the plaits reaching only to its edge, but they are strong and well developed through its entire length.

It is possible this shell may have been previously described, but its broad, flat and very prominent ribs are so peculiar, that if observed and described, it could scarcely escape detection. Figure half the natural size.

FASCIOLARIA SPARROWI.—N. S. (Fig. 115.)

Fig. 115.



Shell rather thick, turbinate: whirls six or seven rounded, ornamented with spiral, and rather rounded ribs; ribs of the body-whirl, about ten, striated longitudinally, but obliquely striated on the upper part of the whirl; plaits. three upon the pillar lip; the ribs alternate, being coarser and finer for the ribs which belong strictly to the aperture; aperture larger than the spire.

This species is quite distinct from the former, the ribs are less numerous, flatter, and the striae are partly oblique and partly longitudinal, or in the direction of the axis of the shell. The five upper whirls have varices in both species. Rare in the miocene marl bed of Mrs. Purdys, Bladen county. One-half the size.

This fine fossil is dedicated to Thos. Sparrow, Esq., of Beaufort county.

FASCIOLARIA ALTERNATA.—N. S.

Shell rather small, but thick turbinate; whirls six or seven slightly inflated, body whirl elongated and ornamented with strong spiral lines, and with fine ones between, but which are frequently obsolete. All the whirls are tuberculated. Spire shorter than the aperture Plaits two.

FASCIOLARIA NODULOSA.—N. S. (Fig. 116.)

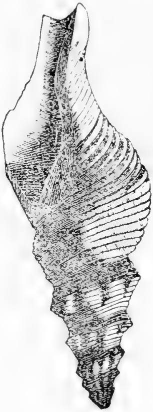
Shell rather thick, whirls about seven, all nodulose or ornamented with varices and spiral subequal striae. Miocene of the Cape Fear river.

Fig. 116.

FASCIOLARIA ACUTA.—N. S. (Fig. 117.)

Shell elongated, acute, whirls about seven, ornamented by spiral subequal ribs, with obsolete ones between them, six upper whirls have also equal varices; longitudinal striae very fine, aperture shorter than the spire. Miocene of the Cape Fear river.

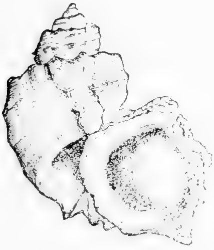
Fig. 117.



CANCELLARIA CAROLINENSIS.—N. S. (Fig. 118.)

Shell thick, angulated, whirls few, oblique, carinated and ornamented by two subspinous spiral bands, body whirl transversely, rugose towards the aperture, rugae subcrenulated, aperture triangular, and acute in front, umbillicus large, open, and funnel shaped.

Fig. 118.



I should have hesitated to have placed this interesting fossil in the genus cancellaria were it not that a closely allied species, the C. acutangulata, Faujas, is thus referred by high authority. The C. acutangulata is one of the characteristic fossils of the miocene beds of Dax, south of France. Its surface is is ornamented like a cancellaria, but the aperture in both the Dax and North-Carolina specimens is triangular, but both have rather obsolete folds upon the pillar lip; they are rather more obscure in our specimen than in that from Dax. The existence of this interesting fossil in North-Carolina proves the close analogy between the miocene of France and that of the southern States, and it seems that the new species really replaces the C. acutangulata in our miocene beds.

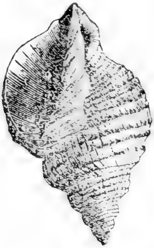
I am indebted to I. Lea, Esq., of Philadelphia, for specimens for comparison.

It occurs at Mr. Flowers' marl bed on the Cape Fear. Bladen county.

CANCELLARIA RETICULATA.—(Fig. 119.)

Shell thick, ovate, spire acute, whirls about six, and angulated and ornamented by prominent, longitudinal and revolving ridges, which produce a cancellated surface. Columulla with several strong oblique sharp folds; outer lip traversely ridged within.

FIG. 119.

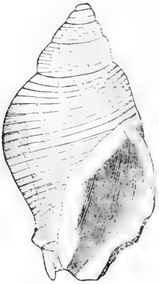


RANELLA CAUDATA.—(Fig 120.)

Shell turbinate, winged; whirls four or five, angulated and strongly ridged longitudinally; surface traversed by lesser revolving ridges. Two opposite ridges are produced more than the others, one of which forms the margin of the outer lip; canal long and straight. Common on the coast, and rather rare in the miocene of North-Carolina.

FIG. 120.

FIG. 121.



FAMILY BUCCINIDAE.—BUCCINUM MULTIRUGATUM.—CON. (Fig. 121.)

Shell thick, ovate; spire composed of five whirls, marked with deep impressed revolving lines; apex rather obtuse; columella, with a strong fold at base and a slight prominence at the base of the body whirl; bicarinate, aperture greater than half the length of the shell. Miocene of Cape Fear River.

BUCCINUM PORCINUM.—SAY.—(Fig. 122.)

Fig. 122

Shell thick, fusiform; spire composed of five or six whirls, ribbed longitudinally, and marked with numerous raised revolving lines; beak short and only slightly reflexed; outer lip marked within by numerous ridges. Buccinum vibex, buccinum trivittatum and obsoletum are associated with the preceding species.

BUCCINUM MULTILINEATUM.—N. S.—(Fig. 124.)

Shell small and thick, turreted; whirls six, and marked by many impressed spiral lines, between which there are also many narrow flat spiral bands: whirls furnished with strong longitudinal ribs, interrupted at the suture, aperture, ovate and less than half the length of the shell; canal short and directed backwards; the body whirl has about thirteen ribs. Rare in the miocene of Cape Fear.

Fig. 123.

Fig. 127.

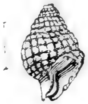


Fig. 170.

Fig. 125.

Fig. 124.

BUCCINUM MONILIFORMIS.—N. S.—(Fig. 125.)

Shell small, thick and robust, rugose; whirls about six, and ornamented with moniliform ribs. This shell, though small, has all the marks of being mature. The flat spiral bands, which as they cross the ribs and give them a beaded appearance, are strongly marked on all the whirls. Rare in the miocene of Cape Fear.

BUCCINUM BIDENTATUM.—(Fig. 126.)

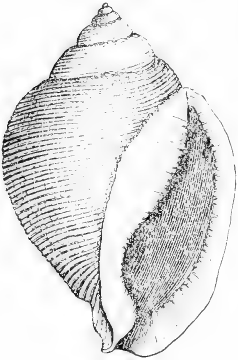
Shell quite small, thick, robust; whirls about five, two upper smooth, the others are ornamented with ribs and spiral bands; aperture oval, acute behind, outer lip furnished with two rather prominent teeth, or short ridges; canal wide and very short.

FIG. 126.

BUCCINUM OBSOLETUM.—(Fig 127.)

Surface granulated; spire shorter than the body. The common species of the coast; is rare in the miocene of North-Carolina. The specimen figured was a young shell, and broken.

FIG. 128.



GALEODIA HODGII.—CON. (Fig. 128.)

Shell rather thick; elliptical, obtuse; whirls about five, inflated, and ornamented with numerous fine spiral lines, which are quite prominent at base; these, with the fine lines of growth, give the surface a cancellated appearance; collumellar lip marked with many irregular plicae; aperture nearly twice the length of the spire. Miocene of Cape Fear.

TEREBRA DISLOCATUM; SAY.—ACUS DISLOCATUM.

Shell thick, elongated, acute; whirls many, slightly convex, upper portion constricted, forming a revolving band, parallel to which, there are numerous spiral raised lines; lines of growth longitudinal and conspicuous, which give to the surface a reticulated appearance.

Common in the miocene marls of North Carolina.

TEREBRA UNILINEATA; TUOMEY AND HOLMES—FOSSILS OF SOUTH-CAROLINA.—(Fig. 129.)

Fig. 129.

Shell thick, elongate bands alternate, acute, tapering gradually to a point; whirls many, seventeen or eighteen, and ornamented by revolving impressed lines, and passing just above the middle of the whirl; the upper part of the spire is also marked by short longitudinal ribs, which are interrupted by spiral lines. Oblique lines of growth are usually conspicuous. In old specimens, the ribs are obsolete.

Common in the miocene of North-Carolina.

TEREBRA NEGLECTA.—N. S.

Shell terete; spire composed of many whirls, traversed spirally by a deeply impressed line, dividing it into two unequal parts; the lower has three or four interrupted spiral lines, the upper, none. The ribs of the upper part are more obtuse than the lower, and die out before they reach the dividing impressed line; in the lower, they cross it from line to line.

In this species, the revolving lines are fewer than in the T. dislocatum, and in the latter, they are common to both parts of the whirl. In the unilineata, there is but one distinct revolving line.

DOLIUM OCTOCOSTATUM.—N. S. (Fig. 129 a.)

Fig. 129 a.

Fig. 181.

Shell small, thin; whirls three, inflated; body-whirl ornamented with eight spiral ribs, connected by short bars, peristome interrupted; aperture ovate; umbilicus small. open; outer lip crenulated.

OLIVA; LAM.—STREPHONA; BROWN.

The olives are shells of great beauty, being highly polished and covered with a porcellanous enamel, the surface of which is marked by spots and bands of a great variety of colors. The shell is cylindrical, dense and heavy; the spire is short, with channelled sutures, and the aperture long and narrow; the anterior part is notched; the columella is callous and striated obliquely. The body-whirl is furrowed near the base. The olives are the inhabitants of warm climates, and are very active.

OLIVA LITERATA.—SAY. (Fig. 130.)

Shell cylindrical, thick and polished; spire depressed; volutions angular and channelled; apex acute; outer lip sharp, inner marked with numerous sharp folds; aperture linear, incised above and notched below.

This shell is very common in many of the miocene marl beds in the State. It is also living and common on the coast. The fossil frequently retains the polish of the living shell; the colors have disappeared.

OLIVA ANCILLARIAEFORMIS.—LEA.

Shell small, oval, thick, and polished; spire elevated, acute; suture channelled; aperture narrow; inner lip thickened by callus and marked by a few obscure folds.

The foregoing description applies to a small oliva, with a large amount of callus upon its inner lip; but it appears to be a thicker shell than the one to which I have referred it. It is the most common upon the Cape Fear river.

OLIVA.

An oliva, (fig. 131a,) larger than the preceding, and more cylindrical, and having a higher spire, is occasionally found in the miocene beds of the Cape Fear. It has six whirls, and the folds upon the inner lip extend to the suture.

OLIVA CANALICULATA.—LEA.

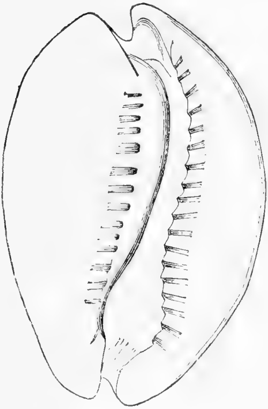
With this addition to the olives, we have four or five species belonging to the miocene period.

FAMILY CYPREIDAE.

The shells in this family are remarkable for their forms, polish and beauty. They are rolled as a scroll, and are covered with a porcellanous enamel. The spire is concealed, the aperture is long and narrow, and the outer lip is inflexed and thickened. It comprehends the beautiful, spotted and banded shells known as the cowry.

CYPRAEA CAROLINENSIS.—(Fig. 131.)

Fig. 131.

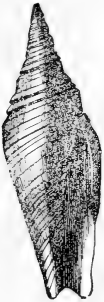


Shell ovate, flattened on the side of the aperture; outer lip prominent at the apex; margins of the lips ornamented with numerous plaits, and receding from each other, beginning at the most prominent part of the whirl. In some of the miocene beds it is quite common.

CYPREA PEDICULUS.

It is a small ovate shell, and transversely ribbed, and with a narrow groove along the back. I have not yet met with it in the marl beds of this State, though it appears to be common in South Carolina.

Fig. 132.



MITRA CAROLINENSIS.—(Fig. 132.)

Shell fusiform, thick, or elongate, and tapering towards each extremity; whirls slightly convex, channeled above, and traversed by numerous spiral raised lines; columella lip, furnished with numerous oblique plaits, of which the upper one is the strongest; canal wide and straight. Miocence marl of North-Carolina. The shell is often found much larger than the figure.

MARGINELLA OLIVAEFORMIS.—PORCELLANA OLIVAEFORMIS: TUOMEY & HOLMES, FOSSILS OF SOUTH-CAROLINA, p. 131.—(Fig. 133.)

"Shell elongated, oval; spire profoundly obtuse; aperture linear; labrum, (or outer lip) tumid, reflexed, profusely crenulated within; columella with three raised plaits."

With this description, several specimens agree, which I have found in the marl beds. It is, however, rare.

FIG. 138.

FIG. 136.

FIG. 133.

FIG. 139.

FIG. 137.

FIG. 135.

FIG. 134.

MARGINELLA LIMATULA.—(Fig. 134.)

Shell ovate; spire short; outer lip unequally crenulated; columella lip four plaited; aperture contracted above by deposition of callus.

MARGINELLA CONSTRICTA.—N. S. (Fig. 135.)

Shell polished, cylindrical; spire short; aperture constricted in the middle by the imbending of the outer lip; plaits four crowded at the base; margin of the outer lip smooth.

MARGINELLA OVATA.—N. S. (Fig. 136.)

Shell ovate; spire much depressed; aperture uniform; outer lip marked with numerous crenulations within; columella with six or seven plaits, the upper becoming obsolete.

MARGINELLA INFLEXA.—N. S. (Fig. 137.)

Shell oval; spire somewhat elevated; obtuse at base; margin of the outer lip inflexed above the middle; smooth inside; plaits four, and very prominent upon the inner lip. Differs from the constricta in the height of the spire.

MARGINELLA ELEVATA.—N. S. (Fig. 238.)

The thickened outer lip and the plaits of the inner, show this to belong to the genus marginella, though it has a close resemblance to an oliva in the elevation of the spire; whirls four.

ERATO LAEVIS?—(Fig. 139.)

Shell obtusely ovate; wide at the base of the spire, spire depressed; both lips crenulate, but most distinct upon the outer lip; resembles very closely a marginella. Miocene marl of Cape Fear river. (Rare.)

It is difficult to distinguish this from the English species with the aid only of figures. It may be indentical, and I have therefore referred it to the English species.

FAMILY VOLUTIDAE.

The volutes have a thick, short ornamented shell. The spire is particularly so, and it is also provided with a mamillated apex. Aperture is large and elongated, and the columella has several plaits.

VOLUTA MUTABILIS.—CON.

The shell is fusiform and thick, and has a conical spire and a papillated apex; whirls, convex and contracted near the sutures, and the two principal whirls are ornamented with short ribs; lines of growth distinct, and crossed by faint revolving lines; plaits, two and rather distant, and faint indications of an intermediate one. Found in the miocene of the Cape Fear river.

VOLUTA TRENHOLMII: TUOMEY & HOLMES, FOSSILS OF SOUTH-CAROLINA, p. 128.—(Fig. 140.)

"Shell fusiform, ventricose; whirls compressed above, spirally and transversely striated; striae wrinkled and coarse at base; spire short and sub-cancellated, papillated; aperture semi-lunar; outer lip acute, smooth within; columella lip very thin, decumbent, almost obsolete, semi-callous, not distinguishable from the body-whirl, but by outline and color.

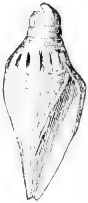
Columellar tumid, tortuous; obliquely plaited with three folds."

FIG. 140

VOLUTA OBTUSA.—N. S. (Fig. 141.)

Shell fusiform, contracted above the body-whirl, and forming thereby a sub-cylindrical spire; spire obtuse apex papillated and hooked; body-whirl plaited longitudinally at its top: columellar lip furnished with only two plaits.

FIG. 141.



Mr. Flowers miocene marl, Bladen county.

FAMILY CONIDAE.

As the name implies, the shells are conical from the great preponderance of the body whirl over the short depressed spire. The aperture is long and narrow, and the outer lip is notched near its suture.

CONUS ADVERSARIUS—CON.—(Fig. 142.)

Shell conical and turned to the left; the surface is marked by revolving lines; towards the face of the pillar lip the lines are strong; whirls of the spire rather concave; edges sub-carinated; labrum sharp, edge convex, and forming a sinus near the suture. Common in all the marl beds upon the Neuse and Cape Fear rivers.

CONUS DILUIVIANUS.—(Fig. 143.)

Shell conical, much smaller than the preceeding, and the whirls are turned to the right; surface markings the same; the revolving lines are less oblique than in the C. adversarius

They are associated together in about equal numbers. Neither species are found in older beds.

Fig. 142.

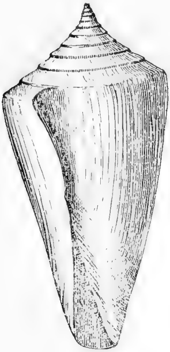


Fig. 143.

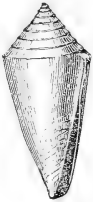


Fig. 130.

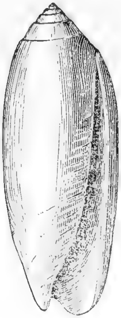


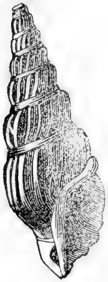
Fig. 131a

PLEUROTOMA LUNATUM.—LEA. TURRIS LUNATUM.—FOSSILS OF SOUTH-CAROLINA.—(Fig. 144.)

Shell thick, elongate, acute, subfusiform; strongly and obliquely ribbed; spire, eight whirled, angulated above and ornamented by a narrow sutural band.

The upper part of the whirls are constructed so as to present to the eye a narrow spiral band. Rather common in the marl of Cape Fear river.

Fig. 144.



PLEUROTOMA LIMATULA.—CON. (Fig. 145.)

Shell rather small, sub-fusiform; spire composed of five or six whirls; whirls constricted above and sub-angulated, forming a sutural spiral collar; ribs oblique and coarse. It is about one inch long.

PLEUROTOMA COMMUNIS.—CON.

Shell small, sub-fusiform; whirls about six, indistinct; body-whirl traversed spirally by four other sharp ridges.

PLEUROTOMA ELEGANS.—N. S. (Fig. 146.)

Shell small, sub-turrited; whirls, about nine, constricted above, ornamented by numerous longitudinal ribs, and traversed by many fine raised spiral lines, which become very distinct upon the pillar lip.

The spiral lines are very regular and equi-distant. The body whirl has about sixteen ribs. Figure natural size.

FIG. 148.

FIG. 147.

FIG. 145.

FIG. 146.

PLEUROTOMA TUBERCULATA.—N. S. (Fig. 147.)

Shell small, thick, sub-acute; whirls, seven or eight; apex sub-tuberculated, constricted above, and traversed spirally by rather coarse raised lines; apex papillated, and the first whirl is spirally lined, and without tubercles or short ribs. It is more widely constricted than the preceding.

PLEUROTOMA FLEXUOSA.—N. S. (Fig. 148.)

Shell small, thick, sub-turbinate; whirls, seven or eight. and ornamented by flexuose ribs, which extend across the whirl; ribs alternating with those of the adjacent whirl. There are about ten ribs belonging to the body-whirl.

FAMILY NATICIDAE.

The genus Natica belongs to a family of shells which is characterised by a globular form, few whirls, or a low and obtuse spire, a semilunar aperture, an acute outer lip, and an umbilicus often covered, wholly or in part, by a thick callus. The species are all marine.

NATICA HEROS.—SAY. Fig. 149.

Shell sub-globose, spire depressed, whirls four, convex; lines of growth obscure; aperture, ovate; umbilicus simple and rather large.

This species is common in the miocene marl of North-Carolina. It is also living upon the coast, but is more abundant, according to Dr. Gould, north of Cape Cod than south of it.

NATICA DUPLICATA.—SAY. FIG. 150.

Shell thick, ovate; spire somewhat prominent and pyramidal by the compression of the whirls; and surface marked by faint revolving lines; the lines of growth more distant; umbilicus partially closed by a thick dense callus.

FIGS. 150.

NATICA.—(Fig. 151.)

Shell thick, spire depressed; umbilicus perfectly closed by a thick rough callus, which extends to the angle where it becomes much thickened; suture distinct. It agrees with the clausa in part, but it is a much larger shell, being one inch and eight-tenths in diameter. Fossils answering in size to the clausa exist in the miocene marl on the Cape Fear river.

NATICA CANRENA.—Fig. 152.

Shell rather thick, lines of growth surrounding the spire, very distinct, resembling wrinkles; umbilicus partially closed with callus.

Occurs frequently in the miocene marl of North-Carolina.

Fig. 151.

Fig. 152.

Fig. 149.

NATICA FRAGILIS.—(Fig. 153.

Shell small, surface marked by revolving lines and lines of growth, which give it a cancellated appearance.

FAMILY PYRAMIDELLIDAE.

This family, when restricted to existing species, embraces shells of a small size, and which are spiral slender, pointed and turrited; aperture small, and the columella has one or more prominent plaits. Shells which, in form, bear a very close resemblance to this family, are found in very ancient rocks, but which, in comparison with those of the present day, were of a gigantic size.

PYRAMIDELLA ARENOSA.—CON. (Fig. 154.)

Shell smooth, and still somewhat polished, subulate; suture angularly channelled, columella with two folds; outer lip provided with three teeth. It is a rare shell in the miocene of North-Carolina.


Fig. 154.


Fig. 161.


Fig. 158.

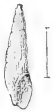


Fig. 160.

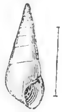


Fig. 157.

PYRAMIDELLA RETICULTA.—N. S. (Fig. 155.)

Shell turrited; whirls, six or seven, and ornamented by numerous longitudinal ribs, and less distinct spiral lines giving the surface a reticulated appearance; columella three plaited. It closely resembles the P. elaborata—H. E. Lea.


Fig. 155.

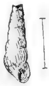


Fig. 156.


Fig. 159.

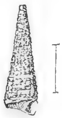


Fig. 162.

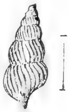


Fig. 164.

CHEMNITZIA.—(Fig. 156.)

Shell slender, elongated; many whirled; whirls longitudinally plaited and marked by obscure spiral lines; aperture simple, ovate. Rather rare in the shell marl at Magnolia.

CHEMNITZIA RETICULATA.—N. S. (Fig. 156a.)

It has six reticulated whirls, and about six revolving ridges to each whirl. Miocene of Lenoir.

FIG. 180.

FIG. 156a.

FIG. 166.

FIG. 165.

GENUS EULIMA; RISSO.

Shell small, white, polished, porcellanous, elongated, whirls numerous, flat; outer lip sharp, but thickened within; pillar lip reflected over the columella.

EULIMA LAEVIGATA.—PASITHEA LAEVIGATA.—H. E. LEA. (Fig 157.)

Shell small, acute, rather conical, polished and porcellanous; whirls, about nine; suture, obscure linear.

EULIMA SUBULATA.—N. S. (Fig. 158.)

Shell subulate, porcellanous; whirls, nine or ten, slightly convex; sutural space rather wide; aperture elongated. This shell is not uncommon in the shell or miocene marl of Lenoir county.

FAMILY CERITHIADAE—CERITHIUM (TRIPHORIS) MONILIFERUM: H. E. LEA.—(Fig. 159.)

Shell subulate, sinistral, thick, costate, sutures small; whirls, ten, flat; ribs three, moniliform; columella smooth; canal short and deep.

CERITHIUM.—(Fig. 160.)

Shell small, elongated; whirls, many, slightly convex, ornamented with numerous longitudinal ribs, which extend across the whirl; canal short and deep.

CERITHIUM ANNULATUM.—N. S. (Fig. 161.)

Shell small but thick; whirls many, ornamented with three sharp spiral ridges. These ridges are but slightly oblique to the axis of the shell.

CERITHIUM BICOSTATA.—N. S. (Fig. 162.)

Shell small, thick, tapering from the base; whirls many, and ornamented with two spiral, nodulose ribs.

TEREBELLUM ETIWANENSIS.—TOUMEY AND HOLMES—FOSSILS OF SOUTH-CAROLINA.

Shell subulate; whirls many, pointed, flattened and ornamented with two sharp spiral ribs; sutural line deep, especially below.

This shell presents considerable variation in passing from its immature to its mature state. In the young the spiral ridges are placed near the suture, and the space between is concave; the waving lines of growth gives it an obscurely beaded appearance. It is the most common univalve in the marl beds of Edgecombe county.

TEREBELLUM CONSTRICTUM.—N. S.

Shell rather thin terete; whirls many convex; lower ones deeply constricted on the line of suture, and ornamented by two principal raised revolving lines placed nearer the lower margin than the upper; the finer parallel lines are numerous; longitudinally, the spire is frequently marked by obsolete ribs; lines of growth indistinct. It differs from the T. Etiwanensis in the position of the principal revolving lines, and the lower rounded whirls.

Fig. 163.

TEREBELLUM BURDENII.—TOUMEY & HOLMES, FOSSILS OF SOUTH-CAROLINA, P. 122. (Fig. 163.)

"Shell subulate, turrited; whirls flattened, spirally ribbed and transversely striated, which give the ribs a beaded character."

SCALARIA MULTISTRIATA.—(Fig. 164.)

Shell, small whirls numerous, rather convex and ornamented with many sharp longitudinal ribs.

All the specimens of this species of scalaria which fell under my observation were imperfect at the aperture. Shell marl of Lenoir county.

SCALARIA CURTA.—N. S. (Fig. 165.)

Shell thin and delicate; whirls about four, ornamented with rather flexuose, sharp, longitudinal ribs. Shell marl of Lenoir county.

SCALARIA CLATHRUS.—(Fig. 166.)

All the specimens of this species, when found, were imperfect. It differs from the preceding in having transverse ribs between the longitudinal ones.

PETALOCONCHUS.—LEA.—PETALOCONCHUS SCULPTURATUS.

(Fig. 169.)

Shell vermiform, tubular, provided with two longitudinal plates internally; externally it has nodulose ribs or costae. The shell is curiously twisted into knots, but sometimes it is rolled up into a coil somewhat conical, as in the figure, after which it is coiled irregularly. It is very common in the miocene marl beds of the State.

Fig. 169.

FAMILY LITORINIDAE.—LITORINA LINEATA.—N. S.

(Fig. 170.)

Shell rather small, thick conical; whirls five nearly flat, and the two lower are ornamented with many spiral ridges, which are crossed by obscure lines of growth; three upper whirls smooth.

FAMILY TURBINIDAE—TROCHUS PHILANTROPUS.—(Fig. 167.)

Fig. 167.

Shell conical, but rather depressed; whirls slightly angular at base, and ornamented with spiral beaded lines, alternating in size.

TROCHUS.—(Fig. 168.)

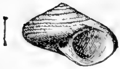


Fig. 168.

It appears to differ from T. armillatus, but I am unable to refer it to any of the species described in the miocene beds.

DELPHINULA QUADRICOSTATA.—N. S. (Fig. 180.)

Shell small, thin; whirls, few, angulated and furnished with four ribs, which are crossed by lines of growth; aperture angular.

Found occupying the interior of the large univalve shells of the miocene.

ADEORBIS.—WOOD. (Fig. 181.)

I have placed this figure under this genus, though it does not agree with it in every particular.

FAMILY TORNATELLIDAE.

This family has a convoluted shell; it is cylindrical, or subcylindrical, with a long narrow aperture; columella plaited.

TORNATINA CYLINDRICA.—N. S. (Fig. 182.)

Fig. 182.

Shell small, convoluted, cylindrical, porcellanous, or polished; spire depressed; whirls. angulated; suture channelled; aperture long and narrow; outer lip arcuate; columella with one fold.

This small shell resembles a cyprea, or some of the smaller species of olivas. It is not uncommon in the miocene; it is usually found in the cavities of the larger univalves.

FAMILY HELICIDAE—LAND-SHELLS.—HELIX TRIDENTATA.
(Fig. 183.)

Shell depressed, or flattened, convex; whirls, four and obliquely wrinkled; aperture contracted and furnished with two teeth on the outer lip, and one upon the inner lip; the latter is curved.

FIG. 186.

FIG. 185.

FIG. 184.

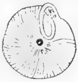
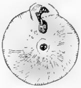


FIG. 183.



H. LABYRINTHICA.—(Fig. 184.)

Shell small and of a conical form; whirls, six and marked with oblique lines of growth; lip reflexed; inner lip furnished with a single tooth extending within the shell.

FAMILY LIMNEIDAE.—FRESH-WATER SHELLS.—PLANORBIS BICARINATUS.—(Fig. 185.)

Shell deeply concave on both sides; whirls, three; carinated on both sides; lip on the left extending beyond the plane of the preceding whirl.

This fresh water shell is rare in the miocene beds of the Cape Fear.

FAMILY PALUDINIDAE.

This family embraces certain gasteropods, most of which live in fresh water, as lakes, ponds and rivers. The form of their shells is conical or globose, covered with a thick green epidermis. The aperture is rounded and the whirls convex: peristome continuous.

PALUDINA SUBGLOBOSA.—N. S. (Fig. 186.)

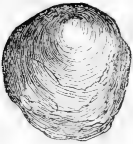
Shell rather thin, turbinated; whirls, four, rounded or convex, short; aperture rounded; third whirl marked by four or five spiral obsolete lines. It has a close resemblance to Gould's and Halderman's genus Amnicola.

Miocene of Cape Fear, but it is by no means a common shell.

CLASS BRACHIOPODA.

ORBICULA LUGUBRIS.—CON. (Fig. 187.)

Fig. 187.



Shell corneous, oblong-ovate, depressed; concentrically lamellose; apex behind the centre; posteriorly, it is marked by a few radiating lines; interiorly, it is smooth, and there is a short longitudinal ridge on the median line. In some of the miocene beds in Wayne county, it is quite common.

FAMILY DENTALIDAE.—TOOTH SHELLS.

The dentalidae are hollow, curved tooth-like shells. They are usually ornamented by longitudinal ridges, but sometimes they are smooth and polished. They have a round or circular aperture.

DENTALUM ATTENUATUM.—SAY. (Fig. 188.)

Shell gently curved, and ornamented with twelve rounded ribs; aperture circular. Common in the shell marl of this State.

Fig. 188.

Fig. 190.

D. THALLUS.—CON. (Fig. 189.)

Shell small, polished, curved and tapering towards both extremities. Common in the shell marl.

Fig. 189.

CAECUM ANNULATUM.—N. S. (Fig. 190.)

Shell minute curved; ends subequal; aperture circular; surface annulated.

This minute shell is quite common in the miocene of this State. It is found in the interior of larger ones, which it probably inhabited.

FAMILY CALYPTRAEIDAE.—LIMPETS.—BONNET LIMPETS—CUP AND SAUCER LIMPETS.

The limpets have but one valve. It is sometimes saucer shaped or sub-conical, and passing into a cone, within which there is an appendage somewhat similar in form to the outer cone. These cones are frequently sub-spiral. They adhere to rocks and stones with their apertures below.

CRUCIBULUM COSTATUM.

Shell rather thick, circular at base, and furnished with strong but rather irregular ribs; apex sub-central; margin crenulated.

CRUCIBULUM RAMOSUN.—CON. (Fig. 191.)

Shell ovate; apex sub-central; ribs prominent and ornamented by a series of subordinate diverging ridges, but partially interrupted by the lines of growth; inner cup sub-conical, entire, and marked by circular ridges, or lines of growth.

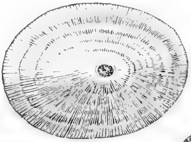


FIG. 196.


FIG 195.

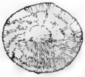


FIG. 192.

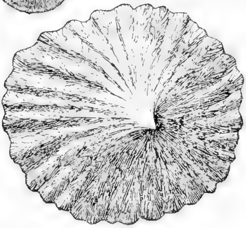


FIG. 191.


FIG. 193.

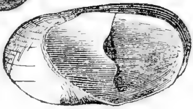


FIG. 194.

C. DUMOSUM.

Shell depressed, sub-conical, oblong or oval at base; surface ornamented with spiral ribs, and whose spines are hollow.

C. MULTILINEATUM.—(Fig. 192.)

Shell rather small, depressed, very thin; apex elevated, sub-central, disk marked with radiating lines. Rather common in the miocene. Usually occupies the interior of other shells.

TROCHITA CENTRALIS.—(Fig. 193.)

Shell rather small, very thin, round, ovate; apex medial minutely spiral and acute. Associated with the foregoing shells of this family.

CREPIDULA.—LAM.

Crepidula has the limpet shape, but a posterior oblique marginal apex. Interior has a horizontal plate, forming a partition which curves the posterior half. They vary in form, which is very much dependent upon the surface to which they are attached.

CREPIDULA FORNICATA.—(Fig. 194.)

Shell obliquely oval; surface convex, smooth or wrinkled; apex turned to one side: diaphragm concave below, occupying half the shell. Common in the miocene of North-Carolina.

CREPIDULA SPINOSA.

Shell depressed, oval, costate and spinous, especially towards the margin. Common in the miocene.

CREPIDULA PLANA.—SAY. (Fig. 195.)

Shell nearly flat, slightly convex; diaphragm convex; the form is very variable, assuming the shape of the surface upon which it rests.

FAMILY FISSURELLIDAE.—KEY-HOLE LIMPETS.

Shell limpet shaped; some have the margin notched in front; in others the apex is perforated. Adhere to rocks and stones.

FISSURELLA REDIMICULA.—(Fig. 196.)

Shell ovate, oblong, elevated, and rather thick; surface ornamented with fine longitudinal ridges, which are intersected by circular lines of growth, which gives the surface a reticulated appearance; margin entire, but ridged internally; apex truncated, figure inclined, oblong.

This shell is not an uncommon occupant of the shell marl beds of this State.

CLASS LAMELIBRANCHIATA.

FAMILY OSTREIDAE.

"Shell inequivalve and nearly inequilateral; free or adherent resting on one valve; beaks central, straight ligament internal; muscular impression single and behind the centre; hinge usually without teeth."

OSTREA VIRGINIANA.

Shell thick, strongly and radiately plicated; concentrically laminated and imbricate; upper valve nearly flat; pliated towards the margin; beaks laterally curved; very variable. Common in the miocene beds of North-Carolina.

OSTREA CAROLINENSIS.

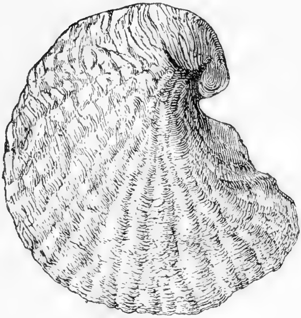
Shell ob-ovate, thick, compressed, concentric lamina imbricated, and transversely plaited; beaks broad and prominent. Fosset large and bounded laterally by strong ridges.

Occurs in the miocene of North-Carolina, but is less common than the preceding.

Ostrea radians and O. sellaeformis belong also to the miocene beds, together with the Anomia ephippium; the latter is always broken.

EXOGYRA COSTATA.—(Fig. A.)

FIG. A.



Shell sub-oval, very thick, lower valve convex, and covered with strong corrugated ribs; apex lateral, with about two volutions; upper valve flat, thick, supplied with numerous elevated concentric squamose plates. It belongs to, and is, one of the characteristic fossils of the green sand at Black Rock, on the Cape Fear, and at Rocky Point, twenty miles north of Wilmington. It is found in the miocene at several places on the Cape Fear, but its presence is due to accident.

CUCULLAEA VULGARIS.—(Fig. B.)

FIG. B.

This fossil occurs in the form of an inside cast of the shell; it is inflated, subtriangular, flattened before, beaks prominent and in-curved; shell thick, and marked with numerous delicate longitudinal striae.

It is associated with the Exogyra and Belemnitella at Black Rock in the green sand.

The C. vulgaris is placed here from its association with the E. costata.

FAMILY PECTENIDAE.—PECTEN, SCALLOP.

Shell sub-orbicular, regular, resting on the right valve, usually ornamented by fretted or scaly ribs radiating from the hinge; right valve most convex, with a notch below the front ear; hinge margin straight, united by a narrow ligament; cartilege internal in a central pit.

The scallop of our coast is regarded as a delicacy. It lives in shallow water, and is taken in great numbers at low tide from banks which are just submerged. They move through the water by opening and shutting their valves. Fossil pectens or scallops are very abundant in most of the miocene marl beds in this State. The large scallops, P. Jeffersonius and P. Madisonius abound in beds upon the Neuse and Tar rivers, while they are less numerous upon the Cape Fear. Another large species is found upon the Meherrin, in Northampton county, which I have not met with elsewhere. It replaces the English species, the Pecten princeps, which it closely resembles.

PECTEN COMPARILIS.

Shell medium size; both valves convex with twenty-three or twenty-four ribs, prominent and angular inside at base; ribs and spaces between nearly equal; ears radiately striate. One of the most common fossils upon the Cape Fear.

PECTEN EBOREUS.—(Fig. 197.)

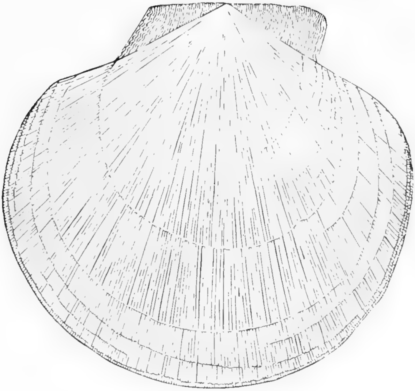
FIG. 197.

Shell comparatively thin, and light and compressed valves; circular, sometimes oblique and equilateral; ribs twenty-four, marked on the outside with concentric squamose lines of growth, which are undulating, the last of which are strong; lower valve less convex than the upper. It differs from the comparilis in being concentrically marked, and thinner, besides it grows much larger.

PECTEN PRINCEPOIDES.—N. S.—(Fig. 198.)

Shell large, rather thick, compresed, sub-inequilateral, radiating striae coarse and very numerous; transversely marked by lines of growth, giving the surface a wrinkled appearance; ears unequal; buccal ear sinuate, radiating striae numerous, inside smooth, striae obsolete; fig. reduced.

FIG. 198.



This is a large species of pecten, is closely allied to the P. princeps of the English crag. It is common in the miocene marl on the Meherrin river, at Murfreesboro'. It is five inches long, and five and a quarter wide. It is readily distinguished by the absence of ribs proper, and the presence of coarse radiating striae, which have intermediate ones, which do not reach the hinge or umbo; many of the striae, however, fork or divide.

P. PEEDEENSIS.

Shell thick and strong, broadly ovate; ribs, eight, broad striae, lines of growth strong towards the margin; beak projecting beyond the hinge line.

Only one valve has been found of this species, and being old and its striae obliterated in part, and its characters are less distinct than is usual in specimens belonging to this genus.

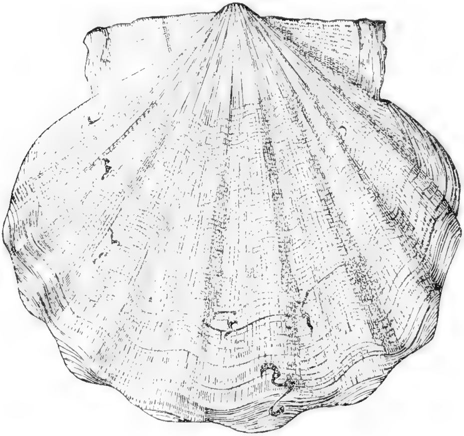
P. MORTONI.

Shell large, circular, compressed, thin, pearly; equivalve equilateral; concentrically marked by fine lines of growth; on the outside, ribs are invisible; inside, ornamented by about eighteen pairs of ribs, which are prominent at the margin, and obsolete towards the hinge.

This beautiful shell occurs in the miocene at Waccamaw Lake, North-Carolina, and has not been observed upon the Neuse or farther north.

P. JEFFERSONIUS.—(Fig. 199.)

FIG. 199.



Shell very large, ribs, ten, and wide, and longitudinally marked by fine ridges, which are not squamose. This species is sometimes between nine and ten inches wide, and seven or eight inches long, and are often used in cooking oysters in place of a frying pan. It is one of the characteristic fossils of this miocene.

P. MADISONIUS.—(Fig. 200.)

In the P. Madisonius, the ribs number about fifteen, and they are ornamented with three squamose ridges each. There is also an equal number between them; they coalesce towards the hinge.

FIG. 200.

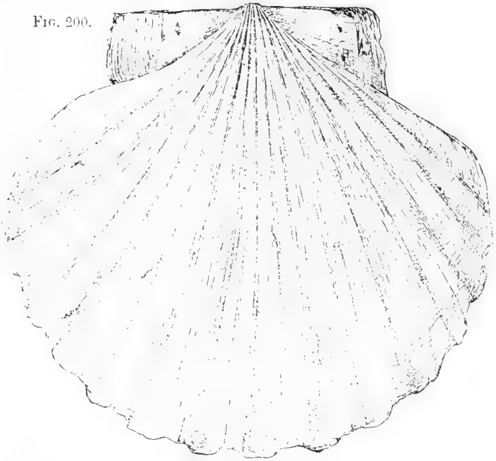
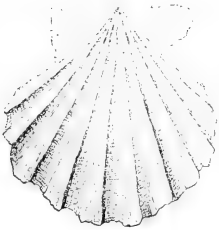


FIG. 201.



A. pecten, (fig. 201,) is quite common in North-Carolina, which I have not been able to refer to its proper species. It is one of the most common in the shell marl of the middle part of the eastern counties. It has ten prominent ribs, but they are ornamented in a different style from that which prevails in the young of the P. Jeffersonius.

One of the most common pectens of the white eocene marl, is represented by figure 202. It differs from the P. membranacea in having only about half the number of ribs. The P. membranacea having upwards of eighty, while this has about forty-four.

An observer cannot fail to perceive the striking difference in the species of pectens of the white eocene marl of New-Hanover and Onslow counties, and those of the miocene.

Fig. 202.

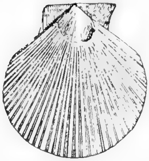
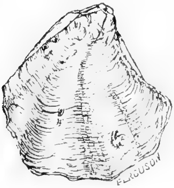


Fig. 203.

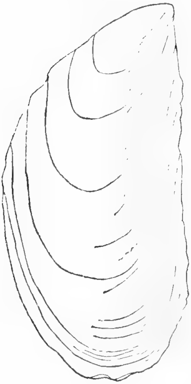


PLICATULA MARGINATA.—(Fig. 103.) Shell strong and thick, but rather small; valves sub-equal, ovate, wedge-form, with three strong radiating plicae.

FAMILY MYTILIDAE.—MYTILUS INCRASSATUS. (Fig. 203A.)

Shell nacreous, thick, somewhat inflated, marked with concentric lines of growth; anterior margin arched acuminate; posterior rounded, somewhat dilated; umbones acute. It is usually much injured by exfoliation and rarely perfect.

Fig. 203A.



CRENELLA.—(Fig. 203B.)

Shell small, short, thin, smooth in the middle; hinge, margin crenulated behind the ligament. It appears to be rare, though it may be owing to its frailness. Miocene.

Fig. 203B.

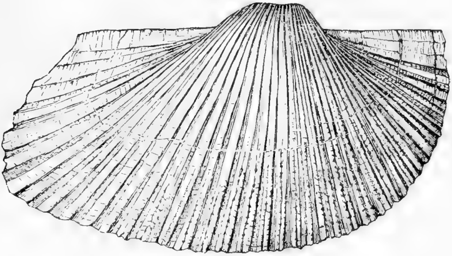
ARCADAE.

The valves in the Arcadae are equal, regular, and usually oblique; the teeth are arranged in long rows, resembling a comb; at the extremes they are longer and frequently curved or corrugated.

ARCA LIENOSA.—SAY.—(Fig. 204.)

Shell large, inflated, oblique; ribs subequal, numerous, with a groove or channel in the middle; anterior side angular; lines of growth distinct, giving a striate appearance; the ligament area is marked by strong lines diverging from beneath the umbo; umbones distant; inside margin strongly sulcate or ribbed. It has about 37 ribs. A living shell upon the Florida coast, but found abundantly in the miocene of North-Carolina.

FIG. 204.



A. SCALARIS.

Shell oblong, ovate; ribs twenty-one, strong and transversely rugose, ligament area short, transversely marked by lines, and crossing striae parallel to the hinge line.

A. INCILE.—SAY.

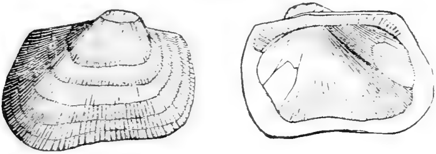
Shell very oblique, sub-quadrangular; anterior side very short, posterior sinuate; ribs unequal, stronger on the posterior margin; rounded before, angular behind, and much produced; umbones incurved, distant; ligament area crossed by transverse lines.

This shell has about thirty-one principal ribs, with intervening raised lines, and transversely marked by lines of growth.

A. CENTENARIA.—(Fig. 205.)

Shell sub-quadrate and ovate, nearly straight and slightly contracted at base; ribs fine, alternating in size; margins rounded; beaks approximate; hinge area narrow; margins entire.

FIG. 205.



The striae or ribs in this species are very numerous and fine, while these together with its quadrangular form will serve to distinguish it from others of the same genus. Common in the miocene of North-Carolina. The figure was drawn from a specimen obtained from the indurated sand beneath the miocene bed at Elizabethtown, Bladen county, and is referred to the centenaria but with doubt.

A. IDONEA.

Subcordate inequivalve ventricose; elongated and only slightly oblique; beaks very prominent and distant; ribs about twenty-five, crenulated, or transversely ridged; hinge area wide and marked by divergent striae or channels. Common in the miocene of North-Carolina.

A. TRANSVERSA.

Shell rather thin, subrhomboidal, rounded with about thirty-two ribs; area rather narrow, with two or three undulated grooves. Common in the miocene, and still living upon the coast. A. limatula and stillicidium are also miocene shells, and common in the marl beds of the Cape Fear river.

VERTICORDIA.—WOOD.—(Fig. 206.)

I have met with two or three specimens only of the fossil which I have referred to this genus. It is found in the interior of large shells.

Fig. 206.

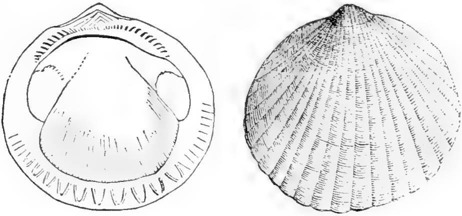
GENUS PECTUNCULUS.

Shell orbicular, nearly eqilateral, smooth and radiately striated; hinge with a semi-circular row of transverse teeth.

PECTUNCULUS SUBOVATUS.—(Fig. 207.)

Shell orbicular, inequilateral, with radiating sulci, becoming obsolete with age; teeth nearly obliterated in the centre: teeth largest on the shorter side of the valve; marginal ones broad and separated;—Conrad. This is probably one of the most common miocene fossils of the shell marl in the State.

Fig. 207.



P. LENTIFORMIS.

Shell orbicular, sub-equilateral; the radiating striae are numerous; beaks small in proportion to the size of the shell; hinge teeth in the centre, wanting or obsolete. This fine species in some marl beds upon the Cape Fear, is quite common, and is very large and thick; some are four to four and a half inches across.

P. ARATUS.—(Fig. 208.)

FIG. 208.

This is the smallest species of this genus belonging to the shell marl. It is also one of the most common. P. passus and P. quinquerugatus are also common in certain localities.

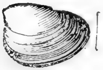
LEDA ACUTA.—(Fig. 208A.)

FIG. 208A.

Shell small, thick, inflated posteriorly; margin acute or beaked, slightly open; anterior margin, short rounded; surface concentrically striated. This fossil resembles nucula, but it is not pearly in the interior, and its abdominal margin is smooth.

NUCULA PROXIMA.—(Fig. 208B.)

FIG. 208B.



Shell small, ovate, smooth, interior pearly; anterior margin short; posterior side elongated, obtuse; margin crenate. N. limatula is more common in the marl beds of this State than the N. proxima; miocene.

FAMILY CHAMACIDAE.

The shell is thick, inequavalve, with sub-spiral beaks, hinge teeth 1—2, muscular impression one, and large; reticulated palleal line simple.

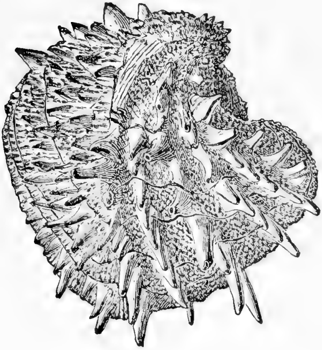
CHAMA.

The shell is attached to other bodies by its left umbo: hinge-tooth of the free valve thick, curved, and received between the teeth of the other valve.

CHAMA ARCINELLA.—(Fig. 209.)

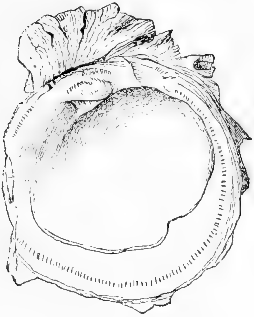
Shell thick, or orbicular-cordate squamose; the radiating ribs spinose, strong, tubular or folded; intervening space coarsely punctate and rugose. Common in the marl bed at Elizabethtown, Bladen county.

FIG. 209.



CHAMA CORTICOSA.—(Fig. 210.)

FIG. 210.



Shell thick, squamose, or concentrically laminated and imbricate; lamina striated, sinistral, crenulated interiorly: upper valve flat. Figure lower valve natural size. Abundant in the miocene of North-Carolina, especially on the Cape Fear.

CHAMA CONGREGATA.

Shell thick, orbicular, with its surface composed of plates or lamina; in the flat valve the plates are crenulated or plaited.

CHAMA STRIATA.—N. S. (Fig. 211.)

Fig. 211.

Shell small, ovate, rather thick for its size; lower valve distinctly striate. Usually found in the hollow or inside of the univalves.

FAMILY CYPRINIDAE.

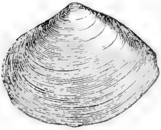
Shell regular, equivalve oval or elongated; valve close, solid; epidermis thick and dark; ligament external, conspicuous cardinal teeth 1—3 in each valve; pedal scars close to or confluent with the adductors; pallial line simple.—Woodward.

ASTARTE

Shell small, thick, compressed, smooth or concentrically furrowed; lunule impressed; ligament external; hinge teeth 2—2; anterior tooth in the right valve large and thick.

ASTARTE CONCENTRICA.—(Fig. 212.)

FIG. 212.



Shell small, thick, triangular, compressed, concentric; furrows close and regular; umbones acute, recurved; margin crenate. It is about one inch long, and one broad. It is rather common in the miocene of North-Carolina.

ASTARTE UNDULATA.—(Fig. 213.)

The broad, variable and concentric furrows will serve to distinguish it from the foregoing. It is comparatively a broader shell. The Undulata seems, however, to be quite variable, and the figure shows one of the extremes of this species.

CRASSATELLA UNDULATA.—(Fig. 214.)

Shell oblong, ovate, compressed, marked upon the outside with coarse concen-

FIG. 213.

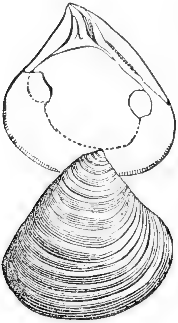
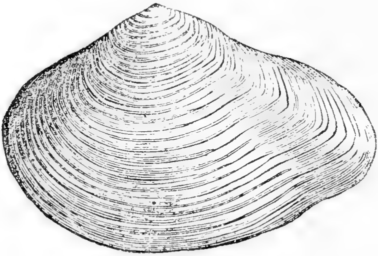


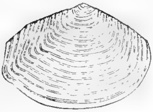
FIG. 214.



tric striae; umbo flattened; apex sub-acute; inner margin entire. One of the most common fossils of the shell marl.

C. GIBBESII : TUOMEY & HOLMES, FOSSILS OF SOUTH-CAROLINA ; p. 74. (Fig. 215.)

FIG. 215.



"Shell somewhat triangular, thick, concentrically furrowed; buccal side rounded; anal side somewhat beaked, angular, with a longitudinal ridge; umbones incurved: lunule somewhat excavated."

In addition to the foregoing, I may add the following as common in the North-Carolina shell marl beds: Crassatella alta, C. Marylandica, C. Protexta, C. Melina.

FAMILY CYCLASIDAE.—CORBICULA DENSATA.—CYRENA DENSATA, CON.—(Fig. 215A.)

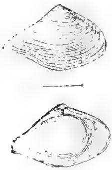
FIG. 215A.

Shell orbicular striated concentrically, polished, lateral teeth elongated.

This shell is very abundant at the miocene marl bed of Mr. Flower, on the Cape Fear.

FAMILY CORBULIDAE.—CORBULA CUNEATA.—(Fig. 215B.)

FIG. 215B.



Shell small, thick, ovate, concentrically striate; anterior margin rounded: posterior elongated, or somewhat rostrate. Common in the shell marl.

FAMILY LUCENIDAE.

This family have orbicular shells, both free and closed with hinge teeth, somewhat variable as one or two laterals, or one and one, and the other obsolete; pallial line simple, muscular impressions two, elongated and rugose. The family is principally composed of tropical and temperate species, and live upon sandy or muddy bottoms, and exist from the sea shore or shallow water to the greatest habitable depths.

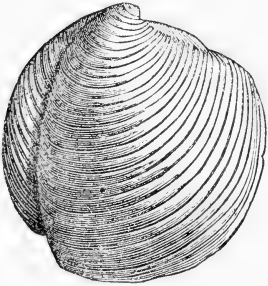
LUCINA BRUGIERE.

The shell is orbicular, white, with depressed umbones, and the margins are either smooth or only finely crenulated; hinge teeth 2—2, laterals 1—1, muscular impressions rugose; anterior, elongated and within the pallial line; umbanal area with an oblique furrow.

LUCINA PENNSYLVANIA.—LINN. (Fig. 216.)

Shell orbicular, thick, solid, and concentrically ribbed, or posteriorly it has a strong fold or groove. The fold extends across the shell, and produces a notch in the pallial margin. Common in the miocene upon Neuse and Cape Fear rivers.

FIG. 216.



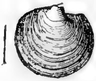
LUCINA CONTRACTA.

Shell orbicular, somewhat inflated; ribs concentric, unequal, marked in the intevals with striae; posteriorly the margin is channeled.

It is larger than the preceding, and has no fold, and its ribs are unequal.

L. CRENULATA.—(Fig. 217.)

FIG. 217.



Shell small, thin, orbicular, somewhat inflated, concentrically lamellated, lunule excavated. Common.

In addition to the foregoing, the following species have been observed in the miocene: Lucina anadonta, L. radians, L. divaricata, L. multilineata, and L. squamosa.

FAMILY VENERIDA.

This important family is represented by many existing species in our seas at the present time. It is too well known to require a minute description. It is, however, known from other forms by its regular oblong thick shell, though it is sometimes nearly round; by its strong external ligament, and its three diverging prominent teeth in each valve. Its pallial line is sinuated.

The venerida are elegant and beautiful shells, often highly colored, though some of the best known are externally dull. This family appeared first in the Oolitie period, and they have increased in number and importance down to the present time, when they have acquired their maximum developement.

VENUS MERCENARIA.

Shell solid, surface marked by numerous concentric lines of growth, obliquely cordate; posterior margin produced: anterior short; umbones recurved, lunule cordate; pallial line sinuated; margin crenulated.

VENUS TRIDAENOIDES.—CON. VENUS DIFFORMIS.—SAY.

Shell very thick and heavy; globose, wrinkles upon the surface undulating; plaits wide, extending from the umbo to the margin.

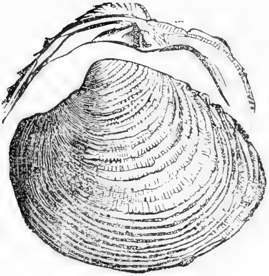
This species may be distinguished by its thickness and wide external plaits, which are usually strongly marked, though sometimes they are feebly developed. It is one of the most common fossils of the miocene beds of North-Carolina.

VENUS RILEYI.

Shell large, thick, oblong, posterior margin prolonged, anterior one short; surface concentrically striate, and marked by fine, longitudinal lines, which are distinct after the dermal covering exfoliates. This is one of the largest species, being sometims 6—7 inches wide. Common in the miocene of Cape Fear river.

V. CRIBRARI—CON. (Fig. 218.)

Fig. 218.

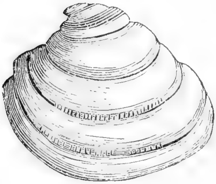


Shell thick, medium size, slightly ventricose, furnished upon the outside by about twenty-five sharp lamelliform concentric and recurved ribs, crenulated upon the umbonal side; ribbed or ridged transversely on the ventral side, the ridges extending across to the adjacent rib; lunule crenulated.

Recent upon the coast of North-Carolina.

V. LATILIRATA CON.—VENUS PAPHIA.—LAM. (Fig. 219.)

Fig. 219.

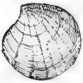


Shell sub-trigonal, thick and ponderous for its size; ribs fine, concentric, and very thick; irregularly stirate, crenulate upon the lower margin; umbo slightly flattened.

This shell is readily known by its thick ribs, and deep subci between them. Common in the miocene of North-Carolina.

VENUS MELTASTRIATA.—(Fig. 220.)

Fig. 220.



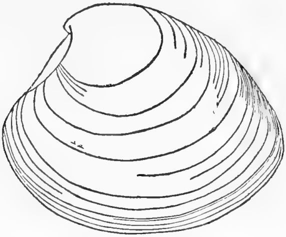
Shell small, sub-orbicular, striated concentrically, rather irregular, interruptedly radiated.

Venus pramagna, cancellata and subnasuta are also rather common fossils of the miocene.

CYTHERCA SAYANA.—(Fig. 221.)

Shell inflated, concentrically striate, anterior side angulated; umbones prominent, incurved; margin smooth; lumule cordate.

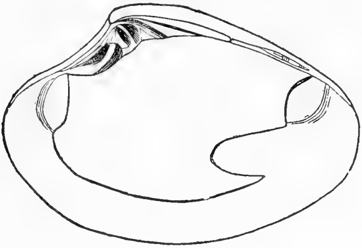
Fig. 221.



C. REPOSTA.—(Fig. 222.)

Shell smooth, moderately inflated, thick, beaks prominent, dorsal margin depressed; anterior margin rounded, lunule lanceolate.

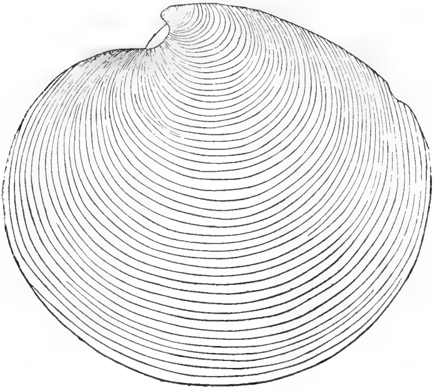
Fig. 222.



C. REPORTA.—(Fig. 223.)

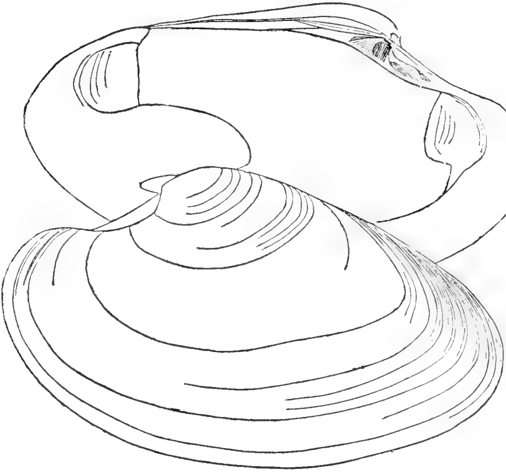
This fossil, which the annexed figures represent, is very common in a sandy marl bed in Brunswick county. It preserves its original polish, and closely resembles the foregoing. It is, however, proportionally wider than the repostia. It is highly polished and smooth, but has concentric striae. Umbones flattened, the flattened part extending across the shell, being bounded anteriorily with an obscure rounded ridge.

FIG. 223.



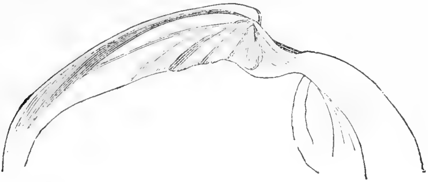
ARTEMES TRANSVERSUS.—N. S. (Figs. 223a and 224.)

FIG. 223a.



Shell sub-orbicular, depressed, sub-equilateral, concentrically striate; broader than long; lumule small, lines of growth or concentric striae regular, simple, and somewhat coarse and distant. Fig. 224 shows the hinge.

FIG. 224.



This fossil appears to differ from the Artimus concentrica of the coast; its linus of growth are about half as numerous and are also continuous from one margin to the other, excepting a few on the anterior margin.

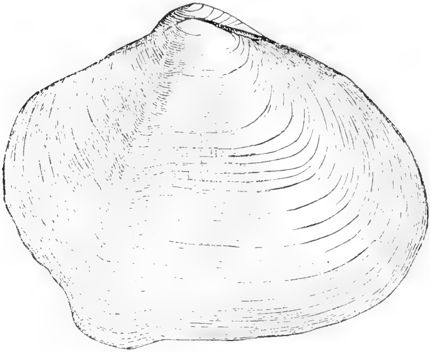
In the living coast species the lines of growth are less regular, and coalescent near both margins; it is orbicular also, being as long as wide. The fossil, however, closely resembles the living one of the coast, though it differs as much from it as Artemis acetalubum of Conrard.

Species which belong to the miocene and which remain undescribed: A. acetabulum, A. concentrica.

FAMILY TELLIMIDAE.—TELLINA BIPLICATA.—CON. (Fig. 225.)

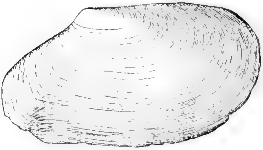
Shell rather large, thin, sub-oval, inequivalve, sub-ventricose, marked with rather obscure radiating lines, and impressed with an oblique fold in each valve. The remaining species of Tellina belonging to the miocene are T. Alternata, T. Polita, and T. Flexuosa.

FIG. 225.



TELLINA LUSORIA.—(Fig. 225A.)

FIG. 225A.



Shell oblong, narrowed posteriorly, slightly gaping or reflected; pallial sinus deep: concentrically striate; posterior margin marked with one or two folds; surface still brown; concentric striae are in the form of raised sharp lines, not impressed lines of growth. The Tiphonal inflection is in contact with the pallial line, in which respect it agrees with P. Sammobia, but its hinge teeth are 2—2 in both valves.

GENUS DONAX.

"The general form is trigonal, or wedge form, valves closed, front produced, posterior short; margins usually crenulated; hinge teeth 2—2; laterals 1—1 in each valve; pallial sinus deep."

DONAX.—(Fig. 226.)

FIG. 226.

Shell triangular, rather abruptly truncate behind, and traversed by a ridge from the umbo to the base; surface marked by obscure radiating lines; base crenulated. This small shell differs from the *variabilis* in its proportion; it is more triangular, and is not produced so much in front.

Donax Variabilis probably occurs in the marl of North-Carolina, but has hitherto been overlooked.

FAMILY MACTRIDAE.—GENUS MACTRA.

"The shell is equivalve, and nearly equilateral; the anterior hinge tooth is in the form of an inverted A; lateral teeth doubled in the right valve."

MACTRA CONGESTA.

Shell rather small, but thick at the umbo; triangular, rather inflated; inequilateral; rounded anteriorly, and posteriorly it is produced. Very common in the marl of Wayne and Edgecombe.

MACTRA LATERALIS.—SAY. (Fig. 227.)

FIG. 227.

Shell small, rather thin, smooth, sub-triangular; lines of growth fine; posterior side elongated, or margins sub-equal, rounded before; umbo rather prominent. A very common fossil of the miocene.

MACTRA SIMILIS.—SAY.

Shell thin, of a medium size, margins sub-equal, concentric, striae very fine, at intervals deep, beaks nearly central. The living ones of the coast have a longitudinal rounded ridge running from the beaks to the base and obscure radiating lines, though only visible in a favorable position.

GNATHODON GRAYII.—(Fig. 226a.)

Shell rather thick, sub-triangular, inflated, inequilateral, anterior margin rounded; posterior elongated or wedge form. Rather common in the shell marl beds of Cape Fear.

FIG. 227a.

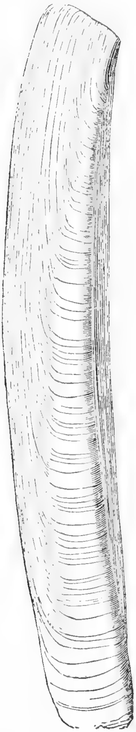
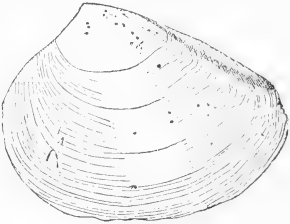


FIG. 226a.



FAMILY SOLENIDAE.—SOLEN ENSIS.

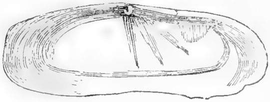
(Fig. 227a.)

This common shell of the coast is sword shaped, with the anterior and posterior margins truncate.

SOLECURTIS SUBTERES.—CON. (Fig. 228.)

Shell rather small, thin, somewhat sword shaped; anterior and posterior margins rounded, ventral margin concave, or arched.

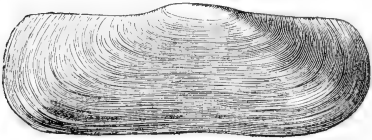
FIG. 228.



P. CARIBOEUS.—(Fig. 228a.)

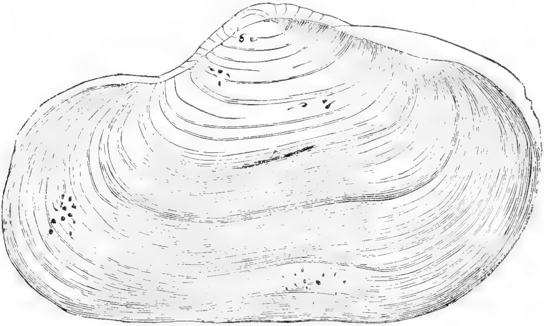
Is common in the miocene, but the valves are rarely entire. I should, however, express some doubt respecting the identity of the specimen figured with this species.

FIG. 228a.



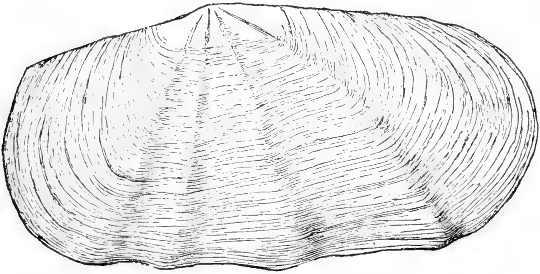
FAMILY ANATINIDAE.—PANOPEA REFLEXA. (Fig. 229.)
Shell large, thin, oblong, ovate; wrinkled and margin gaping widely and reflected. Common in the shell marl of Edgecombe county.

Fig. 229.



PHOLADOMYA ABRUPTA.—(Fig. 231.)
Shell oblong, oval, substance nacreous; surface ornamented with from three to five radiating ridges. This beautiful bivalve is quite common in a marl bed in Edgecombe county but rarely entire.

Fig. 231.



FAMILY PHOLADIDAE.

These species of Pholas have been found in the miocene of this, viz: P. Costata, P. Oblongata, and P. Memmingeri. They are rarely if ever entire, but their fragments are not uncommon.

FAMILY CARDIDAE.*—CARDIUM MAGNUM.—CARDIUM VENTRICOSUM.

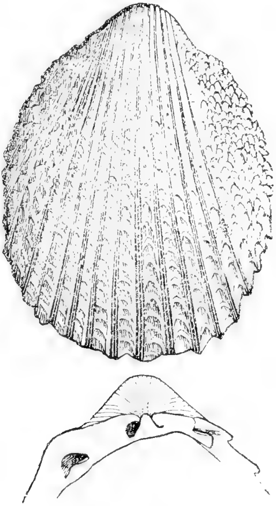
Shell large, inflated, obliquely cordate, radiately ribbed. ribs flattened, anterior ones crenulated.

This magnificent fossil is found occasionally in the miocene. It is quite common in the pliocene, and is now very abundant upon the coast, near Beaufort.

CARDIUM MURICATUM.—(Fig. 232-'3.)

The specimen given in the figure resembles the muricatum,

Fig. 232-'3.



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* The families *cardidae* and *carditidae* should have preceded veneridae.

but it is more elongated, and its crenulations appear to differ. I have obtained only one specimen; and hence, cannot speak of the permanence of its characters. It occurs in Walker's Bluff, on the Cape Fear.

Cardium sublineatum is a common fossil of the Cape Fear and Neuse marl beds.

FAMILY CARDITIDAE.—CARDITA ARATA.—(Fig. 234.)

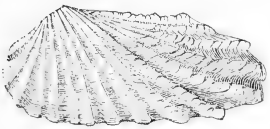


Fig. 234.

Shell rather thick, oblong, and ornamented with fifteen or sixteen elevated scaly ribs; anterior side very short; posterior margin oblique; inner margin crenate.

C. PERPLANA.—(Fig. 235.)

Shell small, rather thick, triangular, inequilateral, radiately ribbed, striated; posterior side produced, anterior short. Common.


Fig. 235.


Fig. 236.

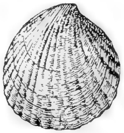


Fig. 236. A.

C. ABBREVIATA.—(Fig. 236.)

Shell small, thick, triangular, oblique; ribs strong and crenate; umbones acute. Common.

CARDITA TRIDENTATA.—(Fig. 236. A.)

Shell round, triangular, thick; ribs strong and crenulate; beaks turned forward; valves with two teeth in the left, and one in the right valve.

CARDITA CARINATA.

Shell small, thick, wide on the abdominal side; ribs strong and radiating; muricated; anterior side short.

CHAPTER XIX.

RADIATA.

Considerations relative to animals belonging to this type.—Aberant forms of the Echinodermata.—Species described.—Bryozoa, Polyparia, etc.

Echinodermata comprehends a class in the Kingdom, Radiata, whose organization belongs to the stellate type. This sub-class derives its name from the character of the integument, and its appendages, which remotely resemble that of the *hedge-hog*. Some are called sea-urchins, others star-fishes. In most of the families of this great class, the integument is protected by calcareous spines. The integument itself is coriaceous, but it takes into its composition a large quantity of lime which imparts to it firmness and durability. The skin is complicated in its structure. It is made up of an immense number of plates of a polygonal form. They amount to 600 pieces in all. These are dove-tailed together in the most perfect manner, and yet they are so invested in living membrane, that additions of carbonate of lime are constantly made to each. By this arrangement, the animal within grows without inconvenience to itself, which it could not do, if the integument or dwelling was composed of one piece.

The forms of the Echinoderms differ much among themselves, and yet it is apparent that they all belong to one type, and are constructed upon one plan. One of the most aberrant of this type is the sea cucumber, (Holothuria,) which is a firm fleshy bag, destitute of plates, composed of carbonate of lime. In another upon our coast, we find the *star-fishes* with five arms extending from a common center; and in another, the globular *sea-urchin*, in which the five arms are folded and soldered together so as to form a ball. Another interesting form has the stellate type, but differs considerably from the star-fish, and most strikingly in the fact that the stellate head is supported on a jointed foot-stalk. These are called *Encrinites*.

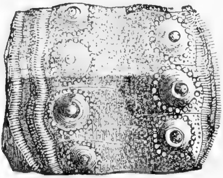
These different families have a special geological interest. The last for example, the Encrinite, lived in the earliest periods of the planet, and are known principally in the oldest palaeozoic rocks. In the lower silurian system, beds are often composed mainly of their disarticulated remains. In modern rocks and seas, they are unknown. On the contrary, the star-fishes without pedicels or jointed supports, are known mostly in modern rocks, only two or three species being known in the earlier formations. Now, the sea-urchins, or the globular forms of this class, lived in great numbers in the Mesozoic or Jurassic period. This type or form has come to us, though none of the species of the Mesozoic period live in our present seas.

I have spoken of the complicated structure of the star-fishes and the provision which has been made for their growth, both of which are worthy of our highest admiration. But nature had not exhausted all her resources when she had provided for their growth and made them the most beautiful objects in the seas. She has in this elaborate structure made their ornamental work subordinate to their instruments of locomotion and reproduction. The flowers which are sculptured upon their integuments form a part of their organs for moving from place to place. These flowers which represent the five petals of a rose, are formed by punctures through the outer envelope. Through them the urchin protrudes fleshy suckers or tubes. If, for example, a sea-urchin is placed in a glass filled with sea-water, it is soon seen to protrude a multitude of slender fleshy threads, each of which is tipped with a little knob. These soon come in contact with the glass to which the knob adheres, on the principle of an exhausted receiver. By means of this adhering apparatus, it moves itself forward or backward. In technical language, the surface from which these fleshy threads protrude, are called *ambulacral areas*, and the spaces between, *interambulacral areas*. Nothing can be seen of these threads when the animal is dead. All its soft parts are strictly encased in a box of hard shell substance, which has received the name of Test, or Shell. The patterns of these different areas vary in form and proportion, and hence are used as characteristics of genera and species. The test is also covered with spines of different forms and sizes. These, too, are formed after different patterns, their shafts being sculptured differently in every species. Their spines, and the mode they are attached to the shell, the character of their surfaces, the position of their oral and excretory orifices, furnish the characters upon which the families, and lesser subdivisions of this class are founded.

FAMILY CIDARIDAE.—CIDARIS MITCHELLII.—N. S. (Fig. 237.)

Test thick, circular or turban shaped; flattened above and below; ambulacral areas narrow, and provided only with minute tubercles, in double rows, and three in each; interambulacral areas nearly four times as wide as the former, and furnished with two distinct rows of large primary tubercles, with about eight in a row, including the smaller ones upon the disks; tubercles perforated; inner rim surrounding the tubercle, smooth; outer, bearing small subordinate spines, giving it a crenulated appearance; miliary zones wide, and covered with small close set unequal granules; poriferous zones, unigeminal, and separated by nearly plane ridges; spines unknown; apical disk unknown; mouth opening, appears to be large, but too much broken to determine its characters.

FIG. 237.



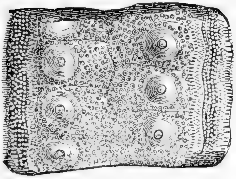
Belongs to the eocene, and accompanies the remains of the Zeuglodon.

Dedicated to the lamented Prof. Mitchell of the University of Chapel Hill.

CIDARIS CAROLINENSIS.—N. S. (Fig. 238.)

Test rather thick, circular and somewhat oval. Ambulacral areas narrow; somewhat undulating, supporting two rows of

FIG. 238.



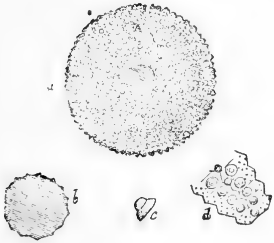
small tubercles with two in a row, and interspersed with minute ones, which appear in some places to be arrayed in subordinate rows; interambulacral areas wide, covered with small subequal and rather prominent tubercles, among which minute granules are scattered; area about four times as wide as the former; plates pentagonal, supporting two rows of large perforated primary tubercles, surrounded by plain circular zones; miliary zone concave or depressed. Poriferous zones narrow; pores unigeminal; outer oblong; the inner circular; margin of the small plates between them marked with an elongated depression. The upper and lower sides crushed.

Belongs to the eocene, and accompanies the former.

Figure 105 represents the jaws of an Echinoderm, p. 246. The separate pieces of the test and jaws are quite common in an eocene bed in Craven county. They belong to the upper part of the bed, and seem to be confined to a space about two feet thick.

FAMILY CIDARITAS.—ECHINUS RUFFINII.—ED. FORBES. (Fig. 239.)

FIG. 239.



“Body sub-depressed; ambulacral and interlambulacral; plates with several primary tubercles on each closely ranged, having circles of secondary tubercles surrounding their bases; rows of pores very oblique, with three pair of pores in each row, the uppermost distant from the other two. Beneath concave; mouth broad; widely notched opposite each avenue.” Ed. Forbes.[*]

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[*] Journal Geological Society, vol. I, p. 426.

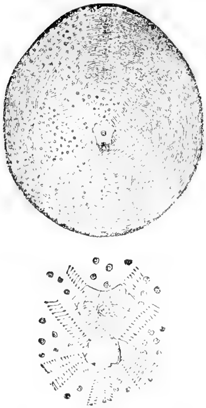
Found in the miocene beds. Four views, *a*, Echinus Ruffinii, viewed from above; *b*, mouth; *c*, spinegerous tubercles; *d*, ambulacral plates, and arrangement of pores: *a*, *b*, natural size, *c*, *d*, enlarged.

FAMILY CLYPEASTARIDAE.—ECHINOLAMPAS APPENDICULATUS.—N. S.

(Fig. 240-'1.)

Test thin; body oval, depressed; margin thick or rounded; somewhat elongated, wider anteriorly than posteriorly; ambulacra narrow, open at their extremities; sub-petaloid; pores connected by furrows; mouth transverse; excretory orifice horizontal, marginal; madriporiform plate excentric; apical disk occupied by a sub-cordate sculptured plate, furnished with a pentangula opening, in the centre of which there is a pore; areolæ more numerous below than above; area around the mouth inflected.

FIG. 240-'1.



ECHINOCYAMUS PARVUS.—N. S. (Fig. 244.)

Test small, oval, with rounded sides; avenues dorsal; mouth sub-central, rounded, large, with a crenulated margin; vent between the mouth and hinder margin; genital pores apparently four. Figure natural size. The mouth is large in proportion to the size of the body and the vent is situated half way between the mouth and margin. Eocene of Craven.

FIG. 244.

SCUTELLA LYELLII.—(Fig. 246.)

FIG. 246.

Shield small, sub-circular, flat, scarcely convex above; below slightly concave; ambulacra open towards the margin and terminating in four pores; in that direction mouth small; vent near the margin. Eocene, Wilmington.

SCUTELLA.—(Fig. 247-'8.

Figures 247-'8 represent a common fossil of the eocene of Craven county. 247 inferior face, showing the relative position of the mouth and excretory orifice. Figure 248 is profile view of the same. The apical summit is before the genital. Since its discovery no opportunity has been furnished by which I could obtain a comparison with the forms already known and described by the palaeonlologists of this country. Wadsworth's eocene marl, Craven county.

FIG. 247-'8.

FAMILY SPATANGIDAE—GONIOCLYPEUS SUBANGULATUS.—N. G.

(Fig. 242.)

Test thick, sub-conical, covered with small spines, anterior and posterior areas somewhat unequal; margin and base somewhat pentangular; posterior or anal orifice lateral, or upon the superior face; interambulacral area grooved, with the continued area beneath projecting; interambulacral areas sub-angulated; mouth rather narrow or small, central; peristome angular, and surrounded by five angular prominences, which terminate in the interambulacral areas, between which is a rosette, perforated by seven pairs of pores, with three odd ones at the end of each petal; ambulacra petaloid and closed; the prolonged zone provided with alternating pores as far as the base; pores connected by oblique grooves; interambulacral wide; plates large, and nine or ten in a column.

FIG. 242.

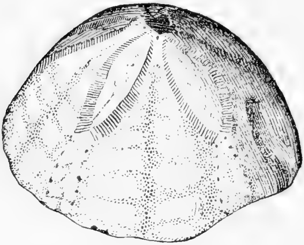


FIG. 243.

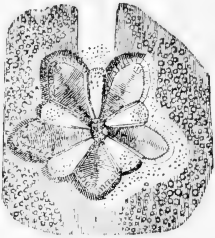


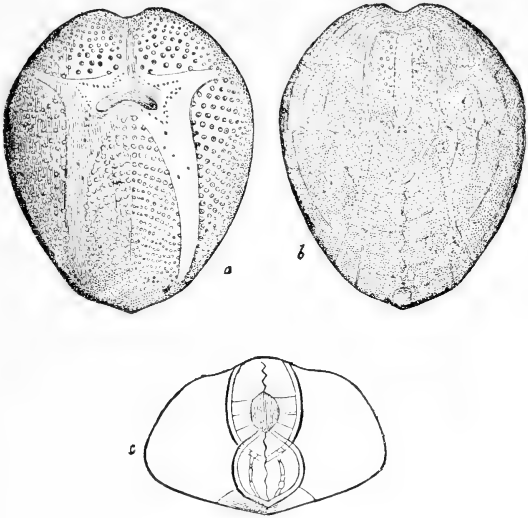
Figure 243, rosette enlarged.

OBSERVATIONS.—The ambulacral areas are narrow, but the poriferous zones are rather wide; and the interambulacral areas are about four times as wide as the ambulacral. The genital plates are indeterminate, but the pores are large and the occular small, and appear to be mere indentations; buccal area ornamented with a rosette; petals transversely wrinkled; pores elongated; the anterior lateral plates appear to have eleven pairs of pores instead of seven. The genus is closely related to Cassidulus of Lamark, but the pores are united by grooves. Eocene, Wardsworth marl, Craven co.

AMPHIDETUS VIRGINIANUS.*—FORBES. (Fig. 245.).

"Body broadly ovate, elevated and truncate posteriorly; back oblique; dorsal impression lanceolate; scutab area very slightly excavated; ambulacral spaces broad, triangular, depressed; interambulacral spaces slightly convex; anteal furrow broad and shallow, sides slightly gibbous; sub-anal impressions broadly ob-cordate; post-oral spinous space broadly lanceolate.—Edw. Forbes."

FIG. 245.



a, lower area; *b*, upper area; *c*, posterior area, showing the relation of the sub-anal impression. Usually found in fragments in the miocene of North-Carolina.

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[*] Journal of the Geological Society, Vol. 1, p. 425.

ORDER CRINOIDEA.—MICROCRINUS CONOIDEUS.—N. G.

(Figs. 246 & 247.)

FIG. 246.

FIG. 247.

Body conical; sub-pentangular at base; areas five, oblique; pores six or seven to each, alternating and arranged in rows, separated by a ridge; apical pores five, base wide; beneath concave; concavity intersected by five bars, which descend and meet in the center; spaces between, triangular, terminating above in the apical pores.

Figure 247 shows the base with the intersecting bars and triangular spaces between.

I am unable to determine whether the head is supported on a foot-stalk; the joints of a crinoid, however, are numerous in the marl in which this curious species is found.

Eocene of Craven county, and associated with Echinocyamus Parvus.

BRYOZOA.—LUNULITES DENTICULATA.—(Figs. 248 & 249.)

"Conical; cells inalternate, oblong externally, interior conical, nearly vertical to the two surfaces of the polypidom; margin of the cell in its immature state open and denticulated; when mature, covered; mouth near the distal extremity; semicircular when imperfect, circular when perfect: gemmuliferous chamber at the distal end of the cell, opening round, concave surface furrowed, irregular and minutely granulated."* Miocene, and common to most of the beds upon the Neuse and Cape Fear.

FIG. 248.

FIG. 249.

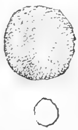


Fig. 249, enlarged view of the fossil, showing the arrangement of the cells, and the small Figure its natural size.

LUNULITES CONTIGUA.—Figs. 250 & 251.

The figures exhibit casts of the concave surface of the

---

* Lonsdale, miocene corals from N. America, Journal Geol. Society, vol. 1, p 503.

coral. Fig. 251, cast of the concave surface natural size; Fig. 250, magnified view of a portion of the surface. Eocene Wilmington.

FIG. 250.

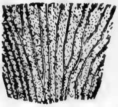
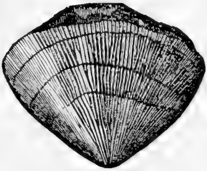


FIG. 251.



LUNULITES OBLONGUS.—N. S. (Figs. 252 & 253.)

Polypidom small, conical; cells arranged along a straight line, from the base to the margin: open cells show that they are nearly quadrangular; the closed cells do not show an orifice; there is a simple film spread over the cell, and the margins are simple and unlike denticulata. Fig. 253, greatly enlarged view of the cells; small figure shows the natural size of the fossil.

FIG. 252.

FIG. 253.

DISCOPORELLA UMBELLATA.—(Figs. 254 & 255.)

It is impossible to discover any difference between our Discoporella and that of the miocene of France; the cells have two orifices at opposite acute angles, and the same arrangement of cells. Fig. 255 greatly enlarged. This figure, however, fails to give a clear and correct view of the fossil. A reference therefore, to Pietet's Pl. XC, page 15, is necessary.

FIG. 255.

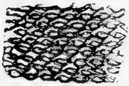
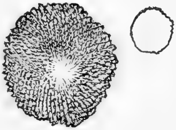


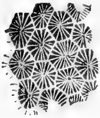
FIG. 254.



The small lunulites begin to form at the apex, and for this purpose they attach themselves to a grain of sand, which will generally be still found at the point of growth; some of the miocene ones are nearly half an inch in diameter.

POLYPAIRA.—ASTRAEA BELLA.—(Fig. 256.)

Fig. 256.



The stars are polygonal, variable, rather deep, lamellar lamellae twelve, with alternating ones, denticulated, contiguous, or separated by their partitions.

Common in the miocene incrusting shells, and various bodies found in a marl bed.

ASTRAEA.—(Fig. 256a.)

Irregularly branched; stars deep and rather distant, though in some places contiguous as in the Bella; intermediate spaces without pores, but bordered by lines to which the lamellae extends; lamellae denticulated, as in A. Bella, and provided also with the same number, and similarly arranged. Miocene.

Fig. 256a.

The foregoing sketch of the fossils of the marl beds of the eastern counties, is far from being complete. Numerous species still remain unnoticed and undescribed. It seemed to be desirable, however, on many accounts, to illustrate some of the interesting contents of these beds, which are truly the only historical mementoes which now remain to us of the ages during which they lived. It will appear, on examination, that I have placed by far the largest number of species in the miocene. I have thus placed them because the shell marl beds contain so large a number of the acknowledged miocene fossils of Virginia; and besides, there are many which replace miocene fossils of Europe.

In conclusion, it is due to myself to remark, that the circumstance under which many of the determinations have been made, rendered it impossible to consult authorities, and hence it may turn out that many species which have been marked as new, will prove to be old ones already described. The course I have pursued may have been injudicious, and hence may open the way for censure; still, under the circumstances, I deemed it the best I could pursue.

ADDITIONS AND CORRECTIONS.

I.—Figures and Names of Species:—

Page 205, for *otololite* read *otolite*.
" 242, fig. 90, read Galeocerdo Egartoni.
" 241, fig. 84a is Sphyrna denticulata.
" " " 82a and 83a, Galeocerdo contortus.
" 243. It is possible *Trygon*, fig. 94, should be referred to Myliobatis.
" 245.—Fig. 105 is the valve of the genus *Scalpellum* of the class *Cirripedes.*
" 261, fig, 139.—This is not Erato laevis, but is closely allied to E. Maugeriæ, of the coralline crag.
" 268.—Fig. 159 resembles *Cerithium adversum* of the English crag.
" 290.—For *Lucenidae* read *Lucinidae.*
" 291.—Place a period before Brugiere.
" " —For *Pennsylcania* read *Pennsylvanica.*
" " sencond line from bottom, for *multihineata* read *multilineata.*
" 292.—For *Venerida* read *Veneridae.*
" " —For *Tridaenoides* read *Tridacnoides.*
" 293.—For Cribrari read Cribraria.
" " second line from bottom, for *pramagna* read *permagna*; for *meltastriata* read *metastriata.*
" 294.—For Cytherca read Cytherea.
" " For reporta read reposta.
" 295.—For Artemes read Artemis.
" 296.—Fig. 224 shows the hinge of Artemis tranversus; and read Artemis for Artemus.
" " sixth line from bottom, for TELLIMIDAE read TELLINIDAE; and ninth line, for Tiphonal read Siphonal.
" 297.—For P. Sammobia read Psammobia.
" 306.—For Cidaritas read Cidarites.
" 307, second line from top, for Spinigerom read Spinigerous.
" 311.—Bryozoa should have been placed under an independant head, as a subdivision of Molusca and not under Radiata.

Certain figs. have been placed wrong side up, particularly Scutella. fig. 247—'8.

In the Eocene of Craven county, I have found the palatine teeth of the Saurodon, or Saurocapalhus, and also fragments of a Xiphioid fish, as the prolonged premaxilary of a sword fish.

Retinasphalt occurs in the marl of Duplin county.

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By

ERWIN C. STUMM

1969

Paleontological Research Institution
Ithaca, New York 14850 U.S.A.

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By

ERWIN C. STUMM
Museum of Paleontology
The University of Michigan

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RUGOSA

TABULATA

REVISION OF R. P. WHITFIELD'S TYPES OF RUGOSE AND TABULATE CORALS IN THE MUSEUM OF PALEONTOLOGY, UNIVERSITY OF CALIFORNIA AND IN THE UNITED STATES NATIONAL MUSEUM

Erwin C. Stumm
Museum of Paleontology
The University of Michigan

ABSTRACT

Thirteen species of Paleozoic corals were described by R. P. Whitfield between 1878 and 1903. Eleven of these are revised and all but one placed in other genera. Three new species, *Amplexizaphrentis ohioensis, Acanthohalysites wisconsinensis,* and *Cystihalysites microporus* are proposed and one new genus, *Syringocolumna infundibula* (Whitfield) is proposed.

INTRODUCTION AND ACKNOWLEDGMENTS

Between 1878 and 1903 R. P. Whifield described 13 species of corals from the Paleozoic rocks of Wisconsin, Ohio, and Iowa. The majority of these were from the Silurian dolomites of Wisconsin. One species was from the Devonian of Ohio, one from the Mississippian of Ohio, and one was a float specimen from the Silurian of Iowa. The specimens are listed under their original designations as follows:

- Silurian of Wisconsin:
  - Rugosa:
    - *Amplexus annulatus* Whitfield, 1878
    - *Amplexus fenestratus* Whitfield, 1878
    - *Cyathaxonia wisconsinensis* Whitfield, 1878
    - *Cystostylus typicus* Whitfield, 1880
    - *Zaphrentis racinensis* Whitfield, 1882
  - Tabulata:
    - *Favosites occidens* Whitfield, 1888
    - *Halysites catenulatus* var. *microporus* Whitfield, 1882
    - *Halysites catenulatus* Linnaeus
    - *Halysites catenulatus labyrinthicus* (Goldfuss)
    - *Syringopora infundibula* Whitfield, 1878
- Devonian of Ohio:
  - Rugosa:
    - *Stylastrea anna* Whitfield, 1882
- Mississippian of Ohio:
  - Rugosa:
    - *Zaphrentis cliffordana* Edwards and Haime
- Silurian of Iowa:
  - Tabulata:
    - *Halysites radiatus* Whitfield, 1903

The syntypes of *Amplexus annulatus* from the Guelph Dolomite of Wisconsin have not been found. The species *Halysites radiatus* Whitfield has been adequately redescribed by Buehler (1955) and will not be described herein. It is a species of *Acanthohalysites.* The remainder of the corals are redescribed and reillustrated in this paper. Part of Whitfield's collection was purchased by the University of California (Peck and McFarland, 1954). The remainder was located at the University of Wisconsin until 1960, when it was transferred to the United States National Museum (Batten, 1960). Two of the syntypes of *Stylastrea anna* are in the Geological Museum, Ohio State University.

The holotype of *Alveolites irregularis* Whitfield from the Upper Ordovician of Wisconsin is a trepostomate bryozoan.

The repositories of the types are indicated as follows: U.S.N.M., United States National Museum; U.C.M.P., Museum of Paleontology, University of California; O.S.U., Geological Museum, Ohio State University.

I wish to thank Dr. J. W. Durham and Dr. Joseph H. Peck, Jr. of the Museum of Paleontology, University of California, for the loan of those of Whitfield's types located there. My thanks are also due to Dr. R. A. Cifelli and Mr. Jesse E. Merida for the loan of the types located in the U. S. National Museum.

SYSTEMATIC DESCRIPTIONS

Order RUGOSA

Family **METRIOPHYLLIDAE**

Genus **ASTHENOPHYLLUM** Grubbs, 1939

1939. *Asthenophyllum* Grubbs, Jour. Paleont., vol. 13, No. 6, p. 546.
1956. *Asthenophyllum* Hill, Treatise on Invert. Paleont., vol. F., p. F 257, fig. 174.

Type species.—*Asthenophyllum orthoseptatum* Grubbs, 1939 (p. 547), by original designation.

Discussion.—The type species is a small ceratoid to trochoid coral in which the calyx extends almost to the base. Protosepta prominent. Metasepta divided into major and minor series. All septa short.

Asthenophyllum? racinensis (Whitfield) Pl. 12, figs. 4-6

1882a. *Zaphrentis racinensis* Whitfield, Geology of Wisconsin, vol. 4, pt. 3, p. 277, pl. 14, figs. 1-2.

Description.—Holotype composed of a dolomitic mold of the interior of the calyx of a simple trochoid rugose coral. A latex cast of this mold reveals the original appearance of the interior of the calyx. Maximum diameter at top of calyx, 30 mm; at base, 7 mm; maximum depth, 22 mm. Septa 70 in number. Protosepta prominent, short; cardinal septa terminating in a small narrow fossula only visible across base of calyx. Metasepta divided into major and minor series both as short peripheral ridges. Major septa extending maximum distance of 1 mm from the periphery and extending across the small base of the calyx to form a low, relatively inconspicuous axial base. Minor septa extending about 0.5 mm from the periphery terminating before reaching base of calyx. All septa thin, smooth, noncarinate.

Remarks.—It is impossible to determine if the original corallum had tabulae or dissepiments, but judging from the shape of the calyx I believe neither was present. *A.? racinensis* is much larger and has many more septa than the type species and, therefore, is tentatively assigned to *Asthenophyllum.*

Occurrence.—Middle Silurian, Racine Dolomite, Racine, Wisconsin.

Type.—Holotype U.S.N.M., No. 136786.

Family **STREPTELASMATIDAE**

Genus **DALMANOPHYLLUM** Lang and Smith, 1939

1939. *Dalmanophyllum* Lang and Smith, Some new Generic names for Paleozoic corals, Ann. Mag. Nat. Hist. ser. 2, vol. 3, p. 153.

Type species.—*Cyathaxonia dalmani* (Edwards and Haime, 1851, p. 322, plate 1, figure 6).

Diagnosis.—Solitary ceratoid rugose corals in which the major septa join a bladelike columella produced upward by joined cardinal and counter septa.

Dalmanophyllum wisconsinensis (Whitfield) Pl. 12, figs. 1-3

1878. *Cyathaxonia wisconsinensis* Whitfield, Wisconsin Geol. Sur., Ann. Rept. for 1877, p. 79.

1882a. *Cyathaxonia wisconsinensis* Whitfield, Geology of Wisconsin, vol. 4, p. 277, pl. 14, figs. 3-5.

Description.—Holotype consisting of a dolomitic cast of the interior of the original calyx. A latex mold reproduces the calyx walls and base. Maximum diameter of calyx 39 mm, maximum depth 23 mm. Calyx walls steeply sloping to a narrow base, most of which being occupied by a bladelike columella 10 mm tall, 6 mm wide in cardinal-counter direction and a maximum of 2 mm wide at right angles to this direction. Septa 76, short, thin, and smooth, the major extending 2-3 mm from periphery, continuing across calyx base to terminate in columella. Minor septa extending about 1 mm from calyx walls, disappearing just before reaching base of calyx.

Cardinal septum forming a prominent fossula 7 mm long, 4 mm wide, and 7 mm deep, almost completely confined to the base of the calyx. No dissepiments visible. Presence or absence of tabulae unknown.

Remarks.—The species resembles *D. herzeri* (Hall), 1882-1884, from the Louisville Limestone of Kentucky but has a much more prominent columella.

Occurrence.—Middle Silurian, Racine Dolomite, Racine, Wisconsin.

Type.—Holotype U.S.N.M., No. 136804.

Family **HAPSIPHYLLIDAE**

Genus **AMPLEXIZAPHRENTIS** Vaughan

1906. *Amplexizaphrentis* Vaughan, Quart. Jour. Geol. Soc. London, vol. 62, pp. 275-323.
1944. *Triplophyllites* Easton, Illinois State Geol. Sur., Rept. Inv. 97., p. 35.

Type species.—*Zaphrentis bowerbanki* Thomson, 1883, by subsequent designation of Lang, Smith, and Thomas, 1940, pp. 16-17.

Amplexizaphrentis ohioensis, n. sp. Pl. 11, figs. 5-8

Zaphrentis cliffordana Whitfield, 1891, p. 576, pl. 13, figs. 1-3; *non Z. cliffordana* Edwards & Haime, 1851.

Description.—Corallum ceratoid, holotype with a maximum length of 39 mm and a maximum diameter of 17 mm. Exterior with weakly developed, faintly wrinkled epitheca through which the interseptal ridges are barely visible. Calyx 10 mm deep with erect walls and a wide, flat base formed on the uppermost tabula. Major septa 1 to 2 mm long on calyx walls, extending across base about one-half distance to axis. Minor septa as weakly developed peripheral ridges. Fossula moderately developed, on concave side of corallum. In transverse section septa 60, major extending about one-half distance to axis, minor as short peripheral ridges. Cardinal septum short producing an indistinct fossula. Major septa thickened peripherally, attenuate axially. Tabulae steeply inclined toward concave side of corallum, complete or incomplete, irregularly spaced from less than 0.5 mm to over 2 mm apart. No dissepiments present.

Remarks.—The species differs from "*Zaphrentis*" *cliffordana* Edwards and Haime, 1851, in having much shorter major septa.

Occurrence.—Middle Mississippian, Maxville Limestone, Maxville, Ohio.

Types.—Holotype, No. 34220, paratypes, Nos. 34219 and 34221 U.C.M.P.

Family **HALLIIDAE**

Genus **NEOCYSTIPHYLLUM** Wedekind

1927. *Neocystiphyllum* Wedekind, Sveriges Geologiska Undersöknung, ser. Ca, No. 19, pp. 77, 78.

Type species.—By original designation, *N. mccoyi* Wedekind, 1927, p. 78, pl. 19, figs. 7, 8.

Diagnosis.—Simple rugose corals with a well-developed dissepimentarium and pinnate or radially arranged septa which may be thin or dilated axially.

Neocystiphyllum? fenestratum (Whitfield) Pl. 12, fig. 8; Pl. 13, figs. 3, 4

1878. *Amplexus fenestratus* Whitfield, Ann. Rept. Geol. Sur. Wisconsin, p. 80.
1882a. *Amplexus fenestratus* Whitfield, Geology of Wisconsin, vol. 4, pp. 278-279, pl. 15, figs. 1-3.

Description.—The only syntype located is a large simple ceratoid coral that has been completely silicified. Maximum length 11 cm, maximum diameter 5.5 cm. Calyx not preserved. Epitheca worn in most places so pheripheral edges of septa and dissepiments visible on external surface. Exterior with widely spaced, periodic swellings. In transverse section septa 107, thin, smooth, and long. Major septa extending at least three-fourths distance to axis; minor septa almost as long. Dissepiments numerous, closely set; dissepimentarium occupying peripheral half of corallum. No fossulae or other modification of the protosepta present in the internal structures. In longitudinal section, dissepimentarium composed of numerous rows of small to medium-sized, axially convex dissepiments. Tabularium partly destroyed by silicification but where tabulae are present they are typically complete, closely set, and distally convex.

Remarks.—The species is placed tentatively in *Neocystiphyllum.* Hill, 1956, placed *Neocystiphyllum* as a junior subjective synonym of *Phaulactis* Ryder (1926), but the genus does not show the characteristic septal thickening and complete lack of pinnate septal development of typical phaulactids. It appears to be a valid genus and possibly should not be included in the family Halliidae. Whitfield's figures of the other syntype (1882a, pl. 15, figs. 1-2) show a relatively deep, bell-shaped calyx with a distinct cardinal fossula.

Occurrence.—Middle Silurian, Niagaran, Waukesha or Racine Dolomite, Cato, Wisconsin.

Type.—Syntype U.S.N.M., No. 136803.

Family **PHILLIPSASTRAEIDAE**

Genus **HEXAGONARIA** Gürich

1896. *Hexagonaria* Gürich, Verh. Russ.-Kais. Min. Gesell. St. Petersburg, ser. 2, vol. 32, p. 171.
1900. *Prismatophyllum* Simpson, Bull. New York State Mus., vol. 8, No. 39, p. 218.
1909. *Hexagoniophyllum* Gürich, Leitfossilien, vol. 2, p. 102.

Type species.—By subsequent designation of Lang, Smith, and Thomas (1940, p. 69) *Cyathophyllum hexagonum* Goldfuss, 1826 *partim*, p. 61, pl. 20, figs. 1a-b.

Diagnosis.—Cerioid, typically hexagonal rugose coralla having corallites with carinate septa small, globose dissepiments and relatively flat, complete or incomplete tabulae.

Hexagonaria anna (Whitfield) Pl. 10, figs. 5, 6

1882. *Stylastrea anna* Whitfield, Annals New York Acad. Sci., vol. 2, pp. 199-200.
1893. *Stylastrea anna* Whitfield, Geol. Sur. Ohio, vol. 7, p. 420, pl. 2, figs. 1-5.
1938. *Prismatophyllum annum* Stewart, Geol. Soc. America, Spec. Paper No. 8, p. 49, pl. 9, figs. 11, 12.
1948. *Hexagonaria anna* Stumm, Contr. Mus. Paleont., Univ. Michigan, vol. 7, No. 2, pp. 25, 26, pl. 5, fig. 3; pl. 9, figs. 1-3; pl. 13, figs. 1, 2; pl. 14, figs. 3-6.

Remarks.—This species has been described in detail by Stewart (1938) and Stumm (1948). In addition, Stumm (1967) wrote a paper on the blastogeny of the species. *H. anna* is a widespread species, occurring in the Dundee Limestone and the Silica Formation of northwestern Ohio and in the Bell Shale, Rockport Quarry Limestone, and Ferron Point Formation in the Traverse Group of north-central Michigan. The type specimens apparently are from the "blue" limestone member at the base of the Silica Formation.

Types.—Lectotype (chosen by Stumm, 1948, p. 26), O.S.U. No. 15347, paratype No. 15349; other paratypes U.C.M.P., Nos. 34216, 34217, 34218.

Family **CYSTIPHYLLIDAE**

Genus **MICROPLASMA** Dybowski

1873. *Microplasma* Dybowski, Mon. der Zoantharia sclerodermata rugosa aus der Silurformation Estlands, Nord-Livlands und der Insel Gotland, p. 340.
1880. *Cystostylus* Whitfield, Wisconsin Geol. Sur., Ann. Rept. for 1879, pp. 63-64.
1882a. *Cystostylus* Whitfield, [as a new genus] Geology of Wisconsin, vol. 4, pt. 3, pp. 273, 274.

Type species.—By subsequent designation of Wedekind, 1927, p. 64, *Microplasma gotlandicum* Dybowski, 1874, p. 508, pl. 5, figs. 5a-d. Silurian, Gotland.

Diagnosis.—Coralla with the internal structures of *Cystiphyllum* but being phaceloid instead of simple in growth form.

Microplasma typica (Whitfield) Pl. 10, figs. 1, 2

1880. *Cystostylus typicus* Whitfield, Wisconsin Geol. Sur., Ann. Rept. for 1879, pp. 64, 65.
1882a. *Cystostylus typicus* Whitfield [as a new species], Geol. Wisconsin, vol. 4, pt. 3, p. 274, pl. 14, figs. 8, 9.

Description.—Corallum phaceloid, composed of parallel or subparallel cylindrical corallites ranging from 7 mm to 9 mm in diameter. External features not preserved. Some corallites in lateral contact; others separated by distances as great as their diameters. Interiors or corallites filled with dissepiments and tabellae from 0.5 to 1.5 mm across and with a maximum length of 1.5 mm. Peripheral zone of dissepiments steeply inclined, convex axially and distally, merging into an axial zone of distally convex tabellae. Border between dissepimentarium and tabularium obscure or lacking. Peripheral spinules, if originally present, obscured by recrystallization of small calcite crystals along walls of dissepiments and tabulae.

Remarks.—The species shows a distinct resemblance to *M. lovenianum* Dybowski from the Wenlock Limestone of England as illustrated by White (1966, pp. 149, 150, pl. 22) but differs in having a smaller, less distinct tabularium.

Occurrence.—Middle Silurian, Niagaran Series, upper coral beds, Sturgeon Bay, Wisconsin.

Type.—Holotype U.C.M.P., No. 34213.

Order TABULATA

Family **FAVOSITIDAE**

Genus **FAVOSITES** Lamarck

1816. *Favosites* Lamarck, Hist. Nat. des Animaux sans Vertèbres, vol. 2, p. 204.

Type species.—By subsequent designation of Edwards and Haime, 1850 (p. 1x), *F. gothlandicus* Lamarck, 1816, p. 205.

Diagnosis.—Compound coralla having pentagonal or hexagonal corallites resembling a honeycomb.

Favosites occidens Whitfield Pl. 12, figs. 9, 10; Pl. 13, figs. 1, 2

1888. *Favosites occidens* Whitfield, Ann Rept. Geol. Sur. Wisconsin, for 1887, p. 78.

1892. *Favosites occidens* Whitfield, Geology of Wisconsin, vol. 4, pp. 313, 314, pl. 23, figs. 6, 7.

Description.—Corallum irregularly hemispherical, composed of pentagonal or hexagonal, slightly subrounded corallites. Most corallites averaging a little less than 1.5 mm in diameter and ranging from less than 1 mm in immature corallites to a maximum of 2 mm in irregularly scattered ones, giving the surface of the corallum a diploid appearance. Tabulae relatively thick, horizontal, relatively evenly spaced at about 0.5 mm to 1 mm apart. No true septal spines or ridges present. The apparent presence of septal spines in some corallites due to recrystallization by small calcite crystals. Mural pores almost completely obliterated by dolomitization but appear to have been originally in one or two rows.

Remarks.—The syntypes have been severely altered by dolomitization, but all structures except the mural pores are visible.

Occurrence.—Middle Silurian, Guelph Dolomite, Saukville, Ozaukee County, Wisconsin.

Types.—Lectotype (here chosen) U.S.N.M., No. 136757; paratype U.S.N.M., No. 135945.

Family **HALYSITIDAE**

Genus **CYSTIHALYSITES** Tchernychev

1941. *Cystihalysites* Tchernychev, Vsesoyuznyy arkticheskyi institut, Trudy, vol. 158, pp. 65-74.

Type species.—By original designation *Cystihalysites mirabilis* Tchernychev, 1941, pp. 70, 71, pl. 2, figs. 5-7; pl. 3, figs. 1-6.

Diagnosis.—Halysitinae with cystose structures in the mesocorallites instead of tabulae and with no septal spinules in the macrocorallites.

Cystihalysites microporus, n. sp. Pl. 11, figs. 1-3

1882a. *Halysites catenulatus* Whitfield, Geology of Wisconsin, vol. 4, p. 271, pl. 13, fig. 5, *non H. catenulatus* Linnaeus.

Description.—Corallum with ranks of small corallites of two sizes. Macrocorallites ranging from 1.1 mm to 1.5 mm in maximum diameter with an average of 1.31 mm. Mesocorallites ranging from 0.4 mm to 0.7 mm in maximum diameter. Macrocorallites lacking septal spinules and having flat, complete tabulae spaced at an average distance of 0.43 mm apart. Mesocorallites filled with small, closely crowded, distally convex cysts in two to five horizontal rows.

Remarks.—This species has much smaller macrocorallites and mesocorallites than any other species of *Cystihalysites* known to me.

Occurrence.—Middle Silurian, Niagaran Group, Sturgeon Bay, Wisconsin.

Type.—Holotype U.C.M.P., No. 34214.

Genus **ACANTHOHALYSITES** Hamada

1957. *Acanthohalysites* Hamada, Jour. Fac. Sci. Univ. Tokyo, sec. 2, vol. 10, pt. 3, p. 404.

Type species.—By original designation, *Halysites australis* Etheridge (1898) Rec. Australian Mus., vol. 3, pt. 4, p. 78, pl. 17.

Diagnosis.—Halysitidae with macrocorallites and mesocorallites. Macrocorallites with septal spinules.

Acanthohalysites wisconsinensis, n. sp. Pl. 10, figs. 3, 4; Pl. 11, fig. 4

1882. *Halysites catenulatus* var. *labyrinthicus* Whitfield, Geology of Wisconsin, p. 272, pl. 13, fig. 7, *non Catenipora labyrinthica* Goldfuss, 1826.

Description.—Corallum with ranks of relatively large macrocorallites and mesocorallites. Macrocorallites ranging from 1.9 mm to 2.3 mm in maximum diameter, with an average of 2.13 mm. Mesocorallites ranging from 0.4 mm to 0.8 mm in maximum diameter with an average of 0.57 mm. Macrocorallites with 12 septal spinules in well-preserved corallites. Spinules extending an average of about one-third distance to axis. Tabulae of macrocorallites horizontal, spaced from 0.5 mm to 1.0 mm apart. Tabulae of mesocorallites closely set less than 0.5 mm apart and distinctly distally convex.

Remarks.—The distally convex tabulae in the mesocorallites are the distinctive feature of this species. The only other species of *Acanthohalysites* with convex mesocorallite tabulae is *A. encrustans* (Buehler) (1955, pp. 66, 67), and this species has larger macrocorallites and an entirely different growth form. *Acanthohalysites louisvillensis* (Stumm) (1965, p. 79, pl. 80, figs. 8-10) has horizontal tabulae in the mesocorallites.

Occurrence.—Middle Silurian, Niagaran Group, Sturgeon Bay, Wisconsin.

Type.—Holotype U.C.M.P., No. 34215.

Genus **CATENIPORA** Lamarck, 1816

1816. *Catenipora* Lamarck, Histoire Naturelle des Animaux sans vertèbres, p. 207.

Type species.—By monotypy, *C. escharoides* Lamarck (1816). For detailed synonymy see Thomas and Smith (1954); Buehler (1955); and Hamada (1957).

Diagnosis.—Corallum composed of ranks of macrocorallites lacking mesocorallites but provided with 12 rows of septal spinules in each corallite. Tabulae complete and horizontal.

Catenipora microporus (Whitfield) Pl. 12, fig. 7; Pl. 13, figs. 5, 6

1882a. *Halysites catenulatus* var. *microporus* Whitfield, Geology of Wisconsin, vol. 4, pt. 3, p. 272, pl. 13, fig. 6.
1955. *Catenipora microporus* Buehler, Peabody Mus. Nat. Hist., Yale Univ., Bull. 8, p. 44, figs. 1-5.
1957. *Catenipora microporus* Hamada, Jour. Fac. Sci., Univ. Tokyo, vol. 10, pt. 3, p. 400.

Remarks.—Buehler's description was taken from specimens from Michigan and Kentucky, and there are a few differences between his specimens and the holotype.

In the holotype the macrocorallites range from 0.3 to 1.2 mm in larger dimension. The septal spines are short, never extending more than one-half the way to the axis. Both Buehler and Hamada indicate that the longer septa meet to form a pseudocolumella. This feature is not shown on the holotype. The walls are greatly thickened at the junction of the corallites and in some of the thickened walls a small circular pore is present. The tabulae are complete, horizontal, and closely set.

Occurrence.—Middle Silurian, Niagaran Series, upper coral beds, Bailey's Harbor, Wisconsin.

Type.—Holotype U.S.N.M., No. 136760.

Family **SYRINGOPORIDAE**

Genus **SYRINGOCOLUMNA,** new genus

Type species.—(Here chosen), *Syringopora infundibula* Whitfield, 1878, Geol. Sur. Wisconsin, Ann. Rept. for 1877, p. 79.

Diagnosis.—Phaceloid coralla with internal structures composed of funnel-shaped tabulae, groups of which coalesce axially to form an intermittent columella; no dissepiments, cystose structures, or septal spinules present.

Syringocolumna infundibula (Whitfield) Pl. 11, figs. 9-11

1878. *Syringopora infundibula* Whitfield, Geol. Sur. Wisconsin, Ann. Rept. for 1877, p. 79.
1882a. *Cystostylus infundibulus* Whitfield, Geology of Wisconsin, vol. 4, pp. 274, 275, pl. 14, fig. 7.

Description.—Corallum known only from holotype. Growth habit phaceloid with subparallel cylindrical corallites ranging from 3 mm to 6 mm in diameter. Increase of corallites by lateral gemmation not by transverse stolons as in *Syringopora.* External features not preserved. Outer walls of corallites thin. Tabulae relatively evenly spaced, funnel-shaped. Groups of adjacent tabulae coalescing to make an axial columella, intermittently developed along each corallite. No other structures present.

Remarks.—Whitfield placed this species in his genus *Cystostylus* in which the type species is a rugose coral.

Occurrence.—Middle Silurian, Niagaran Group, Racine Dolomite, Howley's Quarry, Milwaukee, Wisconsin.

Type.—Holotype U.C.M.P., No. 34350.

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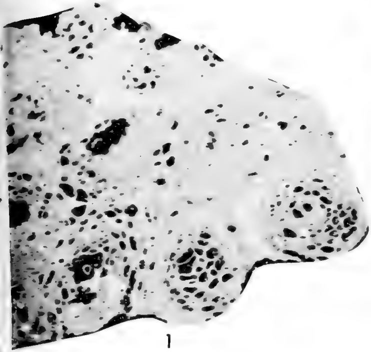
PLATES

EXPLANATION OF PLATE 10

All figures × 2

Figure	Page
1,2. **Microplasma typica** (Whitfield)	241
1. Transverse section of holotype. Upper coral beds. Niagaran Series (Middle Silurian), Sturgeon Bay, Wisconsin. U.C.M.P., No. 34213. 2. Longitudinal section of the same specimen.
3,4. **Acanthohalysites wisconsinensis,** n. sp.	243
3. Transverse section of holotype showing septal spinules. Niagaran Series (Middle Silurian), Sturgeon Bay, Wisconsin. U.C.M.P., No. 34215. 4. Longitudinal section of same specimen showing horizontal tabulae in macrocorallites and convex tabulae in mesocorallites.
5,6. **Hexagonaria anna** (Whitfield)	240
5. Transverse section of paratype. Silica Formation (Middle Devonian), Antwerp, Paulding County, Ohio. U.C.M.P., No. 34218. 6. Longitudinal section of same specimen.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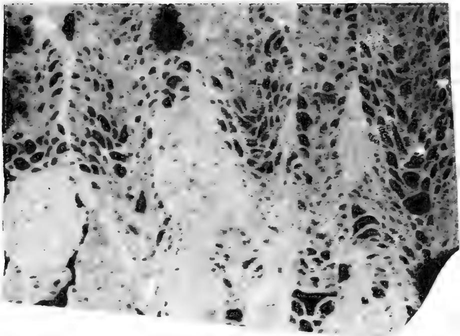
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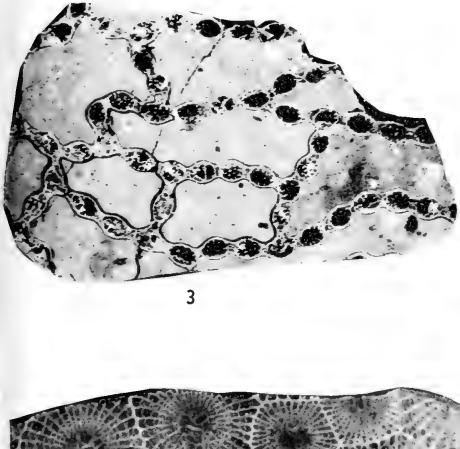
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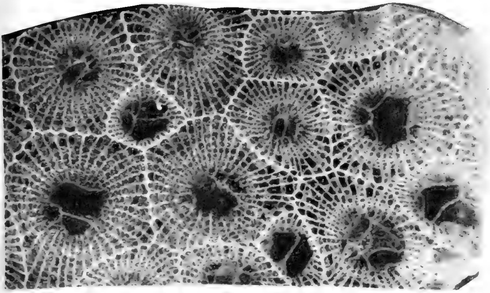
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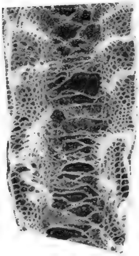
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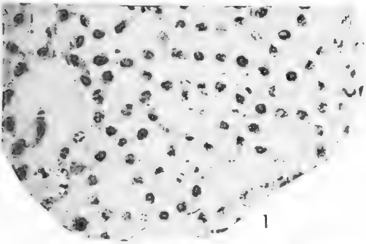
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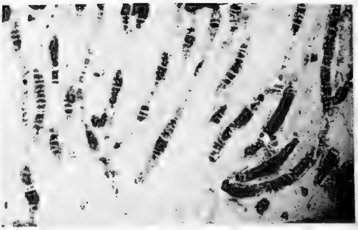
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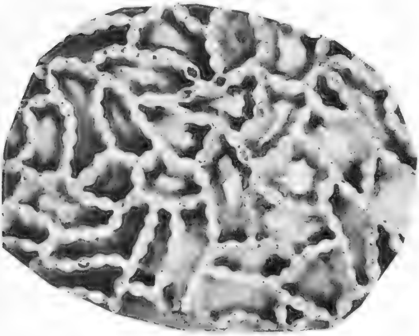
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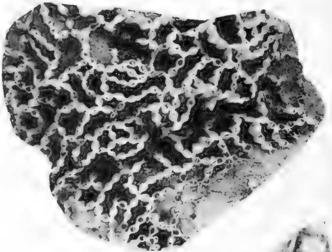
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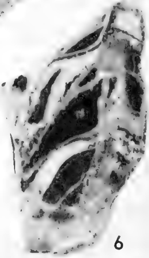
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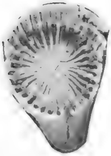
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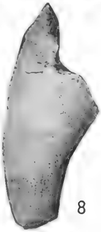
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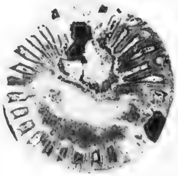
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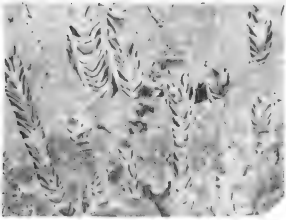
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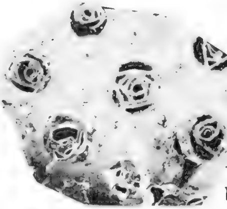
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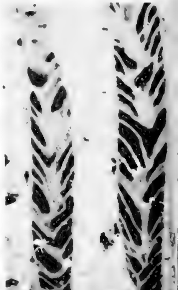
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EXPLANATION OF PLATE 11

Exteriors × 1; sections × 2

Figure		Page
1-3.	**Cystihalysites microporus,** n. sp.	242
	1. Transverse section of holotype, Niagaran Series (Middle Silurian), Sturgeon Bay, Wisconsin. U.C.M.P., No. 34214. 2. Longitudinal section of same specimen showing cysts in mesocorallites. 3. Distal exterior of same specimen.	
4.	**Acanthohalysites wisconsinensis,** n. sp.	243
	Distal exterior of holotype. Upper coral beds, Niagaran Series (Middle Silurian), Sturgeon Bay, Wisconsin. U.C.M.P., No. 34215.	
5-8.	**Amplexizaphrentis ohioensis,** n. sp.	238
	5. Transverse section of paratype. Maxville Limestone (Middle Mississippian), Maxville, Ohio. U.C.M.P., No. 34219. 6. Longitudinal section of paratype. Same occurrence as original of fig. 5. U.C.M.P., No. 34221. 7,8. Transverse and longitudinal views of holotype. Same occurrence as original of fig. 5. U.C.M.P., No. 34220.	
9-11.	**Syringocolumna infundibula** (Whitfield)	244
	9. Side view of holotype. Racine Dolomite, Niagaran Series (Middle Silurian), Howley's Quarry, Milwaukee, Wisconsin. U.C.M.P., No. 34350. 10. Transverse section of same specimen. 11. Longitudinal section of same specimen showing intermittent columella.	

Explanation of Plate 12

All figures × 1

Figure Page

1-3. **Dalmanophyllum wisconsinensis** (Whitfield) 237

1-2. Base and side views of cast of calyx of holotype. Racine Dolomite, Niagaran Series (Middle Silurian), Racine, Wisconsin. U.S.N.M., No. 136804. 3. Stereogram of latex mold of calyx of same specimen, showing bladelike columella and fossula.

4-6. **Asthenophyllum? racinensis** (Whitfield) 236

4-5. Base and side views of cast of calyx of holotype. Racine Dolomite, Niagaran Series (Middle Silurian), Racine, Wisconsin. U.S.N.M., No. 136786. 6. Stereogram of latex mold of same specimen showing cardinal fossula and weak axial boss.

7. **Catenipora microporus** (Whitfield) 244

Distal view of holotype. Upper coral beds, Niagaran Series (Middle Silurian), Bailey's Harbor, Wisconsin. U.S.N.M., No. 136760.

8. **Neocystiphyllum? fenestratum** (Whitfield) 239

Side view of holotype. Waukesha or Racine Dolomite, Niagaran Series (Middle Silurian), Cato, Wisconsin. U.S.N.M., No. 136803.

9,10. **Favosites occidens** Whitfield 241

Distal and proximal views of lectotype (here chosen). Guelph Dolomite, Niagaran Series (Middle Silurian), Saukville, Ozaukee County, Wisconsin. U.S.N.M., No. 136757.


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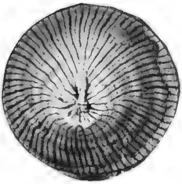
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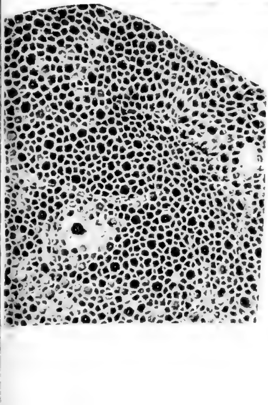
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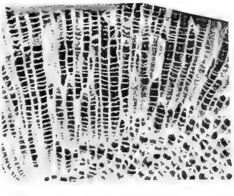
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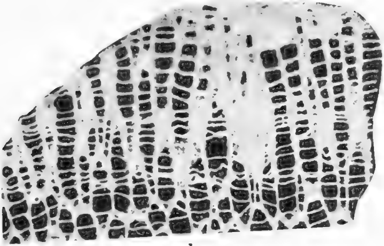

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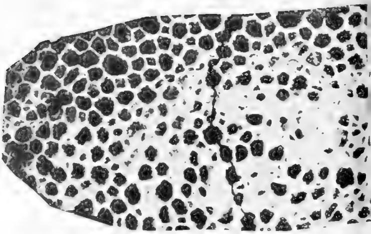

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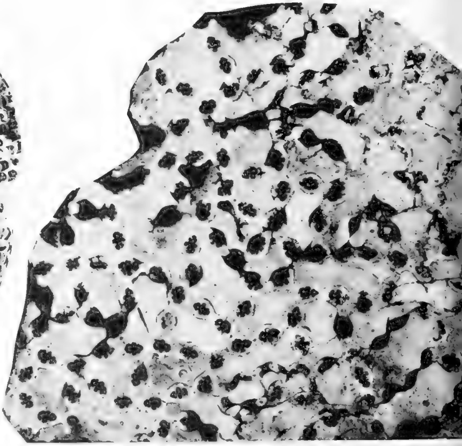

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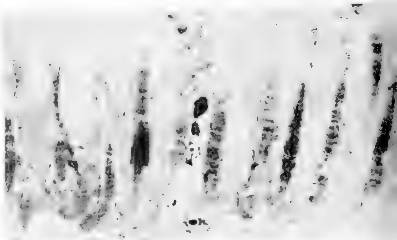

6

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By

HARRELL L. STRIMPLE
and
CALVIN O. LEVORSON

1969

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CONTENTS

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Harrell L. Strimple and Calvin O. Levorson
The University of Iowa and Riceville, Iowa

INTRODUCTION

The purpose of the present study is to list all specimens of the Belanski collections which have been described or published and are in the Repository, Department of Geology, The University of Iowa, Iowa City. The prefix B indicates numbers entered in the Belanski catalogue and the prefix SUI (=UIC) those entered in The University of Iowa catalogue.

Due to the untimely demise of Belanski, many species names have remained in the literature as "zonule" designations, yet in fact are *nomina nuda*. These are clarified herein. Most previously published information did not give clear locality data and an effort is made to provide as precise data as available.

Much interest in the past, and the present for that matter, for this collection is due to comparison with other Devonian faunas from other areas. Most of the material involved was reported by C. H. Belanski, M. A. Fenton, C. L. Fenton, A. O. Thomas, and M. A. Stainbrook and was from Lime Creek Formation and Shellrock Formation of the Upper Devonian and the Cedar Valley Formation of the Middle Devonian. L. R. Laudon described two crinoids, A. K. Miller commented on the cephalopods, and C. C. Branson reported on the *Conocardium.*

Unfortunately much of the Belanski data are missing, but the Station numbers shown on specimen labels are listed and the data, when available, are listed in the Appendix. In some instances the locality is given in the catalogue proper.

There is a total of 82 species listed but one is a junior objective synonym and 16 are *nomina nuda*. The forms are divided as follows: edrioasteroid — 1; crinoids — 8; cystoid — 1; echinoids — 5; corals — 14; brachiopods — 49; pelecypod — 1; sponge — 1. Some notations have been made of current usage but most of the identifications are the original.

C. H. Belanski was an avid fossil collector and naturalist without formal training. He was Research Assistant and Curator in the Department of Geology, The University of Iowa, under Prof. A. O. Thomas during the years 1927 to 1929.

We are grateful to W. M. Furnish and B. F. Glenister, Department of Geology, The University of Iowa, and D. L. Koch, Iowa Geological Survey, for assistance in the preparation of this catalogue.

CATALOGUE

Agelacrinites hanoveri Thomas
Type specimens (=syntypes) SUI (UIC) 3521, SUI (UIC) 3522, SUI (UIC) 3523a, SUI (UIC) 3523b, all missing. Thomas, 1924, pp. 419-421, pl. 46, figs. 1-5. *Stromatopora* reef, Shellrock, Upper Devonian. Near Mason City, Iowa.

Ambocoelia gibberosa Belanski
(Nomen nudum). Specimens labeled as "holotype" B 3368, "paratypes" B 3865, B 3867, B 3389. Belanski, *in* Fenton, C. L., 1931. p. 6. *Leiorhynhus* Zonule, Cerro Gordo Member, Lime Creek, Upper Devonian. All Sta. 4-7.

Aulopora belanksii Fenton and Fenton
Junior objective synonym of *Aulopora elongata* Fenton, 1927. Holotype B 848, Fenton and Fenton, 1937, p. 114, pl. 6, fig. 11.

Aulopora confluens Fenton
Holotype B 3892, paratype B 3670. Fenton, M. A., 1927, p. 380, pl. 1, figs. 1-7. *Pugnoides* Zonule near the top of the Cerro Gordo Member, Lime Creek, Upper Devonian. Sta. 20.
Remarks: Listed and specimen illustrated (probably holotype) by Fenton, M. A. *in* Fenton and Fenton, 1937, p. 112, pl. 2, fig. 2, 3.

Aulopora elongata Fenton
Senior objective synonym of *Aulopora belanskii* Fenton and Fenton, 1937. Holotype B 848, Fenton, M. A., 1927, p. 380, pl. 1, fig. 11. *Camarophoria* Zonule, Mason City Member, Shellrock, Upper Devonian. Sta. 2.

Aulopora irregularis Fenton
Paratypes B 708, B 950 (2 specimens), and B 1128. Fenton, M. A., 1927, p. 376, pl. 2, figs. 11, 12. *Aulopora* Zone, Mason City Member, Shellrock, Upper Devonian. Sta. 38-2.

Aulopora jugalis Fenton
Holotype B 270, paratype B 286. Fenton, M. A., 1927, p. 378, pl. 2, fig. 16. *Aulopora* Zone, Mason City Member, Shellrock, Upper Devonian. Sta. 80-2.

Aulopora linearis Fenton
Holotype B 1943 (in 3 parts), paratype B 2065 (all missing). Fenton, M. A., 1927, p. 379, pl. 1, fig. 10. *Lepidocentrus* Zone, Shellrock, Upper Devonian. Near Nora Springs, Iowa.
Remarks: Referred by Fenton, M. A. *in* Fenton and Fenton, 1937, p. 120, pl. 6, fig. 10, to *Aulocaulis linearis* (Fenton).

Aulopora modulata Fenton
Holotype B 1045; B 175, B 1904, B 2060, B 2061, B 2063. Fenton, M. A., 1927, p. 375, pl. 1, figs. 5-9. *Crania* Zone, Rock Grove Substage and *Schuchertella* Zonule, Nora Member, Shellrock, Upper Devonian. NE ¼ NW ¼ sec. 9, T.95N., R.17W. and SW ¼ NE ¼ sec. 15, T.95N., R.18W. Floyd County, Iowa.
Remarks: Listed and types (B 1045, B 1904 and B 2060) illustrated by Fenton, M. A. *in* Fenton and Fenton, 1937, p. 114, pl. 6, figs. 5-9.

Aulopora multiramosa Fenton
Holotype B 870. Fenton, M. A., 1927, p. 374, pl. 1, fig. 1. *Alveolites* faunule, Mason City Member, Shellrock, Upper Devonian. Sta. 80-2.

Remarks: Listed and holotype figured by Fenton, M. A., *in* Fenton and Fenton, 1937, p. 114, pl. 6, fig. 1.

Aulopora munda Fenton
Figured paratype (=allotype) B 244. Fenton, M. A., 1927, p. 377, pl. 2, figs. 12-14. *Aulopora* Zone, Mason City Member, Shellrock, Upper Devonian. Sta. 38.

Aulopora norensis Fenton
Paratype B 115. Fenton, M. A., 1927, p. 375, pl. 2, figs. 8-10. *Aulopora* Zone, Mason City Member, Shellrock, Upper Devonian. Sta. 38-2.

Aulopora stainbrooki Fenton
Holotype B 6016. Fenton, M. A., 1927, p. 374, pl. 1, fig. 12. *Acervularia davidsoni* beds. Cedar Valley, Middle Devonian, vicinity of Brandon, Iowa.
Remarks: Listed and figured by Fenton, M. A. *in* Fenton and Fenton, 1937, p. 114, pl. 6, fig. 12.

Bactrocrinus westoni Belanski
Holotype B 1675, paratype (=allotype) B 1980, paratypes B 1982, B 1861. Belanski, 1928d, pp. 177-179, pl. 13, figs. 35-37. *Trigonotreta* Zone, *Bactrocrinus* Zonule, Shellrock, Upper Devonian. Sta. 159-9, 38-3, 38-3, 23-2.
Remarks: Bactrocrinites westoni (Belanski), Bassler and Moodey, 1943, p. 315.

Camarophoria nora Belanski
Holotype B 17, paratype B 101 (missing). Belanski, 1928a, pp. 28, 29, pl. 4, figs. 15-19. *Prismatophyllum* Zonule, Shellrock, Upper Devonian. Sta. 93-9.

Camarophoria paupera Belanksi
Holotype B 10, paratypes B 15, B 16, B 18, B 20. Belanski, 1928d, pp. 193-195, pl. 14, figs. 18-26, text-fig. 2-A; 1928a, p. 27, pl. 4, figs. 6-14, text-fig. 13. *Camarophoria* Zonule, Shellrock, Upper Devonian. All Sta. 2-7.
Remarks: Camarophoria paupera Belanski *(nomen nudum),* 1927, p. 334.

Camarophoria perplexa Belanski
Holotype B 4041, paratypes B 3152, B 4014. Belanski, 1928a, pp. 31, 32, pl. 4, figs. 31-34, text-fig. 14. *Douvillina* Zone, *Xenocidaris* Zonule and *Lioclema* Zonule, Lime Creek, Upper Devonian. Sta. 1, 1, 4-5.

Camarophoria planodorsata Belanski
Holotype B 369, paratypes B 290, B 293. Belanski, 1928a, pp. 30, 31, pl. 4, figs. 27-30. Upper *Actinostroma* Zone, *Pseudotectus* Zonule, Shellrock, Upper Devonian. Sta. 78-6, 157-9, 157-9.

Camarophoria prolifica Belanski
Holotype B 4283, paratypes B 3925, B 3960, *B 4085. Belanski, 1928a, pp. 32-34, pl. 4, figs. 35-40, text-fig. 15. Owen Member, Lime Creek, Upper Devonian. All Sta. 105-1.
Remarks: *Illustration shows 4084, which is correct.

Camarophoria retziaformis Belanski
Holotype B 104, paratype B 105. Belanski, 1928a, pp. 29, 30, pl. 4, figs. 20-26. *Prismatophyllum* Zonule, Shellrock, Upper Devonian. All Sta. 93-9.

Camarophoria swallovi (Branson)
Hypotypes (=plesiotypes) B 6030, B 6411. SUI 6671. Belanski, 1928a, pp. 25-27, pl. 4, figs. 1-5, text-fig. 12. *Acervularia profunda* beds, Cedar Valley, Middle Devonian. Near Brandon, Iowa.

Chonetes schucherti Cleland
Hypotypes B 6618; B 6442 (all missing). Stainbrook, 1943, pp. 48, 49. *Bellula* Zone, Cedar Valley, Middle Devonian.

Conocardium ventricosum Hall
Hypotypes B 6528 (52 specimens). B 6829, B 6707 (2 specimens), B 6832, B 6864, B 6722 (4 specimens), B 6496 (24 specimens) and B 6713 (4 specimens). Branson, 1942, pp. 390, 391, pl. 59, figs. 9, 10, 12-15. Cedar Valley Formation, Middle Devonian. Sta. 185-5, 179-3, 185-5, 179-4, 147-2, 185-8, 145, 185-4.

Cranaena brevilamella Belanski
Holotype B 1591, paratypes B 238, B 400, B 712. Belanski, 1928b, pp. 16, 17, pl. 2, figs. 23-27, text-fig. 7. Upper *Actinostroma* Zone, Shellrock, Upper Devonian. Sta. 78-6, 78-6, 93-9, 115-1.
Remarks: Labels show *Cranaena rhomboidalis.*

Cranaena brevisyrinx Belanski
Holotype B 1179, paratypes B 52, B 1177, B 1178. Belanski, 1928b, pp. 14-16, pl. 2, figs. 19-22, text-fig. 6.

Cranaena calvini (Hall and Whitfield)
Hypotypes (=plesiotypes) B 3159, B 3176, B 3561, B 3920, B 4286, B 4475. Belanski, 1928b, pp. 17-19, pl. 3, figs. 1-7, text-fig. 8. *Nortonechinus* Zonule, Lime Creek, Upper Devonian. Sta. 4-18, 1, 1, 4-18, 1.

Cranaena infrequens Belanski
Holotype B 7041, paratypes B 7042, B 7044, B 7045. Belanski, 1928, pp. 9, 10, pl. 1, figs. 18-21, text-fig. 3. *Atrypa lineata* Zonule, Cedar Valley, Middle Devonian. Sta. 123-16, 123-16, 60-5.

Cranaena iowensis (Calvin)
Hypotypes (=plesiotypes) B 6133, B 6134, B 6136. Belanski, 1928b, pp. 7, 8, pl. 1, figs. 1-8, text-fig. 2. Cedar Valley, Middle Devonian. All Sta. 200.

Cranaena maculata Belanski
Holotype B 1813, paratypes B 265, B 1182, B 1183, B 1184, SUI 6898. Belanski, 1928b, pp. 10, 11, pl. 1, figs. 22-28, text-fig. 4. *Eatonia* Zonule, Shellrock, Upper Devonian. Sta. 32-3, 89-5, 64-5, 89-5, 64-5.

Cranaena micula Belanski
Holotype B 3173, paratypes B 4010, B 4279. Belanski, 1928b, pp. 21, 22, pl. 3, figs. 21-25, text-fig. 10. *Stuartella* Zonule, Lime Creek, Upper Devonian. All Sta. 105-1.

Cranaena navicella (Hall)
Hypotypes (=plesiotypes), B 3144, B 3145, B 3174, B 3177. Belanski, 1928b, pp. 19-21, pl. 3, figs. 8-16, text-fig. 9. *Pugnoides* Zonule, Cerro Gordo Member, Lime Creek, Upper Devonian. All Sta. 19-18.

Cranaena parvirostra Belanski
Holotype B 847, paratypes B 196, B 438, B 1001, B 1708, SUI 6897. Belanski, 1928b, pp. 11-13, pl. 2, figs. 1-5, text-fig. 5. *Camarophoria* Zonule, Shellrock, Upper Devonian. Sta. 2-7, 25-5, 26-4, 26-4, 25-5.

Cranaena rockwellensis Belanski
Holotype B 4330, paratypes B 4042, B 4731. Belanski, 1928b, pp. 22, 23, pl. 3, figs. 17-20, text-fig. 11. *Stuartella* Zonule, Lime Creek, Upper Devonian. All Sta. 105-1.

Cranaena romingeri (Hall)
Hypotypes (=plesiotypes) B 6316, B 6317, B 10123, B 10125, B 10126. Belanski, 1928b, pp. 5-7, pl. 1, figs. 9-17, text-fig. 1. Middle Cedar Valley, Devonian. Sta. 180-15, 145, (specimens 6316 and 6317). Transverse Group, Devonian, Rose Quarry, Petoskey, Mich. (specimens 10123, 10125, 10126).

Cranaena sarcophaga Belanski
Holotype B 1135. Belanski, 1928b, pp. 13, 14, pl. 2, figs. 6-9. *Alveolites* Zonule Shellrock Middle Devonian, Sta. 80-2.

Cranaena seminule Belanski
Holotype B 563, paratypes B 1332, B 1333, B 1334. Belanski, 1928, p. 14, pl. 2, figs. 10-18. *Strobilocystites* Zonule, Shellrock, Upper Devonian. All Sta. 158-17.

Cranaena subcylindrica Cooper and Cloud
Hypotypes B 6790, B 6810, SUI 6216, all missing. Stainbrook, 1941, p. 54, pl. 7, figs. 21-24. *Profunda* Zone, Cedar Valley, Johnson County and near Troy Mills and Shellburg, Iowa.

Crania millepunctata Belanski
Holotype B 60, paratypes B 61, B 62, B 64. Belanski, 1928d, pp. 186, 187, pl. 12, figs. 4-6. *Crania* Zonule, Shellrock, Upper Devonian. All Sta. 112-3.

Cyathophyllum floydense Belanski
(=*Cyathophyllum floydensis* Belanski, 1927), Holotype B 2001, paratype (=allotype) B 1361, paratypes, B 364, B 753, B 2003. Belanski, 1928c, pp. 176, 177, pl. 12, fig. 1. *Lepidocentrus* Zone, Shellrock, Upper Devonian. Sta. 2-7, 38-6, 2-7, 2-7, 2-7.
Remarks: Listed as *Cyathophyllum floydensis* by Belanski, 1927, p. 334 but changed to a neuter ending by Belanski, 1928.

Dactylocrinus stellatimbasalis Thomas
Holotype SUI (UIC) 3709. Thomas, 1922, pp. 469-471, pl. 44, figs. 1-5. Lime Creek, Upper Devonian; SE ¼ sec. 13, T. 95 N., R. 19 W., near top of beds near Bird Hill, Cerro Gordo County, Iowa.

Decadocrinus crassidactylus Laudon
Holotype SUI 1998a, Laudon, 1936, p. 64, figs. 7, 8. Rapid Creek Member (=Littleton Member), Cedar Valley Formation, Middle Devonian, Rapid Creek, north of Iowa City, Johnson County, Iowa.

Decadocrinus pachydactylus Laudon
Holotype SUI 1997A. Laudon, 1936, p. 64, fig. 9. Rapid Creek Member (=Littleton Member), Cedar Valley Formation, Middle Devonian, Brandon, Iowa.

Devonocidaris primaevus Belanski
(=*Devonocidaris phimaevus* Belanski, 1927). Syntypes B 1738 (25 specimens). Belanski, 1928d, pp. 184-186, pl. 13, figs. 29-34. *Lepidocentrus* Zone, Mason City Member (=substage), Upper Devonian. Sta. 43-16.
Remarks: Listed as *Devonocidaris phimaevus* by Belanski, 1927, p. 335, apparently as a printing error. The name is not available.

Dielasmella praecursor Belanski
Holotype B 3171, paratypes B 3131, B 3169, B 3172, B 4415. Belanski, 1928b, pp. 28, 29, pl. 4, figs. 13-20, text-fig. 15. *Nortonechinus* Zonule and *Devonocidaris* Zonule, Lime Creek, Upper Devonian. Sta. 4-18, 4-18, 19-3, 4-18, 19-13.

Douvillina planumbona Belanski
Nomen nudum. Specimens labeled "paratypes" B 3395, B 3489, B4137, B 4404. Belanski, *in* Fenton, C. L., 1931, p. 6. *Atrypa hackberryensis* Zonule, Cerro Gordo Member, Lime Creek, Upper Devonian. All Sta. 4-10.

Eatonia gregaria Belanski
Nomen nudum. Belanski, 1927, p. 335. *Eatonia gregaria* Belanski. Holotype B1323, paratypes B 1193, B 1322. Belanski, 1928d, pp. 196-198, pl. 15, figs. 7-17, text-fig. 3-A. *Eatonia* Zonule, Shellrock, Upper Devonian. Sta. 89-4, 89-4, 155-5.

Gypidula comis (Owen)
Hypotypes (=plesiotypes) B 8176, B 8177, B 8180, B 8181. Belanski, 1928a, pp. 9-11, pl. 1, figs. 1-11, text-fig. 3. Cedar Valley, Middle Devonian. Sta. 168-3.

Gypidula cornuta Fenton and Fenton
Hypotypes (=plesiotypes) B 3153, B 3685, B 3897. Belanski, 1928a, pp. 14-16, pl. 1, figs. 12-24, pl. 2, fig. 14, text-fig. 6. *Xenocidaris* Zone, Lime Creek, Upper Devonian. All Sta. 4-6.

Gypidula nucleolata Belanski
Holotype B 5005, paratypes B 5006, 5009. Belanski, 1928a, pp. 19, 20, pl. 3, figs. 12-19, text-fig. 8. *Goldius* Zonule, Lime Creek, Upper Devonian. All Sta. 9-3.

Gypidula occidentalis Hall
Hypotypes (=plesiotypes) B 8076, B 8077, B 8085, SUI 6418. Belanski, 1928a, pp. 8, 9, figs. 1-8, text-fig. 2. Davenport substage, Cedar Valley, Middle Devonian. All Sta. 149-2.

Gypidula papyracea Belanski
Holotype B 1445, paratypes B 511, B 644, B 1316, *B 2059. Belanski, 1928a, pp. 12, 13, pl. 2, figs. 9-13; pl. 3, figs. 20-24, text-fig. 4. *Camarophoria* Zonule Shellrock, Upper Devonian. Sta. 2-7, 25-5, 15-10, 2-7, 2-7.
Remarks: *B 2059 designated as the holotype on plate explanation in error.

Gypidula parva Fenton and Fenton
Hypotypes (=plesiotypes) B 3417, B3425, B 3764. Belanski 1928a, pp. 16-18, pl. 3, figs. 1-11, text-fig. 7. *Devonocidaris* zonule, Lime Creek, Upper Devonian. All Sta. 19-13.

Gypidula rostrata Belanski
Holotype B 1317, paratypes B 164, B 288, B 339, *B 301. Belanski 1928a, pp. 13, 14, pl. 2, figs. 15-19, text-fig. 5. *Loxonema* Zonule, Shellrock, Upper Devonian. All Sta. 93-5.
Remarks: *B 301 designated as the holotype on plate explanation in error.

Hexacrinus iowensis Thomas
"the type" SUI (UIC) 3708, "the cotype" SUI (UIC) 3707. Thomas, 1922, pp. 462, 463, pl. 42, figs. 10-13. Shellrock, Upper Devonian. SW 1/4 NW 1/4 sec. 28, T. 96 N., R. 18 W., in gutter along wagon road on the east side of Shellrock River, Floyd County, Iowa.
Remarks: Hexacrinites iowensis (Thomas), Bassler and Moodey, 1943, p. 509.

Hexacrinus springeri Thomas
Holotype SUI (UIC) 3631 paratypes SUI (UIC) 3722, SUI (UIC) 3723, SUI (UIC) 3724, SUI (UIC) 3725. Thomas, 1922, pp. 461, 462, pl. 42, figs. 2-9; pl. 43, figs. 1-9. Shellrock, Upper Devonian. NW ¼ NE ¼ sec. 4, T. 95 N., R. 18 W., in left bank of Shellrock River, Floyd County, Iowa.
Remarks: Hexacrinites springeri (Thomas), Bassler and Moodey 1943, p. 510.

Hypothyridina magister Belanski
Nomen nudum, Belanski, 1927, p. 334. *Hypothyridina magister* Belanski. Holotype B 935, paratypes B 1711, B 1255 (missing), paratype B 462 (missing). Belanski, 1928d, pp. 198-200, pl. 15, figs. 1-6, text-fig. 4. *Lepidocentrus* Zone, Shellrock, Upper Devonian. Sta. 26-4, 25-5.

Iowaspongia annulata Thomas
Syntype SUI 2801. Thomas, 1922, p. 88, pl. 1, fig. 2. Plastic blue shale Lime Creek, upper Devonian. Pit of the Rockford Brick & Tile Co., Rockford, Iowa.

Lepidocentrus thomasi Belanski
Nomen nudum, Belanski, 1927, p. 334. *Lepidocentrus? thomasi* Belanski. Syntypes B 1808 (19 specimens). Belanski, 1928d, pp. 181-183, pl. 13, figs. 1-16. *Lepidocentrus* Zone, *Camarophoria* Zonule, Shellrock, Upper Devonian. All Sta. 2-7.

Lingula milwaukeensis Cleland?
Hypotypes B 6400, B 6460 (all missing). Stainbrook, 1942, p. 606. *Bellula* Zone, Cedar Valley, Middle Devonian, Buffalo, Iowa.

Manticoceras regulare? Fenton and Fenton
Figured specimen (=hypotype) B 3850. Miller, 1936, p. 234, pl. 1, figs. 11, 12, *Ptyctodus* Zonule, Cerro Gordo Member, Lime Creek, Upper Devonian. Sta. 1.

Melocrinus belanskii Thomas
Holotype SUI (UIC) 3602, paratype SUI (UIC) 3751. Thomas, 1924, pp. 440-442, pl. 37, figs. 11-12. Lime Creek, Upper Devonian. SE 1/4 sec. 13, T. 95 N., R. 19 E., near Bird Hill, Cerro Gordo County, Iowa.
Remarks: Melocrinites belanskii (Thomas), Bassler and Moodey, 1943, p. 554.

Nassoviocrinus goldringae Belanski
Holotype B 1981, paratype B 1983. Belanski, 1928d, pp. 179-181, pl. 13, figs. 38-39. *Trigonotreta* Zone, *Nassoviocrinus* zonule, Shellrock, Upper Devonian. All Sta. 38-3.

Nortonechinus owensis Thomas
Type specimens (=syntypes), SUI (UIC) 3063, SUI (UIC) 3064a-e, SUI (UIC) 3065a-b, SUI (UIC) 3066a-f. Thomas, 1924, pp. 493-495, pl. 50, figs. 26-35. Owen Member, Lime Creek, Upper Devonian. In gutters along roadside between secs. 36 Mason Township and 31 Portland Township about 75 yards north of Owen Creek, Cerro Gordo County, Iowa.

Nortonechinus welleri Thomas
"the type specimen" (=holotype) SUI (UIC) 3044, other specimens SUI (UIC) 3051a-d, SUI (UIC) 3046a, c, SUI (UIC) 3045a, SUI (UIC) 3048a-b, SUI (UIC) 3051 a-d, SUI (UIC) 3047, SUI (UIC) 3052a-d, SUI (UIC) 3053a-c, SUI (UIC) 3055a-d, SUI (UIC) 3059a,b. Thomas, 1924, pp. 483-492, pl. 47, figs. 1-7; pl. 48, figs. 1-49; pl. 49, figs. 1-6, 8-23. Lime Creek, Upper Devonian. In marly shales 10-15 feet above the pastic blue shales near the Rockford Brick & Tile pit, Rockford, Iowa.
Remarks: This species has been restudied by Kier (1968, pp. 1163-70, pl. 151, fig. 1-4).

Orbiculoidea telleri Cleland
Hypotypes B 6395, B 6572 (all missing), Stainbrook, 1942, p. 608. *Bellula* Zone, Cedar Valley, Middle Devonian, Buffalo, Iowa.

Pachyphyllum websteri Belanski
Holotype B 2176, paratypes B 529, B 646, B 626 (missing). Belanski, 1928d, pl. 12, fig. 3, text-fig. 1. *Aulopora* Zone, *Pachyphyllum* Zonule, Shellrock, Upper Devonian. All Sta. 38-2.

Petrocrania sp.
B 6734 (missing). Stainbrook, 1942, p. 610, pl. 88, fig. 44. *Cranaena* Zone, Cedar Valley, Middle Devonian.

Platyrachella ballardi Belanski
Holotype B 277, paratypes B 702, B 1042 (missing). Belanski, 1928d, pp. 204-206, pl. 16, figs. 1-10. *Platyrachella* Zone, Shellrock, Upper Devonian. All Sta. 78-3.

Remarks: Platyrachella ballardi Belanski *(nomen nudum)*. Belanski, 1927, p. 325.

Platyrachella ulsterensis Belanski
Holotype B 1905, paratype B 647. Belanski, 1928d, pp. 206, 207, pl. 17, fig. 1-8. *Crania* Zonule, Shell Rock, Upper Devonian. All Sta. 112-3.
Remarks: Listed as *Spirifer ulsterensis* Belanski, 1927 *(nomen nudum)*.

Prismatophyllum oweni Belanski
Holotype B 471, paratypes B 134, B 1522 (missing). Belanski, 1928, pp. 174-176, pl. 12, fig. 2. *Prismatophyllum* Zonule, Shellrock, Upper Devonian. All Sta. 93-9.
Remarks: Prismatophyllum oweni Belanski *(nomen nudum)*. Belanski, 1927, p. 327.

Productella fragilis Belanski
Holotype B 130, paratypes B 390, B 299, B 232 (missing). Belanski, 1928d, pp. 192, 193, pl. 14, figs. 15-17. Shellrock, Upper Devonian. Sta. 112-2, 112-3, 112-2.

Schizophoria floydensis Belanski
Holotype B 500, paratypes B 61, B 62, B 64. Belanski, 1928d, pp. 187-189, pl. 14, figs. 1-7. *Schizophoria* Zone, Shellrock, Upper Devonian. All Sta. 112-3.
Remarks: Schizophoria floydensis Belanski *(nomen nudum)*. Belanski, 1927, p. 329.

Sieberella emarginata Belanski
Holotype B 1440, paratypes B 128, B 940. Belanski, 1928a, pp. 21, 22, pl. 3, figs. 25-31, text-fig. 9. *Camarophoria* Zonule, Shellrock, Upper Devonian. Sta. 2-7, 2-7, 26-4.

Sieberella insolita Belanski
Holotype B 1200, paratypes B 273, B 420. Belanski, 1928a, pp. 22-24, pl. 3, figs. 32-36, text-fig. 10. Upper *Actinostroma* Zone, *Pseudotectus* Zonule, Shellrock, Upper Devonian. Sta. 115-1, 36, 36.

Spirifer cardinalis Belanski
Holotype B 969, paratypes B 315, B 370. Belanski, 1928d, pp. 201, 202, pl. 16, figs. 23-30. *Eatonia* Zonule, Shellrock, Upper Devonian. Sta. 64-5, 89-4, 126-5.

Spirifer ulsterensis Belanski
(Nomen nudum), Belanski, 1927, p. 329.
Remarks: See *Platyrachella ulsterensis* Belanski, 1928.

Strobilocystites schucherti Thomas
"the types" (syntypes) SUI (UIC) 3505, 3506, figured specimen SUI (UIC) 3507, Thomas, 1924, pp. 418, 419, pl. 35, figs. 12, 19. Shellrock, Upper Devonian. Belanski quarry a Nora Springs, Iowa, Middle Cedar Valley, 1-1/2 Mi. west of Solon, Iowa.

Strophalosia iowa Belanski
(Nomen nudum), Belanski *in* Fenton, C. L., 1931, p. 3. *Devonocidaris* Zonule, Cerro Gordo Member, Lime Creek, Upper Devonian. Sta. 19-13.
Remarks: Specimens labeled as *Productella iowa* Belanski *(nomen nudum)*, "holotype" B 3719, "paratypes" B 3474, B 4012.

Strophalosia multispinosa Belanski
(Nomen nudum). Specimens labeled as "holotype" B 3441, "paratypes" B 3266, B 3312, B 3505, B 4104. Belanski, *in* Fenton, C. L., 1931, p. 4. *Stropholosia* Zonule, Cerro Gordo Member, Lime Creek, Upper Devonian. Sta. 108, 19-9, 19-9, 19-9, 19-13.

Stropheodonta cicatricosa Belanski
Holotype B 242, paratypes B 349, B 356, B 409, B 176. Belanski 1928d, pp. 189, 190, pl. 14, figs. 11-14. *Camarophoria* Zonule, Shellrock, Upper Devonian.
Remarks: Stropheodonta cicatricosa Belanski *(nomen nudum)*. Belanski, 1927, p. 334.

Stropheodonta nortoni Belanski
(Nomen nudum). Specimens labeled as "Holotype" B 3755, "paratypes" B 3454, B 3475, B 4104, B 4105. Belanski, *in* Fenton, C. L., 1931, p. 6. *Nortoni* Zonule, Owen Member, Lime Creek, Upper Devonian. Sta. 9-11.

Stropheodonta scottensis Belanski
Holotype B 300, paratypes B 1088, B 174, B 542. Belanski, 1928d, pp. 190, 191, pl. 14, figs. 8-10. *Trigonotreta* Zone, Shellrock, Upper Devonian. Sta. 159-9, 159-9, 56-5, 159-9.
Remarks: Stropheodonta scottensis Belanski *(nomen nudum)*. Belanski, 1927, p. 337.

Stuartella devoniana Belanski
Holotype B 1181, paratypes B 533, B 1180, B 1439, B 2150. Belanski, 1928b, pp. 26, 27, pl. 4, figs. 10-12, text-fig. 12. *Camarophoria* Zonule, Shellrock, Upper Devonian. Sta. 25-5, 25-5, 25-5, 2-7, 2-7.

Stuartella vera Belanski
Holotype B 4290, paratypes B 4370, B 4511. Belanski, 1928, pp. 26, 27, pl. 4, figs. 10-12, text-fig. 13. *Stuartella* Zonule, Lime Creek, Upper Devonian. All Sta. 105-1.

Tornoceras (Tornoceras) uniangulare? (Conrad)
Figured specimen (=hypotype) SUI 33407. Miller, 1936, p. 231, pl. 1, fig. 16. *Amana* beds, (?Lime Creek), Upper Devonian. Near Amana, Iowa.

Trigonotreta shellrockensis Belanski
Holotype B 720, paratype (=allotype) B 728, paratypes B 2242, B 1799. Belanski 1928d, pp. 202-204, pl. 16, figs. 11-18. *Trigonotreta* Zone, *Bactrocrinus* Zonule, Shellrock, Upper Devonian. All Sta. 159-9.
Remarks: Trigonotreta shellrockensis Belanski *(nomen nudum)*. Belanski, 1927, p. 327.

Xenocidaris americana Thomas
Type specimens (=syntypes), SUI (UIC) 3073. Thomas, 1924, pp. 497-499, pl. 50, fig. 1. *Xenocidaris* Zone, Lime Creek, Upper Devonian. In the marly shale just above the contact with the blue plastic shale of the Lime Creek beds, near east end of Rockford Brick & Tile Co., pit, Rockford, Iowa.
Remarks: A total of 15 specimens were studied but the others were apparently collected by Thomas and Belanski jointly. The contour of the pit has changed considerably through the years.

APPENDIX

Data from Belanski's Locality Register

Station No. (including zones)

1-0 NW 1/4, NE 1/4, sec. 34, T. 96 N., R. 19 W., about 4 miles SW of Nora Springs, Cerro Gordo County, Iowa. Juniper Hill stage. Lime Creek, Upper Devonian.

2-7 SW 1/4 NE 1/4 sec. 7, T. 96 N., R. 18 W., Belanski's quarry, Nora Springs, Floyd County, Iowa. *Camarophoria* Zonule, Mason City Member (=substage), Shellrock, Upper Devonian.

4-0 SE 1/4 NW 1/4 sec. 16, T. 95 N., R. 18 W., 3 miles West of Rockford, Floyd Conunty, Iowa, Upper Devonian.

-5 Juniper Hill stage, Lime Creek.

-6 *Xenocidaris* Zonule, Cerro Gordo Member (=substage), Lime Creek.

-7 Leiorhynchus Zonule, Cerro Gordo Member, Lime Creek.

-10 *Atrypa hackberryensis* Zonule, Cerro Gordo Member, Lime Creek.

-18 *Nortonechinus* Zonule, Cerro Gordo Member, Lime Creek.

9-0 NW 1/4 SW 1/4 sec. 31, T. 96 N., R. 19 W., about 3 miles SE of Mason City, Cerro Gordo County, Iowa.

-3 *Goldius* Zonule, *Idiostroma* Zone, Owen Member (=substage) Lime Creek, Upper Devonian.

15-10 NE 1/4 NW 1/4 sec. 22, T. 95 N., R. 19 W., about 6 miles west of Rockford, Cerro Gordo County, Iowa. Owen Member, Lime Creek, Upper Devonian.

19-0 SW 1/4 NW 1/4 sec. 19, T. 95 N., R. 18 W., about 3-1/2 miles west of Rockford, Floyd County, Iowa. Lime Creek, Upper Devonian.

20-0 NW 1/4 NE 1/4 sec. 24, T. 95 N., R. 19 W., Bird Hill about 4 miles west of Rockford, Cerro Gordo County, Iowa. Lime Creek, Upper Devonian.

23-2 NE 1/4 SW 1/4 sec. 10, T. 95 N., R. 18 W. abandoned quarries in northern edge of Rockford, Floyd County, Iowa. *Synbathocrinus* Zonule, *Trigonatreta* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

25-5 NW 1/4 SW 1/4 sec. 7, T. 96 N., R. 18 W., mill dam at Nora Springs, Floyd County, Iowa. *Camarophoria* Zonule, *Lepidocentrus* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

26-4 SE 1/4 NE 1/4 sec. 7, T. 96 N., R. 18 W., abandoned quarry on the North bank of Kidney Creek in northwest part of Nora Springs, Floyd County, Iowa. *Athyris* Zonule, *Lepidocentrus* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

32-3 NE 1/4 SE 1/4 sec. 7, T. 96 N., R. 18 W., abandoned quarry in east bank of Shellrock River, about 1/4 mile north of Nora Springs, Floyd County, Iowa. Expansum? zonule, Lower *Actinostroma* Zone, Nora Member (=substage), Shellrock, Upper Devonian.

36-0 NW 1/4 NE 1/4 sec. 18, T. 96 N., R. 18 W., south part of Nora Springs, Floyd County, Iowa. Shellrock, Upper Devonian.

38-0 NW 1/4 NW 1/4 sec. 17, T. 96 N., R. 18 W. Abandoned quarry in southern part of Nora Springs, Floyd County, Iowa. Shellrock, Upper Devonian.

-2 *Pachyphyllum* Zonule, *Aulopora* Zone, Mason City Member (=substage).

-3 *Decadocrinus* Zonule, *Trigonatreta* Zone, Mason City Member (=substage).

-6 *Athyris* Zonule, *Lepidocentrus* Zone, Mason City Member (=substage).

43-16 SW 1/4 SW 1/4 sec. 28, T. 96 N., R. 18 W., about 2-1/2 miles SE of Nora Springs, Floyd County, Iowa. *Lepidocentrus* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

56-5 SW 1/4 SW 1/4 sec. 7, T. 94 N., R. 17 W., road gutter two miles due west of Marble Rock, Iowa. *Stereocrinus* Zonule, *Trigonotreta* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

60-5 SE 1/4 NW 1/4 sec. 7, T. 95 N., R. 15 W., dry run entering Cedar River from north in eastern part of Charles City, Floyd County, Iowa. Cedar Valley Formation (=substage), Middle Devonian.

64-5 SE 1/4 SW 1/4 sec. 33, T. 96 N., R. 18 W., Cooper's bend, Shellrock River, about 2 miles NW of Rockford, Floyd County, Iowa. *Eatonia* Zonule, Mason City Member (=substage), Shellrock, Upper Devonian.

78-0 SW 1/4 NE 1/4 sec. 15, T. 95 N., R. 18 W., southern bank of Lime Creek, about 1/4 mile south of Rockford, Floyd County, Iowa.

-3 *Schuchertella* Zonule, *Platyrachella* Zone, Nora Member (=substage), Shellrock, Upper Devonian.

-6 *Pseudotectus* Zonule, Upper *Actinostroma* Zone, Nora Member (=substage), Shellrock, Upper Devonian.

80-2 SE 1/4 NW 1/4 sec. 10, T. 96 N., R. 20 W., cliff in east bank of Willow Creek just south of State Street Bridge, Mason City, Cerro Gordo County, Iowa. *Alveolites* Zonule, *Lepidocentrus* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

89-0 NW 1/4 SW 1/4 sec. 28, T. 96 N., R. 18 W., north bank of Baumgardners Creek, about 2 miles SE of Nora Springs, Floyd County, Iowa. Shellrock, Upper Devonian.

-4 *Eatonia* Zonule, Mason City Member (=substage).

-5 *Cladopora* Zonule, Mason City Member (=substage).

93-0 NW 1/4 SE 1/4 sec. 13, T. 96 N., R. 18 W., eastern bank of Flood Creek, west edge of Rudd, Floyd County, Iowa. Shellrock, Upper Devonian.

-5 *Loxonema* Zonule, *Schizophoria* Zone, Rock Grove Member (=substage).

-9 *Prismatophyllum* Zonule, Lower *Actinostrema* Zone, Nora Member (=substage).

105-1 SW 1/4 SW 1/4 sec. 22, T. 94 N., R. 20 W., road cut three miles directly south of Rockwell, Cerro Gordo County, Iowa. *Stuartella* Zonule, *Floydia* Zone, Owen Member (=substage), Lime Creek, Upper Devonian.

108-0 No data as to locality. Cerro Gordo Member, Lime Creek, Upper Devonian.

112-0 NE 1/4 NW 1/4 sec. 9, T. 95 N., R. 17 W., road cut about 4 miles east of Rockford, Floyd County, Iowa. Rock Grove Member (=substage), Shellrock, Upper Devonian.

-2 *Productella* Zonule, *Paracyclas* Zone.

-3 *Crania* Zonule, *Schizophoria* Zone.

115-1 SE 1/4 SW 1/4 sec. 30, T. 96 N., R. 18 W., road gutter between secs. 30 and 31, about 2-1/2 miles south of Nora Springs, Floyd County, Iowa. Nora Member (=substage). Shellrock, Upper Devonian.

123-16 SE 1/4 SE 1/4 sec. 20, T. 95 N., R. 15 W., two small abandoned quarries on the northern bank of Bloody Run Creek about three miles southeast of Charles City, Iowa. *Atrypa lineata* Zonule, Cedar Valley Formation, Middle Devonian.

126-5 NW 1/4 NW 1/4 sec. 13, T. 93 N., R. 17 W., road cut just north of Coldwater Creek, 1 mile south of Greene, Butler County, Iowa. *Eatonia*? Zonule, *Lepidocentrus* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

145-0 No locality data. Cedar Valley Formation, Middle Devonian.

147-2 No locality data. Cedar Valley Formation, Middle Devonian.

149-2 No locality data, other than Davenport substage which is now called Solon. Cedar Valley Formation, Middle Devonian.

155-5 NE 1/4 NE 1/4 sec. 4, T. 95 N., R. 18 W., cliffs along south bank of the Shellrock River, about 1-1/2 miles north of Rockford, Floyd County, Iowa. *Eatonia* Zonule, *Hexacrinus* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

157-9 SE 1/4 SE 1/4 sec. 9, T. 95 N., R. 18 W., eastern bank of Lime Creek, west edge of Rockford, Floyd County, Iowa. *Platyrachella* Zone, Nora Member (=substage), Shellrock, Upper Devonian.

158-17 SE 1/4 NW 1/4 sec. 14, T. 95 N., R. 18 W., east bank of Shellrock River southeast about 1/4 mile south of Rockford, Floyd County, Iowa. *Strobilocystites* Zonule, *Schizophoria* Zone, Rock Grove Member (=substage), Shellrock, Upper Devonian.

159-9 NE 1/4 SW 1/4 sec. 14, T. 95 N., R. 18 W., about 1/4 mile south of 158-17, cliff opposite mouth of Lime Creek, Floyd County, Iowa. *Poteriocrinus* Zonule, *Trigonatreta* Zone, Mason City Member (=substage), Shellrock, Upper Devonian.

168-3 SW 1/4 NW 1/4 sec. 24, T. 81 N., R. 5 W., south bank of Cedar River about 5 miles east of Solon, Johnson County, Iowa. Cedar Valley Formation, Middle Devonian.

179-0 No further data available. Cedar Valley Formation, Middle Devonian.

180-0 No further data available. Cedar Valley Formation, Middle Devonian.

185-0 No further data available. Cedar Valley Formation, Middle Devonian.

200-0 No further data available. Cedar Valley Formation, Middle Devonian.

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CONTENTS

SOME LATE CENOZOIC ECHINOIDEA FROM CABO BLANCO, VENEZUELA

NORMAN E. WEISBORD

ABSTRACT

Eight species of echinoids plus a number of isolated echinoid spines are described and illustrated. Six of the species are fossil, occurring in the Playa Grande, Mare, or Abisinia Formations of the Cabo Blanco Group, two are Recent, and one is both fossil and Recent. All but one (and possibly even that) of the fossil species are known to be living, and at least six of the eight species are allopatric, having evolved into valid geographic forms by virtue of their restriction to Atlantic waters between eastern America and western Africa within the 30 degree parallels. Three of the fossils are recorded for the first time from the Pliocene, and one from the Pleistocene, of Venezuela.

Tables are presented showing the percentage of Recent species by class and formation, in which is given a) the total number of fossil marine invertebrates collected from a particular formation, and b) the number and per cent of fossil species therein which are known also in the Recent. The tables disclose that although there is considerable variation in the survival rate to the Recent among different classes of Venezuelan Neogene invertebrates, each group has its particular life span, and the thesis is developed that once the Recent percentage is established everywhere for all groups of Tertiary fossils in all sedimentary units of established stratigraphic position, the percentage of one biologic entity should be as indicative of a particular interval of Cenozoic time as any other biologic entity.

INTRODUCTION

With the completion of the present work on the Echinoidea, the writer will have described, compared, and illustrated in the Bulletins of American Paleontology 539 species of Pliocene to Recent invertebrates collected during 1955 and 1956 in northern Venezuela at three coastal localities: La Salina de Guaiguaza, Estado Carabobo; Cabo Blanco, Distrito Federal; and Higuerote, Estado Miranda. Among the classes represented were the Gastropoda (1962, 285 species); Pelecypoda [Bivalvia] (1964a, 173 species); Scaphopoda (1964b, 15 species); Polychaetia (1964b, 7 species); Cirripedia (1966a, 9 species); Gymnolaemata [Bryozoa] (1967, 28 species); Anthozoa and Hydrozoa (1968a, 14 species); and Echinoidea (1969, 8 species).

This particular paper deals with eight species of echinoids from the Cabo Blanco area. Six of the species are fossil and occur in the Playa Grande, Mare, or Abisinia Formations of the Cabo Blanco Group; two of the species are Recent and were collected on the beach facing the Caribbean Sea and lying immediately north of the Cabo Blanco hills; and one, *Eucidaris tribuloides* (Lamarck), is both fossil and Recent. All but one (and possibly even that) of the fossil species have survived to Recent time, and are known to be living in the Caribbean Sea, the Gulf of Mexico, or the Atlantic Ocean generally between the 30 degree parallels. Three of the fossils are recorded for the first time from the Pliocene, and one from the Pleistocene, of Venezuela. At least six of the eight species are allopatric in the sense that although they are closely related to species elsewhere, they have evolved into valid geographic species by virtue of their isolation or restriction to "Atlantic" waters between eastern America and western Africa.

Under the synonymy of each species dealt with in this work there are listed all of the references to that species I have been able to find. Each citation, however, rests on the authority of the taxonomist responsible for its usage.

The specimens illustrated herein have been deposited with the Paleontological Research Institution, Ithaca, New York. The remaining material is available in the Department of Geology, Florida State University, Tallahassee, Florida.

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For the courtesies extended to me in the preparation of this paper, I am indebted to Dr. C. Wythe Cooke of the U.S. Geological Survey, Mrs. Bertha M. Cutress of the University of Puerto Rico, Dr. J. Wyatt Durham of the University of California, Dr. Leo G. Hertlein of the California Academy of Sciences, Dr. Porter M. Kier of the U.S. National Museum, Dr. Luiz Roberto Tommasi of the Instituto Oceanográfico, Universidade de São Paulo, and Dr. Katherine V. W. Palmer of the Paleontological Research Institution. I am also grateful to the National Science Foundation for supporting this study through its Research Grant GB-1676.

Most of the photographs were taken and processed by Werner Vagt of Florida State University and Gerritt Mulders of Tallahassee. A number of echinoid spines were loaned to Bertha Cutress who kindly sent to me the excellent photographic enlargements reproduced in this work. Katherine Palmer supervised the editing and publication, and for this I am particularly appreciative since concurrently she was directing the renovation and occupancy of the newly acquired facility of the Paleontological Research Institution.

LOCALITIES

The localities at which the echinoids were collected are listed below and are shown on the geologic map of the writer's 1957 paper. The letter preceding each locality is also used as a prefix for each species number. For each locality the formation and lithology are noted.

A. Beach at Playa Grande Yachting Club, Distrito Federal. Moderately coarse and mostly noncalcareous beach sand, and patches of calcareous beach rock. Recent.

D. Eastern edge of Playa Grande village at W-30. Elevation approximately 61 meters. Granule to pebble gravel. Abisinia Formation. Absolute age, determined by the ionium disequilibrium method, is in excess of 300,000 years. (See Weisbord, 1966a, p. 11.)

G. On hillside above west bank of Quebrada Mare Abajo near W-14. Soft, tan, fine-grained sandstone. Mare Formation.

H. Fifteen meters south of axis of Punta Gorda anticline near W-25, on face of scarp fronting the shoreline. Highly fossiliferous wedge of loosely coherent calcareous sandstone. Mare Formation. (See Fig. 5 in Weisbord, 1964a.)

I. On hillside above west bank of Quebrada Mare Abajo at W-13. Uniform coarse sand. Lower Mare Formation.

J. In small stream 100 meters west of Quebrada Mare Abajo. Uniform coarse sand at about the same stratigraphic position as locality I. Lower Mare Formation.

K. Bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road, and about 95 meters due south of shoreline. Tan, fine-grained calcareous sandstone. Playa Grande Formation (Catia Member).

L. South side of Playa Grande road about 220 meters west of W-15. Brown, fine-grained calcareous sandstone. Playa Grande Formation (Catia Member).

M. South side of Playa Grande road at W-15, 40 meters southeast of the intersection with the Playa Grande road. Yellowish sandy limestone. Playa Grande Formation (Catia Member).

N. Near W-21 and to the south of that station, in stream flowing along the north flank of the Litoral anticline. Tan siltstones and sandstones with knobs of hard sandstone. Playa Grande Formation (Catia Member).

O. Dip slope 100 meters west of Costa fault and 130 meters south of shoreline at W-22. Dull gray pebbly sandstone. Playa Grande Formation (Catia Member).

S. On and near the "*Lithothamnium*" reef at W-23, north flank of Punta Gorda anticline. Reef of calcareous algae with layer of cobbles at base. Playa Grande Formation (Maiquetía Member).

T. In stream 250 meters south-southwest of the mouth of Quebrada Las Pailas and 255 meters east-northeast of wireless station. Soft silty sandstone. Mare Formation.

THE CABO BLANCO GROUP

STRATIGRAPHIC TABLE

As indicated in the list of localities, the fossil echinoids described in this paper were collected from the Playa Grande, the Mare, and the Abisinia Formations of the Cabo Blanco Group. The Playa Grande Formation is lower Pliocene, the Mare, lower to middle Pliocene, and the Abisinia, lower Pleistocene. The stratigraphic succession within the Cabo Blanco Group is the following:

Subrecent

Bench-forming beach rock, and reworked clays, sands, and gravels. Thickness 3 meters max.

Disconformity

ABISINIA FORMATION

(Lower Pleistocene)

Clays, silts, sands, and gravels, the latter locally with marine fossils. Thickness 13 meters max.

Disconformity

MARE FORMATION

(Middle-lower Pliocene)

Uniformly coarse friable sandstone at base grading upward to soft siltstones. Highly fossiliferous. Thickness 19 meters max.

Angular unconformity to disconformity

PLAYA GRANDE FORMATION (MAIQUETIA MEMBER)

(Lower Pliocene)

Shales, siltstones, calcareous sandstones, and conglomerates. Bioherms of coralline algae. Fossils moderately abundant. Thickness 68 meters +.

Fault

Playa Grande Formation (Catia Member)

(Lower Pliocene)

Calcareous siltstones and sandstones, conglomerates, some shales and impure limestones, and local occurrences of barnacle coquinas. Fossils moderately abundant, in places as molds and casts. Thickness 156-233 meters.

Angular unconformity

Las Pailas Formation

(Middle Tertiary)

Nonfossiliferous mudstones, siltstones, sandstones, and conglomerates. Thickness 375 meters +.

LIST OF THE ECHINOIDEA COLLECTED

The echinoids collected in the Cabo Blanco area are listed below. Under Formation, the abbreviation Re refers to Recent; Ab = Abisinia Formation; Ma = Mare Formation; PGm = Playa Grande Formation (Maiquetía Member); PGc = Playa Grande Formation (Catia Member).

Species	Formation	Previously recorded range of known species
Eucidaris tribuloides (Lamarck)	Re;Ab;PGm;PGc	Oligocene ? - Recent
Tripneustes cf. T. ventricosus (Lamarck)	PGc	Recent
Echinometra lucunter (Linnaeus)	Re	Upper Mio. - Recent
Echinometra viridis A. Agassiz	Re	Recent
Encope emarginata (Leske)	Ma	Upper Mio. - Recent
? Echinolampas sp. indet.	PGm	?
Moira atropos (Lamarck)	PGc	Pliocene - Recent
Brissopsis cf. B. atlantica Mortensen	PGc	Pliocene - Recent

All of the recognized fossil species have survived to Recent time and all of the Recent species save *Echinometra viridis* are known to occur in both the Western and Eastern Atlantic between the latitudes of 30° North and 30° South. Thus they are widespread geographically and long-lived (up to 25 million years) geologically. The forms, though indicative of different bottom environments *(Encope emarginata,* coarse sand, *Moira atropos,* silt) are shallow-water and tropical *in habitus.*

The range of *Tripneustes* cf. *T. ventricosus,* formerly known only from the Recent is extended back to the early Pliocene of

Venezuela. *Eucidaris tribuloides* is reported for the first time from the Pleistocene and Pliocene of Venezuela, as are *Eucope emarginata* and *Brissopsis* cf. *B. atlantica* from the Pliocene.

AGE DETERMINATION OF THE FOSSILS FROM THE CABO BLANCO GROUP AND FROM THE GUAIGUAZA CLAY

In the tabulation below there is listed under the hierarchy of Class the number of fossil species collected in each formation of the Cabo Blanco Group, and the percentage of the species that have survived to Recent time. Included in the tabulation are the Echinoidea described in the present work, as well as, for the sake of completeness, the fossils collected by the writer (Weisbord, 1962, 1964 a,b and 1968a) in the Guaiguaza Clay some 115 kilometers or so west of Cabo Blanco.

The age determinations are based fundamentally on Lyell's subdivision of the Tertiary by the per cent of the fossil Mollusca that have survived to Recent time. Complementing the Mollusca as age indicators are 1) the percentages in the Recent of other classes of organisms, 2) the local stratigraphy and succession of beds, and 3)the dating of the Abisinia Formation by the ionium disequilibrium method.

PERCENTAGE OF RECENT SPECIES BY CLASS AND FORMATION

Abisinia Formation (Lower Pleistocene)

Class or Order		Total number of species	Number of fossil species in Recent	Per cent of species in Recent
Anthozoa (Scleractinia)		2	2	100
Echinoidea		1	1	100
Gymnolaemata (Cheilostomata)		1	1	100
Polychaetia (Sedentarida)		1	1	100
Cirripedia		1	1	100
Gastropoda	MOLLUSCA	34	26-31	76-91
Pelecypoda		18	15-16	83-90
TOTAL		58	47-53	81-91
MOLLUSCA ONLY		52	41-47	80-90

Guaiguaza Clay (Upper Pliocene)

Class or Order	Total number of species	Number of fossil species in Recent	Per cent of species in Recent
Anthozoa (Scleractinia)	2	2	100
Scaphopoda	2	1	50
Gastropoda MOLLUSCA	25	9	36
Pelecypoda	14	11	79
TOTAL	43	23	53
MOLLUSCA ONLY	41	21	51

Mare Formation (Middle-Lower Pliocene)

Class or Order	Total number of species	Number of fossil species in Recent	Per cent of species in Recent
Foraminiferida[1]	72	60	83
Anthozoa (Scleractinia)	3	3	100
Echinoidea	1	1	100
Gymnolaemata (Cheilostomata)	10	6	60
Polychaetia (Sedentarida)	2	1	50
Cirripedia	5	1-2	20-40
Scaphopoda	8	4-5	50-63
Gastropoda MOLLUSCA	140	23-52	16-37
Pelecypoda	82	32-58	39-46
TOTAL	323	131-168	40-52
MOLLUSCA ONLY	230	59-95	26-41

Playa Grande Formation Undifferentiated (Lower Pliocene)

Class or Order	Total number of species	Number of fossil species in Recent	Per cent of species in Recent
Chlorophyceae (Dasycladales)	1	0	0
Foraminiferida[1]	140	106	76
Anthozoa (Scleractinia)	5	4	80
Echinoidea	5	5	100
Gymnolaemata (Cheilostomata)	7	4	57
Polychaetia (Sedentarida)	4	0	0
Cirripedia	8	2	25
Scaphopoda	9	3-5	33-55
Gastropoda MOLLUSCA	84	9-20	11-24
Pelecypoda	72	30-37	42-52
TOTAL	335	163-183	49-54
MOLLUSCA ONLY	165	42-62	25-37

[1] Data obtained from Bermúdez (1966), and Bermúdez and Fuenmayor (1966).

Playa Grande Formation [Maiquetía Member] (Lower Pliocene)

Class or Order		Total number of species	Number of fossil species in Recent	Per cent of species in Recent
Chlorophyceae (Dasycladales)		1	0	0
Anthozoa (Scleractinia)		4	3	75
Echinoidea		2	2	100
Gymnolaemata (Cheilostomata)[2]		5	4	80
Polychaetia (Sedentarida)		1	0	0
Cirripedia		3	0-1	0-33
Scaphopoda	MOLLUSCA	6	3	50
Gastropoda		79	7-25	9-32
Pelecypoda		53	23-29	43-55
TOTAL		154	42-67	27-43
MOLLUSCA ONLY		138	33-57	25-41

Playa Grande Formation [Catia Member] (Lower Pliocene)

Class or Order		Total number of species	Number of fossil species in Recent	Per cent of species in Recent
Anthozoa (Scleractinia)		1	1	100
Echinoidea		4	4	100
Gymnolaemata (Cheilostomata)		2	0	0
Polychaetia (Sedentarida)		3	0-1	0-33
Cirripedia		6	1	16
Scaphopoda	MOLLUSCA	2	1	50
Gastropoda		5	0-2	0-40
Pelecypoda		26	8-10	31-40
TOTAL		49	15-20	30-40
MOLLUSCA ONLY		33	9-13	27-40

[2] Includes one species, *Reteporellina marsupiata* (Smitt), described in Weisbord (1968b).

The foregoing tabulation confirms a number of basic premises. The first is that in a normal succession of Tertiary strata there are more Recent species in younger beds than in older beds. An example of this is shown by the pelecypods: in the Catia Member, or the lowest fossiliferous division of the Cabo Blanco Group, the number of species that have survived to Recent time amounts to 31-40 percent; in the Mare Formation it is 39-46 per cent; and in the Abisinia Formation, or highest division of the Cabo Blanco Group, it is 83-90 per cent. For the phylum Mollusca the ratios are 25-37 per cent in the Catia, 26-41 per cent in the Mare, and 80-90 per cent in the Abisinia. These Lyellian percentages, taking into consideration the local stratigraphy and comparison with the survival index of Mollusca elsewhere, suggest that the Playa Grande and Mare Formations were deposited early in the Pliocene, and the Abisinia Formation early in the Pleistocene. The stratigraphic position of the Guaiguaza Clay is not known, but as it contains 51 per cent of Recent Mollusca, it is faunally younger than the Mare Formation and faunally older than the Abisinia, and is, therefore, thought to have been deposited during late Pliocene time.

The tabulation also reveals that the longevity or survival capability of Cenozoic invertebrates differs greatly among the classes of organisms. In the Playa Grande Formation, which is the oldest of the fossiliferous formations comprising the Cabo Blanco Group, the survivorship of species to the Recent amounts to 25-37 per cent for the Mollusca, 25 per cent for the Cirripedia, or barnacles, 57 per cent for the cheilostomatous Bryozoa, 76 per cent for the Foraminiferida, 80 per cent for the Anthozoa, or stony corals, and 100 per cent for the Echinoidea. In the Mare Formation, which lies above the Maiquetía Member of the Playa Grande Formation, the survivorship of species to the Recent is 26-41 per cent for the mollusks, 20-40 per cent for the Cirripedia, 50 per cent for the Polychaetia, or tubiculous annelids, 60 per cent for the Bryozoa, 83 per cent for the Foraminiferida, and 100 per cent for the Anthozoa and Echinoidea. In the Abisinia Formation, or youngest division of the Cabo Blanco Group, the survivorship of species is 80-90 per cent for the Mollusca and 100 per cent for the Cirripedia, Polychaetia, Bryozoa, Anthozoa and Echinoidea. Except for the Mollusca in the Abisinia Formation there are too few species present in all of the other hierarchies in that formation, but were more numbers available it is nearly certain that their surviving species would be a little less than 100 per cent.

The Abisinia Formation comprises the higher terraces of the Cabo Blanco area and is judged to be Pleistocene in age by virtue of 1) the high content of Recent species, 2) its high stratigraphic position, and 3) its high elevation. An early rather than late Pleistocene age is indicated for the following reasons:

a—The formation occupies a high Quaternary terrace (61 meters) and is, therefore, older than the lower Quaternary terraces in the same area.

b—A few of the mollusks have not survived to the present. If the age were late Pleistocene nearly all of the fossils would also be living.

c—The ionium disequilibrium determination, by Dr. J. K. Osmond, of the gastropod *Mazatlania aciculata* (Lamarck) (see Weisbord, 1966a, pp. 11, 12) suggests an absolute age in excess of 300,000 years.

Through the study of the fossils of the Cabo Blanco Group of Venezuela and of the Recent invertebrates in the Caribbean Sea immediately adjacent, the writer is more than ever persuaded that the biologic chronometer devised by Sir Charles Lyell for dating the epochs of the Tertiary period by the per cent of Recent mollusks, is not only a good general chronometer but can be refined significantly by applying the percentage method to *all* classes of organisms. Thanks to Lyell, it has been shown that the Mollusca with their relatively short life span and great abundance are ideally suited for dating the past by using the living (Recent) fauna as a datum. However, all other invertebrates have *their* life span, and what can be done with the Mollusca surely can be done with the Foraminiferida, or corals, or barnacles, or Bryozoa, or fossils of any other group that are available in sufficient numbers. By establishing percentage standards throughout the world for all classes of Tertiary fossils, Lyell's chronometer can be adjusted to register shorter and shorter time divisions of the Tertiary. As an example of what needs to be done for all phyla in all epochs everywhere is what F. E. Eames and W. J. Clarke (1967) have done with the Mollusca of the Aquitanian Stage of southwest France. In their paper, which deals with the molluscan fauna of Mayer's type section of the Aquitanian, Eames and Clarke list 397 species, of which, according to a letter written to me by Eames, 27 to 31 (or seven to eight per cent) are found in the Recent fauna. These species, tied in as they are to a type section, represent one of the most complete faunal assemblages of a single phylum for the Aquitanian that is known, and it is to be hoped that many more such studies will be made of various phyla of the Tertiary period. It is safe to predict that the per cent of Recent species in the Aquitanian for other phyla will differ from the eight per cent for the Mollusca, but once a standard has been established for one biologic hierarchy, in this case the Mollusca, the (statistically valid) percentage for each of the other biologic hierarchies becomes a standard. Thus if the per cent of Recent species in the Aquitanian is X, let us say, for the Foraminiferida, or Y for the Anthozoa, each of these represent the same survival factor as eight per cent for the Mollusca. Once the Recent percentage is established for all groups of Tertiary invertebrates in all sedimentary units of established position, the percentage of one biologic entity should be as indicative of geologic time as any other biologic entity, and by comparing the percentage survival of one or more biologic entities with the same entities in a standard section, biogeologic time, as determined by fossils can be more finely adjusted to sidereal time, as determined by absolute dating with radioactive isotopes.

SYSTEMATIC DESCRIPTIONS
ECHINOIDEA

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The two Recent specimens collected on the beach are circular in outline, plumply discoidal, and flattened above and below. The apical system, with a diameter about two-fifths that of the test, is pentagonal, the angles of the pentagon pointing toward the interambulacra. The periproct is also pentagonal but the angles of that point toward the ambulacra. The periproctal plates are swollen, the outer ring asymmetriclly pentagonal, the inner ones irregularly polygonal. The genital plates are subtrapezoidal, the narrower end abutting the interambulacra; the genital pores are near the outer margin of the plates. The madreporite is slightly larger than the other genital plates. The ocular plates are triangular, the base abutting the ambulacra. The peristome, which is composed of imbricating plates, is circular, a little less than half the diameter of the test, bearing numerous small spatulate spines arranged in columns, with each succeeding spine loosely overlapping the lower part of the next.

The ambulacra are gently sinuous at the ambitus where they are a fourth the width of the interamulacra; the poriferous zones are a little narrower than the interporiferous zones; the pore-pairs are slightly oblique, and each pair is separated from the ones above and below by a fine groove; each pore is oval, and is separated from its twin by a wall as thick as the long diameter of the pore; on an amulacrum having a height of 13 mm; there are

44 pore-pairs on each side. The interporiferous zone consists of two columns of secondary tubercles, one on each border, and a column of staggered miliary tubercles between. The secondary spines on the ambulacra are so disposed on the dead specimen that each flattened spine covers each pore-pair. The interambulacra are nearly straight, and on specimen A607b there are eight tiers of plates. Each plate supports at its outer margin one raised perforated primary tubercle surrounded by a scrobicular ring of imperforate secondary and miliary tubercles; the area between the columns of primary tubercles is relatively broad and is covered at the ambitus by two ranges of small imperforate tubercles. The primary tubercles are provided with a smooth perforated mamelon and an evenly sloping boss; nonprimary tubercles are imperforate.

Primary spines are stout, circular in cross section, a little compressed above the annulus, somewhat inflated at the middle of the shaft, gently tapering distally, and blunted at the tip. The outer surface of the primary spines is ornamented by regular rounded nodules disposed in a regularly spaced longitudinal series around the shaft; on a spine 10 mm long and 2 mm in diameter there are 13 columns of nodules and 15 nodules on each column; near the tip the nodules coalesce into ribs which form a rosette around the blunt, segmented, and slightly protruding apex. Secondary spines are short, broad, and flattish, widening gradually to the subtruncate or slightly rounded distal end; these spines are engraved by fine longitudinal riblets separated by wider interspaces and crenated by numerous minute transverse striae. Tertiary spines of the ambulacral region are smaller and narrower than the secondaries but are similarly sculptured. The smallest miliary spines are pinlike.

The teeth of the lantern are vitreous and white and are divided on the outer surface into three broad longitudinal segments.

The color of the corona on the two dead Recent specimens is faded to a nondescript tan; the interambulacrum of specimen A612a is bleached to white; unbleached primary spines are deep purple; primary spine A608a which was collected apart from the test on the beach is light tan girdled by five chocolate-brown bands.

Measurements. — Specimen A607a: diameter 17 mm, height 9 mm. Specimen A607b: diameter 26 mm, height 16 mm; width of apical system 10 mm, of periproct 5.5 mm, of peristome 11 mm;

width of ambulacrum at ambitus 3.5 mm, of interambulacrum 12.5 mm. Specimen A612a: width of ambulacrum at ambitus 3.5 mm, of interambulacrum 12.5 mm; width of coronal plate 10.5 mm, height 13 mm. Specimen A608a: length of primary spine 24 mm, diameter 3.5 mm. Specimen D608a: length of primary spine 20 mm, diameter 3 mm. Specimen K599a: length of primary spine 21.5 mm, diameter 3.1 mm.

Localities. — Beach at Playa Grande Yatching Club, Distrito Federal. Recent. Two dead specimens and a few detached elements. Eastern edge of Playa Grande village at W-30. Abisinia Formation (Pleistocene). Numerous spines only. North flank of Punta Gorda anticline at W-23. Playa Grande Formation (Maiquetía Member). Pliocene. Two spines. Bluff 125 meters west of the intersection of the Playa Grande Yatching Club road and coast road. Playa Grande Formation (Catia Member). Pliocene. One spine.

Range and distribution. — This species has been reported from the Oligocene of Cuba (at Finca Santa Ana near Ciego de Avila, Camagüey) by Sánchez Roig (1949, p. 25) and from the Miocene (?) of Cuba near Santiago de Cuba by Jackson (1922, p. 23). In the present paper *Eucidaris tribuloides* is noted from the Pliocene, Pleistocene, and Recent of northern Venezuela, though its identification in the Pliocene and Pleistocene is based on spines only.

The living form of *Eucidaris tribuloides* is found in both the Western and Eastern Atlantic. Its depth range is from near shore to 37 fathoms but it has been dredged as deep as 250 fathoms. It lives on sandy bottoms and among rocks to which it may adhere firmly. Species of Algae and Bryozoa have been found in its intestine by Mortensen.

Western Atlantic localities are the following: Bermuda (North Rock, Coopers Island); Bahamas (Great Bahama Bank, Egg Island, Turks Island); North Carolina; South Carolina; Florida (Key West 37-50 fathoms, Key Largo 2-85 feet, Virginia Key, Tortugas 30-37 fathoms); between Cedar Keys, Florida and the delta of the Mississippi River (21-60 fathoms); Mexico (Cabo Catoche off Yucatan 21-26 fathoms, Vera Cruz); Panama (Colon 25-34 fathoms); Swan Island; Jamaica (Port Antonio and along the coast in rocky areas); Cuba (Habana 33-201 fathoms, Cabo Cruz 11.5-15 fathoms, south of Catalina Creek); Puerto Rico 6-14 fathoms (San

Juan at Condado Rocks and San Gerónimo, Guayanilla, Guanica, Ensenada, Mayagüez, Aguadilla); Albatross Bank between Jamaica and Haiti (23 fathoms); Virgin Islands (St. Thomas); St. Kitts (Flanegan Passage 250 fathoms); Antigua; Dominica (Massacre 2 ft.); St. Vincent; Barbados; Tobago; Colombia (Goajira Peninsula northeast of Rio Hacha, Sabanilla); Curaçao (Caracasbaai); Aruba (Punta Braboe 1 meter); Venezuela (Playa Grande, Cubagua Island); Brazil (Ilhas Fernando Noronha at Sambaquicha and Morro de Chapeo in shallow water, Bahía 4-20 fathoms, Ubatuba, Ilha Trinidade, Arquipélago Abrolhos, Rio de Janeiro, Baía Guanabara, Ilha São Sebastião).

Eastern Atlantic localities are the following: Azores; Cape Verde Islands (15-20 fathoms); Ascension Island; St. Helena; off Ghana; Gulf of Guinea (Annobón 18-30 meters, Ilha São Thomé, Ilha do Principe).

Observations. — Attached to a primary spine of the Venezuelan Recent specimen A607a is a sabelariid worm tentatively identified by David Kirtley as *Phalocrostemma.*

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The following description is based on four fragments, all from the same locality and all presumed to represent the same species: L600a is the ambital part of an ambulcarum; L600b is a slightly convex abactinal segment consisting of part of an ambulacrum joined to part of an interambulacrum; L600c is half an epiphysis; and L600a1 is a spine found adhering to the inner surface of L600a.

The original shape of the test can only be conjectured, but judging from the curvature of the ambitus and the appearance of the abactinl segment, it is inferred that the test was subhemispheric.

Interpolating from the measurements of L600b, the ambulacra are roughly four-fifths the width of the interambulacra on the abactinal aspect near the ambitus.

The tubercles on the test are of many different sizes, and all of them, however large or small, are mamilliform, imperforate, and noncrenulate. In addition to the true tubercles there are minute granules scattered throughout, and the surface of the test itself where unweathered is finely shagreened on the plates near the interradial suture. In their respective hierarchy of size the tubercles of the interambulacra seem to be larger than those of the ambulacra.

The pore-pairs are trigeminate, those of the same pair disposed a little obliquely. The pairs are arrayed in three vertical columns and are staggered horizontally across each plate. The pore-pair adjacent to the marginal primary tubercles of the interporiferous zone is located at the adoral (?) suture; the pore-pair at the opposite (interambulacral) margin is more or less in the middle of the plate; and the pore-pairs of the medial series, which are not superposed as regularly as those in the other two columns, are situated near the adapical suture of the plate. The wall separating each pore-pair is nodulous, and in the poriferous zone there are two or three small tubercles of slightly different diameter on each plate, with a single tubercle above or below a pore-pair, and so disposed that they fall in more or less regular columns.

On the convex ambital region of specimen L600a the interporiferous zone of the ambulacrum consists of two columns of primary tubercles on each side of the perradial suture. The tubercles in the column adjacent to the margin of the poriferous zone of each side are regularly disposed one above the other, and there is one primary tubercle to each plate; the inner columns of primary tubercles are not quite as regularly aligned as the outer, and here and there a primary tubercle is missing on a plate or two. Farther in toward the perradial suture there is a staggered column of secondary tubercles, and here too they are missing on an occasional plate or rarely on two consecutive plates. Miliary tubercles are scattered between the secondaries and primaries and are more abundant on the plates lacking the latter two.

On specimen L600b which is thought to represent the abactinal aspect, the tubercles of the poriferous zone are smaller than in the ambital region of specimen L600a. On both specimens there is a single regular column of primary tubercles adjoining the poriferous zone, with one primary tubercle to each plate; however, inward from this column, and unlike the tuberculation at the ambitus of specimen L600a, primarly tubercles are rare on the interporiferous zone, although secondary, and especially tertiary and miliary tubercles are numerous and haphazardly distributed on the plates near the perradial suture.

Part of an interambulacrum pertaining to the abactinal (?) aspect of the test is preserved on specimen L600b, and on this fragment the interambulacrum is a little wider than the ambulacrum. Immediately adjacent to the poriferous zone there is a somewhat irregular column of secondary and tertiary tubercles, rarely with one secondary tubercle or generally two tertiary tubercles to a plate; the next column in consists of primary tubercles with generally one to a plate and in regular succession except locally where there are two primaries of slightly different diameter side by side; farther in from this column of primaries, the plate is covered haphazardly by tertiary and miliary tubercles (about 22 per plate) and still smaller granules; and, at the interradial suture the plates are devoid of mamilliform tubercles though the surface is finely shagreened. Around the tubercles of the two columns near the poriferous zone there is a scrobicular ring.

The single spine (L600a1) is broken at the apex, and as the sides of the shaft are nearly parallel there is virtually no taper. The solid shaft is sculptured by 24 longtiudinal riblets crossed by numerous microscopic transverse striae, and the riblets thicken at the annulus to form a milled ring. The base of the spine is smooth, and there is a narrow gently constricted area between the milled ring and the top of the base.

The half-epiphysis (L600c) is relatively thin and united to the other half by a suture. The complete epiphysis is "U" shaped, with a narrow tapering process extending in nearly a right angle from the ends of the connecting arch. The arch is gently convex-concave and is deeply furrowed on one face, the furrow widening toward the suture; on the obverse face the counterpart of the furrow is a prominent ridge rounded at the crest. The glenoid cavity is triangular. The crest of the arch is partly broken away.

Measurements. — Specimen L600a (ambulacrum): height of fragment 13.2 mm, width 20 mm; width of interporiferous zone 12 mm, of poriferous zones 7 mm. Specimen L600b (part of ambulacrum and interambulacrum connected): height of fragment 24.5 mm, maximum width 20 mm; width of poriferous zone 3.7 mm (×2=7.4 mm). Specimen L600a1 (spine): length 5.1 mm, width of shaft above neck 1.2 mm, diameter of acetabulum 0.93 mm, diameter of cavity 0.57 mm. Specimen L600c (half-epiphysis): height 10 mm, breadth of arch (broken near suture) 7.5 mm (×2=15 mm), width of arch 3.6 mm.

Locality. — South side of Playa Grande road about 220 meters west of W-15. Four fragments. Playa Grande Formation (Catia Member).

Comparisons. — According to Mortensen (1943) and Mayr (1954) the three Recent allopatric species of *Tripneustes* are the Atlantic *T. ventricosus* (Lamarck), the West American *T. depressus* A. Agassiz, and the Pacific *T. gratilla* (Linnaeus). Comparing the width of the poriferous and interporiferous zones, the Venezuelan fossil is closest to *T. ventricosus,* but in the disposition of the tubercles it resembles the West American *T. depressus* as on that species they are less regularly arranged than on *T. ventricosus.* In the character of the pore-pairs on the abactinal aspect, the Venezuelan Pliocene fossil is much like the upper Miocene *T. tobleri* Jeannet, also from Venezuela; however, on the ambitus the tuberculation of the two species is dissimilar, and the poriferous zone of Jeannet's *T. tobleri* is nearly twice as wide as the interporiferous zone whereas on the Playa Grande form it is only three-fifths as wide. On the Pliocene *Tripneustes californicus* (Kew) from Carrizo Creek, California, the interambulacral area is twice as wide as the ambulacral area and the poriferous zone equal in width to the interporiferous zone, whereas on the Pliocene Venezuelan form under discussion the interambulacra are only slightly wider than the ambulacra, and the poriferous zone only three-fifths the width of the interporiferous zone.

Although the fossil here described can not be identified definitively without more material, it seems to be the same as the polytypic *Tripneustes ventricosus* (Lamarck) and its alias *T. esculentus* (Leske). *T. ventricosus* is itself a variable species, and one example of this can be seen in the epiphysis of *T. esculentus* (Leske) from the Bahamas illustrated by Bell (1879, pl. 49, fig. 2a) and of that from Florida illustrated by Jackson (1912, p. 184, fig. 213A). The epiphysis of the Venezuelan form is nearly identical with Bell's but only remotely similar to Jackson's which lacks the pronounced oblique furrow in the arch.

Range and distribution. — Fragments of a *Tripneustes* from the Ponce Limestone (lower Miocene ?) of Puerto Rico seem fairly similar to the living *Tripneustes ventricosus* (Lamarck), according to Gordon (1963), and if the determination is confirmed the range of *T. ventricosus* will be extended back to the middle Tertiary. Should the Venezuelan form described above be authentically identified as *T. ventricosus*, this will be the first report of its occurrence in the Pliocene of northern South America.

Aside from the foregoing possible fossil occurrences, *T. ventricosus* is reported only as a living species inhabiting subtropical to tropical waters of the Western Atlantic from Bermuda to mid-Brazil, and of the Eastern Atlantic along the coast of West Africa and outlying islands. It is found generally in the littoral to depths of 14 fathoms between the 30-degree parallels, though Mortensen (1907, p. 193) recorded a maximum depth of 450 fathoms.

Western Atlantic and Caribbean localities where *T. ventricosus* and the synonymous *T. esculentus* have been reported are the following: Bermuda (North Rock); Bahamas (Great Bahama Bank, New Providence, Eleuthera Island, Harbor Island, Spanish Wells, Turks Island); Florida (Tortugas, Key West, Virginia Key, Key Largo 2-35 ft., Boca Raton); Mexico (Cozumel Island); Yucatan Bank (14 fathoms); Cuba (Puerto Padre, Cabo Cruz 11.5-13 fathoms); Jamaica (Port Henderson, Montego Bay); Haiti; Puerto Rico (Arroyo, Ponce, Guanica, Aguadilla); Virgin Islands (St. John, St. Thomas, St. Croix); Anguilla; Antiqua; Dominica (Massacre, Rodney's Rock, Woodford Hill Bay 2-60 ft.); Martinique; Barbados; Grenada; Tobago; Trinidad; French Guiana (Cayenne); Surinam; Venezuela (Cumaná, La Guaira); Colombia (Sabanilla); Aruba (Boekoeti 0.5 meters); Curaçao (Caracasbaai, Spaansche Water, Boca Grandi, Savonet); Bonaire (Kralendijk 1 meter, Pasanggrahan 5 meters, Boca Washikomba, Lagoen); Klein Bonaire (east coast); Brazil (Ilha Fernando Noronha, Ilha Trindade, Rio Formosa, Baía Guanabara, Ilha São Sebastião).

Eastern Atlantic localities are along the west coast of Africa from the Gulf of Guinea (Annobón, Islet La Piramide, Ilha São Thomé) to Swakopmund (southwest Africa).

Remarks. — A list of the diatoms obtained from the stomachs of *T. esculentus* in Barbados is given by Robinson (1935).

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The Recent specimens are inflated and oval to oblong-elliptical in outline, with the long axis passing through genital 3 and ocular I. The test is thin, the ambitus broadly rounded, the adoral face gently concave, and the aboral face gently convex. The ambulacra widen regularly from the apex to the ambitus where they are two-thirds the width of the ambulacra; both the ambulacra and interambulacra decrease in width from the ambitus to the peristome where the width of each is then about the same. There are generally six rarely five, and often seven pore-pairs in the arcs composing the poriferous areas; the pores are large, distant, and separated by a wall with a thickness nearly equal to the diameter of the pores.

There are two columns of staggered primary tubercles on the ambulacra and interambulacra, with a column of small tubercles on the side of each; a single medial column of staggered secondary tubercles is present between the primaries, and miliary tubercles are interspersed between the secondaries; also a row of miliaries separates each primary tubercle of the interambulacra.

The apical system with its large, somewhat swollen madreporite, is typical of the species. On specimen A606f, ocular V is insert and all of the others exsert. The genital pores are large and circular. The periproct is oval, slightly eccentric. The peristome is oval-decagonal with gently indented gill slits. The perignathic girdle is sturdy, bearing a broad, paddle-shaped auricle extending about halfway into the body cavity. The teeth of the lantern are white, vitreous, and marked by several longitudinal grooves.

The primary tubercles are imperforate, pale olive in color. The primary spines are stout, fairly straight, and moderately attenuated; the shaft is sculptured by closely spaced longitudinal striations which are minutely crenulated by numerous transverse lineations; the tip of the shaft is deep violet, the rest black or gray-black; the milled ring of the collar is marked by strong, evenly spaced riblets which are thickened extensions of the longitudinal striations, and there are about 50 such riblets on a spine 17 mm in length; the base is smooth and whitish. The minor spines on the peristome are fine, pinlike, white.

The test is blackish brown above, with the ambulacra darker than the interambulacra, and chocolate brown below.

Measurements. — Specimen A606a: length 45 mm, width 39 mm, height 21 mm; periproct 7.5 mm x 6 mm; peristome 19 mm x 17 mm. Specimen A606b: length 45 mm, with 34 mm, height 23 mm; periproct 7 mm x 5 mm; peristome 21 mm x 18 mm. Specimen A606c: lantern, length 25 mm, diameter at apex 16mm. Specimen A606d: spine, length (broken at tip) 18 mm, diameter at neck 2.5 mm. Specimen A606e: pyramid and tooth of lantern, length 19.5 mm, width at apex 8 mm.

Locality. — Beach at Playa Grande Yachting Club, Distrito Federal. Recent. Four specimens.

Range and distribution. — The range of *Echinometra lucunter* (Linnaeus) is stated to be middle Tertiary to Recent. A single specimen provisionally identified as *E. lucunter* by Gordon (1963) occurs in the San Sebastian Formation (early Miocene ?) of Puerto Rico. In the late Miocene *E. lucunter* is reported from Bowden, Jamaica; in the Pliocene, from the Caloosahatchee Formation of Florida; and in the Pleistocene of Cuba (Cantera Toledo, Marianao; hospital "Nona Machado", Matanzas; Santiago de Cuba) and of Angola. The living *E. lucunter* inhabits the Western Atlantic from South Carolina, U.S.A. south to Argentina, and in the Eastern Atlantic from the Cape Verde Islands south to Angola on the west coast of Africa. The species clings to surf-beaten rocks, and prefers reef flats covered by a few inches of water at low tide. It is found generally at depths from the littoral to 14 fathoms, though A. Agassiz (1881a, p. 224), in the Challenger Report, noted it from a depth of 250 fathoms. The form occupies depressions in limestones and other hard rocks such as granites, and is, therefore, thought to be a rock borer. This, however, has been questioned by Boone (1933, p. 139) who examined more than a hundred museum specimens and noted that not one of them possessed the worn spines that might be expected were they used in excavating the rock.

Western Atlantic and Caribbean localities are the following: South Carolina; Florida (Tortugas, Key West, Key Largo 2-15 ft.); Bahamas (Great Bahama Bank, Little Cat Island, Eleuthera Island, Harbor Island); Bermuda (North Rock); Mexico (Blanquilla Reef, Vera Cruz, Yucatan); Panama (Colon); Isla de Providencia; Cuba (Bahía Honda, Habana, Matanzas Bay, Cayo La Vela); Jamaica (Port Henderson); Haiti; Puerto Rico (San Juan, Fajardo, Arroyo, Isla Caja de Muertos, Ponce, Talleboa, Guayanilla, Montalvo Bay, Guanica, Ensenada, Parguera, Boquerón, Aguadilla); Virgin Islands (St. Croix, St. Thomas, St. John); Anguilla; Barbuda; Dominica (Massacre, NW of Grande Savane, Woodford Hill Bay 2-8 ft.); St. Vincent; Barbados (east and west coasts); Tobago; Curaçao (Caracasbaai, Spaansche Baai); Bonaire (Kralendijk, Pasanggrahan, Boka Washikomba, Plaja Grandi); Klein Bonaire (south coast); Aruba (Punta Braboe, Lagoen Boekoeti); Venezuela (Puerto Cabello, Playa Grande, La Guaira, Cumaná, Isla Margarita, Isla Cubagua); Colombia (Sabanilla); Brazil (Ilha Queimada Grande, Fernando Noronha, Natal ?, Pernambuco, Bahía, Pôrto Seguro, Victoria, Guarapary, Campos, Ilhas Maricás, Arquipélago dos Abrolhos, Ilha Trinidade, Rio de Janeiro, Baía Guanabara, Ilha São Sebastião, Ilha dos Acatrazes, Ubatuba, Caraguatatuba, Santos, Ilha das Palmas, Itanhaem, Cananéia, Florianópolos); Argentina (Ensenada).

Eastern Atlantic and west African localities are the following: Cape Verde Islands (Praia, São Tiago, São Vicente 9 meters); Dakar; Iles de Los; coast of Liberia; Gulf of Guinea (São Thomé, Fernando Pó, Islotes de Enrique, Annobón, Islet La Piramide, Rolas); Gold Coast (Takoradi); Ascension Island (Clarence Bay); St. Helena (St. James); coast of Angola (Elephant Bay).

Echinometra viridis A. Agassiz Pl. 51, figs. 6-12

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1863. *Echinometra plana* A. Agassiz, Mus. Comp. Zool., Bull., vol. 1, No. 2, p. 22. [*Fide* A. Agassiz, 1872, p. 117 and Mortensen, 1943, p. 368.]

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1914. *Echinometra viridis* A. Agassiz, Lambert and Thiéry, Essai de Nomenclature raisonnée des Échinides, p. 257.
1918. *Echinometra viridis* A. Agassiz, H. L. Clark, Lab. Nat. Hist. State Univ. Iowa, Bull., vol. 7, No. 5, p. 35.
1919. *Echinometra viridis* A. Agassiz, Nutting, Lab. Nat. Hist. State Univ. Iowa, Bull., vol. 8, No. 3, p. 83.
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1965. *Echinometra viridis* A. Agassiz, Kier and Grant, Smithsonian Misc. Coll., vol. 149, No. 6, pp. 1,5,6-7,9,12,20-21,59,60, pl. 10, fig. 6.

The two Recent specimens referred to *Echinometra viridis* A. Agassiz are bleached white and lack the apex, peristome, and spines. Both specimens are oval-orbicular, with the long axis passing through interambulacrum 3 and ambulacrum I. The test is thin and slightly appressed, the ambitus rounded, the adoral face a little concave, the aboral face hardly convex. The ambulacra, interambulacra, and tubercles are much the same as in *Echinometra lucunter* (Linnaeus). The pore-pairs are arranged generally in arcs of five, but in places there are four, and rarely there are six. The apical system is suboval, the peristome subcircular. The primary tubercles are pale green, the small ones around the periproct dark green.

Measurements. — Specimen A611a: length 18 mm, width 16.5 mm, height, 7.5 mm. Specimen A611b: length 17.5 mm, width 15 mm, height 8 mm.

Locality. — Beach at Playa Grande Yachting Club, Distrito Federal. Recent. Two specimens.

Remarks. — The specimens are assigned to *E. viridis* rather than *E. lucunter* because the pore-pairs are arranged generally in arcs of five, occasionally four, and rarely six, whereas the pore-pairs of *E. lucunter* are disposed generally in arcs of six, occasionally seven, and rarely five. My specimens of *E. lucunter* are considerably larger than the two specimens of *E. viridis,* and inasmuch as they are all from the same beach one might consider the fewer pore-pairs to be correlated with smaller size. However, H. L. Clark (1933, p. 85) stated that "in *lucunter,* even when small, the abactinal arcs have six pore-pairs", and this criterion for differentiation has been accepted by a number of authors.

Range and distribution.—*Echinometra viridis* A. Agassiz is a shallow-water species living in the Gulf of Mexico and the Caribbean Sea west of longitude 60 degrees. It is often found on reef flats, and occurs from near shore to a depth of seven fathoms. Following are the localities reported: Florida (Key Largo 4-35 ft., Key Biscayne, Tortugas, Apalachee Bay); Cuba; Jamaica (Port Henderson); Haiti; Puerto Rico (Ponce); Colon ["Aspinwall"]; Virgin Islands (St. Thomas, St. John); St. Martin; Curaçao (Caracasbaai, Spaansche Water, St. Kruis Baai, Boca Grandi, Savonet); Bonaire (Kralendijk, Pasanggrahan); Venezuela (Puerto Cabello, Playa Grande, Isla Tortuga); Barbados.

Encope emarginata (Leske) Pl. 52, figs. 1-4

1754. Grand Oursin de mer étoile, Klein, Ordre naturel des Oursina, pp. 231, 232, pl. 25, fig. A; pl. 26, fig. B. [*Fide* L. Agassiz, 1841, p. 47.]

1758. [*Encope emarginata*] Seba, Locupletissimi Rerum Naturalium Thesauri . . . , vol. 3, pl. 15, figs. 5,6 [*Fide* A. Agassiz, 1872, p. 126.]

1774. *Echinoglycus frondosus* van Phelsum, Zee-Egelen, p. 34. [*Fide* Gray, 1851, p. 34.]

1778. *Echinodiscus emarginatus* Leske, Klein's Naturalis dispositio Echinodermatum, p. 136, pl. 50, figs. 5,6.

1778. *Echinodiscus quaterperforatus* Leske, Klein's Naturalis dispositio Echinodermatum, p. 140. [*Fide* A. Agassiz, 1872, p. 126.]

1791. *Echinus emarginatus* (Leske), Gmelin, Systema Naturae, ed. 13, p. 3189.

1791. *Echinus tetraporus* Gmelin, Systema Naturae, ed. 13, p. 3189. [*Fide* A. Agassiz, 1872, p. 126.]

1816. *Scutella emarginata* (Leske), Lamarck, Hist. Nat. Anim. sans Vert., vol. 3, p. 9.

1816. *Scutella quadrifora* Lamarck, Hist. Nat. Anim. sans Vert., vol. 3, p. 9. [*Fide* A. Agassiz, 1872, p. 126.]

1827. *Scutella quadrifora* Lamarck, Blainville, Dictionnaire des Sciences Naturelles, vol. 48, p. 224.

1827. *Scutella emarginata* (Leske), Eudes-Deslongchamps, Encyclopédie Méthodique, Zoophytes, Livr. 98, p. 675.

1829. *Scutella quinqueloba* Eschscholtz, Zoologische Atlas, pl. 20, fig. 1. [*Fide* A. Agassiz, 1872, p. 216.]

1830. *Scutella emarginata* (Leske), Blainvillle, Dictionnare des Sciences Naturelles, vol. 60, p. 201. Also *S. tetrapora,* p. 200.

1834. *Scutella emarginata* (Leske), Blainville, Manuel d'Actinologie ou de Zoophytologie, p. 219, pl. 18, fig. 4.

1835. *Scutella emarginata* (Leske), L. Agassiz, Soc. Sci. Nat. Neuchâtel, Mém., vol. 1, p. 188.

1837. *Scutella emarginata* (Leske), Desmoulins, Études sur les Échinides, vol. 3, pp. 68,70.

1837. *Scutella cassidulina* Desmoulins, Études sur les Échinides, vol. 3, p. 78. [*Fide* Mortensen, 1948, p. 438.]

1840. *Scutella emarginata* (Leske), Lamarck, Hist. Nat. Anim. sans Vert., vol. 3, ed. 2, p. 279, Also *S. quadrifora,* p. 280.

1841. *Mellita lobata* L. Agassiz, Monographies d'Échinodermes, Mon. 2, p. 44, pl. 4a, fig. 13. [*Fide* A. Agassiz, 1872, p. 127.]

1841. *Moulinia cassidulina* L. Agassiz, Monographies d'Échinodermes, Mon. 2, pp. 139,140, pl. 22, figs. 1-6. [*Fide* A. Agassiz, 1872, p. 126.]

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1841. *Encope oblonga* L. Agassiz, Monographies d'Échinodermes, Mon. 2, pp. 53,54, pl. 9. [*Fide* Gray, 1851, p. 37.]

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The identification of this species is based on a number of fragments and one nearly complete specimen which has been so compressed that it is much thinner than normal and slightly distorted. The outline of this specimen (Pl. 52, fig. 1) as reconstructed is suborbicular, a little wider than long, and truncated at the posterior margin in such fashion that the margin is concave downward. Other fragments indicate that the test is moderately thick, that the upper surface is gently convex and higher in front than behind, that the lower surface is flat, and that the margin is thin but not sharp and is more or less indented at the lunules when those are closed.

The apical system is pentagonally stellate, subcentral, situated a few millimeters nearer the anterior margin. Details of the system cannot be made out but it is inferred that there are five genital pores and five smaller ocular pores.

The petals are lanceolate, moderately broad, and open at the extremities which are near, but do not touch, the lunules. The three anterior petals seem to be nearly the same in length, and are shorter than the paired posterior ambulacral ones. The latter extend around the interambulacral lunule so that at their extremities about half of the lunule is enclosed. The poriferous zones are relatively wide and curved together but not quite meeting at their distal ends. The pore zone of the anterior ambulacra is a little wider than the interporiferous zone. On ambulacrum IV of specimen 1596a there are about 80 ambulacral plates over a length of 24.4 mm.

There are six lunules, all of them swollen around the border on the aboral surface; on the adoral surface, however, the borders are hardly raised and merge with the flattened test. The posterior interambulacral lunule is by far the largest; the posterior ambulacral pair is smaller than that, the anterior ambulacral pair still smaller, and the anterior ambulacral lunule the smallest. On specimen 1596a all of the lunules are probably closed, and only the anterior one is ovate, the five others elongate-elliptical. On other fragments the ambulacral lunules may be ovate or oval, and on one specimen (J596a) the anterior lunule seems not closed to judge from the presence of tubercles on the unbroken inner rim at the marginal tip.

The peristome is small, directly below the apex, and vaguely pentagonal in outline. The periproct is situated on the infra-anterior wall of the posterior lunule, its size and configuration obscured by adhering sandstone. The food grooves diverge from near the peristome, the main ones curving nearly together around the lunules, a few lesser ones bifurcating away from the primaries near the margin, and some still smaller ones branching off laterally into the area below the lunule.

Internally the test is made up of numerous supporting pillars imparting the porous structure typical of the genus. Specimen I596a and one other fragment from the same locality are composed of a dense tan limestone; all of the other fragments, wherever collected, are white and chalky.

Measurements. — Specimen I596a: Length 94 mm, estimated width 103 mm; ambulacra IV and II, length about 24.4 mm max., width about 12.8 mm; ambulacra V and I, length about 33 mm, max. width about 13 mm; posterior lunule 23 mm × 11 mm; paired posterior lunules 19.5 mm × 8.5 mm; anterior lunule (closed?) 9 mm × 6 mm; diameter of peristome 3 mm. Specimen J596a (fragment), 47 mm × 35 mm; thickness of test below anterior ? lunule 11 mm; anterior lunule (inferred to be slightly open at the margin) 20 mm × 7 mm.

Localities. — Hillside above west bank of Quebrada Mare Abajo at W-13; eight large and numerous small fragments — Lower Mare Formation. Small stream 100 meters west of Quebrada Mare Abajo in same bed as above; six fragments — Lower Mare Formation. Hillside above west bank of Quebrada Mare Abajo near W-14; one large fragment — Mare Formation. In stream 250 meters south-southwest of mouth of Quebrada Las Pailas; five fragments — Mare Formation.

Remarks. — The Venezuelan fossil readily fits within the range of variation of *Encope emarginata* (Leske), and is strikingly similar to certain Recent forms with elliptical lunules found in Brazil (Tommasi, 1957 [1959a], 1966b) and in Argentina (Bernasconi, 1953).

Range and distribution. — Upper Miocene to Recent. The upper Miocene or lower Pliocene form is reported from the Duplin and Waccamaw Formations of North Carolina and Duplin and Waccamaw Formations of South Carolina, and the same from Florida. The Pliocene form occurs in the Mare Formation of Venezuela (this report). The Pleistocene form is recorded from South Carolina. And the living *Encope emarginata* extends from South Carolina, U.S.A., to Argentina in the Western Atlantic at depths ranging from the littoral to 70 fathoms. The localities are the following: North Carolina; South Carolina; Florida; Yucatan; Nicaragua; Martinique; Colombia (Cartagena, Sabanilla); Venezuela (Cumaná); French Guiana (42 meters); Trinidad; Brazil (Ilhas Santa Anna, coast of Maranhão, Pernambuco, María Farinha, Bahía, Ilha do Francês, Rio de Janeiro, Ilha das Cabras, Baía Guanabara, Cabo Frio, Angra dos Reis, Ilha São Sebastião, São Vicente, Cananeía, Ensenada de Ubatuba, São Francisco, Ibicui, Florianopolis); Uruguay; Argentina (Cabo San Antonio).

Species of *Encope* in the eastern Americas

The fossil and Recent species of *Encope* that have been reported from the Atlantic or Caribbean side of the Americas are the following:

annectans Jackson, 1917, pp. 491-494, pl. 65, figs. 1,2; pl. 66, fig. 1. Gatun Formation, Panama Canal Zone. Middle-upper Miocene.

sp. *A* Jeannet, 1928, pp. 28-30, pl. 3, fig. 9; text-fig. 9. Capadare Limestone, Venezuela. Middle Miocene.

sp. *B* Jeannet, 1928, p. 30. Capadare Limestone, Venezuela. Middle Miocene.

sp. *C* Jeannet, 1928, pp. 30,31, pl. 3, fig. 10. Capadare Limestone, Venezuela. Middle Miocene.

cassidulina (Desmoulins), 1837, p. 78 [As *Scutella, Moulinsia, Desmoulinaster.*] Martinique. Recent. [= *E. emarginata* (Leske).]

ciae de Cortázar, 1880, pp. 227-232, pls. G-H. Canteras de Calabazar, near Habana, Cuba. Upper Miocene.

sp. *D* Jeannet, 1928, p. 31, pl. 3, fig. 11. Ojo de Agua Formation, Venezuela. Upper Miocene.

desmoulinsii (Duchassaing), 1850, p. 1. [As *Scutella.*] Guadeoupe (Duchassaing 1855, p. 756) and Trinidad (Guppy 1867, p. 165). Recent. [= *E. emarginata* (Leske).]

sp. *E* Jeannet, 1928, pp. 31,32, pl. 3, fig. 12. Capadare Limestone and Ojo de Formation, Venezuela. Middle and upper Miocene.

emarginata (Leske), 1778, p. 200, pl. 50, figs. 5,6. Upper Miocene — Recent.

falconensis Cooke, 1961, pp. 19,20, pl. 8, figs. 2-4. [As *E. Melitella).*] Chiguaje Formation and Gregorio Formation, Venezuela. Upper Miocene and Pliocene.

gatunensis Toula, 1911, pp. 489-491, pl. 30, fig. 2. Gatun Formation, Panama Canal Zone. Middle-upper Miocene.

ghiesbrechtii Belval, 1863, p. 419. [= *E. emarginata* (Leske), *fide* Mortensen, 1948, p. 438.]

kugleri Jeannet, 1928, pp. 23-26, pl. 3, figs. 5,6, text-figs. 4-6. Capadare Limestone and Chiguaje Formation, Venezuela. Middle and upper Miocene.

latus Jackson, 1922, p. 51, pl. 7, fig. 7; text-fig. 5. Arecibo Formation, Puerto Rico. Miocene.

lobata (L. Agassiz), 1841, pl. 4a, fig. 13 [= *E. emarginata* Leske).]

macrophora (Ravenel), 1842, p. 334, text-fig. South Carolina, upper Miocene or lower Pliocene. Caloosahatchee Formation, Florida. Pliocene.

megatrema Jackson, 1917, pp. 496-498, pl. 68, fig. 1; text-fig. 3. Gatun Formation, Panama Canal Zone. Middle-upper Miocene.

michelini L. Agassiz, 1841, p. 58, pl. 6a, figs. 9-10. Middle-upper Miocene, Venezuela. Pliocene — Venezuela, Florida, South Carolina, North Carolina. Pleistocene, Florida. Recent, Gulf of Mexico from off Alabama to Yucatan.

michelini imperforata Kier, 1963, pp. 33-36, pl. 5, fig. 1; pl. 6, figs. 3,4; text-figs. 25-30, table 2. Florida. Tamiami and Caloosahatchee Formations. Upper Miocene and lower Pliocene.

oblonga L. Agassiz, 1841, pp. 53,54. [= *E. emarginata* (Leske), *fide* Gray, 1851, p. 37.] Rio de Janeiro. Recent.

platytata Jackson, 1917, pp. 494,495, pl. 67, figs. 1,2; text-fig. 2. [= ? *E. michelini* L. Agassiz, *fide* Cooke, 1961, p. 17.]

quadrifora (Lamarck), 1816, p. 9. [= *E. emarginata* (Leske).]

quaterperforatus (Leske), 1778, p. 140. [= *E. emarginata* (Leske).]

quinqueloba (Eschscholtz, 1829, pl. 20, fig. 1. [= *E. emarginata* (Leske), *fide* Gray, 1851, p. 37.] Florida to Brazil. Recent.

raveneli (Conrad), 1865a, p. 74, as *Macrophora*. [= *E. emarginata* (Ravenel), *fide* Clark and Twitchell, 1915, pp. 206, 207.]

secoensis Cooke, 1961, pp. 18,19, pl. 8, fig. 1; pl. 9, figs. 1,2. Chiguaje and Cadore Formations, Venezuela. Upper Miocene. San Gregorio Formation, Venezuela. Pliocene.

subclausa L. Agassiz, 1841, pp. 56,57, pl. 5. [= *E. emarginata* (Leske), *fide* Gray, 1851, p. 37.] Brazil and eastern Mexico (Duchassaing, 1855, p. 759). Recent.

tamiamiensis Mansfield, 1932, pp. 48,49, pl. 17, fig. 8. Tamiami and Caloosahatchee Formations, Florida. Upper Miocene and Pliocene. [As *Encope macrophora tamiamiensis*.]

tatetlaensis Böse, 1906, pp. 71,72; pl. 6, figs. 1,2; pl. 7, figs. 1,2. Barranca de Santa María Tatetla, Estado Veracruz, México. Lower Pliocene.

tetrapora (Gmelin), 1791, p. 3190. [= *E. emarginata* Leske), *fide* H. L. Clark *in* Grant and Hertlein, 1938, p. 99.]

valenciennesii L. Agassiz, 1841, p. 54, pls. 7,8. [=*E. emarginata* (Leske), *fide* Bernasconi 1953, p. 28, pl. 32, fig. 3.] Martinique and Rio de Janeiro. Recent.

vonderschmitti Jeannet, 1928, pp. 26-28, pl. 3, fig. 7; text-figs. 7,8. Ojo de Agua Beds, Venezuela, Middle Miocene.

wiedenmayeri Jeannet, 1928, pp. 20-23, pl. 3, figs. 1-4; text-figs. 3. [= *E. michelini* L. Agassiz, *fide* Cooke, 1961, p. 17.] Ojo de Agua Beds, Venezuela. Middle Miocene.

Species of *Mellita* in the eastern Americas

aclinensis Kier, 1963, pp. 41-44, pl. 15, figs. 1-3; text-figs. 36-41; tables 3,4. Tamiami Formation, Florida. Upper Miocene.

ampla Ravenel, 1848, p. 4. [= *M. quinquiesperforata* (Leske), *fide* Mortensen, 1948, p. 423.]

caroliniana (Ravenel), 1842, p. 333, text-fig. [= *Leodia caroliniana* (Ravenel).]

hexapora (Gmelin), 1791, p. 3189. [= *Leodia sexiesperforata* (Leske).]

lata H. L. Clark, 1940, pp. 437-439, pl. 60, fig. 1; pl. 61, fig. 1; pl. 62, figs. 1,2. Mexico (Vera Cruz) and Costa Rica (near Limón). Recent.

latiambulacra H. L. Clark, 1940, pp. 439-442, pl. 62, figs. 3-6. Recent. Venezuela (Cumaná); Trinidad (Manzanillo beach and Mayaro Bay); Barbados (100 fathoms); Brazil (Bahía, Itabapoana, Ilha Nova, Cantos, Cananéia, Santos, Itajai).

nummularia L. Agassiz and Desor, 1847, p. 139. [= *M. quinquiesperforata* (Leske), *fide* Mortensen, 1948, p. 423.]

pentapora (Gmelin), 1791, p. 3189. [= *M. quinquiesperforata* (Leske).]

platensis Bernasconi, 1941, pp. 106-108; 1953, pp. 31,32, pl. 16, figs. 1-7; pl. 17, figs. 1-7. [= *Leodia sexiesperforata* (Leske), *fide* Bernasconi, 1966, p. 25.] Recent. Argentina (Estuary of Rio de La Plata, 9 fathoms).

quinquefora (Lamarck), 1816, pp. 3,9. [= *M. quinquiesperforata* (Leske).]

quinquefora ampla Holmes, 1858, p. 3, pl. 1, figs. 6-6b. [= *M. quinquiesperforata* (Leske).]

quinquiesperforata (Leske), 1778, p. 197, pl. 21, figs. C-D. Pleistocene to Recent. Pleistocene: Pimlico Formation, South Carolina, U.S.A. Recent: Massachusetts (Nantucket); Georgia; South Carolina; Florida; Texas; Bermuda; Mexico (Vera Cruz; Nicaragua; Puerto Rico; Venezuela (Isla de Margarita and Cumaná); Surinam; Trinidad; Barbados; Brazil (coast of Maranhão, Bahía, Ubatuba, Ilha das Palmas, Caraguatatuba, Espirito Santo, Itanhaem, Guarujá, São Sebastião, Santos, Cananéia, Itajai).

quinquiesperforata tenuis H. L. Clark, 1940, p. 442, pl. 60, fig. 2; pl. 61, fig. 2. Recent. West Florida (Sanibel Island, Tarpon Springs, Charlotte Harbor).

sexforis (Lamarck), 1816, p. 9. [= *Leodia sexiesperforata* (Leske).]

similis (L. Agassiz), 1841, p. 43, pl. 4, figs. 1-3. [= *Leodia sexiesperforata* (Leske).]

sp. Jackson, 1922, p. 52, text-fig. 6. Mayo village quarry, Trinidad. Miocene.

sp. Sánchez Roig, 1926, pp. 64-65. Cuba. Miocene.

sp. Weber and Raup, 1968, p. 41. Melbourne, Florida. Pleistocene.

testudinata Klein, 1734, p. 25, pl. 21, figs. C-D. [= *M. quin*quiesperforata (Leske).]

testudinea Gray 1855b, p. 22. [= *? M. quinquiesperforata* (Leske), *fide* Mortensen, 1948, p. 423.] Recent. South Carolina, Florida, Texas.

texana Meek, 1864, p. 2. [= *M. pentapora* (Gmelin), *fide* Clark and Twitchell, 1915, p. 225, = *? M. quinquiesperforata* (Leske).] Pleistocene ?. Texas.

Species of *Leodia* in the eastern Americas

caroliniana (Ravenel), 1841, p. 33, fig. Upper Miocene to Pleistocene ? Upper Miocene: Yorktown Formation, Virginia. Upper Miocene — Pliocene: Duplin and Waccamaw Formations, South Carolina. Pleistocene: Miami Oolite ?, Florida.

sexiesperforata (Leske), 1778, p. 199, pl. 50, figs. 3,4. Pleistocene to Recent. Pleistocene: Pimlico Formation, South Carolina and Miami Oolite, Florida. Recent (littoral to 25 fathoms): South Carolina; Bahamas; Bermuda; Jamaica; Puerto Rico (Arroyo); St. Thomas; Brazil (Rio de Janeiro) Uruguay (Rio de La Plata).

? **Echinolampas** sp. indet. Pl. 53, figs. 1-3

The single specimen is poorly preserved and so devoid of definable characters that even the identity of the genus is questionable.

The test is small, subangularly ovate, narrowed posteriorly, and depressed, with the anterior part behind the apical system a little higher than the posterior end. The abactinal surface is nearly plane, and slopes gently forward from the higher area; the actinal surface is concave and deeply invaginated at the peristome. The peristome lies a little nearer the anterior end and is jaggedly semicircular with a subtruncate posterior rim. The periproct is completely hidden beneath an overlay of carbonate near the ambitus, and its exact position is not known. There are two deep excavations of unequal size below and to one side of the peristome, and in the larger of these there is imbedded a small white shell. Diverging away from the peristome are vague, gentle depressions possibly representing the positions of ambulacra IV and II, and even vaguer ones at ambulacra V and I. Neither the petals nor the apical system can be seen, and the surface of the test is nearly wholly veneered by a growth of Bryozoa.

Measurements. — Specimen S605a: length 18 mm, width 13.7 mm, maximum height 6.7 mm.

Locality. — North flank of Punta Gorda anticline at W-23. Playa Grande Formation (Maiquetía Member). One specimen.

Remarks. — As all of the other fossil echinoids from the Cabo Blanco Group described in this paper are found in the Recent

Caribbean fauna, it is possible that this form may also be living. I have, therefore, compared in the literature the Cabo Blanco fossil with a number of Recent species having a superficial resemblance, and find that in horizontal outline and certain general characters it is reminiscent of *Echinolampas depressa* Gray. References to that species (which occurs from Florida to Barbados at depths of 65 meters to 320 fathoms) are the following:

1851. *Echinolampas depressus* Gray, Ann. Mag. Nat. Hist., ser. 2, vol. 10, p 448; Zool. Soc. London, Proc., p. 38.
1855. *Echinolampas depressus* Gray, Catalogue of the Recent Echinida or Sea-Eggs in the British Museum, Part 1, p. 36, pl. 2, fig. 4.
1868. *Echinolampas caratomoides* A. Agassiz, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 1, pt. 2, p. 349 foonote. [*Fide,* A. Agassiz, 1872, p. 114.]
1869. *Echinolampas caratomoides* A. Agassiz, Mus. Comp. Zool., Bull., vol. 1, No. 9, pp. 269-270. [*Fide* Mortensen, 1948, p. 287.]
1872-74. *Echinolampas depressa* Gray, A. Agassiz, Mus. Comp. Zool., Mem., vol. 3, pts. 1,2, pp. 114,181,335-339,367,369,372,551, pl. 16, figs. 6,7,17-22 (1872); pts. 3,4, pp. 551,626 (1873).
1878. *Echinolampas depressa* Gray, A. Agassiz, Mus. Comp. Zool., Bull., vol. 5, No. 9, p. 190.
1881. *Echinolampas depressa* Gray, A. Agassiz, Voyage of H.M.S. Challenger, Rept. Sci. Results, Zoology, vol. 3, pt. 9, pp. 217,228,235,255.
1883. *Echinolampas depressa* Gray, A. Agassiz, Mus. Comp. Zool., Mem., vol. 10, No. 1, pp. 46-47, pl. 16; pl. 24, figs. 1-5.
1886. *Echinolampas depressa* Gray, Rathbun, U.S. Nat. Mus., Proc., vol. 9, p. 286.
1889. ? *Echinolampas depressa* Gray, Cotteau, Soc. Zool. France, Bull., vol. 14, p. 341.
1895. *Echinolampas depressus* Gray, Mazzetti, Reg. Accad. Sci., Lettere ed Arti Modena, ser. 2, vol. 11, pp. 415,437,445,460.
1904. *Echinolampas depressa* Gray, A. Agassiz, Mus. Comp. Zool., Mem., vol. 31, p. 119, fig. 155; pl. 64, figs. 2-5; pl. 65, figs. 1-4.
1904. *Echinolampas depressa* Gray, Meissner, *in* Bronn, Klassen und Ordnungen des Thier-Reichs, vol. 2, pt. 3, No. 4, p. 1387.
1907. *Echinolampas depressa* Gray, Mortensen, Danish Ingolf-Exped., vol. 4, pt. 2, pp. 183,185,186,189,190,193.
1910. *Echinolampas depressa* Gray, Mortensen, U.S. Nat. Mus., Bull. 74, p. 24.
1911. *Echinolampas depressus* Gray, Hawkins, Geol. Mag., decade 5, vol. 8, No. 6, pp. 257-258, pl. 13, fig. 1.
1917. *Echinolampas depressa* Gray, H. L. Clark, Mus. Comp. Zool., Mem., vol. 46, No. 2, pp. 111,112,113,115,116,117, pl. 144, figs. 18,19; pl. 153, fig. 8.
1921. *Echinolampas (Miolampas) depressa* Gray, Lambert and Thiéry, Essai de nomenclature raisonnée des Échinides, p. 381.
1921. ? *Echinolampas (Progonolampas) Blanchardi* Lambert and Thiéry, Essai de nomenclature raisonnée des Échinides, p. 387. [*Fide* Mortensen, 1948, p. 287.]
1925. *Echinolampas depressa* Gray, H. L. Clark, A Catalogue of the Recent Sea-Urchins (Echinoidea) in the Collection of the British Museum (Natural History), p. 183.
1948. *Echinolampas depressa* Gray, Mortensen, A Monograph of the Echinoidea, vol. IV, pt. 1, pp. 287-289, pl. 11, fig. 4; pl. 13, fig. 7; pl. 14, fig. 3.

1954. *Echinolampas depressa* Gray, A. H. Clark, U.S. Fish and Wildlife Ser., Fish. Bull., vol. 55, No. 89, p. 375.
1962. *Echinolampas depressa* Gray, Kier, Smithsonian Misc. Coll., vol. 144, No. 3, p. 112, pl. 31, fig. 2, text-fig. 91.
1966. *Echinolampas depressus* Gray, Chesher, Studies Tropical Oceanography, No. 4, (pt. 1), p. 211.
1966. *Echinolampas depressa* Gray, Cerame-Vivas and Gray, Ecology, vol. 47, No. 2, p. 263.
1966. *Echinolampas depressa* Gray, Kier, *in* Moore, R. C., Treatise on Invertebrate Paleontology, Pt. U, Echinodermata 3, p. 506.

Localities given for the living *E. depressa* are North Carolina, Tortugas (35, 68 fathoms), the Straits of Florida (40-320 fathoms), Florida Gulf Stream, and Yucatan Bank (35-160 fathoms); Grenada (92 fathoms); and Barbados. The species has also been reported from the Miocene of Italy by Mazzetti (1895).

In discussing the similarity of Recent species of Echinoidea on both sides of the Atlantic, Chesher (1966) wrote as follows: "In many cases, it seems that the African species were erected mainly on the basis of their supposed geographic isolation from the West Indian species. Lack of either African or American specimens has prevented settling the question of whether the species are really distinct as, for example, is the case with *Echinolampas depressus* (West Indies) and *Echinolampas blanchardi* (Gulf of Guinea). When material is available, the differences between the 'species' are found to be slight and often within the range of variation of a single population."

Moira atropos (Lamarck) Pl. 53, figs. 4-10

1771. [*Moira atropos*] Knorr, Deliciae Naturae Selectae . . . , pl. DIII, fig. 3. [*Fide* A. Agassiz, 1872, p. 146.]
1816. *Spatangus atropos* Lamarck, Hist. Nat. Anim. sans Vert., vol. 3, p. 32.
1825. *Echinocardium atropos* (Lamarck), Gray, Ann. Philos., ser. 2, vol. 10, art. 4, p. 430.
1827. *Spatangus atropos* Lamarck, Eudes-Deslongchamps, Encyclopédie Méthodique, Zoophytes, Livr. 98, p. 688, pl. 155, figs. 9-11.
1830. *Spatangus atropos Lamarck,* Blainville, Dictionnaire des Sciences Naturelles, vol. 60, Zoophytes, p. 183.
1834. *Spatangus atropos* Lamarck, Blainville, Manuel d'Actinologie ou de Zoophytologie, p. 202.
1837. *Schizaster atropos* (Lamarck), L. Agassiz, Ann. Sci. Nat. Paris, sér. 2, Zoologie, vol. 7, p. 278.
1837. *Spatangus atropos* Lamarck, Desmoulins, Études sur les Échinides, vol. 3, p. 230.
1840. *Spatangus atropos* Lamarck, Hist. Nat. Anim. sans Vert., vol. 3, ed. 2, p. 327.
1847. *Schizaster atropos* (Lamarck), L. Agassiz, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 8, p. 22, pl. 16 of vol. 6, fig. 10.
1848. *Schizaster atropos* (Lamarck), Ravenel, Echinidae, Recent and Fossil, of South Carolina, p. 4.

1850. *Schizaster lachesis* Girard, Boston Soc. Nat. Hist., Proc., vol. 3, p. 368. [*Fide* A. Agassiz, 1872, p. 146.]
1850. *Schizaster atropos* (Lamarck), Girard, Boston Soc. Nat. Hist., Proc., vol. 3, p. 368.
1855. *Moira atropos* (Lamarck), Michelin, Soc. Géol. France, sér. 2, vol. 12, p. 759.
1855. *Schizaster atropos* (Lamarck), Gray, Catalogue of the Recent Echinida or Sea Eggs of the British Museum, Part I, pp. 61,62.
1855. *Moera atropos* (Lamarck), Michelin, Rev. Mag. Zool., vol. 7, p. 246. Also *M. lachesis* (Girard), p. 247.
1855. *Moera lachesis* (Girard), Desor, Synopsis des Échinides fossiles, p. 394.
1858. *Moera atropos* (Lamarck) and *M. lachesis* (Girard), Desor, Synopsis des Échinides fossiles, p.394, pl. 43, fig. 3.
1858. *Schizaster atropos* (Lamarck), Holmes, Post-Pleiocene Fossils of South Carolina, pp. 5,6, pl. 2, fig. 3.
1862. *Moera atropos* (Lamarck) and *M. lachesis* (Girard), Dujardin and Hupé, Histoire Naturelle des Zoophytes, p. 603.
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1883. *Moira atropos* (Lamarck), Lovén, Kongl. Svenska Vetensk.-Akad., Handl., vol. 19, No. 7, pl. 10, figs. 94,95,110.
1887. *Moira atropos* (Lamarck), Rathbun, U.S. Nat. Mus., Proc., vol. 9 (1886), p. 292.
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1906. *Moera atropus* (Lamarck), Cary, Gulf Biol. Sta. Cameron, La., Bull., vol. 6, p. 52.
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1915. *Schizaster atropos* (Lamarck), Clark and Twitchell, U.S. Geol. Sur.. Mon. 54, p. 227.
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1942. *Moira atropos* (Lamarck), H. L. Clark, Mus. Comp. Zool., Bull., vol. 89, No. 8, p. 383.
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The following description is based on two incomplete and somewhat shattered specimens, with many of the diagnostic characters broken away or worn.

The test is inflated, angularly ovoid in horizontal outline, truncated behind. The apical system, though not revealed in detail, seems to lie a little nearer the posterior end. The test is highest at the apex, and from it the upper surface slopes forward. The lower surface is nearly flat at the sternum, the sides diverging upward.

The sternum is elongate-ovate, its width two-thirds the length, and not markedly widening posteriorly. Along the length there is a gentle medial keel which, however, is more angular and a little higher at the posterior end. Crossing the sternum transversely are obliquely sinuous, regularly spaced rows of tubercles, with approximately 30 rows of tubercles over a length of 27 mm. The labrum at the head of the sternum is sturdy, projecting, and arcuate.

The dorsal surface is characterized by its deeply sunken ambulacra, and on both specimens the depressions of the anterior lateral petals are roofed over through the expansion of the ambulacra. The anterior petal is the largest, and the anterior laterals are longer than the posterior pair.

There is both a peripetalous and lateral fasciole. The former is immediately adjacent to the petal, lying on an elevated shelf or ramp which slopes toward the petaliferous depression. The lateral fasciole cannot be traced in its entirely but on specimen K598e it joins the peripetalous fasciole at nearly a right angle about one-third down from the distal end of the left anterior ambulacrum.

Adherent here and there on the test are occasional spines. These are slender, hardly tapering, and recrystallized, and appear to be sculptured by longitudinal striae.

Details of the apical system, peristome, and periproct have not been discerned.

Measurements. — Specimen K598a (incomplete): length 41 mm, height near anterior end 20 mm; length of left anterior petal 18 mm. Specimen K598e (somewhat crushed): length 45 mm, width 32 mm, height at apex 31 mm; sternum, length from labrum to posterior end 31 mm, width 17 mm.

Locality. — Bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road. The two incomplete specimens are embedded in tan, fine-grained calcareous sandstone. Playa Grande Formation (Catia Member).

Remarks. — There are a number of important morphologic characters that are indeterminable but the unique configuration of the test, the outline and tuberculation of the sternum, the deeply sunken petals, and the nature of the fascioles all suggest that the species is *Moira atropos* (Lamarck).

Range and distribution. — Pliocene to Recent. *M. atropos* has been recorded from two Pliocene localities in Venezuela, one in the Playa Grande Formation at Cabo Blanco (this report), the other some 300 kilometers or so to the northwest in the San Gregorio Formation of north-central Falcon. Pleistocene localities are Langleys Bluff, Maryland(?), Johns Island, South Carolina, and Bermuda. The living form inhabits the Western Atlantic, Gulf of Mexico, and Caribbean Sea, from North Carolina, U.S.A., to Santos Bay, Brazil at depths ranging from the littoral to 80 fathoms: North Carolina (Beaufort); South Carolina (Charleston); Florida (Biscayne Bay, less than three meters, salinity 30-40 parts per thousand; Apalachee Bay, inshore to 40 ft., salinity 25-37 parts per thousand; Panama City beach); Louisiana (Chandeleur Islands); Texas; Bermuda; Straits of Florida; Cuba (Puerto Padre); Jamaica; Puerto Rico (Guanica); Virgin Islands (St. Thomas, St. John); Guadeloupe; and Brazil (Ribeiro de Almeida, Clarimundo de Jesus, Ilha Nova, Ilha São Sebastião, Santos Cananéia, Ilha do Cardosa).

Brissopsis cf. **B. atlantica** Mortensen Pl. 54, figs. 1-5; Pl. 55, figs. 1-9

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The following description is based on two badly worn and incomplete specimens, and on a number of small fragments believed to represent the same species.

The test is subdiscoidal, suborbicular in horizontal outline, a little longer than wide, the margins well rounded, the ambitus gently indented at the ambulacra and interambulacra; the height is greatest well forward of the apical system and is about half the length of the test, with the aboral surface sloping gently therefrom toward the posterior; the posterior end is subtruncate, concave inward; the adoral surface is gently rounded posteriorly, nearly flat anteriorly. The apical system is eccentric, lying nearer the anterior end.

The petals are moderately deep, with III the longest, and II and IV a little longer than the posterior pair I and V; the latter are curved outward distally and are confluent proximally. On specimen N597a the posterior petals consist of a narrow interporiferous zone and much wider poriferous zones on either side. The latter are pierced by relatively large oval pore-pairs of which there are some 28 pairs in the petal length of 16 mm. The plates of the petals, as represented on fragment K597c, are regular and rectangular, and on the upper surface of each plate there is a single, somewhat irregular horizontal row of minute tubercles passing below the pore-pairs near the lower suture; between the sutures of each plate, in the interporiferous zone, there are generally six to nine minute tubercles, with a row of two or three at each suture, and a row between.

The tubercles of the interambulacra are relatively small, mammilliform, perforate, and crenulate.

The primary spines are long and slender, the shafts tapering but slightly for much of their length, the milled ring of the collar sharp. Some of the spines are curved, indicating flexibility, and all of them are sculptured by microscopic longitudinal striae of which there are 28 or so around the shaft with a diameter of 0.26 mm.

The peripetalous fasciole as exhibited on fragment K597b veers angulately where it changes its course.

The characters of the apical system, peristome, sternum, and periproct are not known.

Measurements. — Specimen N597a: Length 80 mm, width (reconstructed) 72 mm, height at apex 42 mm. Specimen N597b: length of anterior? petal 16 mm, width 4.43 mm, with of interporiferous zone 0.7 mm.

Localities. — K: Bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road. Tan calcareous sandstone. Ten fragments. L: South side of Playa Grande road about 220 meters west of station W-15. Brown fine-grained sandstone. Two fragments. N: Near station W-21 on north flank of Litoral anticline. Tan siltstones and sandstones with knobs of hard sandstone. Two incomplete specimens. O: Dip slope 100 meters west of Costa fault at station W-22. Dull gray pebbly sandstone. One fragment.

All of the above are from the Catia Member of the Playa Grande Formation.

Remarks. — It is not possible to identify this Venezuelan fossil definitively, but insofar as it can be compared it seems to be close to *Brissopsis atlantica* Mortensen. The two other Recent Caribbean species of *Brissopsis* are *B. alta* Mortensen (1907, pp. 107,159-160,161,162,168,174,189,194, pl. 3, figs. 5,8,9,13,16; pl. 18, figs. 4, 11,22,27,29; pl. 19, figs. 7,24,26,27) and *B. elongata* Mortensen (1907, pp. 44,159,162,163,-165,167,168,175,186,194, pl. 3, figs. 4,14, 15,19; pl. 4, figs. 1,4,13,18; pl. 18, figs. 2,15-17; pl. 19, figs. 12,17). *B. atlantica* is subdiscoidal, *B. alta* subglobose, and thus are readily differentiated. *B. atlantica* attains a much larger size than *B. elongata,* and as my specimens are large and more orbicular than elongated they are referred to *B. atlantica.*

Range and distribution. — The geologic range of *Brissopsis atlantica* is Pliocene to Recent. If correctly identified, it is reported here for the first time from the Pliocene of Venezuela. It was recorded also from the Pliocene of Anguilla Island by Lambert (1915), though Hoffstetter suggested (1956, p. 290) that the formation in which the species was found may be Quaternary.

The living *B. atlantica* is reported in Western Atlantic waters off North Carolina, southeast Florida, west Florida, and the Tortugas, U.S.A.; in Cuban waters (Old Bahama Channel, Bahía de Matanzas, Puerto de Tanamo, Bahía de Cochinos, Cienfugos, and Banco Paz) at depths of 190 to 1440 fathoms; off Panama; off northwest Colombia; and off Rio de Janeiro, Brazil. Further details of distribution in Florida, Panama, and Colombia are given by Chesher (p. 44, 1968).

Mortensen (1951) pointed out that the well-known *Brissopsis lyrifera* (Forbes) is a North Atlantic species and that some southern forms referred by authors to that species might well be *Brissopsis atlantica* or *Brissopsis elongata.* Mortensen identified *B. elongata* from Puerto Rico (7 fathoms), the northwest coast of Panama (25 fathoms), and Puerto Cabello, Venezuela (12-15 fathoms. Recent forms in the Western Atlantic between the 30° parallels identified as *B. lyrifera* by authors but which may prove to be *B. atlantica* or *B. elongata,* have been reported in the Gulf of Mexico between the Mississippi River delta and Cedar Keys, Florida (21-1330 fathoms); between Cuba and Florida in deep water; off Habana, Cuba (122-279 fathoms); and the Antilles. For the latest and best work on the *B. atlantica* complex the reader is referred to Chesher's 1968 monograph. Unfortunately this was not available to me until several months after I had submitted the typescript of the present paper.

Observations. — Specimens K597b (23.2 X 16 mm), K597c (24 X 16.3 mm), K597d (15.3 X 12 mm), K597e (7 X 3.5 mm), and L601a X 6.2 mm) were collected as discrete fragments unassociated with a whole test. As these components resemble, and occur in the same formations as specimens N597a and N597b, they are also referred to *Brissopsis* cf. *B. atlantica* Mortensen. This identification, however, must be considered highly tentative.

Species of *Brissopsis* in the eastern Americas

The genus *Brissopsis* ranges from Eocene to Recent. The fossil and Recent species that have been reported from the Atlantic side of the Americas are the following:

aguayoi Sánchez Roig, 1952, pp. 15,16, pl. 6, figs. 1,2. Finca Las Cuevos de Pedro Pozo, Morón, Prov. Camagüey, Cuba. Upper Oligocene.

alta Mortensen, 1951, pp. 390-392, pl. 57, fig. 21 Gulf of Mexico, Dry Tortugas, and southeast Florida. Recent.

antillarum Cotteau, 1875, p. 37, pl. 6, figs. 19-25. Anguilla Formation, Anguilla, lower Miocene. Cevicos Limestone, Dominican Republic, Upper Oligocene-lower Miocene. La Vela Formation, Venezuela, Upper Miocene.

atlantica Mortensen, 1907, p. 160, pl. 3, figs. 6,10,17; pl. 18, figs. 5,9,10,13,19,20,24; pl. 19, figs. 1,4,5,11,25,28,32,33. Pliocene to Recent. Playa Grande Formation (Catia Member), Venezuela, Lower Pliocene. Island of Anguilla, probably Pleistocene. Recent from North Carolina, U.S.A. to Brazil.

biarritzensis Cotteau, 1884, p. 30; 1886, p. 193, pls. 56,57,58, figs. 1-3. Alabama, U.S.A., Ocala Limestone, upper Eocene. Also Lou Cout near Biarritz, France, *fide* Cooke, 1959, p. 85.

blanpedi Grant and Hertlein, 1938b, pp. 482-486, figs. 5,6,8-10. Mississippi U.S.A., Byram Formation, middle Oligocene.

elongata Mortensen, 1951 pp. 424-427, pl. 57, fig. 1; text-figs. 202a,203a. Recent in Eastern Atlantic off Ghana and Fernando Póo; in Western Atlantic off Puerto Rico, Colombia, and Venezuela (Puerto Cabello).

jimenoi Cotteau, 1875, p. 6; 1881, p. 33, pl. 3, figs. 5-9. "Miocene" of Cienfuegos, Cuba. Forest Clay, Trinidad, lower-middle Miocene.

lyrifera (Forbes), 1841, p. 187. Recent, North Atlantic and Eastern Atlantic.

poriferus Ravenel, 1848, p. 4, figs. 5,6. [= *Agassizia porifera* (Ravenel).]

rimulatus Ravenel, 1848, p. 4, figs. 3,4. [= *Agassizia porifera* (Ravenel).]

steinhatchee Cooke, 1942, p. 49, pl. 5, figs. 29-32. Ocala Limestone, Florida, upper Eocene.

ECHINOID SPINES

The few loose and broken echinoid spines collected from the Cabo Blanco Group are illustrated on Plate 56. As these particular spines were not associated with the test or other recognizable elements their identity is not known. Nevertheless they are listed below for the sake of completeness and for possible identification in the event more material becomes available in the future. The photographs with the black background were taken by Bertha M. Cutress to whom the spines were sent some years ago for study.

Specimen M602a, Pl. 56, figs. 1,2: length 4.9 mm, diameter 1.07 mm. There are 24 longitudinal riblets crossed by microscopic revolving striae. The spine is densely calcified within. Another specimen of the same species has a fairly prominent milled ring. Locality: south side of Playa Grande road at W-15, 40 meters southeast of the intersection with the Playa Grande Yachting Club road. Playa Grande Formation (Catia Member).

Specimen H603a, Plate 56, figs. 3-5: length 4.7 mm, diameter above milled ring 1.6 mm. There are 28 longitudinal riblets on which the sculpture has been obliterated. The interior of the spine is wholly calcified, the material of the wall and of the small annulus crystalline, that between the annulus and the wall minutely cellular. Separating the annulus and the intermediate thickness of carbonate is a ring of regular quadrangular cells equal in number to the longitudinal riblets of the outer surface of the spine. Locality: south of the Punta Gorda anticline near W-25. Mare Formation.

Specimen H603b, Plate 56, fig. 6: length 11.1 mm, diameter at larger end 1.5 mm. Slender, with 30 longitudinal riblets crenulated by microscopic revolving striae. Interior calcified and porous in texture. Locality: south of the Punta Gorda anticline near W-25. Mare Formation.

Specimen T603a, Plate 56, figs. 7,8: length 3.5 mm, diameter above milled ring 1.3 mm, diameter of milled ring 2.07 mm. There are 28 longitudinal, finely crenulated riblets. The interior is wholly calcified, the texture porous. Locality: in stream 250 meters south-southwest of the mouth of Quebrada Las Pailas. Mare Formation.

Specimen K604a, Plate 56, fig. 9: spine subvitreous and slightly bent. Length 4.0 mm, diameter 1.4 mm. Crenulated longitudinal riblets on outer surface. Interior recrystallized. Locality: bluff 125 meters west of the intersection of the Playa Grande Yachting Club road and coast road. Playa Grande Formation (Catia Member).

Specimen S610a, Plate 56, fig. 10: length 3.5 mm, diameter 1.0 mm. Outer surface sculptured by 28 longitudinal riblets, the crests finely crenated. The interior is completely calcified the material finely porous. Locality: north flank of Punta Gorda anticline at W-23. Playa Grande Formation (Maiquetía Member).

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PLATES

EXPLANATION OF PLATE 14

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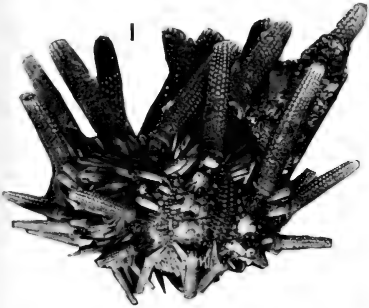
1-9.	**Eucidaris tribuloides** (Lamarck)	**287**

1. Specimen A607a. PRI 27653. Diameter 17 mm, height 9 mm. General view of corona, × 1.8. Recent. 2,3. Specimen A607b. PRI 27654. Diameter 26 mm, height 16 mm. Ambital and apical views showing secondary spines, × 2.3. Recent. 4. Specimen A608a. PRI 27655. Primary spine, length 24 mm, diameter 3.5 mm, × 1.4. Recent. 5,6. Specimen A612a. PRI 27656. Height 13 mm, width 10.5 mm. Denuded coronal plate, × 3.8. Recent. 7. Specimen D608a. PRI 27657. Primary spine, length 20 mm, diameter 3 mm, × 2. Abisinia Formation. 8. Primary spines from the Abisinia Formation (photographed by Bertha M. Cutress). 9. Specimen K599a. PRI 27658. Primary spine, length 21.5 mm, diameter 3.1 mm, × 2.4. Playa Grande Formation (Catia Member).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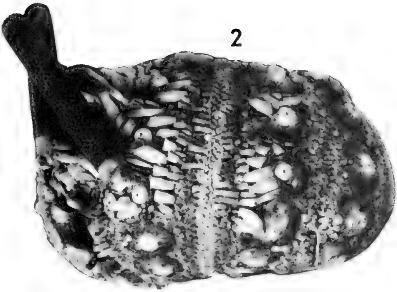
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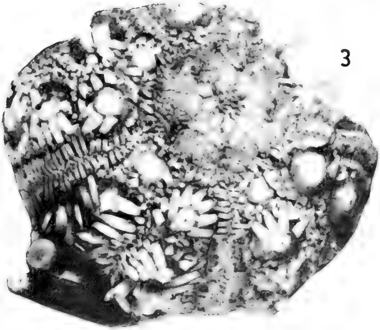
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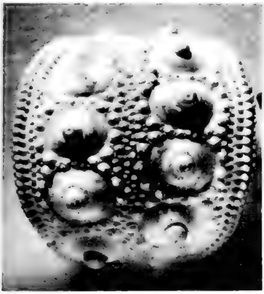
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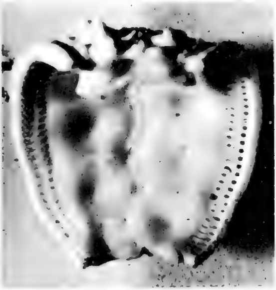
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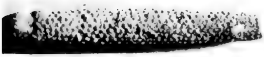
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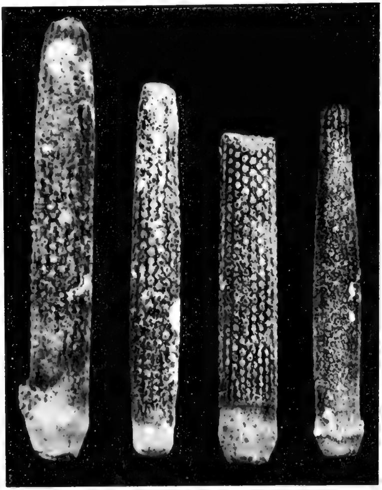
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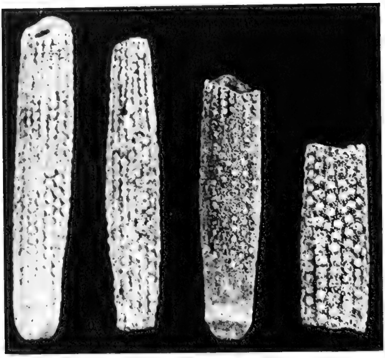
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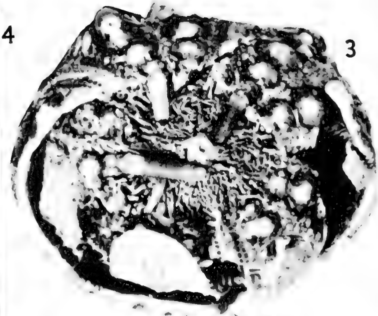
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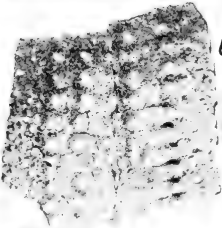
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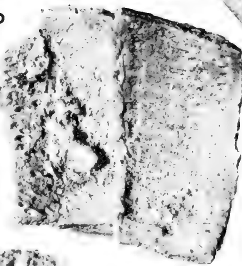
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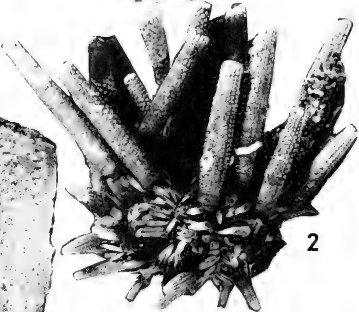
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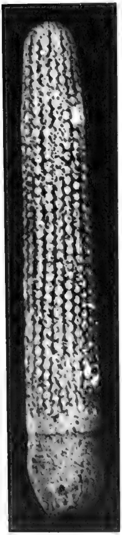
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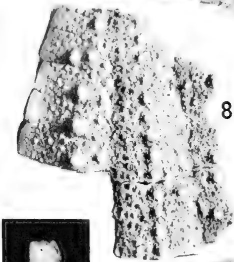
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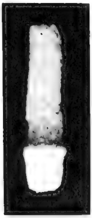
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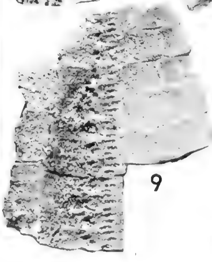
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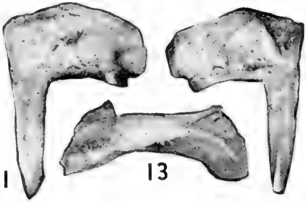
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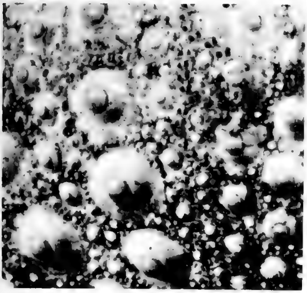

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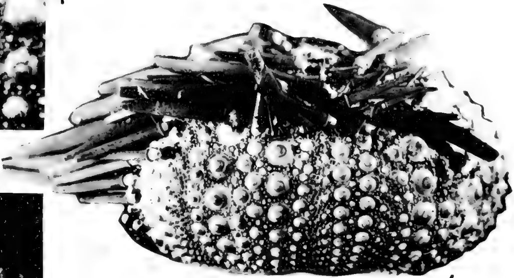

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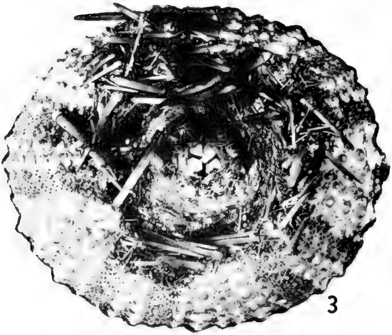

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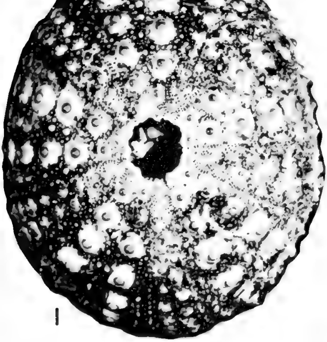

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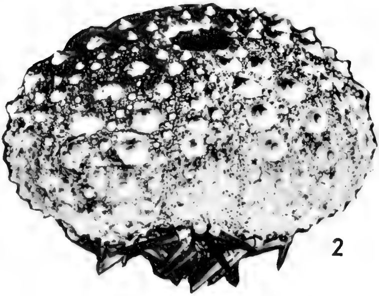

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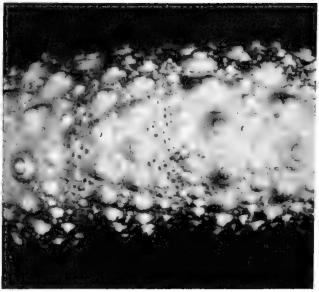
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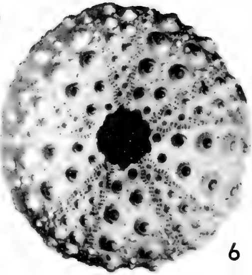
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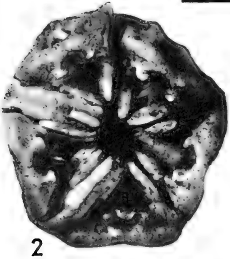
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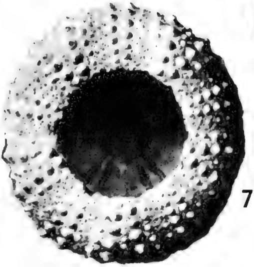
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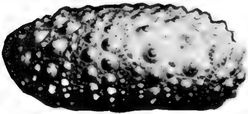
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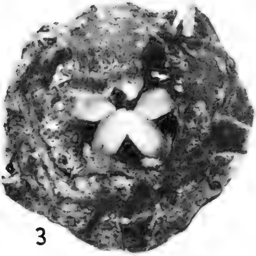
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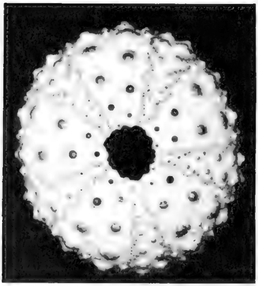
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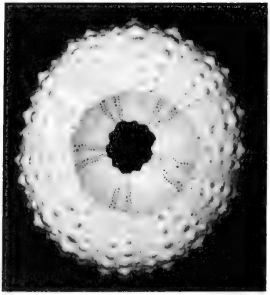
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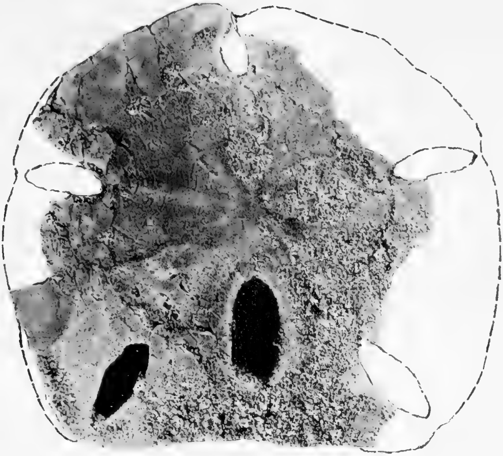

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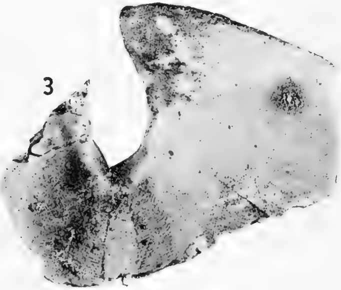

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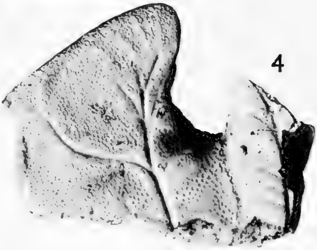

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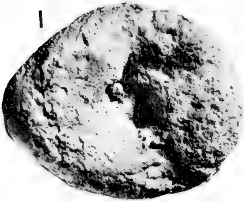

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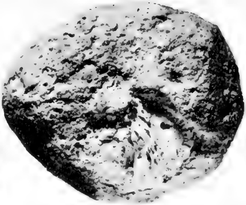

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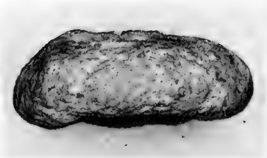

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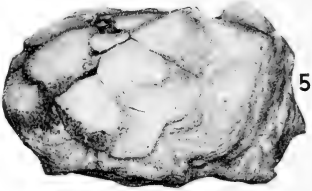

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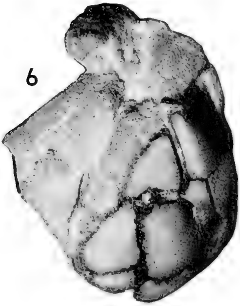

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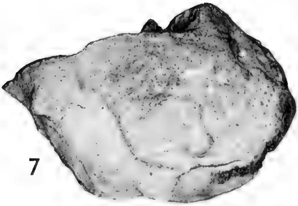

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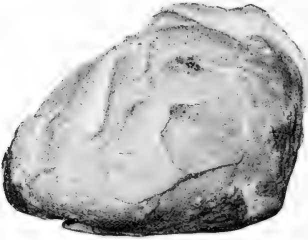

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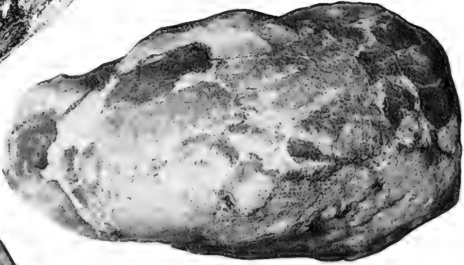

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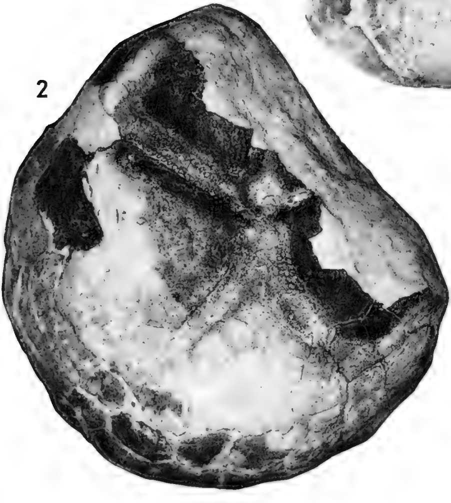

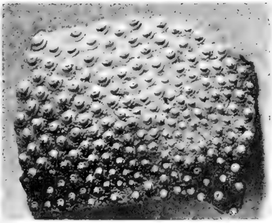

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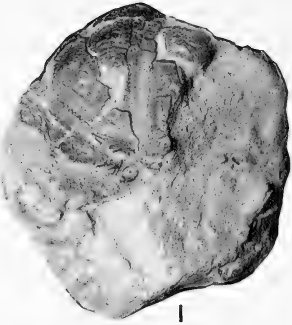

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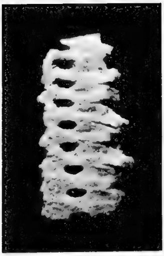

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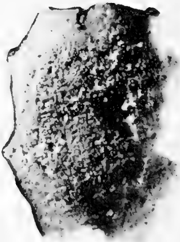

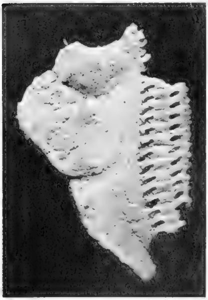

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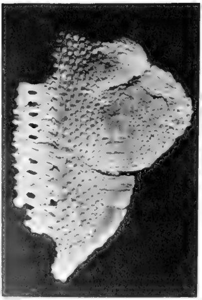

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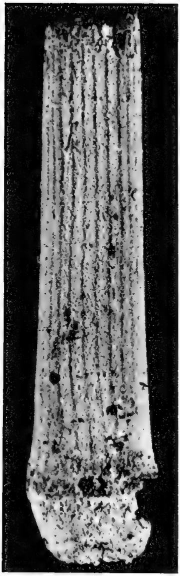

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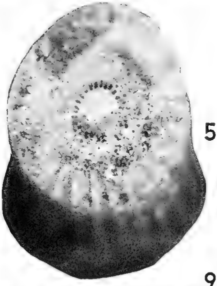

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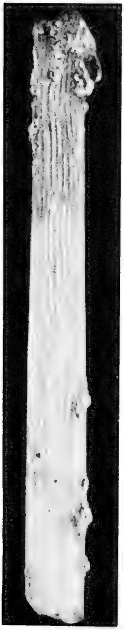

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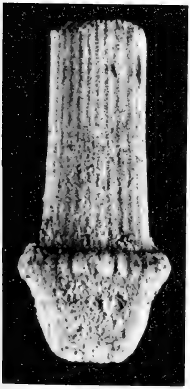

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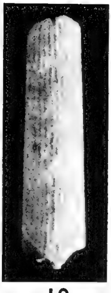

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THE NEOSCIADIOCAPSIDAE, A NEW FAMILY OF UPPER CRETACEOUS RADIOLARIA

By
Emile A. Pessagno, Jr.

1969

Paleontological Research Institution
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CONTENTS

THE NEOSCIADIOCAPSIDAE, A NEW FAMILY OF UPPER CRETACEOUS RADIOLARIA

Emile A. Pessagno, Jr.

ABSTRACT

The Neosciadiocapsidae Pessagno, n. fam., include dicyrtid Nassellariina with (1) helmet-shaped tests; (2) nine cephalic skeletal elements (apical, vertical, median bar, dorsal, primary right lateral, primary left lateral, secondary right lateral, secondary left lateral, and axial); and (3) a thoracic velum. A tubular structure, termed the *cephalopyle,* is usually present on the distal portion of the cephalis near the collar stricture (or in its absence, a vertical spine).

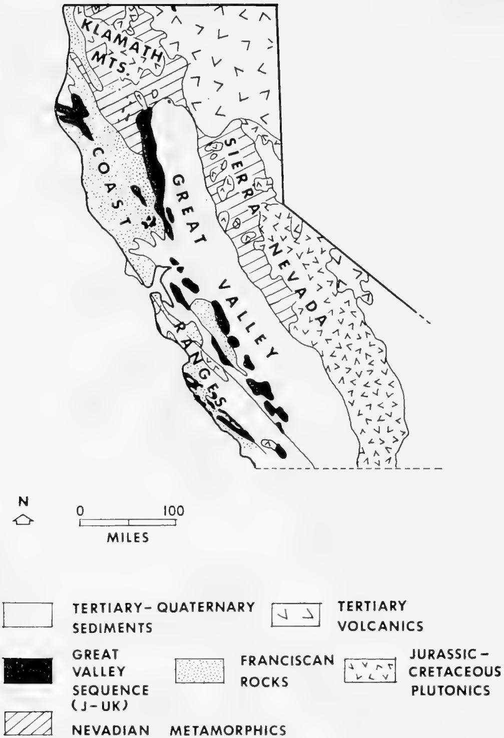
The Neosciadiocapsidae display rapid faunal change during much of Late Cretaceous time. The family probably originated in the Jurassic and ultimately became extinct by Eocene times. Twenty-one new species and nine new genera are described in this report from the Upper Cretaceous portion of the Great Valley Sequence of the California Coast Ranges.

INTRODUCTION

In the thick, relatively unfossiliferous, and often highly disturbed Mesozoic succession of the California Coast Ranges, Radiolaria are one of the few groups of invertebrate fossils that are consistently common. A large number of well-preserved specimens have been extracted from limestones nodules, concretions, mudstones, and occasional radiolarites which occur in the Upper Cretaceous portion of the Great Valley Sequence. Over 1200 samples have been collected from measured sections of strata cropping out in the Coast Ranges from Contra Costa County (near Mt. Diablo) northward to Tehama County (Text-figure 1). A rich, diversified radiolarian assemblage containing well over 250 species (mostly new) is present in strata ranging in age from early Cenomanian to latest Campanian (dating based on associated planktonic Foraminifera and Mollusca). The rapid faunal change displayed by Radiolaria at the specific, generic, and family levels indicates that Radiolaria can be affectively used to subdivide the Upper Cretaceous portion of the Great Valley Sequence into a minimum of 10 zonal units.

This report represents the first of a series of studies on the stratigraphic distribution, morphology, and phylogeny of California Upper Cretaceous Radiolaria. The Neosciadiocapsidae, n. fam., is one of the many family groups of Mesozoic Radiolaria that show great potential biostratigraphically. Many of the forms encountered in this study are short ranging and distinctive (cf. Text-figure 2).

Contribution No. 98 Geosciences Division, University of Texas at Dallas, P.O. Box 30365, Dallas, Texas 75230



TEXT - FIGURE 1: INDEX MAP. After Ojakangas, 1968, p.975

ACKNOWLEDGMENTS

This work has been supported by grants from the National Science Foundation: GP-4043 to the University of California, Davis and GP-1224 to the Southwest Center for Advanced Studies, Dallas, Texas, and by the general NASA grant (NGL – 44-004-001) to the Southwest Center for Advanced Studies. The writer wishes to thank Mr. Verne Harlan for his assistance in the field; Mr. Walter Brown for his care in taking the scanning electron micrographs; and Mrs. Sheila Moiola and Miss Maria Bilelo for their aid in preparing the text-figures and numerous prints for the plates. He particularly wishes to thank Dr. Helen P. Foreman (Oberlin College) and William R. Reidel (Scripps Institution of Oceanography) for their critical review of the manuscript. Mr. Pat Patterson, California Department of Water Resources, was instrumental in obtaining valuable samples from the Del Valle Dam Site (USGS Tesla Quad.; 15′). Numerous megafossils were generously identified for the writer by Dr. David L. Jones, Paleontology and Stratigraphy Branch, U.S. Geological Survey, Menlo Park, California.

PREVIOUS INVESTIGATIONS

The first nasselariinid probably referable to the Neosciadiocapsidae, n. fam., was described by Rüst (1898, p. 51, pl. 15, fig. 8) from the Jurassic ("Lias – Koprolithen von Ilsede") of Europe. *"Clathrocyclas" reginae* Rüst was regarded by Rüst as tricyrtid in nature. The figured specimen shows a massive primary horn and a helmet-shaped test analagous to that of *Neosciadiocapsa diabloensis* Pessagno, n. sp.

In 1903, Squinabol (pp. 131, 132, pl. 9, figs. 16, 16a; 20, 20a) described two species from the Upper Cretaceous (Cenomanian?) of Italy which probably are referable to the Neosciadiocapsidae. Both species, *"Sethoconus" speciosus* Squinabol and *"Sethocephalus" haeckeli* Squinabol have the typical helmet or sombrero-shaped tests of the Neosciadiocapsidae. However, the somewhat schematic nature of the illustrations prohibits their precise assignment generically. It is interesting to note that Squinabol *(ibid.)* regarded both species as dicyrtid in character. In 1904 Squinabol (pp. 211, 212, pl. 7, figs. 5, 5a) described a third species, *Sciadiocapsa euganea* Squinabol from the Upper Cretaceous ("Senonian") of Italy. *S.*

euganea is the type species of *Sciadiocapsa* Squinabol. Squinabol's schematic illustrations of *S. euganea* depict a neosciadiocapsid which (1) lacks an apical horn (2) possesses a thoracic velum (3) is elliptical in shape: and (4) lacks a well-developed collar stricture. Squinabol *(ibid.)* regarded *E. euganea* as monocyrtid.

In 1945 Clark and Campbell (p. 46, pl. 6, fig. 30) figured a form which appears to be a neosciadiocapsid from the Eocene Kreyenhagen Formation of California. This species, *"Clathrocyclas (Clathrocycloma)" aurelia* Clark and Campbell possesses a single long apical horn, a well-developed collar stricture, and a broad thoracic skirt with an inturned periphery. The authors made no mention of structures referred to herein as the cephalopyle or thoracic velum. Furthermore, they regarded this species as tricrytid in nature. Eocene Neosciadiocapsidae observed by the writer seem to show the same basic cephalic skeletal elements that are present among the Upper Cretaceous forms.

Foreman (1968, pp. 43-46) recently described three neosciadiocapsids from the Upper Maestrichtian Moreno Formation of Fresno County, California. *?Scoadiocapsa causia* Foreman, *?Sciodiocapsa petasus* Foreman, and *?Sciadiocapsa ptesimolecis* Foreman. The probable stratigraphic distribution of these species is indicated in Text-figure 2. Foreman regarded her forms as either dicyrtid or tricyrtid in character.

TERMINOLOGY (See Text-figure 3)

Plane of projection: Imaginary plane parallel to base of thoracic skirt and situated directly above highest point of cephalis. Plane of page in Text-figure 3A is taken as the plane of projection.

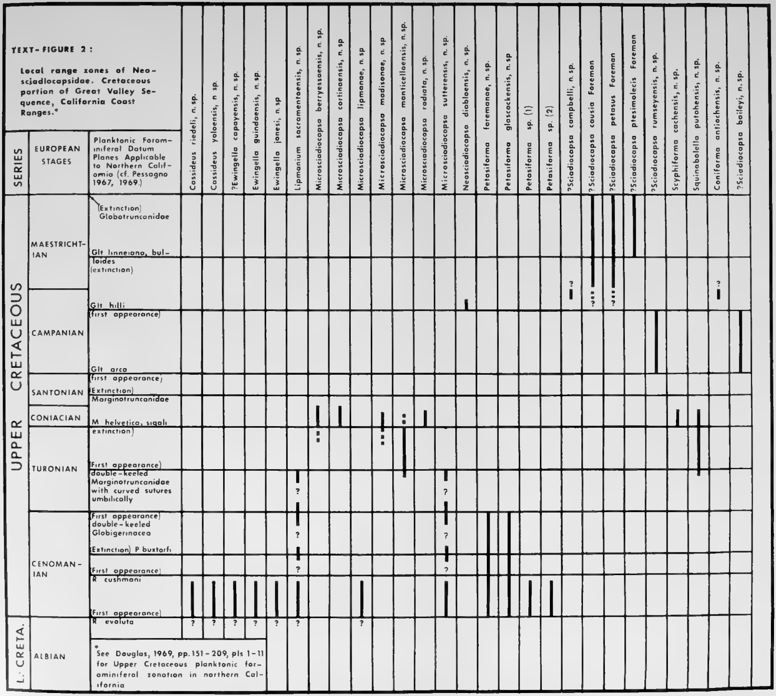
Point H: Right angle projection of center of apical horn (or point of intersection of apical skeletal bar with cephalic roof) onto plane of projection.

Point K: Right angle projection of cephalopyle (or intersection of vertical skeletal bar with cephalic roof) onto plane of projection.

Line $A-A'$: Line drawn through points H and K in plane of projection.

Point a: Right angle projection of point on anterior margin of thoracic skirt to line $A-A'$ on plane of projection.

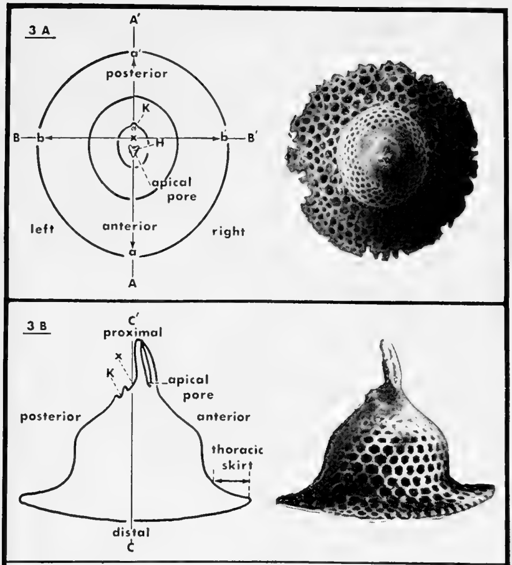
Point a': Right angle projection of point on posterior margin of thoracic skirt to line $A-A'$ on plane of projection.



TEXT-FIGURE 2:

Local range zones of Neosciadiocapsidae. Cretaceous portion of Great Valley Sequence, California Coast Ranges.*

* See Douglas, 1969, pp. 151-209, pls 1-11 for Upper Cretaceous planktonic foraminiferal zonation in northern California



TEXT - FIGURE 3: Schematic diagram depicting Neosciadocapsid terminology (See section entitled "Terminology" in text).

x: Right angle projection of a point midway between apical horn and cephalopyle to line A — A′ on plane of projection.

Line B — B′: Line drawn at right angles to line A — A′ through point x and in the plane of projection.

Point b: Right angle projection of a point on left margin of thoracic skirt to line B — B′ on plane of projection.

Point b′: Right angle projection of point on right margin of thoracic skirt to line B — B′ on plane of projection.

Line C — C′: Line drawn through point x and normal to plane of projection.

Cephalopyle: Opening (usually tubular) on posterior side of cephalis at or near juncture of vertical cephalic skeletal bar with roof of cephalis. (GK *kephale* = head; *pyle* = gate or entrance).*

Primary horn(s): Horn (s) of variable size and shape connected internally to either apical cephalic skeletal bar or vertical cephalic skeletal bar.* Includes two types: apical horn and vertical horn.

Vertical horn: Primary horn connected internally with vertical cephalic skeletal bar. Only observed among the Neosciadiocapsidae on *Cassideus* Pessagno, n. gen.

Apical horn: Primary horn connected internally with apical cephalic skeletal bar. Variable in size and shape; single or double; often with apical bridge.

Apical bridge: Ridgelike structure usually extending in an anterior direction from the apical horn of *Microsciadiocapsa* Pessagno, n. gen. (See Pl. 31, figs. 1, 2); sometimes terminating anteriorly with short spine.*

Secondary horn: Short spines on surface of cephalis not connected with apical or vertical cephalic skeletal bars.*

Cephalic skeletal elements: With Neosciadiocapsidae, n. family, consist of apical bar, vertical bar, median bar, dorsal bar, primary right lateral bar, primary left lateral bar, secondary right lateral bar, and secondary left lateral bar. A subsidiary element known as the axial spine is usually present (see Pl. 24, fig. 1).

Velum: Cover-plate over mouth of thorax with or without accessory aperture (See Pl. 23, fig. 9). Perforate to imperforate. First applied by Riedel and Campbell (1952, pp. 667-669).

Thoracic skirt: Flared portion of thorax.

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* = new term.

Apical pores(s): Pore or pores situated at base of apical horn (See Pl. 35, fig. 9).*
Breadth: Measured along line A – A′ from point a to point a′.
Width: Measured along line B – B′ from point b to point b′
Length: Measured along C – C′ between top of cephalic and basal portion of thorax.
Posterior in direction: Toward point *a′* or toward vertical bar.
Anterior in direction: Toward point *a* or toward dorsal var.
Distal in direction: Toward base of thorax.
Proximal in direction: Toward top of cephalis.

Much of the terminology cited above has been proposed as a framework for future detailed biometric studies. No attempt has been made herein to utilize this terminology in its full extent.

CRITERIA FOR CLASSIFICATION (See Text-figure 4)

Mesozoic Radiolaria are still in need of a great deal of investigation before the phylogenetic relationship of various families and superfamilies can be interpreted. It is likely that the classification used in this paper will be regarded as artificial even by the writer ten years from now. As one can discern from Text-figure 4, multiple criteria for classification are used in defining taxa at the family, generic, and specific levels. The relative importance of most of these criteria is difficult to assess at the present time.

At the family level many workers such as Popofsky (1913), Petrushevskaya (1964, 1965), and Goll (1968) feel that the arrangement of the cephalic skeletal elements is of primary importance in the study of Nassellariina. Although the writer is in agreement with such a conclusion, he feels that this criterion will be far more useful in future investigations at the superfamily level. It could be used, for example, to correlate the Neosciadiocapsidae with other family groups among the Nassellariina. The presence of a thoracic velum the distinctive geometry of the test, and the presence of a cephalopyle are regarded coequally as second in importance. Whether or not the Neosciadiocapsidae are dicyrtid or tricyrtid in character is likely to remain a much debated issue.

At the generic level it is felt that the structure of the thoracic velum will eventually become the most important criterion for

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* = new term.

TEXT-FIGURE 4: CRITERIA FOR CLASSIFICATION

FAMILY LEVEL	GENERIC LEVEL	SPECIFIC LEVEL
Arrangement of cephalic skeletal elements. Presence of a thoracic velum. Geometry of test. Number of chambers. Presence of cephalopyle or in its place a vertical horn.	Character and arrangement of apical pores. Structure of thoracic velum. Presence, absence, number and structure of primary horn(s). Presence, absence and structure of cephalopyle. Presence or absence of perforations in cephalis other than apical pores.	Minor differences in geometry of test. Character of meshwork. Presence of concentric ridges, radial beams, and so forth. Minor differences in arrangement of apical pores. Minor differences in arrangement of cephalic skeletal needles. Presence of an epithecal layer covering cephalis and part of thorax. Character of collar stricture. Width of thoracic skirt.

the resolution of classification. Unfortunately, this structure does not always occur intact in the writer's California material. Of the remaining criteria cited in Text-figure 4 (1) the presence, absence, number, and structure of the primary horn (s) and (2) the presence, absence, and structure of the cephalopyle are regarded as the most important. The writer regards the criteria cited in Text-figure 4 for defining species as more or less coequal in importance.

METHOD OF STUDY

The peculiar shape of the neosciadiocapsid test makes it difficult to illustrate effectively with light optics. In this investigation a JSM-1 scanning electron microscope equipped with a goniometer stage was used as the primary means of illustrating and studying neosciadiocapsid morphology (cf. Honjo and Berggren, 1967, pp. 393-404, pls. 1-4; Hay and Sandberg, 1967, pp. 407-418, pls. 1-2.) Many important morphological attributes of the Neosciadiocapsidae subsequently observed with the scanning electron microscope were overlooked by the writer when he first began his study of this group with light optics. However, once the morphological features of the Neosciadiocapsidae were recognized and mapped through the use of the scanning electron microscope, they could be located with the light microscope.

Gold paladium or gold used during shadow casting can be removed in a matter of seconds with a drop of agua regia. Once this is done specimens can be mounted in hyrax or other suitable mounting media for optical analysis with transmitted light.

LOCALITY DESCRIPTIONS

NSF 55-B. Lower part of the Forbes Formation (upper part of so-called "Dobbins Shale" Member) ; 424 feet above contact between Forbes Formation with underlying Guinda Formation. Gray calcareous mudstones with sparse limestone nodules. Sample from limestone nodules. Tributary to Petroleum Creek, Yolo County, California. USGS Rumsey Quad. (7.5′). T12N; R3W; Section 10. 1.5 miles N35°W of VABM Guinda 1798. Associated planktonic Foraminifera recorded by the writer from this horizon include *Globotruncana arca* (Cushman), *Globotruncana rosetta* (Carsey), *Globotruncana loeblichi* Pessagno, *Rugoglobigerina* sp. aff. *R.*

rugosa (Plummer), *Globotruncana linneiana s.s.* (d'Orbigny), *Globotruncana lapparenti s. s.* Brotzen, and *Gublerina ornatissima* (Cushman and Church). The lack of *Globotruncana hilli* Pessagno and *Globotruncana churchi* Martin in this assemblage suggests an early Campanian (See data presented by Douglas, 1968, p. 154 and Pessagno, 1967, 1969, text-figure 5). *"Inoceramus orientalis"* (identified by D. L. Jones, U. S. Geol. Survey Menlo Park, California) was collected by the writer at NSF 40-B in the lower Forbes ("Dobbins Shale" Member). According to Jones this species is indicative of an early Campanian age. NSF 40-B is situated 295 feet below NSF 55-B.

NSF 291-B. Yolo Formation (upper part of type Yolo at Cache Creek, (north bank) Yolo County). Limestone nodules interbedded with dark gray calcareous mudstones and siltstones; 140 feet below the contact of the Yolo Formation with the overlying Sites Formation. USGS Glascock Mountain Quad. (7.5′); T12N; R4W; Section 2; 0.15 miles downstream from northwest end of Rt. 16 bridge over Cache Creek. An ammonite collected from this locality by the writer and identified by D. L. Jones (USGS, Menlo Park, Calif.) as *"Kossmaticeras* aff. *K. japonicum"* indicates (*fide* Jones) that NSF 291-B is Coniacian in age.

NSF 319-B. Upper part of the Sites Formation at Cache Creek, Yolo County, California. Sample from limestone nodules occurring in gray siliceous mudstones cropping out along Rt. 16. USGS Glascock Mountain Quad. (7.5′); T12N; R4W; Section 2; 0.25 miles due north of Camp Haswell (Boy Scouts of Amer.); about 1961.0 feet above the base of the Sites Formation. A Coniacian ammonite, collected by the writer and identified by D. L. Jones (USGS) as *"Kossmaticeras* aff. *K. japonicum"* has been recovered from the top of the underlying Yolo Formation. Coniacian planktonic Foraminifera (correlative with the *M. renzi* Assemblage Zone of Pessagno, 1967, 1969) have been recovered by the writer from the lower portion of the overlying Funks Formation at nearby Rumsey Canyon.

NSF 327-C. Upper part of the Sites Formation at Cache Creek, Yolo County, California. Sample from limestone nodules occurring in gray siliceous mudstones cropping out along Rt. 16. USGS

Glascock Mountain Quad. (7.5′); T12N; R4W; Section 2; 0.22 miles due north of Camp Haswell (Boy Scouts of Amer.); about 2675.0 feet above the base of the Sites. See biostratigraphic data presented for NSF 319-B.

NSF 350. Limestone nodules from the lower portion of the "Antelope Shale"/"Fiske Creek Formation" cropping out along the north bank of Cache Creek, Yolo County, California. USGS Glascock Mountain Quad. (7.5′); T12N; R4W; Section 4; 0.13 miles S35°W of Rayhouse Road crossing of Cache Creek at "Low Water Bridge". NSF 350 occurs 542 feet above a horizon containing common *Praeglobotruncana stephani* (Gandolfi) and 658 feet below beds containing *Rotalipora greenhornensis* (Morrow) and *Rotalipora appenninica* (O. Renz). NSF 350 likewise occurs 1,047 feet below beds containing *Calycoceras sp.* (late Cenomanian form), *Rotalipora cushmani* (Morrow), *Rotalipora appenninica* (O. Renz), and *Hedbergellla brittonensis* Loeblich and Tappan. (Planktonic foraminiferal identifications are the writer's; ammonite identification by D. L. Jones, U. S. Geological Survey, Menlo Park, California.) The planktonic foraminiferal data indicate that NSF 350 is definitely of Cenomanian age. In that NSF 350 appears to occur below the *R. cushmani* (Morrow) datum point (cf. Text-Figure 2), it is most likely correlative with the *Rotalipora evoluta* Subzone of Pessagno, 1967, 1969. Data presented by Renz, Luterbacher, and Schneider (1963, 1073-1116) indicate that *R. cushmani* makes its first appearance within the upper part of the *Mantelliceras mantelli* Zone (early Cenomanian) of the Neuenburger Jura.

NSF 405. Limestone nodules from the late Cenomanian portion of "Antelope Shale"/"Fiske Creek" Formation; 0.6 miles southwest of Monticello Dam on Route 128; USGS Monticello Dam Quad. (7.5′). T8N; R2W; Section 29. Ammonites identified for the writer from this locality by D. L. Jones (U. S. Geol. Survey, Menlo Park, Calif.) include *Acanthoceras* sp. and *Puzosia* sp. A preliminary report by Jones indicates that the ammonites are of late Cenomanian age.

NSF 432. Venado Formation. Small limestone nodules occurring in dark fissile shales interbedded with massive sandstones. Route 128 near Monticello Dam about 70 feet east of the Solano – Napa County line. NSF 432 is in close proximity to locality UC B – 2040 (cf. Matsumoto, 1960, pp. 37-38) where Turonian ammonites have been recorded (*i.e., Romaniceras* sp. aff. *R. inerme* (de Grossouver). Douglas (personal communication and 1968, p. 169) notes *"Praeglobotruncana" helvetica* (Bolli) from the lower portion of the Venado Formation at Putah Creek.

NSF 440. Yolo Formation. Limestone nodules interbedded with dark gray shales. Monticello Dam Quad. (7.5′); T8N; R2W; Section 28. North side of Putah Creek (Yolo County); mouth of Thompson Canyon; 0.35 miles due east of north end of Monticello Dam.

NSF 450 – NSF 451 – Limestone nodules associated with light gray calcareous mudstones. Upper part of Panoche Group (undifferentiated). Exploration Adit number 1: 110 – 270 feet. California Dept. of Water Resources, Div. of Design and Construction; Del Valle Dam and Reservoir Damsite Foundation Exploration. U. S. Army Corps. of Engineers, Tesla Quad. (15′). Coordinates E 1,639,000; N 408, 250. Associated planktonic Foraminifera at this horizon include *Globotruncana churchi* Martin, *Globotruncana hilli* Pessagno, *Globotruncana linneiana* (d'Orbigny), *Globotruncana arca* (Cushman), *Globotruncana bulloides* Vogler, *Globotruncana rosetta* (Carsey), and *Gublerina ornatissima* (Cushman and Church). Data presented by Pessagno (1967, 1969) indicate that *Globotruncana hilli* Pessagno first appears at the base of the *Globotruncana calcarata* Zonule. Douglas (1968, p. 154) indicated that *G. churchi* is restricted to the late Campanian.

NSF 482. Forbes Formation; lower part of "Dobbins Shale" Member near contact with underlying Guinda Formation. Abundant limestone nodules associated with dark gray mudstones. USGS Brooks Quad. (7.5′); R2W; T10N; Section 30; 0.22 miles N20°E of Big Spring, Yolo County, California. Associated megafossils collected at this locality by the writer and identified by D. L. Jones (USGS, Menlo Park, Calif.) include *"Inoceramus orientalis, Bostrychoceras* sp. and *Anagaudryceras* sp." Jones indicated that the megafossils are of early Campanian age.

NSF 483. Yolo Formation. Horizon of small limestone nodules in a sequence of dark gray mudstones, siltstones, and sandstones. Monticello Dam Quad. (7.5′); T8N; R2W; Section 28. Route 128 (Solano County) at southeast side of horseshoe bend in road; Cold

Canyon; 0.23 miles southwest of Route 128 highway bridge over Putah Creek.

NSF 498-B. "Antelope Shale"/"Fiske Creek Formation". Limestone nodules associated with gray siltstones, mudstones, and sandstones. USGS Monticello Dam Quad. (7.5′). T8N; R2W; Section 29, Napa County, California. 0.31 miles southwest of NSF 405 on Rt. 128.; locality occurs along strike with respect to NSF 405. See megafossils data presented for NSF 405.

NSF 529-B. Forbes Formation: "Dobbins Shale" Member. Light gray mudstones with abundant limestone nodules occurring in 75 foot exposure at Sand Creek, Colusa County. USGS Rumsey Quadrangle (7.5′); R3W; T13N; Section 7. 0.25 miles S20°W of BM 584 near Dobbins Ranch. Ammonites from this section collected by the writer were identified by D. L. Jones (USGS, Menlo Park, Calif.) as "*Patagoisites arbucklensis* (Anderson)". According to Jones they are Campanian in age.

NSF 568-B, 571, 572-B. "Marsh Creek Formation". Samples from limestone nodules interbedded with dark gray siliceous to calcareous mudstones. Antioch South Quad. (7.5′). T1N; R2E; Sect. 32 South bank of Marsh Creek, Deer Valley Road Crossing of Marsh Creek, Contra Costa County, California. NSF 568-B by bridge; NSF 571 and NSF 572-B 0.10 to 0.15 miles downstream from bridge respectively. Associated planktonic Foraminifera present at this horizon include *Globotruncana churchi* Martin, *Globotruncana arca* (Cushman), and *Gublerina ornatissima* (Cushman and Church). Biostratigraphic data from the Putah Creek, Pleasants Valley, and Tesla areas indicate that the radiolarian assemblage present at NSF 658-B, NSF 571, and NSF 572 is assignable to the upper part of the *G. calcarata* Zonule of Pessagno (1967, 1969).

NSF 584. "Antelope Shale"/"Fiske Creek Formation". Limestone nodules occurring in rhythmically bedded sandstones and mudstones/shales. USGS Sites Quad. (7.5′). T17N; R4W; Section 8 (northeast corner); Funks Creek, Colusa County. Cenomanian planktonic Foraminifera have been figured from this locality by Küpper (1956, pp. 40-47, pl. 8) and Douglas (1968, pp. 151-209, pl. 1). The presence of *Rotalipora cushmani* (Morrow) and *Rotalipora greenhornensis* (Morrow) suggests a middle to late Cenomanian age. Ammonites collected by the writer at this outcrop were identified by D. L. Jones (USGS, Menlo Park, California) as "*Calycoeras* sp." Matsumoto (1960, p. 36) recorded middle to late Cenomanian ammonites *Calycoceras boulei* Collignon and *Calycoceras* cf. *stolickai* Collignon from this same locality and other localities in its vicinity.

NSF 641. Yolo Formation – Venado Formation (undifferentiated). Dark gray mudstones, siltstones, and sandstones with limestone nodules. USGS Sites Quad. (7.5′). T17N; R4W; Section 28 (middle) on Sites, Maxwell Road. 0.41 miles N30°W of BM 200.

NSF 644-B. Yolo Formation–Venado Formation (undifferentiated). Gray calcareous and siliceous mudstones interbedded with massive sandstones. USGS Sites Quad. (7.5′). T17N; R4W; Southeast portion of Section 9. Funks Creek (Colusa County); east side of creek; 1.17 miles N4°W of BM 244 in Section 16.

NSF 697. Venado Formation. Thick shale interval interbedded with massive sandstones; sample from limestone nodules in shales. USGS Glascock Mountain Quad. (7.5′); T12N; R4W; Section 3; south bank of Cache Creek, Yolo County; 0.9 miles due west of BM 527 in southern part of Section 2. Early Turonian megafossils (*i.e., Inoceramus labiatus* (Schlotheim) and *Kanabiceras* (?) sp. were collected by the writer from the "Antelope Shale"/"Fiske Creek Formation" 242 feet below the base of the Venado Formation (megafossils identified by D. L. Jones, USGS, Menlo Park, Calif.)

NOTATIONS ON THE INTEGRATION OF RADIOLARIAN RANGE ZONES WITH PLANKTONIC FORAMINIFERAL ZONATION

(1) *Rotalipora evoluta datum (first appearance).* Corresponds to base of *R. evoluta* Subzone (Pessagno, 1967, 1969) which in turn corresponds approximately to the lower part of the *Mantelliceras mantelli* Zone of ammonite workers; earliest Cenomanian.

(2) *Rotalipora cushmani datum (first appearance).* Corresponds to base of *R. cushmani – greenhornensis* Subzone (Pessagno, 1967, 1969) which in turn corresponds to upper part of *Mantelliceras mantelli* Zone of ammonite workers; late early Cenomanian. See Renz, Luterbacher, and Schneider (1963, pp. 1073 – 1116, pls. 1-9).

(3) *Planomalina buxtorfi datum (extinction).* Corresponds to the lower part of *R. cushmani – greenhornensis* Subzone (Pessagno,

ibid.). Data available appear to indicate that this datum point occurs within the *Acanthoceras rhotomagense* Zone (middle Cenomanian) of ammonite workers.

(4) *First appearance of double keeled Globigerinacea.* Corresponds to base of *M. sigali* Subzone (Pessagno, *ibid.)* and to base of *Actinocamax plenus* Subzone in the Anglo-Parisian Basin (Jefferies, 1961, p. 618, pl. 79, figs. 30 a-c). Jefferies considered the *A. plenus* Subzone early Turonian. (See discussion of Cenomanian — Turonian boundary problem in Pessagno, 1969).

(5) *First appearance of double keeled Marginotruncanidae with curved, raised sutures umbilically.* Corresponds to base of *W. archaeocretacea* Subzone (Pessagno, *ibid.).* Impossible at present to integrate precisely with ammonite zonation.

(6) *M. helvetica — M. sigali datum (extinction).* Corresponds to top of *M. helvetica* Assemblage Zone, *W. archaeocretacea* Subzone (Pessagno, *ibid.*). Late Turonian ammonites such as *Prionocyclus, Prionotropis,* and *Coilposceras* occur in the upper part of the *W. archaeocretacea* Subzone. For more detailed discussion see Pessagno (1969).

(7) *Marginotruncanidae datum (extinction).* Corresponds to top of *M. concavata* Subzone (Pessagno, *ibid.*); early Santonian. See Pessagno (1969) for integration of planktonic foraminiferal and megafossil data.

(8) *Globotruncana arca datum (first appearance).* Corresponds to base of *G. fornicata — stuartiformis* Assemblage Zone (Pessagno, *ibid.*); basal Campanian. See Pessagno (1969) for integration of megafossil and planktonic foraminiferal data and for discussion of Santonian — Campanian boundary problem.

(9) *Globotruncana hilli datum (first appearance).* Corresponds to base of *G. calcarata* Zonule of Pessagno *(ibid.)* and to base of *Bostrychoceras polyplocum* Zone of ammonite workers latest Campanian. See Pessagno (1969) for a more detailed discussion.

(10) *Globotruncana linneiana — bulloides datum (extinction).* Corresponds to the top of the *G. fornicata — stuartiformis* Assemblage Zone of Pessagno *(ibid.);* latest early Maestrichtian. No precise data available for the integration of planktonic foraminiferal and megafossil zonation.

(11) *Globotruncana datum (extinction).* Corresponds to top of *G.*

contusa — stuartiformis Assemblage Zone, *A. mayaroensis* Subzone *(Pessagno, ibid.).* No precise data available for the integration of planktonic foraminiferal zonation with megafossil zonation.

SYSTEMATIC DESCRIPTIONS

Phylum PROTOZOA

Subphylum SARCODINA

Class ACTINOPODEA

Subclass RADIOLARIA

Order POLYCYSTIDA

Remarks. — Riedel (1967, p. 291) emended the Polycystida Ehrenberg to include only those Radiolaria having a skeleton comprised of opaline silica lacking admixed organic compounds.

Suborder NASSELLARIINA

Family **NEOSCIADIOCAPSIDAE** Pessagno, new family

Type genus. — *Neosciadiocapsa* Pessagno, n. gen.

Description. — Test microgranular dicyrtid, umbrella or helmet-shaped in longitudinal view; elliptical to circular transversely (Text-fig. 3). Cephalis hemispherical to conical, imperforate or perforate, with or without primary horn (s), secondary horns. A single large tube or pore, termed here the cephalopyle (GK *kephale* = head; *pyle* = gate or entrance) usually occurring posteriorly at or near juncture of vertical cephalic needle with inner wall of cephalis; sometimes replaced by a vertical horn as in *Cassideus,* n. gen. Cephalis with nine cephalic skeletal elements: apical, vertical, median bar, primary right lateral, primary left lateral, dorsal, secondary right lateral, secondary left lateral, and axial (see Pl. 24, fig. 1); apical, vertical, primary right lateral, primary left lateral, dorsal, secondary left lateral, and secondary right lateral elements tending to trifurcate near their juncture with wall of cephalis. Cephalic skeletal elements dividing base of cephalis into six collar pores. Poorly developed to pronounced collar stricture. Thorax conical to cylindrical in shape proximally; flaring to form a narrow to broad thoracic skirt distally; thoracic pore frames, variable in size; polygonal to circular to elliptical often arranged in concentric rows. Thoracic mouth usually covered by a convex to planiform to cylindrical plate termed the thoracic velum (See Pl. 23, fig. 9): velum perforate to imperforate with or without accessory aperture (s). Cephalis and proximal portion of thorax frequently covered by secondary layer of epithecal deposits which tend to obscure primary meshwork (*e.g.*, Pl. 32, figs. 6, 7).

Remarks. — The Neosciadiocapsidae, n. fam. are characterized (1) by the type, number, and structure of their cephalic skeletal needles (2) by their helmet-shaped tests (3) by the presence of a thoracic velum and (4) usually by the presence of a cephalopyle. At present, the family includes the following genera: *Cassideus* Pessagno, n. gen.; *Coniforma* Pessagno, n. gen.*; *Ewingella* Pessagno, n. gen. *Lipmanium* Pessagno, n. gen., *Microsciadiocapsa* Pessagno, n. gen.; *Neosciadiocapsa* Pessagno, n. gen.; *Petasiforma* Pessagno, n. gen.; *Sciadiocapsa* Squinabol; *Scyphiforma* Pessagno, n. gen.; and *Squinabolella* Pessagno, n. gen.

It is difficult, if indeed not impossible, to relate the Neosciadiocapsidae to Haeckelian classification. Haeckel (1887) emphasized the number of chambers present in the "Cyrtoid" test (*e.g.*, monocyrtid vs. dicyrtid vs. tricyrtid) as the underlying criterion in his classification. Utilizing this criterion one would first have to decide whether the forms considered in this report are dicyrtid or tricyrtid — a subjective decision which in itself is difficult to make If one assumes the Neosciadiocapsidae are dicyrtid (and lack radial apophyses), by Haeckelian classification, he is forced to correlate them with Haeckel's (*ibid.*, pp. 1288, 1289) "Sethocyrtida". The Neosciadiocapsidae differ from the "Sethocyrtida" in the detailed structure of their cephalic skeletal elements, by usually possessing a cephalopyle (or where absent a vertical horn), by possessing a distinctive umbrella or hat-shaped test, and by possessing a thoracic velum. On the other hand, if one assumes that the Neosciadiocapsidae are tricyrtid by Haeckelian classification, he is forced to correlate them with Haeckel's (*ibid.* pp. 1365, 1366) "Phormocyrtida". Although some "Phormocyrtid" genera such as *Clathrocyclas (Clathrocycloma)* display similar test shapes to those of the Neosciadiocapsidae, they differ from neosciadiocapsid genera

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**Note: Coniforma* is only tentatively placed in the *Neosciadiocapsidae.*

by lacking a thoracic velum, a cephalopyle, and in the detailed structure of their cephalic skeletal elements (*e.g.*, neosciadiocapsids display cephalic skeletal bars that trifurcate upon infringing on the cephalic wall).

Most recent workers such as Riedel (1958, 1967); Petrushevskaya (1964, 1965); and Goll (1968) have stressed the importance of cephalic structure in the classification of "Cyrtoid" Nassellariina. Once the cephalic skeletal elements of "Cyrtoid" Nassellariina have been more thoroughly studied, it should be possible to place the Neosciadiocapsidae within their proper phylogenetic framework. It is probable that a classification based on cephalic structure will completely transgress Haeckelian classification. Riedel's (1967 and in press) recent classification, though somewhat abbreviated, forms the nucleus of a more phylogenetic classification. His treatment of the "Cyrtoid" Nassellarina is largely based on cephalic structure. The Artostrobiidae Riedel (1967, p. 296), though dissimilar to the Neosciadiocapsidae, n. fam., in terms of test shape and lacking a thoracic velum, do possess a cephalopyle and analogous cephalic skeletal elements.

The presence of a neosciadiocapsid-like species, *"Clathrocyclas" reginae* Rüst, in the Jurassic of Germany suggests that this family has a lengthy geologic history. Furthermore, although no Neosciadiocapsidae have been found to date in Early Cretaceous deposits, their diversification and abundance during early Cenomanian times suggests that they had undergone a considerable amount of change during the Early Cretaceous (cf. Text-fig. 2). During the Late Cretaceous the Neosciadiocapsidae seem to have enjoyed their greatest development during the Cenomanian, Turonian, and Coniacian times. It would appear that they gradually declined and finally became extinct by Eocene times.

Range.—Jurassic?; Lower Cretaceous?; Upper Cretaceous (Cenomanian) to Lower Tertiary (Eocene).

Occurrence.—Upper Cretaceous and Eocene of California Coast Ranges at numerous localities. Cretaceous of Italy. ?Jurassic of Germany.

Genus **CASSIDEUS** Pessagno, n. gen.

Type species.—*Cassideus riedeli* Pessagno, n. sp.

Description. — Test microgranular, dicyrtid, helmet-shaped about half as high as wide. Cephalis hemispherical with two long primary horns: an apical horn and a vertical horn; horns triradiate in cross-section with three longitudinal grooves, three prominent apical pores present at base of each horn in position of grooves. Series of dendritic ridges (see Pl. 25, figs. 3-5, 7, 8) radiate downwards from horns over most of cephalis. Perforations in cephalis small, circular; dispersed irregularly between dendritic ridges. Cephalic skeletal elements rodlike, circular in transverse section; divide cephalis into six colar pores (see Pl. 27, fig. 1). Cephalopyle lacking on both the type species and *C. yoloensis,* n. sp. Thorax proximally quite conical; distally flaring to form broad thoracic skirt. Thoracic wall coarsely perforate; pore frames subhexagonal proximally; becoming heagonal distally. Thoracic velum not observed though probably present on well-preserved specimens.

Remarks. — *Cassideus,* n. gen., differs from all other Neosciadiocapsidae genera, (1) by possessing two primary horns; an apical horn and a vertical horn and (2) by lacking a cephalopyle.

Cassideus (Latin) = helmet-shaped.

Range. — Early Cenomanian.

Occurrence. — Great Valley Sequence of California.

Cassideus riedeli Pessagno, n. sp. Pl. 25, figs. 1-8; Pl. 27, fig. 1

Description. — Pore frames subhexagonal to circular proximally; become larger and markedly hexagonal distally. Both proximal and distal portions of thorax covered by a series of staggered, prominent, concentric ridges. Thoracic velum not observed on specimens under study.

Remarks. — *Cassideus riedeli,* n. sp., differs from *Cassideus yoloensis,* n. sp., by the possession of numerous concentric ridges on its thorax. Furthermore, the proximal portion of the thorax (above thoracic skirt) of *C. riedeli,* n. sp., is more rounded and not so perfectly coniform as that of *C. yoloensis.* The peculiar staggered nature of the concentric ridges seems to be present only on the proximal portion of the thorax (see Pl. 25, fig. 3).

Cassideus riedeli, n. sp., is named for William R. Riedel (Scripps Institution of Oceanography) in honor of his numerous contributions to the study of Cenozoic Radiolaria.

Type locality. — NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *C. riedeli,* n. sp., will be deposited in the collections of the U. S. National Museum, Washington, D. C. The paratypes will be deposited at the U. S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164218
Paratypes = USNM 164219 - 164221

Range. — Early Cenomanian. There is no evidence to indicate that *C. riedeli* does not occur in the Albian. The Albian was not extensively studied during this project.

Occurrence. — See Text-figure 5.

Cassideus yoloensis Pessagno, n. sp. Pl. 25, figs. 9-12; Pl. 26, figs. 1-3

Description. — Cephalis conical. Cephalic skeletal elements rod-like; similar to those of *C. riedeli,* n. sp. Thorax above thoracic skirt markedly conical; slight change in slope of proximal portion of thorax about in position of single ridge which extends around thorax. Distal portion of thorax flaring to form well-developed, broad thoracic skirt. Pore frames on proximal portion of thorax subhexagonal to circular; becoming rapidly hexagonal distally. Thoracic velum not observed on specimens thus far encountered.

Remarks. — *Cassideus yoloensis,* n. sp., differs from *C. riedeli,* n. sp., by having a much more conical test and by lacking the numerous concentric ridges characteristic of *C. riedeli. Cassideus yoloensis,* n. sp., is named for Yolo County, California.

Type locality. — NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *C. yoloensis,* n. sp., will be deposited in the collections of the U. S. National Museum, Washington, D.C. The paratypes will be deposited in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas, and at the U. S. National Museum.

Holotype = USNM 164222
Paratype = USNM 164223

Range. — Early Cenomanian. There is no evidence to indicate that *C. yoloensis* does not occur in Albian strata. The Albian was not extensively sampled during this sutdy.

Occurrence. — See Text-figure 5.

Genus **CONIFORMA** Pessagno, n. gen.

Type species. — *Coniforma antiochensis* Pessagno, n. sp.

Description. — Test microgranular, dicyrtid, cone-shaped. Cephalis globular, elliptical transversely with anteriorly placed long, massive apical horn; horn triradiate in transverse section near its junction with the cephalis largely due to presence of three prominent apical pores; horn becoming circular in transverse section toward its proximal end. Perforations in cephalis small, irregularly shaped and dispersed. Cephalic skeletal elements massive, somewhat bladelike; divide base of cephalis into six collar pores (Pl. 38, fig. 1); secondary and primary lateral bars merging with prominent shelflike ridge which tends to frame the cardinal and cervical collar pores along the cephalic wall. Cephalopyle posterior; an elongate moderately, well-developed tube, directed somewhat distally (downwards). Collar stricture well-developed marked difference between finely and sparsely perforate wall of cephalis and coarsely perforate thorax. Thorax conical proximally; distally becoming cylindrical; eventually flaring to form small thoracic skirt. Thoracic velum not observed on numerous specimens; probably missing.

Remarks. — *Coniforma,* n. gen., is tentatively included with the Neosciadiocapsidae, n. fam. Although its cephalic skeletal elements are similar to those of other neosciadiocapsid genera, *Coniforma,* n. gen., displays a prominent shelflike cephalic ridge which tends to frame the cardinal and cervical collar pores along the cephalic wall. An examination of numerous well-preserved specimens of the type species of *Coniforma* appears to indicate that *Coniforma* lacks a thoracic velum. Furthermore, *Coniforma* differs from all other neosciadiocapsid genera by possessing a narrow thoracic skirt. It is conceivable that *Coniforma* is more closely related to species described by Foreman (1968, pp. 46-48) from the Maestrichtian of California as *?Clathrocyclas diceros* Foreman, *?C. lepta* Foreman, and *?C. hyronia* Foreman. Foreman *(ibid.)* stated that all three of the forementioned species possess six collar pores and that their jugular pores are extremely small. *Coniforma antiochensis,* n. sp. (See Pl. 38, fig. 1) likewise possesses extremely small jugular pores;

like *Coniforma antiochensis* all three of Foreman's species possess what is called herein a cephalopyle. The axial spine of *C. antiochensis* like those of Foreman's species is rudimentary and often difficult to see. All cephalic skeletal bars of *C. antiochensis* trifurcate when they join the cephalic wall. Trifurcation of analogous cephalic skeletal bars has not been documented on Foreman's three species. This, however, is a feature common to all Neosciadiocapsidae.

Range. — Latest Campanian. There is no evidence available at present to indicate that *Coniforma* does not range into the Maestrichtian.

Occurrence. — "Marsh Creek Formation" of Contra Costa County.

Coniforma antiochensis Pessagno, n. sp. Pl. 37, figs. 9-12; Pl. 38, fig. 1

Description. — As with genus except as follows: Marked difference between sparsely perforate wall of cephalis and coarsely perforate wall of thorax. Pore frames of thorax large, subhexagonal to nearly circular in aspect.

Remarks. — See remarks under genus.

Type locality. — NSF 568-B. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *C. antiochensis,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. The paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164264
Paratypes = USNM 164265-164267

Range. — As for genus.

Occurrence. — See Text-figure 5.

Genus **EWINGELLA** Pessagno, n. gen.

Type species. — *Ewingella jonesi* Pessagno, n. sp.

Description. — Test microgranular, hat-shaped, dicyrtid. Cephalis hemispherical often rugose with well-developed sparsely perforate epithecal covering. Single, large to medium-sized triradiate primary (apical) horn with three pocket-like apical pores (Pl. 28, fig. 3). Cephalopyle posterior in position; a large tube directed upwards with bladelike partition which probably represents trifurcating terminal portion of vertical cephalic needle (Pl. 28, fig. 7). Cephalic skeletal needles rodlike; divide base of cephalis into six collar pores. Collar stricture weakly developed to moderately well developed. Thorax conical to subconical proximally; flaring distally to form a broad thoracic skirt. Thoracic velum sparsely perforate, planiform to slightly convex in a distal direction, completely covering thoracic mouth.

Remarks.—*Ewingella,* n. gen., differs from *Lipmanium,* n. gen., (1) by possessing a triradiate horn (lacking prominent apical bridges) with three pocket-like apical pores and (2) by having a velum which completely covers the mouth of the thorax. Both genera possess bladelike partitions in their cephalopyles. Foreman (1968, p. 7) noted the latter feature in her Maestrichtian forms.

Ewingella, n. gen., is named for Dr. Maurice Ewing, (Lamont Geological Observatory) in honor of his many contributions to oceanography, geology, and geophysics.

Range.—Early Cenomanian. Range may extend into Albian. Albian not extensively sampled during this study.

Occurrence.—Great Valley Sequence of California Coast Ranges.

?**Ewingella capayensis** Pessagno, n. sp. Pl. 29, figs. 1-3, 6

Description.—Test as with genus except as follows: Collar stricture poorly developed. Cephalis with slightly perforate epithecal covering which extends downwards to proximal portion of thorax. Thoracic pores frames concentric, hexagonal proximally; often becoming somewhat rectangular near the margin of the thoracic skirt. Thoracic velum fragmentary.

Remarks.—*E. capayensis,* n. sp. differs from *E. jonesi,* n. sp., (1) by having a test which is proportionately lower in relief and (2) by having a uniformly sized, markedly concentric thoracic meshwork.

E. capayensis, n. sp., is named for the Capay Valley, Yolo County, California.

This species is questionably placed within *Ewingella* in that the structure of its thoracic velum and cephalopyle are not well substantiated at the present time.

Type locality. — NSF 350. See Locality Description and Text-figure 5.

Deposition of types. — The holotype of *?E. capayensis,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. Paratypes will be deposited in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164236

Range. — Early Cenomanian. — Range may extend into Albian. Albian not extensively sampled during this study.

Occurrence. — See Text-figure 5.

Ewingella guindaensis Pessagno, n. sp. Pl. 29, figs. 4, 5, 7, 8

Description. — Test as with genus except as follows: Collar stricture weakly developed. Sparsely perforate epithecal covering extending distally from cephalis to proximal portion of thorax. Thorax proximally subconical, coarsely perforate with hexagonal pore frames; flaring distally to form much smaller elliptical pores which are better developed posteriorly than anteriorly. Thoracic mouth with subcircular rim. Thoracic velum planiform, depressed; coarsely perforate along its juncture with rim surrounding mouth; remainder of velum with sparse, irregularly distributed small pores.

Remarks. — *Ewingella guindaensis* Pessagno, n. sp., differs from *E. jonesi* (1) by its lower relief (2) by its smaller size (3) by the presence of small, sparse, irregularly distributed elliptical pores on its thoracic skirt (4) by the marked decrease in thoracic pore size in a distal direction; and (5) by the depressed nature of its thoracic velum.

E. guindaensis is named for the town of Guinda, Yolo County, California.

Type locality. — NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *E. guindaensis,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. The paratypes will be deposited in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164237

Range. — Early to middle or late Cenomanian.

Occurrence. — See Text-figure 5.

Ewingella jonesi Pessagno, n. sp. Pl. 27, fig. 2; Pl. 28, figs. 1-7

Description. — Test as with genus except as follows: Cephalis rugose with well-developed imperforate epithecal covering. Individual rays of triradiate horn knifelike in aspect; terminating in weakly developed apical ridges. Collar stricture moderately well developed. Thorax subconical proximally; partially covered by secondary epithecal layer extending down from cephalis; flaring distally to form a broad thoracic skirt. Thoracic pore frames, concentric, rounded to hexagonal, rapidly increasing in size in a distal direction. Larger specimens like holotype developing one or two final rings of smaller rectangular frames at the edge of skirt. Thoracic velum sparsely perforate, slightly convex in a distal direction.

Remarks. — *Ewingella jonesi,* n. sp., differs from *?E. capayensis,* n. sp., by having somewhat coarser meshwork and somewhat greater length.

E. jonesi, n. sp., is named after D. L. Jones (U.S. Geol. Survey, Menlo Park, California) in honor of his contributions to the geology of the California Coast Ranges.

Type locality. — NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *E. jonesi,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D. C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164228

Paratypes = USNM 164229; 164227

Range. — Early Cenomanian. Range may extend into Albian. Albian not extensively sampled during this study.

Occurrence. — See Text-figure 5.

Genus **LIPMANIUM** Pessagno, n, gen.

Type species. — *Lipmanium sacramentoensis* Pessagno, n. sp.

Description. — Test microgranular, hat-shaped, dicyrtid. Cephalis hemispherical often rugose or spinose with secondary epthecal covering which is largely imperforate. Single long apical horn with three radially arranged apical bridges at its base; apical bridges separating three prominent apical pores (Pl. 26, fig. 6). Cephalopyle large, tubular with bladelike partition which represents portion of trifurcating terminal part of vertical cephalic skeletal needle (Pl. 26, fig. 5). Cephalic skeletal needles typically rodlike; divide base of cephalis into six collar pores. Collar stricture poorly developed. Thorax conical proximally; flaring distally to form well-developed thoracic skirt. Velum a crescent-shaped plate covering about half of thoracic mouth; largely imperforate.

Remarks.—*Lipmanium,* n. gen., differs from *Neosciadiocapsa,* n. gen., by its possession of (1) an apical horn with three prominent, radially arranged apical bridges (2) a bladelike partition in its cephalopyle and (3) an imperforate, crescent-shaped velum. The presence of a bladelike partition in its cephalopyle may indicate that *Lipmanium* is phylogenetically linked to *Microsciadiocapsa,* n. gen.

Lipmanium is named for Dr. R. K. Lipman in honor of her many contributions to the study of the Upper Cretaceous Radiolaria of the USSR.

Range.—Early Cenomanian. Range may extend into Albian. Albian not extensively studied during present project.

Occurrence.—Great Valley Sequence of the California Coast Ranges.

Lipmanium sacramentoensis Pessagno, n. sp. Pl. 26, figs. 4-12

Description.—Test as with genus except as follows: Cephalis largely imperforate due to secondary epithecal covering; hemispherical in shape; somewhat rugose and spinose. Single long apical horn which is circular in cross-section. Thoracic skirt with large subhexagonal to nearly circular pore frames. Proximal portion of thorax with rather pronounced spines; meshwork partly obscured by secondary epithecal layer.

Remarks.—*Lipmanium sacramentoensis,* n. sp. differs from *Neosciadiocapsa diabloensis,* n. sp. (1) by possessing a bladelike partition in its cephalopyle (2) by possessing a primary (apical) horn which is circular in cross-section and has three pronounced apical bridges (3) by being lower in relief (length) (4) by having a proportionately wider thoracic skirt; and so forth.

Lipmanium sacramentoensis, n. sp., is named for Sacramento, California.

Type locality. — NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *L. sacramentoensis,* n. sp. will be deposited in the collections of the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164224
Paratypes = USNM 164225-164226

Range. — Early Cenomanian. No evidence to deny an extension of range zone into Albian. Albian not extensively sampled during this project.

Occurrence. — See Text-figure 5. Probably reworked into NSF 697 (M. Turonian).

Genus **MICROSCIADIOCAPSA** Pessagno, n. gen.

Type species. — *Microsciadiocapsa monticelloensis* Pessagno, n. sp.

Description. — Test microgranular, hat-shaped, dicyrtid. Cephalis hemispherical, smooth to punctuate; imperforate with short primary (apical) horn which may be secondarily double (e.g., Pl. 32, figs. 4, 5). Apical horn often with single anteriorly directed apical bridge separating two to four apical pores (e.g. Pl. 33, fig. 2) which are also situated towards the anterior side of horn (toward point *a;* see Text-figure 3). Cephalopyle posterior in position; large, tubular always divided internally by bladelike partition; bladelike partition representing portion of trifurcating part of vertical spine (Pl. 32, fig. 9). Cephalic skeletal needles typically massive, bladelike; divide base of chepalis into six collar pores (cf. Pl. 30, figs. 1, 2; Pl. 34, figs. 1, 2). Collar stricture weakly to strongly developed. Thorax subconical to cylindrical proximally; flaring to form thoracic skirt distally. Thoracic velum an imperforate to slightly perforate sheet covering thoracic mouth; planiform or slightly convex in distal direction; lacking accessory apertures.

Remarks. — *Microsciadiocapsa,* n. gen., differs from *Neosciadiocapsa,* n. gen., and *Squinabolella,* n. gen., (1) by the nearly imperforate and planiform character of its thoracic velum (2) by the presence of a bladelike partition in its cephalopyle and (3) by having an apical horn with two to four anteriorly placed apical pores.

Range. — Cenomanian to Coniacian.

Occurrence. — Great Valley Sequence of the California Coast Ranges.

Microsciadiocapsa berryessaensis Pessagno, n. sp. Pl. 31, figs. 8-12

Description. — Test as with genus. Elliptical in transverse section. Cephalis imperforate, often somewhat rugose; hemispherical in shape with single short apical horn lacking apical bridge, but showing a triad of apical pores; apical pores separated by thin-walled partitions; situated at base of horn (Pl. 31, figs. 10-12). Poorly developed collar stricture. Thorax conical proximally. Thoracic pore frames large, circular, elliptical, to subhexagonal proximally becoming irregular and often minute on thoracic skirt; portions of skirt almost imperforate.

Remarks. — *M. berryessaensis,* n. sp. differs from *M. monticelloensis,* n. sp. (1) by its more elliptical outline in transverse section (2) by possessing a triad of apical pores (3) by having a horn which is single rather than double and (4) by having more irregularly shaped and dispersed thoracic pore frames which are often minute particularly on the thoracic skirt.

This species is named for Lake Berryessa, Napa County, California.

Type locality. — NSF 483. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *M. berryessaensis,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164240
Paratype = USNM 164241

Range. — Late Turonian/Coniacian - Coniacian.

Occurrence. — See Text-figure 5.

Microsciadiocapsa cortinaensis Pessagno, n. sp. Pl. 32, figs. 1, 2

Description. — Test as with genus. Cephalis imperforate, somewhat roughened, hemispherical in shape with single apical horn; horn triangular in cross section basally; titled somewhat anteriorly. (Pl. 32, fig. 2). Weakly developed collar stricture. Thorax conical proximally. Thoracic pore frames circular, sparse proximally; becoming hexagonal and eventually rectangular toward the periphery of thoracic skirt. Thoracic skirt with irregular shelflike structure on its inner portion.

Remarks. — *M. cortinaensis,* n. sp., differs from *M. monticelloensis,* n. sp., by having four rather than three anteriorly placed apical pores and by having a more massive and less perforate test. This species is named for Cortina Ridge in the USGS Glascock Mt. Quadrangle (7.5′).

Type locality. — NSF 319-B. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *M. cortinaensis,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. The paratypes will be deposited in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164242

Range. — Coniacian.

Occurrence. — See Text-figure 5.

Microsciadiocapsa lipmanae Pessagno, n. sp. Pl. 28, figs. 8-12; Pl. 30, figs. 1, 2; Pl. 31, figs. 1-3

Description. — Test as with genus except as follows: Cephalis imperforate highly rugose, conical; rounded in its apical portion. Apical horn, short; circular in cross-section except at its base where it tends to become triradiate; horn with well-developed apical bridge separating two apical pores (Pl. 31, figs. 1, 2). Marked shelflike collar stricture between cephalis and thorax; usually defined externally by presence of circumferential ridge; weak ridges extend distally from base of cephalis to shelflike stricture, merging with circumferential ridge where present. Proximal portion of thorax (above thoracic skirt) nearly cylindrical in shape; thoracic skirt markedly planiform. Thoracic meshwork consisting of coarse hexagonal frames of uniform size. Thoracic velum slightly convex in a distal direction; finely perforate (Pl. 28; fig. 8).

Remarks. — *Microsciadiocapsa lipmanae,* n. sp., differs from all other species of *Microsciadiocapsa* (1) by the shelflike nature of its collar stricture and (2) by the cylindrical character of the proximal portion (above thoracic skirt) of its thorax. This species is named for R. K. Lipman in honor of her many contributions to the study of Cretaceous Radiolaria.

Type locality. — NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *M. lipmanae,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164232

Paratypes = USNM 164230-164231; 164233-164235

Range. — Early Cenomanian. Range zone may extend into Albian. Albian not extensively sampled during this study.

Microsciadiocapsa madisonae Pessagno, n. sp. Pl. 33, figs. 11-12; Pl. 35, figs. 1-4; Pl. 36, fig. 2

Description. — Test as with genus for most part, but tending to have an overall bowl-shaped appearance. Cephalis on well-preserved specimens with rugose epithecal layer tending to mask large irregularly shaped pore frames. Apical horn subtriangular in transverse section often tending to be markedly tilted in an anterior direction; horn with short apical bridge terminating anteriorly in a pronounced subsidiary spine. Apical bridge separating two apical pores (Pl. 33, fig. 11). Collar stricture poorly developed. Proximal portion of thorax conical with large, irregular polygonal pore frames. Thoracic skirt with smaller, concentrically arranged, rectangular to subrectangular pore frames. Thoracic velum fragmentary; poorly known.

Remarks. — *M. madisonae,* n. sp., differs from *M. monticelloensis,* n. sp., by (1) possessing a thoracic skirt with small, concentrically arranged, rectangular to subrectangular pore frames (2) in the large irregular pore frames comprising the proximal portion of its thorax and (3) by the highly perforate character of its cephalis. It differs from all other species of *Microsciadiocapsa* by the second character cited above.

This species is named for Mrs. Winifred Madison, Davis, California, in honor of her many contributions as an illustrator of Cretaceous microfossils.

Type locality. — The holotype of *M. madisonae,* n. sp., is from NSF 483. Paratypes are from NSF 483, NSF 427-C, and NSF 291-C. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *M. madisonae,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. The paratypes will be deposited in the collections of the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164253
Paratype = USNM 164254

Range. — Late Turonian/Coniacian — Coniacian.

Occurrence. — See Text-figure 5.

Microsciadiocapsa monticelloensis Pessagno, n. sp. Pl. 32, figs. 3-9; Pl. 34, figs. 1, 2

Description. — Test as for genus except as follows. Cephalis with short, double, V-shaped apical horn (having two apical pores) (see Pl. 32, figs. 4-5). Collar stricture weakly developed. Layer of epithecal material extends down from cephalis onto proximal portion of thorax, tending to mask thoracic meshwork (Pl. 32, figs. 3, 6, 7). Thoracic meshwork coarse; pore frames subhexagonal to circular. Some specimens with concentric, discontinuous ridges on proximal portion of thorax just above thoracic skirt. Thoracic velum imperforate, sheetlike, slightly convex in a distal direction; (Pl. 32, fig. 8).

Remarks. — *M. monticelloensis,* n. sp. differs from *M. radiata,* n. sp. (1) by lacking a coarsely punctate cephalis (2) by lacking radial bars extending from the proximal portion of the cephalis to the middle of the thoracic skirt and (3) by having a double, V-shaped apical horn. *M. monticelloensis,* n. sp., differs from *M. berryessaensis,* n. sp., by having two rather than three apical pores; by having a double rather than a single apical horn; and by having coarse, regularly arranged pore frames comprising its thoracic skirt.

Type locality. — NSF 483. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype and *M. monticelloensis,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164243

Paratypes = USNM 164244-164247

Range. — Middle Turonian to Coniacian.

Occurrence. — See Text-figure 5.

Microsciadiocapsa radiata Pessagno, n. sp. Pl. 32, figs. 10-12; Pl. 33, figs. 1, 2

Description. — Test as with genus except as follows. Cephalis imperforate, coarsely rugose with small triradiate apical horn having anteriorly directed apical bridge which separates two apical pores (see Pl. 33; fig. 2). Collar stricture weakly developed. Thoracic meshwork subhexagonal to elliptical or circular both proximally and distally. Holotype with 25 radial bars extending down from lower row of pore frames on proximal portion of thorax onto thoracic skirt; overlay of bars lending a pseudorectangular appearance to pore frames of thoracic skirt.

Remarks. — *Microsciadiocapsa radiata,* n. sp., differs from *M. monticelloensis,* n. sp. (1) by having a coarsely rugose cephalis (2) by having radial bars extending downwards from the proximal portion of the thorax to the middle of the thoracic skirt and (3) by having a single apical horn with an apical bridge. *M. radiata* closely resembles *M. lipmanae,* n. sp., in the type of ornamentation and shape of its cephalis and in the character of its apical pores, apical horn, and apical bridge. (cf. Pl. 31, figs. 1-3; Pl. 33, figs. 1, 2).

Type localities. — The holotype and one paratype of *M. radiata* are from NSF 327-C. Two paratypes are from NSF 319-B. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *M. radiata,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. The paratypes will be deposited in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164248

Range. — Coniacian.

Occurrence. — See Text-figure 5.

Microsiadiocapsa sutterensis Pessagno, n. sp. Pl. 29, fig. 9; Pl. 31, figs. 4-7

Description.—Test as with genus except as follows: Cephalis similar in shape and ornamentation to those of *M. radiata,* n. sp. and *M. lipmanae,* n. sp. Apical horn small with bladelike apical bridge separating two small apical pores. Collar stricture weakly developed. Slightly perforate epithecal layer extending in a distal direction from cephalis to the thorax (near juncture with thoracic skirt). Thorax subconical proximally; flaring to form a very broad, planiform thoracic skirt; thoracic skirt with rectangular pore frames of uniform size; pore frames arranged concentrically. Thirteen to 16 radially arranged barlike structures extending distally to thoracic skirt. Thoracic mouth small relative to size of thoracic skirt. Thoracic velum planiform; sparsely perforate.

Remarks.—*Microsciadiocapsa sutterensis,* n. sp., differs from all other neosciadiocapsid species by its possession of concentrically arranged rectangular pore frames and by the small size of its thoracic mouth relative to the width of its thoracic skirt.

This species is named for the Sutter Buttes in the Sacramento Valley.

Type locality.—NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types.—The holotype of *M. sutterensis,* n. sp. will be deposited in the collections of the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164239

Paratypes = USNM 164238, 164255

Range.—Early Cenomanian. Range zone may extend into Albian. Albian not extensively sampled during the present study.

Occurrence.—See Text-figure 5. Turonian occurrence at NSF 697 is believed to be due to reworking. Such a conclusion is supported by the physical stratigraphy of the lower part of the Venado Formation.

Genus **NEOSCIADIOCAPSA** Pessagno, new genus

Type species.—*Neosciadiocapsa diabloensis* Pessagno, n. sp.

Description.—Test microgranular, dicyrtid, helmet-shaped in longitudinal view; elliptical transversely. Cephalis conical with long, massive apical horn. Horn triradiate in transverse section with three longitudinally placed grooves; three prominent apical pores present at base of triradiate horn in position of grooves. Perforations in cephalis small, irregularly shaped and dispersed. Cephalic skeletal needles dividing base of cephalis into six collar pores. Cephalopyle tubular when well preserved; circular in cross-section. Thorax conical proximally; distally subcylindrical; eventually flaring to form broad thoracic skirt. Thoracic velum highly arched, convex in a distal direction with row of large irregularly shaped polygonal pores near its junction with thoracic skirt; pores in velum distally irregularly shaped and dispersed.

Remarks. — *Neosciadiocapsa,* n. gen., differs from *Sciadiocapsa* Squinabol by possessing a long, massive triradiate apical horn with three apical pores at its base. It differs from *Microsciadiocapsa,* n. gen. in the structure of its apical horn and position of its apical pores; by lacking a partition in its cephalopyle; and by having a highly arched thoracic velum with much larger pores.

Range. — Late Campanian.

Occurrence. — To date *Neosciadiocapsa* has only been encountered in the late Campanian portion of the Panoche Group of Alameda County, California.

Neosciadiocapsa diabloensis Pessagno, n. sp. Pl. 35, figs. 3-10; Pl. 36, fig. 1

Description. — Test as with genus except as follows: Poorly developed collar stricture. Marked difference between finely and sparsely perforate wall of cephalis and coarsely perforate thorax. Thorax and thoracic skirt with large, hexagonal frames arranged in a concentric fashion; pore frames gradually enlarging distally, reaching largest size on thoracic skirt; last row of pores of gerontic individuals, the exception, being smaller in size and in subhexagonal in shape.

Remarks. — This species differs from other neosciadiocapsids by the character of its thoracic velum and primary (apical) horn. *N. diabloensis* is named for Mt. Diablo, Contra Costa County, California.

Type locality. — NSF 451. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *N. diabloensis* Pessagno will be deposited in the collections of the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164257

Paratypes = USNM 164256, 164258

Range. — Late Campanian.

Occurrence. — See Text-figure 5.

Genus **PETASIFORMA** Pessagno, new genus

Type species. — *Petasiforma foremanae* Pessagno, n. sp.

Description. — Test microgranular, dicyrtid, hat-shaped. Cephalis hemispherical, imperforate, rather small, lacking primary horns, but possessing numerous secondary horns. Cephalic skeletal elements rodlike to somewhat bladelike dividing the cephalis into six colar pores (see Pl. 24; figs. 1, 2). Cephalopyle prominent tube. Well to poorly developed stricture. Thorax subconical proximally; flaring distally to form broad, convexly arched thoracic skirt. Thorax coarsely perforate; pore frames variable in shape. Thoracic velum present on well-preserved specimens.

Remarks. — *Petasiforma,* n. gen., differs from *Neosciadiocapsa,* n. gen., by lacking a primary horn with apical pores and by possessing secondary horns. It differs from *Cassideus,* new genus, by lacking two primary horns with apical pores and by showing a well-developed cephalopyle.

Petasus (Latin, M.) = a broad brimmed felt hat worn by travellers + *forma* (Latin, F.) = form.

Range. — Cenomanian.

Occurrence. — Great Valley Sequence of California Coast Ranges.

Petasiforma foremanae Pessagno, n. sp. Pl. 23, figs. 6-10; Pl. 24, fig. 2

Description. — Test as with genus except as follows: Cephalis possessing a few secondary horns. Well-developed collar stricture. Thoracic pore frames subhexagonal, circular to elliptical proximally; gradually increasing in size distally. Gerontic specimens with proliferation of markedly smaller rectangular frames on skirt periphery (Pl. 23, figs. 7, 8). Thoracic velum, finely perforate, dome-shaped, convex downwards with a large, centrally placed circular accessory aperture; velum somewhat spongy in character.

Remarks.—*P. foremanae,* n. sp., differs from *P. glascockensis,* n. sp., (1) by having a coarser, more open thoracic meshwork (2) by having a narrower, more convex thoracic skirt (3) by having a smaller cephalopyle (4) by lacking concentric ribbing and (5) by having a cephalis with fewer secondary horns.

This species is named after Helen P. Foreman, Department of Geology, Oberlin College, in honor of her contributions to the study of Cretaceous radiolaria.

Type locality.—NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types.—The holotype of *P. foremanae,* n. sp., will be deposited at the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164216
Paratypes = USNM 164212-164215, 164217

Range.—Early to late Cenomanian. Range may extend into Albian. Albian not extensively sampled during this study.

Occurrence.—See Text-figure 5.

Petasiforma glascockensis Pessagno, n. sp. Pl. 23, figs. 1-5; Pl. 24, fig. 1

Description.—Test microgranular, dicyrtid, hat-shaped. Cephalis imperforate, hemispherical, rather small; lacking primary horns, but possessing numerous secondary horns. Cephalic skeletal elements slender, rodlike; (see Pl. 24, fig. 1). Poorly developed collar stricture. Thorax quite spinose proximally. Pore frames small, subhexagonal distally; often becoming spatulate or subrectangular on margin of skirt. Pore frames separated by series of well-developed concentric ridges which are better developed on the proximal portion of the thorax and which weaken in the middle of the thoracic skirt. Thoracic velum thus far not observed in its entirety.

Remarks.—*P. glascockensis,* n. sp., differs from *P. foremanae,* n. sp., by virtue of (1) its finer meshwork with hexagonal pore frames (2) numerous concentric ribs (3) more highly spinose cephalis and upper thorax (4) larger cephalopyle (5) broader thoracic skirt and (6) its generally lower relief (length).

This species is named for Glascock Mountain (USGS Glascock Mountain Quad.; 7.5′).

Type locality. — NSF 350. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *P. glascockensis,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies.

Holotype = USNM 164208
Paratypes = USNM 164209-164211

Range. — Early to late Cenomanian. Range may extend into Albian. Albian not extensively sampled during this study.

Occurrence. — See Text-figure 5.

Petasiforma n. sp. (1) Pl. 23, fig. 12

Remarks. — This form is characterized by the concentric arrangement of prominent ridges on the proximal portion of its thorax. It is placed in *Petasiforma* because it possesses secondary horns and lacks a primary (apical horn). To date, neither a cephalopyle nor a thoracic velum have been observed. The character of the thoracic meshwork suggests a relationship to *P. foremanae,* n. sp.

Range. — Early Cenomanian.

Occurrence. — See Text-figure 5.

Petasiforma, n. sp. (2) Pl. 23, fig. 11

Remarks. — This form is characterized by possessing a series of dendritic ridges which extend from the cephalis to near the margin of the thoracic skirt. It lacks a primary horn but possesses secondary horns. Cephalic skeletal elements riblike; divide base of cephalis into six collar pores. A thoracic velum is absent on the specimen figured herein.

Range. — Early Cenomanian.

Occurrence. — See Text-figure 5.

Genus **SCIADIOCAPSA** Squinabol

1904. *Sciadiocapsa* Squinabol, Atti R. Acad. Padova, vol. 18, n. s., pp. 211, 212, pls. 7, figs. 5, 5A.

Type species. — *Sciadiocapsa euganea* Squinabol.

Remarks. — It is apparent that the type species of *Sciadiocapsa* is in thorough need of restudy. Squinabol's illustrations of *S. euganea* are too generalized to be of much value. Providing the illustrations are accurate, they depict the type species as (1) lacking a well-developed apical horn (2) possessing a thoracic velum and (3) possessing a coarse meshwork. No stricture is shown between the thorax and cephalis and the cephalis is shown as rather coarsely perforate.

The generic assignment of the three species described below is queried. It is likely that these species will have to be placed in new genera once they are more thoroughly studied.

?**Sciadiocapsa baileyi** Pessagno, n. sp. Pl. 29, figs. 10-12

Description. — Test microgranular, helmet-shaped, dicyrtid; length about equal to breadth. Cephalis hemispherical; secondarily imperforate due to epithecal covering which extends downwards to proximal portion of thorax. Apical horn anteriorly placed; long and massive, seeming to lack discrete apical pores; horn circular in transverse section. Cephalopyle large with bladelike partition representing portion of trifurcating vertical cephalic skeletal bar. Cephalic skeletal elements massive, circular in cross-section; divide base of cephalis into six collar pores. Collar stricture weakly developed. Thorax subconical; flaring distally to form thoracic skirt; pore frames on that part of thorax above thoracic skirt subhexagonal; pore frames of skirt circular to elliptical somewhat smaller in size; better developed on posterior portion of skirt than anterior portion of skirt; anterior part of skirt almost imperforate. Thoracic velum fragmentary; surrounded by prominent rim with small tubular pores on its posterior portion (Pl. 29, fig. 10).

Remarks. — *?S. baileyi,* n. sp. differs from both *?S. campbelli,* n. sp. and *?S. rumseyensis,* n. sp. by possessing a prominent apical horn and by possessing a partition in its cephalopyle. The presence of this latter feature may indicate a correlation with *Microsciacapsa,* n. gen.

This species is named after Edgar H. Bailey (U.S. Geol. Survey, Menlo Park, Calif.) in honor of his contributions to the geology of the California Coast Ranges.

Type locality. — NSF 482. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *?S. baileyi,* n. sp. will be deposited in the collections of the U.S. National Museum, Washington, D.C. The paratypes will be deposited in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas and at the U.S. National Museum.

Holotype = USNM 164538
Paratype = USNM 164539

Range. — Early Campanian.

Occurrence. — See Text-figure 5.

?**Sciadiocapsa campbelli** Pessagno, n. sp. Pl. 37, 1-8; Pl. 38, fig. 2

Description. — Test microgranular, helmet-shaped, dicyrtid; half as low as wide. Cephalis hemispherical; secondarily imperforate due to presence of an epithecal covering (Pl. 37, figs. 1-3). Apical horn short, circular in cross-section with several irregularly distributed apical pores (Pl. 37, fig. 3). Cephalopyle a well-developed tube. Cephalic skeletal elements massive, somewhat blade-like; divide base of cephalis into six collar pores. Poorly developed collar stricture between cephalis and thorax. Epithecal material extending from cephalis to proximal portion of thorax covering primary meshwork. Thorax conical proximally; flaring to form thoracic skirt distally. Thoracic meshwork hexagonal, subhexagonal to circular. Thoracic velum fragmentary; poorly known.

Remarks. — *?Sciadiocapsa campbelli* Pessagno, n. sp., differs from *?Sciadiocapsa causia* Foreman (1968, p. 45, pl. 7, figs. 2a, b) by possessing thoracic pore frames which are hexagonal to subhexagonal rather than circular and by possessing a wider thoracic mouth. Examination of topotypic material kindly sent to the writer by H. P. Foreman indicates that both species possess similar apical horns and apical pores.

This species is named after A. S. Campbell in honor of his contributions to the study of radiolaria.

Type locality. — NSF 568-B. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *?S. campbelli,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. The paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164261
Paratypes = USNM 164262, 164263, 164540

Range. — Latest Campanian.

Occurrence. — See Text-figure 5.

?Sciadiocapsa rumseyensis Pessagno, n. sp. Pl. 35, figs. 11, 12

Description. — Test microgranular, dicyrtid, low in relief. Cephalis small, hemispherical lacking an apical horn. Cephalopyle not observed on the specimens thus far encountered. Cephalic skeletal needles rodlike; dividing cephalics into six collar pores. Poorly developed stricture between cephalis and thorax. Proximal portion of thorax (above thoracic skirt and below base of cephalis) finely perforate, markedly spongy in appearance; lacking polygonal pore frames. Thoracic skirt coarsely perforate; consisting of concentrically arranged variably shaped polygonal pore frames. Thoracic velum a convexly arched, slightly perforate plate. *?S. rumseyensis,* n. sp., is named for the Rumsey Hills, Yolo County, California.

Type locality. — NSF 55-B. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype and figured paratype of this species will be deposited in the collections of the U.S. National Museum, Washington, D.C.

Holotype = USNM 164259
Paratype = USNM 164260

Range. — Early Campanian.

Occurrence. — See Text-figure 5.

Genus **SCYPHIFORMA** Pessagno, n. gen.

Type species. — *Scyphiforma cachensis* Pessagno, n. sp.

Description. — Test microgranular, dicyrtid about as high as wide. Cephalis hemispherical, imperforate with single large apical pore placed anteriorly at base of single apical horn. Cephalopyle large, tubular. Cephalic skeletal elements divide base of cephalis

TEXT-FIGURE 5: OCCURRENCE AND RELATIVE ABUNDANCE OF NEOSCIADIOCAPSIDAE IN UPPER CRETACEOUS GREAT VALLEY SEQUENCE. BASED ON PRELIMINARY ANALYSES OF A LIMITED NUMBER OF SAMPLES. MANY SAMPLES STILL UNDER STUDY.

KEY.

░ = Rare: 1-2 specimens.
☒ = Common 3-5 specimens.
■ = Abundant: 6 or more specimens.
✱ = Probable reworking of Cenomanian
NSF = Prefix to all locality numbers

	"Fiske Creek Fm"/"Antelope Sh."				Venado Fm		Yolo Fm			Venado/Yolo Fms undifferentiated		Sites Fm.		Forbes Fm "Dobbins Shale Member			Panoche Group undifferentiated		Marsh Creek Fm. (part)		
	early Ceno.	late Cenomanian			middle Turonian		Coniacian	late Turonian - early Coniacian				Coniacian		early Campanian			late Campanian		latest Campanian		
	350	405	498 B	584	432	697 ✱	291 B	440	483	641	644 B	319-B	327 C	55 B	482	529-B	450	451	568 B	571	572-B
Cassideus riedeli, n. sp	■																				
Cassideus yoloensis, n. sp.	■																				
Coniforma antiochensis, n. sp.																			■	■	■
?Ewingella capayensis, n. sp	■																				
Ewingella guindaensis, n. sp.	■			☒																	
Ewingella jonesi, n. sp	■																				
Lipmanium sacramentoensis, n. sp	■					☒															
Microsciadiocapsa berryessaensis, n. sp.							■	░	☒												
Microsciadiocapsa cortinaensis, n. sp							■					☒									
Microsciadiocapsa lipmanae, n. sp.	■																				
Microsciadiocapsa madisonae, n. sp.							■														
Microsciadiocapsa monticelloensis, n. sp					☒	░	■	░	■												
Microsciadiocapsa radiata, n. sp							☒					☒	☒								
Microsciadiocapsa sutterensis, n. sp	■					☒	░														
Neosciadiocapsa diabloensis, n. sp																	░	■			
Petasiforma foremanae, n. sp	■	■	☒	☒																	
Petasiforma glascockensis, n. sp	■	■		☒																	
Petasiforma sp. (1)	░																				
Petasiforma sp. (2)	░																				
?Sciadiocapsa baileyi, n. sp														░	■	■					
?Sciadiocapsa campbelli n. sp																			■	☒	☒
?Sciadiocapsa rumseyensis, n. sp														■	■	☒					
Scyphiforma cachensis, n. sp												☒									
Squinabolella putahensis, n. sp						☒	■	░	■	☒	☒										

into six collar pores. Weakly developed collar stricture. Thorax conical in shape flaring distally to form elliptical, relatively narrow thoracic skirt. Thoracic velum fragmentary; poorly known.

Remarks. — *Scyphiforma,* n. gen., differs from *Microsciadiocapsa,* n. gen. (1) by lacking a bladelike partition in its cephalopyle and (2) by possessing a single, large, heart-shaped apical pore on the anterior side of its apical horn.

Scyphus (Latin) = a drinking cup; goblet, + *forma* (Latin) = form.

Range. — Coniacian.

Occurrence. — Great Valley Sequence, California Coast Ranges.

Scyphiforma cachensis Pessagno, n. sp. Pl. 33, figs. 3-5

Description. — Test as with genus. Cephalis with somewhat roughened surface. Layer of epithecal material extending from cephalis onto proximal portion of thorax tending to mask thoracic meshwork. Thoracic meshwork circular to subhexagonal; frames massive.

Remarks. — *S. cachensis,* n. sp., differs from *Microsciadiocapsa monticelloensis,* n. sp. (1) by having a more elliptically shaped thoracic skirt (2) by possessing a single large, heart-shaped apical pore on the anterior side of its apical horn (3) by having a test which is greater in relief (length) and (4) by lacking a partition in its cephalopyle.

This species is named for Cache Creek, Yolo County, California.

Type locality. — NSF 319-B. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *Scyphiforma cachensis,* n. sp., will be deposited in the collections of the U.S. National Museum, Washington, D.C. The paratypes will be deposited in the Pessagno Collection, Southwest Center for Advanced Studies, Dallas, Texas.

Holotype = USNM 164249

Range. — Coniacian.

Occurrence. — See Text-figure 5.

Genus **SQUINABOLELLA** Pessagno, n. gen.

Type species.—*Squinabolella putahensis* Pessagno, n. sp.

Description.—Test microgranular, dicyrtid, hat-shaped. Cephalis hemispherical, markedly perforate; pores medium-sized, irregularly shaped and dispersed between massive dendritic ridges extending distally from large triradiate apical horn. Four apical pores situated between ridges at base of horn. Cephalopyle a short tube directed upwards. Cephalic skeletal elements rodlike; divide base of cephalis into six collar pores. Well-developed collar stricture. Thorax large, conical proximally; flaring distally to form a broad thoracic skirt. Thoracic velum well developed, cylindrical in shape; basal portion circular, somewhat depressed with rim along its periphery; pores of velum irregular in their shape and distribution. (see Pl. 33, fig. 10).

Remarks.—The dendritic arrangement of ridges present on the exterior portion of the cephalis of *Squinabolella* are somewhat similar to those of *Cassideus,* n. gen. Both genera show pores, irregularly shaped and dispersed between massive ridges. However, whereas *Squinabolella* possesses both a cephalopyle and an apical horn, *Cassideus* lacks a cephalopyle and possesses two primary horns: an apical horn and a vertical horn. The cylindrical thoracic velum of *Squinabolella* does not occur on any other neosciadiocapsids.

Squinabolella is named for Senofonte Squinabol in honor of his contributions to the study of the Mesozoic Radiolaria of Italy.

Range.—Late Turonian/Coniacian.

Occurrence.—Great Valley Sequence of the California Coast Ranges.

Squinabolella putahensis Pessagno, n. sp. Pl. 33, figs. 6-10

Description.—Test as with genus except as follows: Thorax with circular pores frames proximally which increase in size distally; thoracic skirt with hexagonal to subhexagonal pore frames.

Remarks.—*Squinabolella putahensis,* n. sp., can be readily distinguished from most other neosciadiocapsids (1) by the cylindrical shape of its thoracic velum and (2) by the presence of numerous prominent dendritic ridges with interspersed pores on its cephalis.

This species is named for Putah Creek, Yolo, Solano, and Napa Counties, California.

Type locality. — NSF 483. See Locality Descriptions and Text-figure 5.

Deposition of types. — The holotype of *S. putahensis,* n. sp., will be deposited in the collection of the U.S. National Museum, Washington, D.C. Paratypes will be deposited at the U.S. National Museum and in the Pessagno Collection, Southwest Center for Advanced Studies.

Holotype = USNM 164250

Paratypes = USNM 164251-164252

Range. — Late Turonian/Coniacian — Coniacian.

Occurrence. — See Text-figure 5.

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PLATES

EXPLANATION OF PLATE 23

All figures scanning electron micrographs of Cenomanian Neosciadiocapsidae.

Figure Page

1-3. **Petasiforma glascockensis** Pessagno, n. sp. 412
Holotype (USNM 164208). NSF 350. "Antelope Shale"/"Fiske Creek Formation." Figure 1: marker = 100 microns. 2. Shows cephalis and proximal portion of thorax. Note cephalopyle in lower left; marker = 50 microns. 3. Highly magnified picture of cephalopyle: Marker = 10 microns.

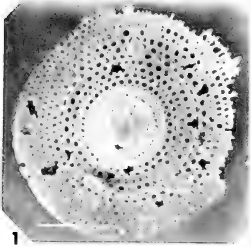
4,5. **Petasiforma glascockensis** Pessagno, n. sp. 412
Paratypes (USNM 164209, 164210 respectively). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 4. Marker = 100 microns. 5. Note cephalopyle and development of secondary horns; Marker = 50 microns.

6,7,9,10. **Petasiforma foremanae** Pessagno, n. sp. 411
Paratypes (USNM 164212-164215 respectively). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 6. Cephalis and proximal portion of thorax greatly magnified; showing cephalopyle and secondary horns; marker = 25 microns. 7. marker = 100 microns. 9. Thoracic velum. Note large, centrally placed, accessory aperture. Marker = 50 microns. 10. Marker = 100 microns.

8. **Petasiforma foremanae** Pessagno, n. sp. 411
Holotype (USNM 164216). NSF 350 "Antelope Shale"/"Fiske Creek Formation." Note proliferation of smaller rectangular pore frames on periphery of thoracic skirt. Marker = 100 microns.

11. **Petasiforma** sp. 2 413
NSF 350. "Antelope Shale"/"Fiske Creek Formation." Marker = 50 microns.

12. **Petasiforma** sp. 1 413
NSF 350. "Antelope Shale"/"Fiske Creek Formation." Marker = 100 microns.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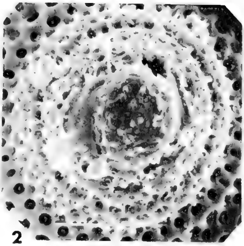
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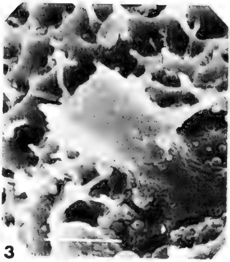
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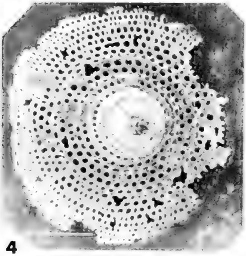
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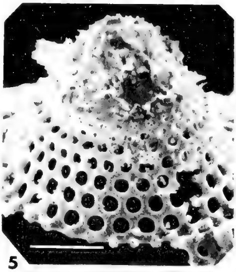
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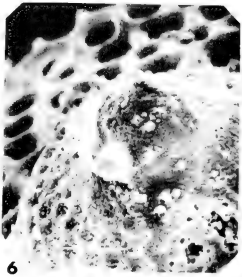
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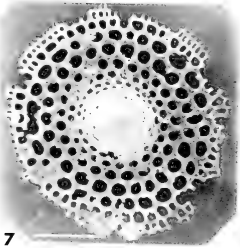
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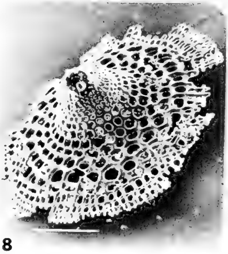
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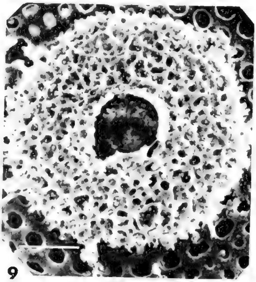
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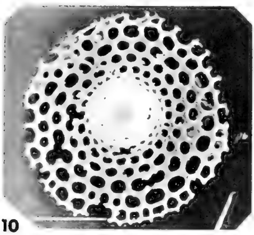
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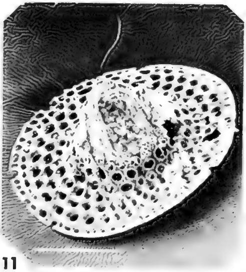
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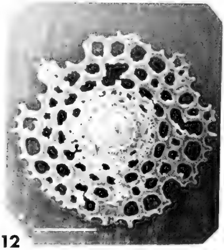
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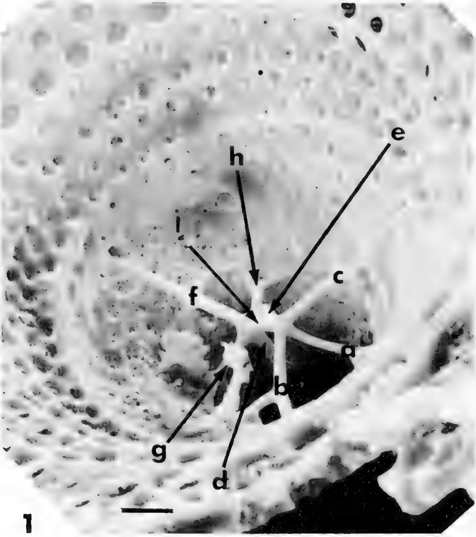

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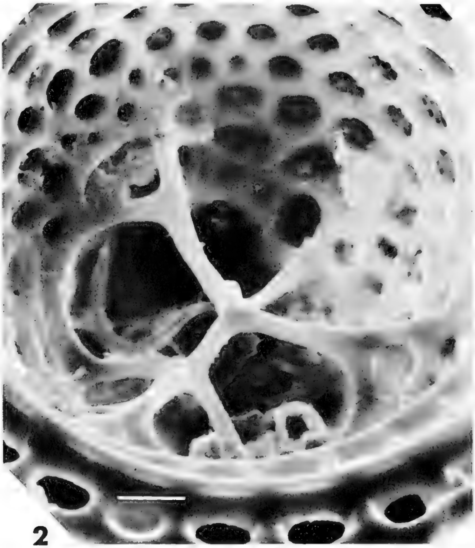

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EXPLANATION OF PLATE 24

All specimens figured are scanning electron micrographs of Cenomanian Neosciadiocapsidae.

Figure Page

1. **Petasiforma glascockensis** Pessagno, n. sp. 412
   Paratype; USNM 164211. NSF 350. Interior of cephalis at high magnification; showing cephalic skeletal elements and collar pores.* Marker = 10 microns.
   a = Vertical bar.
   b = Primary left lateral bar.
   c = Primary right lateral (lateral of some workers) bar.
   d = Apical bar.
   e = Axial spine.
   f = Dorsal bar.
   g = Secondary left lateral bar.
   h = Secondary right lateral bar.
   i = Median bar.

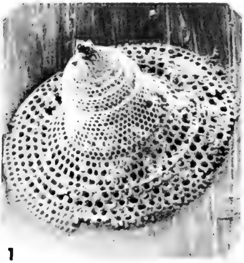
2. **Petasiforma foremanae** Pessagno, n. sp. 411
   Paratype; USNM 164217. NSF 350. Enlargement of interior of cephalis showing cephalic skeletal element and collar pores. Marker = 10 microns.

*Terms *bar* and *spine* defined in the sense of Goll (1968, p. 1413). *Right* and *left* conform to Goll *(ibid.)* and to Text-figure 3A herein. Designations right and left differ from those of Petrushevskaya (1964, 1965).

EXPLANATION OF PLATE 25

All figures scanning electron micrographs of Cenomanian Neosciadiocapsidae.

Figure		Page
1-4.	**Cassideus riedeli** Pessagno, n. sp. .... Holotype (USNM 164218). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 1,2. Markers = 100 microns. 3. Cephalis and proximal portion of thorax. Note dendritic ridges on cephalis and staggered concentric ridges on thorax; marker = 25 microns. 4. Marker = 25 microns.	395
5,6-8.	**Cassideus riedeli** Pessagno, n. sp. .... Paratypes (USNM 164219-220 respectively). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 5. Cephalis and proximal portion of thorax; marker = 25 microns. 6. Marker = 100 microns. 7. Cephalis and proximal portion of thorax; same specimen as in Figure 6; marker = 25 microns. 8. Same specimen as in Figure 6; marker = 25 microns.	395
9-11.	**Cassideus yoloensis** Pessagno, n. sp. .... Topotype (broken after photography). NSF 350. "Antelope Shale"/"Fiske Creek Formation." Figures 9,10. Markers = 100 microns. 11. Marker = 25 microns.	396
12.	**Cassideus yoloensis** Pessagno, n. sp. .... Holotype (USNM 164222). NSF 350. "Antelope Shale"/"Fiske Creek Formation." Marker = 25 microns.	396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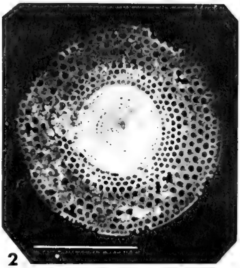
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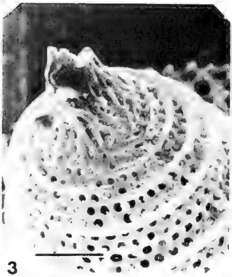
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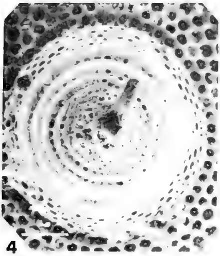
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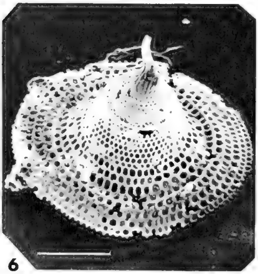
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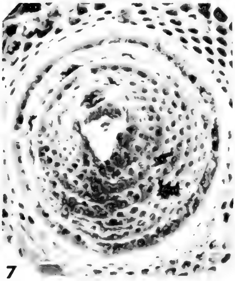
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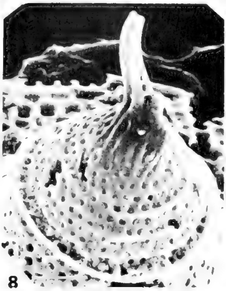
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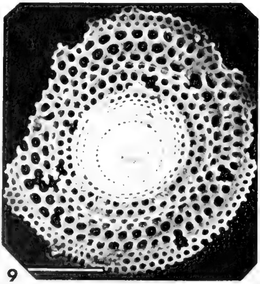
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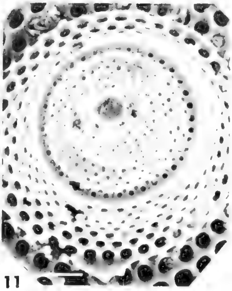
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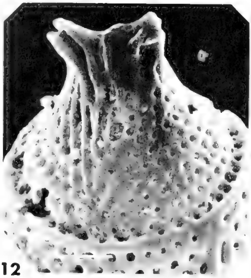
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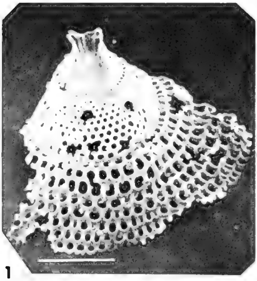
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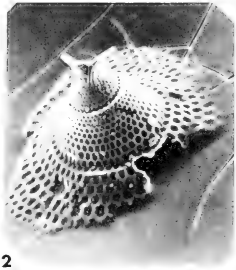
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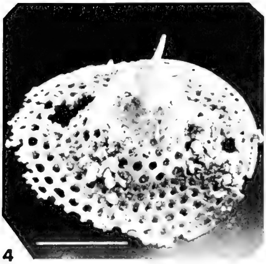
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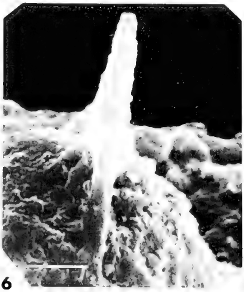
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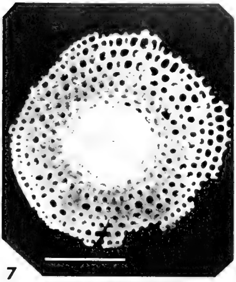
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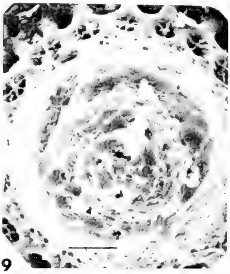
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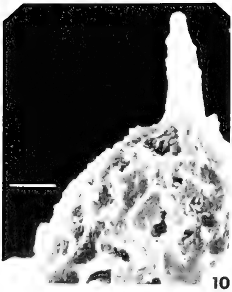
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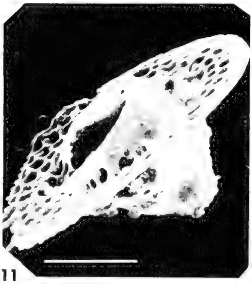
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EXPLANATION OF PLATE 26

All figures scanning electron micrographs of Cenomanian Neosciadiocapsidae.

Figure		Page
1.	**Cassideus yoloensis** Pessagno, n. sp. .... Holotype (USNM 164222). NSF 350. "Antelope Shale"/"Fiske Creek Formation." Marker = 100 microns.	396
2,3.	**Cassideus yoloensis** Pessagno, n. sp. .... Paratype (SEM 646-647; Pessagno Collection). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 2. Marker = 100 microns. 3. Marker = 50 microns.	396
4-6.	**Lipmanium sacramentoensis** Pessagno, n. sp. .... Holotype (USNM 164224). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 4. Marker = 50 microns. 5. Cephalis and proximal portion of thorax greatly magnified. Note bladelike partition in the cephalopyle; marker = 10 microns. 6. Enlargement of apical horn and prominent apical bridges; marker = 5 microns.	402
7-10.	**Lipmanium sacramentoensis** Pessagno, n. sp. .... Paratype (USNM 164225). NSF 350. "Antelope Shale/"Fiske Creek Formation." 7. Marker = 50 microns. 8. Marker = 10 microns. 9. Marker = 10 microns. 10. Marker = 5 microns.	402
11,12.	**Lipmanium sacramentoensis** Pessagno, n. sp. .... Paratype (USNM 164226). NSF 350. "Antelope Shale"/"Fiske Creek Formation." Note crescent-shaped thoracic velum with large pores situated near its contact with thoracic skirt; 11. Marker = 50 microns. 12. Marker = 25 microns.	402

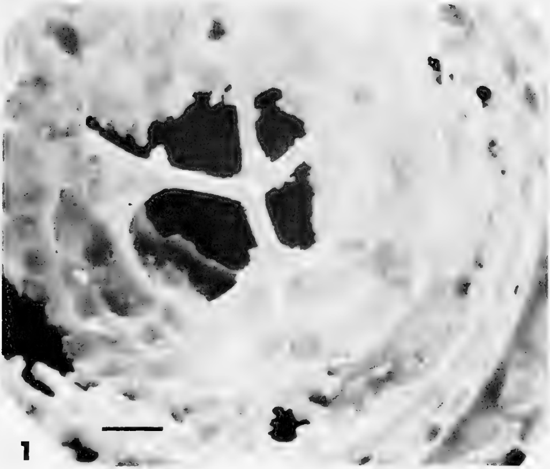
EXPLANATION OF PLATE 27

Both figures scanning electron micrographs of Cenomanian Neosciadiocapsidae.

Figure Page

1. **Cassideus riedeli** Pessagno, n. sp. 395
   Paratype (USNM 164221). Cephalic skeletal elements and collar pore structure; marker = 10 microns.

2. **Ewingella jonesi** Pessagno, n. sp. 400
   Paratype (USNM 164227). Cephalic skeletal elements (partially broken) and collar pore structure; marker = 10 microns.



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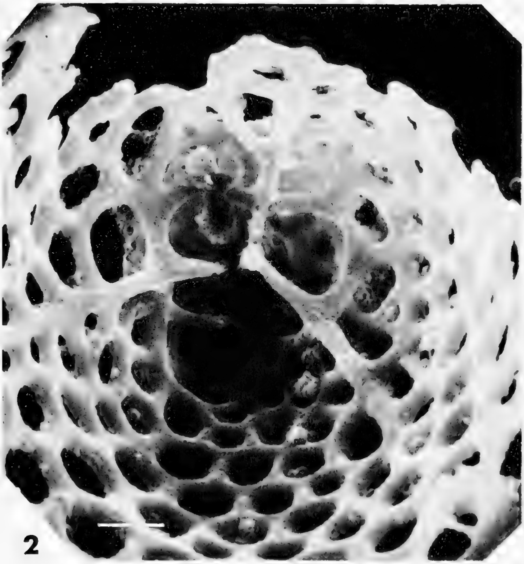

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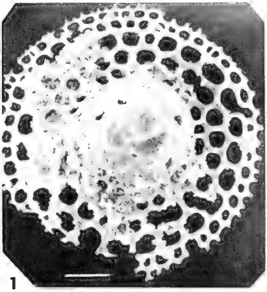
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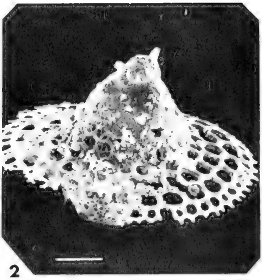
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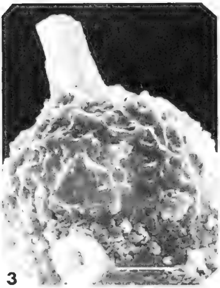
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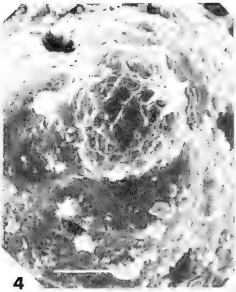
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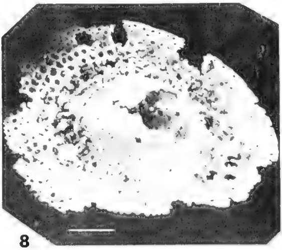
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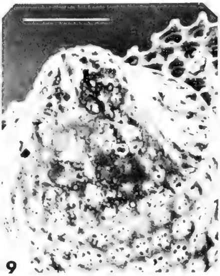
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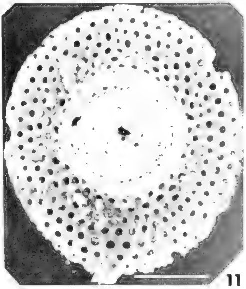
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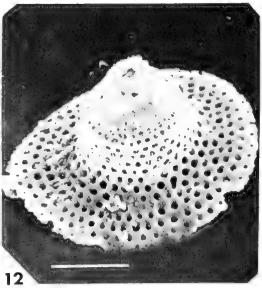
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EXPLANATION OF PLATE 28

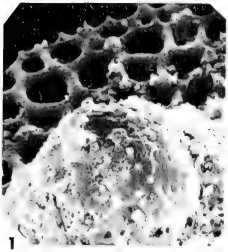
All figures scanning electron micrographs of Cenomanian Neosciadiocapsidae.

Figure		Page
1-4.	**Ewingella jonesi** Pessagno, n. sp. .... Holotype (USNM 164228). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 1,2. Marker = 50 microns. 3. Note pocket-like apical pore on triradiate horn. 4. Marker = 25 microns.	401
5-7.	**Ewingella jonesi** Pessagno, n .sp. .... Paratype (USNM 164229). NSF 350. "Antelope Shale"/"Fiske Creek Formation." Note triradiate apical horn and partition in cephalopyle. Markers = 10 microns.	401
8,11,12.	**Microsciadiocapsa lipmanae** Pessagno, n. sp. .... Paratypes (USNM 164230 and 164231 respectively). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 8. Note convex, finely perforate thoracic velum; marker = 50 microns. 11,12. Markers = 50 microns.	405
9,10.	**Microsciadiocapsa lipmanae** Pessagno, n. sp. .... Holotype. (USNM 164232). NSF 350. "Antelope Shale"/"Fiske Creek Formation." 9. Note small apical horn; marker = 25 microns. 10. Marker = 50 microns.	405

EXPLANATION OF PLATE 29

Figures 1-9 scanning electron micrographs of Cenomanian Neosciadiocapsidae. Figure 10-12 = early Campanian Neosciadiocapsidae.

Figure		Page
1-3,6.	?**Ewingella capayensis** Pessagno, n. sp. Holotype (USNM 164236). NSF 350. “Antelope Shale”/“Fiske Creek Formation.” 1,2. Note pocket-like apical pore in figure 2; markers = 10 microns. 3,6. Markers = 50 microns.	399
4,5,7,8.	**Ewingella guindaensis** Pessagno, n. sp. Holotype (USNM 164237). NSF 350. “Antelope Shale/“Fiske Creek Formation.” 4. Marker = 10 microns. 5. Marker = 50 microns. 7. Note rim around mouth of thorax and recessed, planiform nature of thoracic velum. Diatom cemented to thoracic skirt in lower left in position of marker; marker = 10 microns. 8. Marker = 50 microns.	400
9.	**Microsciadiocapsa sutterensis** Pessagno, n. sp. Paratype (USNM 164238). NSF 350. “Antelope Shale”/“Fiske Creek Formation”; marker = 50 microns.	409
10.	?**Sciadiocapsa baileyi** Pessagno, n. sp. Paratype (Pessagno Collection). NSF 482 “Dobbins Shale” Member of Forbes Formation. Thoracic mouth at high magnification. Note pronounced rim around mouth with tubular pores on its posterior portion (lower right of photo). Marker = 10 microns.	414
11,12.	?**Sciadiocapsa baileyi** Pessagno, n. sp. Holotype (USNM 164538). NSF 482. “Dobbins Shale” Member of Forbes Formation. Marker = 25 microns.	414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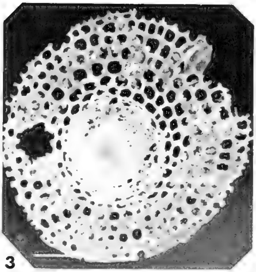
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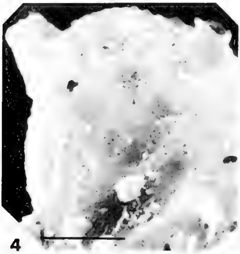
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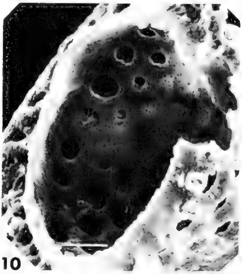
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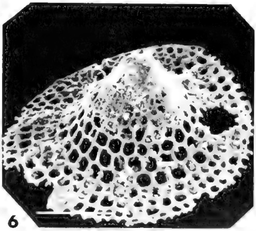
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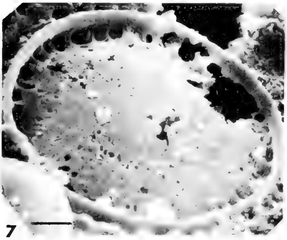
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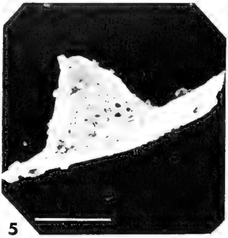
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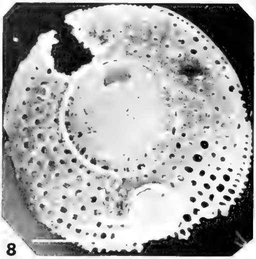
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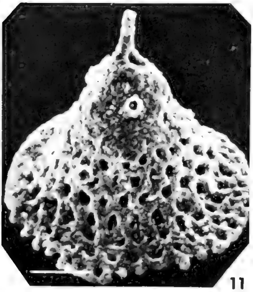
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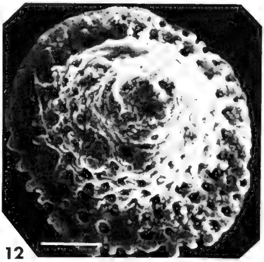
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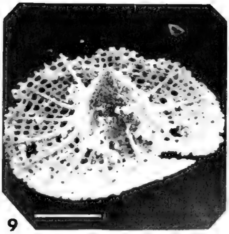
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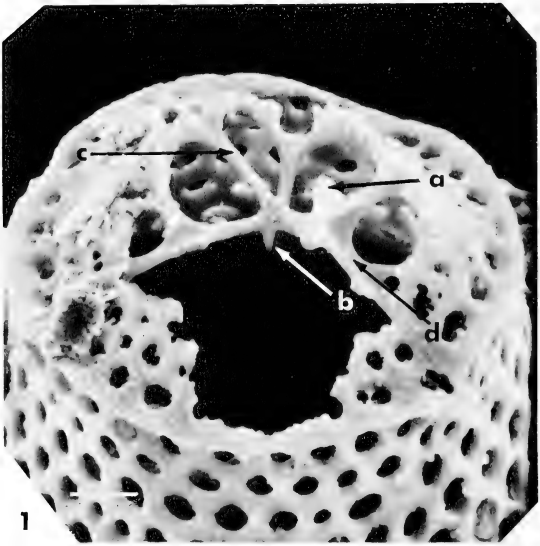
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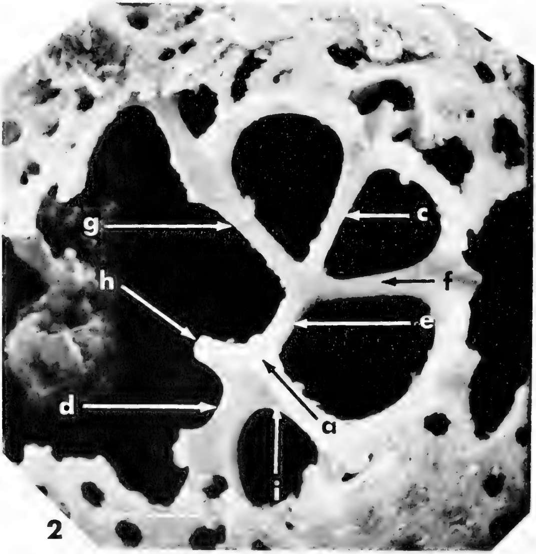
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EXPLANATION OF PLATE 30

Both figures scanning electron micrographs of *Microsciadiocapsa lipmanae* Pesagno, n. sp. Paratype (USNM 164233). NSF 350: early Cenomanian part of the "Antelope Shale"/"Fiske Creek Formation."

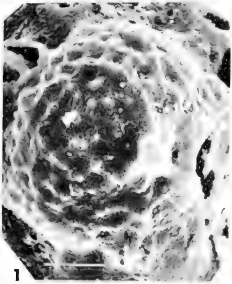
Figure		Page
1.	Cut away side view with most of cephalis removed showing cephalic skeletal elements. Note juncture of cephalic skeletal needles (primary lateral, secondary lateral, dorsal, and verticle) with rim bordering shelflike collar structure. Marker = 10 microns* a = Apical bar (broken). b = Axial spine. c = Vertical bar. d = Dorsal bar.	405
2.	Cut away view of same specimen illustrated in figure 1. Roof of cephalis removed. Cephalic skeletal elements viewed from top of cephalis in a distal direction (see Terminology). Marker = 10 microns. a = Apical bar. b = Axial spine (not seen in this view). c = Vertical bar. d = Dorsal bar. e = Median bar. f = Primary right lateral bar. g = Primary left lateral bar. h = Secondary left lateral bar. i — Secondary right lateral bar.	405

*Note: Terms *bar* and *spine* used in the sense of Goll (1968, p. 1413). Terms *left* and *right* conform to Goll *(ibid.)* and Text-figure 3 herein; differ from *left* and *right* of Petrushevskaya (1964, 1965).

EXPLANATION OF PLATE 31

All figures scanning electron micrographs of Cenomanian to Coniacian Neosciadiocapsidae.

Figure		Page
1,3.	**Microsciadiocapsa lipmanae** Pessagno, n. sp. .... Paratype (USNM 164234). Cenomanian NSF 350. "Antelope Shale"/"Fiske Creek Formation." Apical horn in figure 1 with apical bridge separating two apical pores. Note partition in cephalopyle in figure 3. Markers in both figures = 10 microns.	405
2.	**Microsciadiocapsa lipmanae** Pessagno, n. sp. .... Paratype (USNM 164235). Cenomanian. NSF 350. "Antelope Shale"/"Fiske Creek Formation." Marker = 10 microns.	405
4,5.	**Microsciadiocapsa sutterensis** Pessagno, n. sp. .... Holotype (USNM 164239). Cenomanian. NSF 350. "Antelope Shale"/"Fiske Creek Formation." Markers = 50 microns.	409
6,7.	**Microsciadiocapsa sutterensis** Pessagno, n. sp. .... Paratype (USNM 164255). Cenomanian. "Antelope Shale"/"Fiske Creek Formation." Note partition in cephalopyle in figure 6. Markers = 10 microns.	409
8-10.	**Microsciadiocapsa berryessaensis** Pessagno, n. sp. .... Holotype (USNM 164240). Late Turonian/Coniacian. NSF 483. Yolo Formation. 8,9. Markers = 50 microns. Figure 10. Marker = 10 microns.	404
11,12.	**Microsciadiocapsa berryessaensis** Pessagno, n. sp. .... Paratype (USNM 164241). NSF 483. Late Turonian/Coniacian. Yolo Formation. 11. Marker = 50 microns. 12. Marker = 10 microns.	404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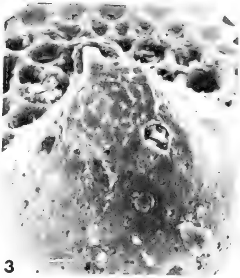
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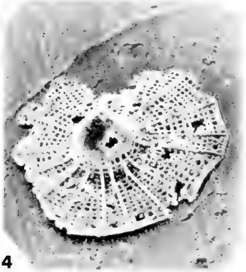
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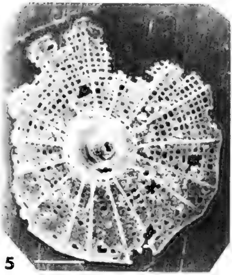
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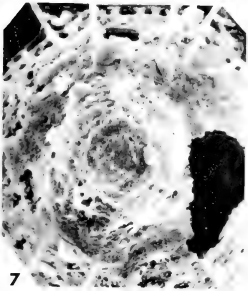
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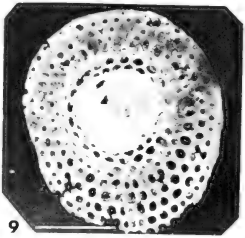
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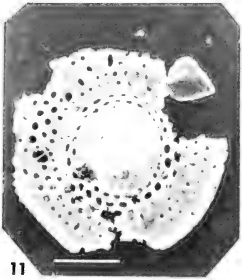
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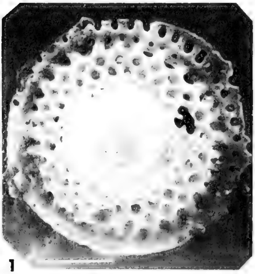
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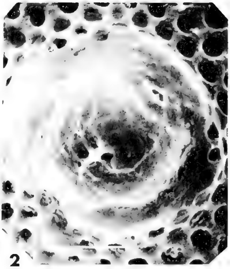
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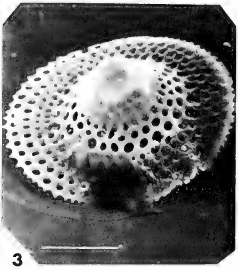
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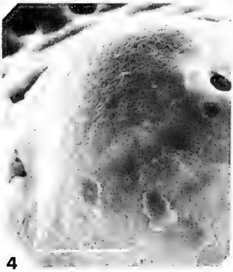
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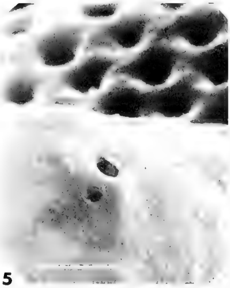
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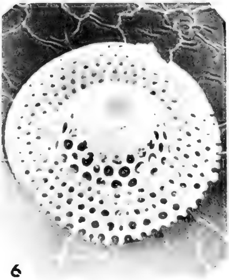
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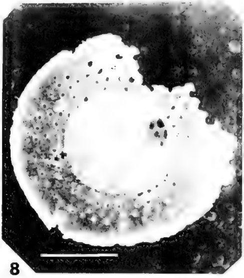
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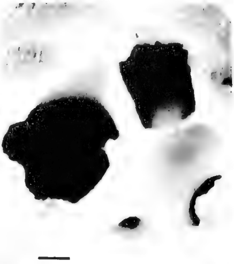
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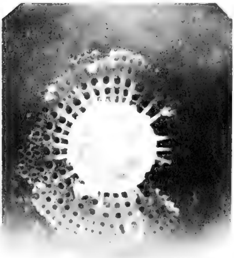
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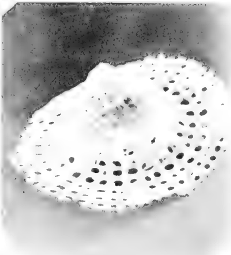
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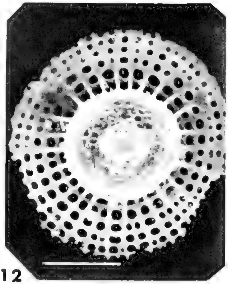
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EXPLANATION OF PLATE 32

All figures scanning electron micrographs of late Turonian and Coniacian Neosciadiocapsidae.

Figure		Page
1,2.	**Microsciadiocapsa cortinaensis** Pessagno, n. sp. Holotype (USNM 164242). Coniacian. NSF 319-B. Sites Formation. 1. Marker = 50 microns. 2. Marker = 25 microns.	404
3-5.	**Microsciadiocapsa monticelloensis** Pessagno, n. sp. Holotype (USNM 164243). Late Turonian/Coniacian. NSF 483. Yolo Formation. 3. Marker = 10 microns. 3,4. Note V-shaped (double) apical horn with 2 apical pores. Markers = 10 microns.	407
6.	**Microsciadiocapsa monticelloensis** Pessagno, n. sp. Paratype (USNM 164244). Late Turonian/Coniacian. NSF 483. Yolo Formation. Marker = 50 microns.	407
7.	**Microsciadiocapsa monticelloensis** Pessagno, n. sp. Paratype (USNM 164245). Late Turonian/Coniacian. NSF 483. Yolo Formation. Marker = 50 microns.	407
8.	**Microsciadiocapsa monticelloensis** Pessagno, n. sp. Paratype (USNM 164246). Late Turonian/Coniacian. NSF 483. Marker = 50 microns.	407
9.	**Microsciadiocapsa monticelloensis** Pessagno, n. sp. Paratype (Pessagno Collection). Late Turonian/Coniacian. Yolo Formation. Cephalopyle with bladelike partition representing trifurcating terminal portion of vertical cephalic skeletal needle. Marker = 10 microns.	407
10.	**Microsciadiocapsa radiata** Pessagno, n. sp. Paratype (Pessagno Collection; SEM 406). Coniacian Sites Formation. NSF 319-B. Marker = 50 microns.	408
11,12.	**Microsciadiocapsa radiata** Pessagno, n. sp. Holotype (USNM 164248). NSF 327C. Coniacian. Sites Formation. Markers = 50 microns.	408

Explanation of Plate 33

All figures scanning electron micrographs of late Turonian to Coniacian Neosciadiocapsidae.

Figure		Page
1,2.	**Microsciadiocapsa radiata** Pessagno, n. sp. Holotype (USNM 164248). NSF 327-C. Coniacian. 1. Note partition in cephalopyle; marker = 10 microns. 2. Note broken triradiate apical horn with prominent apical bridge separating 2 apical pores; marker = 10 microns.	408
3-5.	**Scyphiforma cachensis** Pessagno, n. sp. Holotype (USNM 164249). NSF 319-B. Sites Formation. 3. Note single heart-shaped apical pore at base of apical horn. Marker = 10 microns. 4,5. Marker = 50 microns.	417
6-8.	**Squinabolella putahensis** Pessagno, n. sp. Holotype (USNM 164250). NSF 483. Sites Formation. Late Turonian/Coniacian. 6. Marker = 50 microns. 7,8. Note dendritic pattern of ridges at base of apical horn (horn broken; long and massive when entire). Cephalopyle visible in lower left.	418
9.	**Squinabolella putahensis** Pessagno, n. sp. Paratype (USNM 164251). Late Turonian/Coniacian. NSF 483. Sites Formation. Marker = 50 microns.	418
10.	**Squinabolella putahensis** Pessagno, n. sp. Paratype (USNM 164252). NSF 483. Sites Formation. Late Turonian/Coniacian. Note cylindrical nature of thoracic velum. Marker = 50 microns.	418
11.	**Microsciadiocapsa madisonae** Pessagno, n. sp. Paratype (Pessagno Collection). NSF 291-C. Yolo Formation, Coniacian. Cephalis and thorax (part) at high magnification. Note apical horn with apical bridge separating two apical pores. In profile apical bridge terminates in a prominent spine. Marker = 10 microns.	406
12.	**Microsciadiocapsa madisonae** Pessagno, n. sp. Holotype (USNM 164253). NSF 483. Yolo Formation. Late Turonian/Coniacian. Marker = 50 microns.	406


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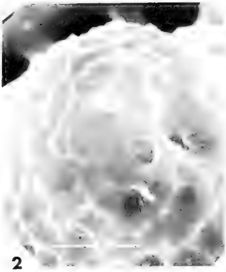
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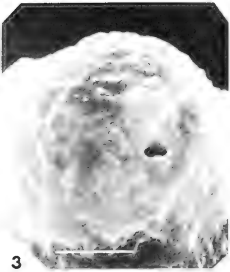
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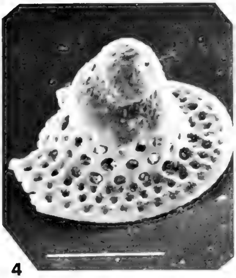
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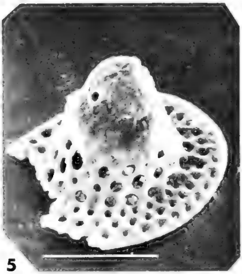
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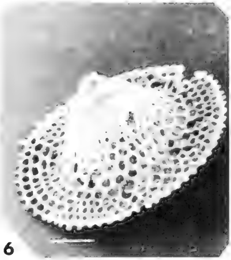
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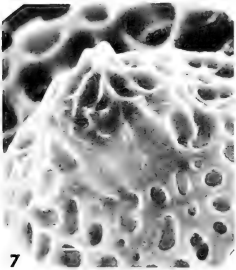
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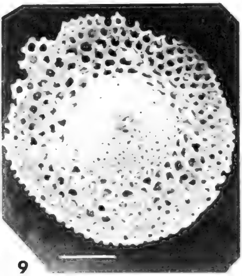
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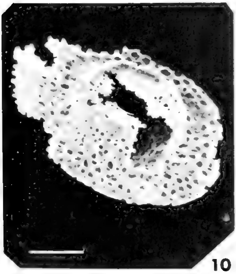
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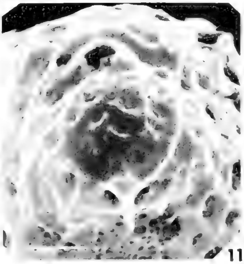
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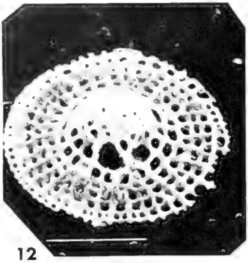
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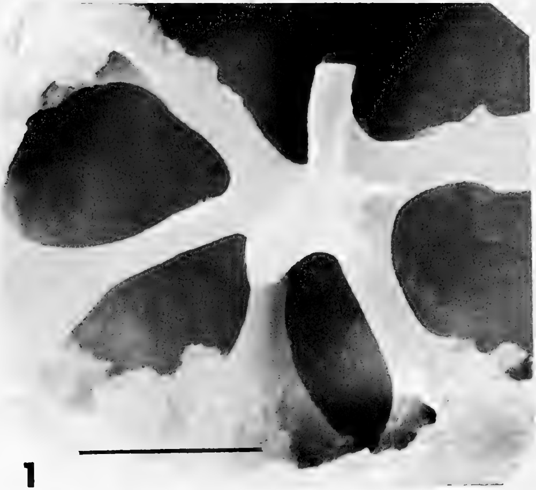

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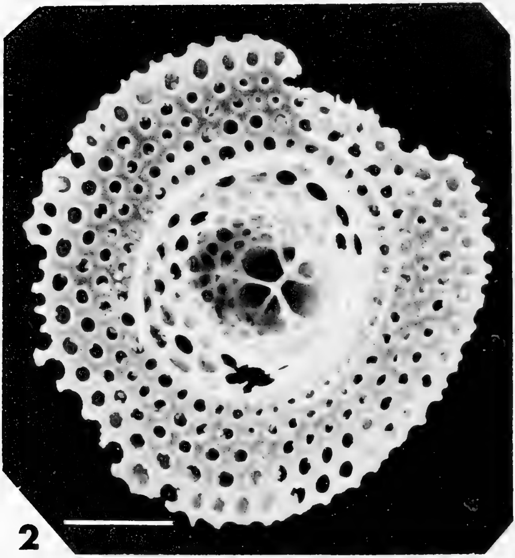

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EXPLANATION OF PLATE 34

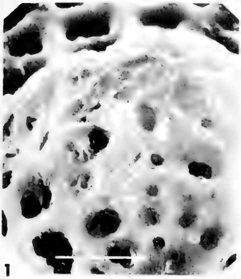
Both figures scanning electron micrographs of Turonian to Coniacian Neosciadiocapsidae.

Figure		Page
1.	Cephalic skeletal needles of **Microsciadiocapsa monticelloensis** Pessagno, n. sp. .... Topotype. Pessagno Collection (SEM 436). Natural cut away; looking into the cephalis in a distal direction; apical cephalic skeletal needle broken; projecting upwards. Marker = 10 microns.	407
2.	**Microsciadiocapsa monticelloensis** Pessagno, n. sp. .... Paratype (USNM 164247). Figure showing thoracic skirt, thoracic mouth, cephalic skeletal needles, and collar pores. Marker = 100 microns.	407

EXPLANATION OF PLATE 35

All figures (except figure 11) scanning electron micrographs of Coniacian to late Campanian Neosciadiocapsidae.

Figure		Page
1,2.	**Microsciadiocapsa madisonae** Pessagno, n. sp. .... Holotype (USNM 164253). Late Turonian/Coniacian. NSF 483. Yolo Formation. 1. Note small apical horn (center of photo); marker = 10 microns. 2. Small cephalopyle visible in lower right. Marker = 10 microns.	406
3,4.	**Microsciadiocapsa madisonae** Pessagno, n. sp. .... Paratype (USNM 164254). NSF 327-C. Sites Formation. Markers = 25 microns.	406
5,7,10.	**Neosciadiocapsa diabloensis** Pessagno, n. sp. .... Paratypes (USNM 164258); Pessagno Collection (SEM 57); and Pessagno Collection (SEM 20) respectively). Late Campanian. NSF 451. Panoche Group. Figure 5: Note thoracic velum (broken); marker = 100 microns. Figure 7: Cephalic skeletal needles of same specimen shown in Pl. 36, fig. 1: Marker = 50 microns. 10. Marker = 100 microns.	410
6,8,9.	**Neosciadiocapsa diabloensis** Pessagno, n. sp. .... Holotype (USNM 164257). Late Campanian. NSF 451. Panoche Group. Figures 6 and 8: markers = 100 microns. 9. Illustration of a single apical pore at base of triradiate apical horn; marker = 25 microns.	410
11.	?**Sciadiocapsa rumseyensis** Pessagno, n. sp. .... Holotype (USNM 164259). Early Campanian. NSF 55-B. Forbes Formation ("Dobbins Shale" Member). Light photomicrograph. Marker = 100 microns.	416
12.	?**Sciadiocapsa rumseyensis** Pessagno, n. sp. .... Paratype (USNM 164260). Early Campanian. NSF 55-B. Forbes Formation ("Dobbins Shale" Member). Marker = 100 microns.	416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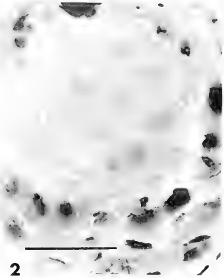
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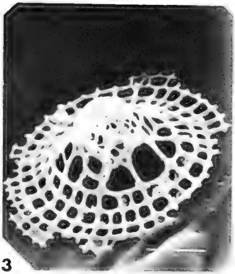
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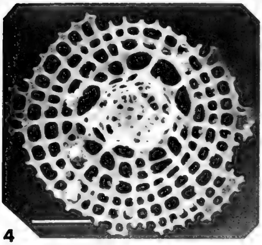
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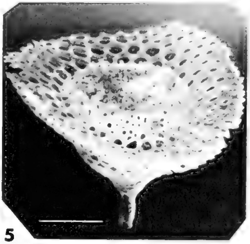
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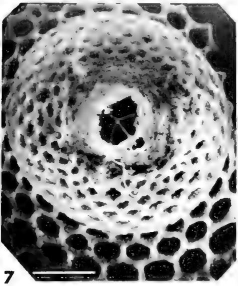
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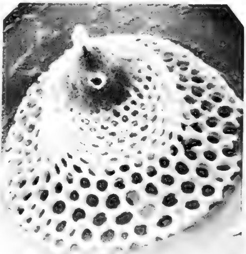
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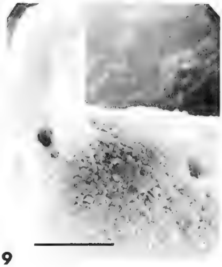
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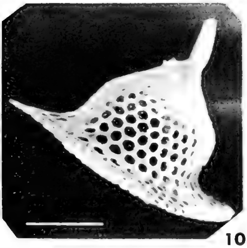
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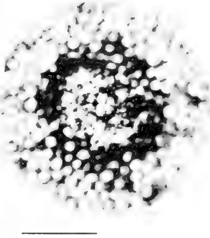
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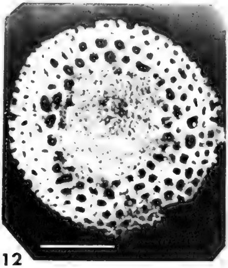
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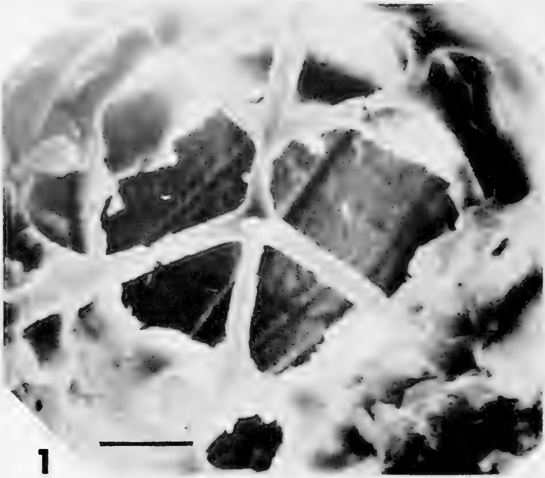

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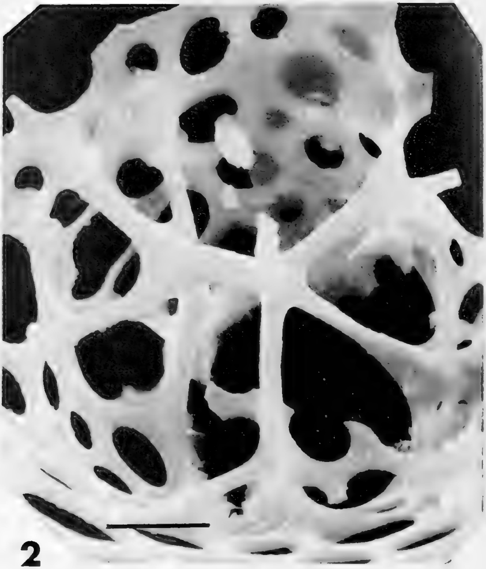

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EXPLANATION OF PLATE 36

Both figures scanning electron micrographs illustrating cephalic structure of (late Turonian-Caniacian to late Campanian) Neosciadiocapsidae.

Figure		Page
1.	**Neosciadiocapsa diabloensis** Pessagno, n. sp. .... Paratype (USNM 164258). Late Campanian. NSF 451. Panoche Group. Same specimen as Pl. 35, fig. 7. Cephalic skeletal needles and collar pores viewed looking into cephalis in a proximal direction. (See Terminology, p. 382. Roof of cephalis broken away. Marker = 10 microns.	410
2.	**Microsciadiocapsa madisonae** Pessagno, n. sp. .... Paratype (Pessagno Collection (SEM 619). Coniacian. NSF 327-C. Sites Formation. View showing all 9 cephalic skeletal needles. For interpretation see either Pl. 24, fig. 1, or Pl. 30, fig. 2. Marker = 10 microns.	406

Explanation of Plate 37

All figures scanning electron micrographs of late Campanian Neosciadiocapsidae.

Figure — Page

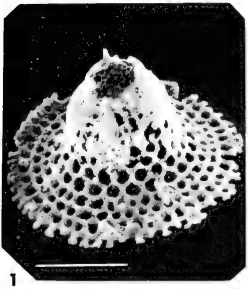
1,2,3. ?**Sciadiocapsa campbelli** Pessagno, n. sp. 415
Holotype (USNM 164261). Latest Campanian. NSF 568-B. Panoche Group ("Marsh Creek Formation"). 1. Note small apical horn; marker = 50 microns. 3. Note apical horn (white area above right end of marker) with 2 small apical pores at its base; marker = 10 microns.

4,8. ?**Sciadiocapsa campbelli** Pessagno, n. sp. 415
Paratype (USNM 164262). Latest Campanian. NSF 568-B. Panoche Group ("Marsh Creek Formation"). 4. Marker = 10 microns. 8. Marker = 50 microns.

5,6,7. ?**Sciadiocapsa campbelli** Pessagno, n. sp. 415
Paratypes (USNM 164263 and USNM 164540 respectively). Latest Campanian. NSF 568-B. Panoche Group ("Marsh Creek Formation"). 5. Cephalic skeletal needles and collar pores of same specimen shown at higher magnification in Pl. 38, fig. 2; marker = 50 microns. 6. Marker = 10 microns. Figure 7: Same specimen as figure 6; marker = 50 microns.

9. **Coniforma antiochensis** Pessagno, n. sp. 398
Holotype (USNM 164264). Latest Campanian. NSF 568-B. Panoche Group ("Marsh Creek Formation"). Note cephalopyle in lower right. Marker = 50 microns.

10,11,12. **Coniforma antiochensis** Pessagno, n. sp. 398
Paratypes (USNM 164265-164266 and Pessagno Collection SEM 127 respectively). Latest Campanian. NSF 568-B. Panoche Group ("Marsh Creek Formation"); markers = 50 microns each.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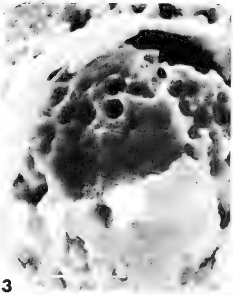
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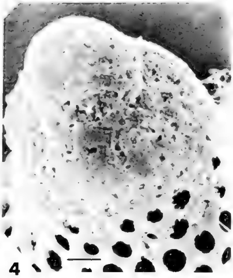
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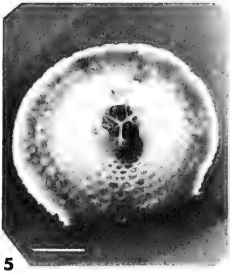
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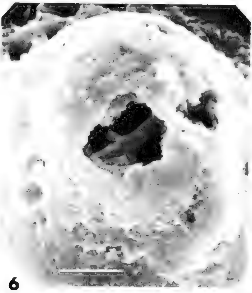
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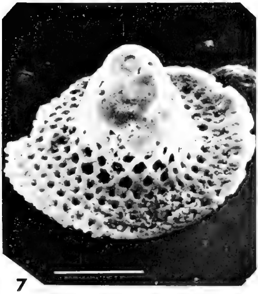
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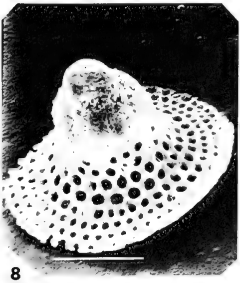
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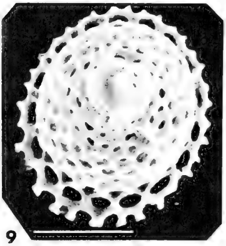
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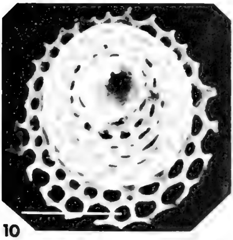
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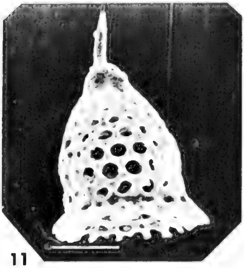
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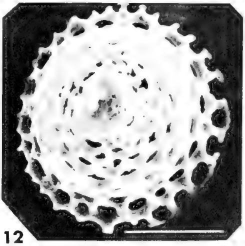
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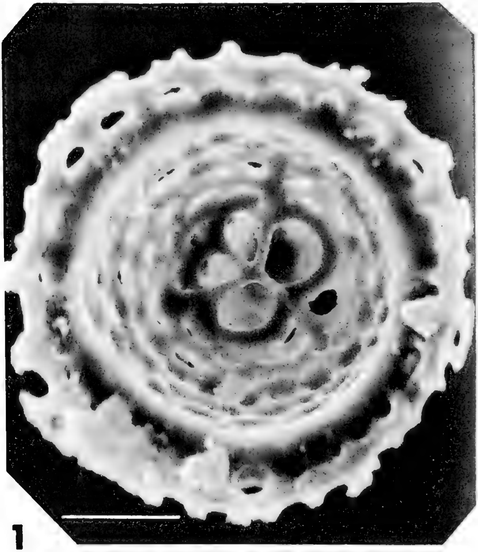

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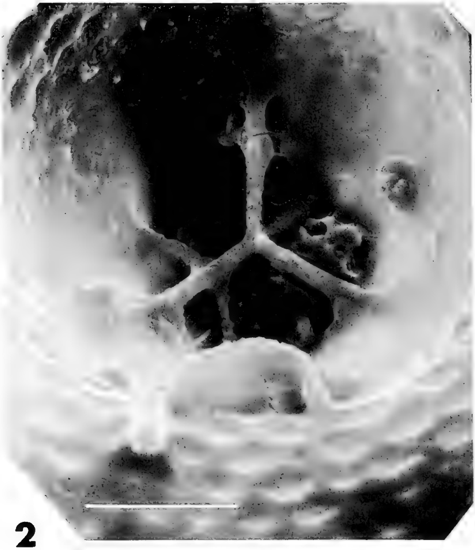

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EXPLANATION OF PLATE 38

Both figures scanning electron micrographs of latest Campanian Radiolaria.

Figure		Page
1.	**Coniforma antiochensis** Pessagno, n. sp. .... Paratype (USNM 164267). Latest Campanian. NSF 568-B. Panoche Group ("Marsh Creek Formation"). Cephalic skeletal needles and collar pores. Axial element appears missing; marker = 25 microns.	398
2.	?**Sciadiocapsa campbelli** Pessagno, n. sp. .... Paratype (USNM 164263). Latest Campanian. NSF 568-B. Panoche Group ("Marsh Creek Formation"). Cephalic skeletal needles and collar pores viewed looking into test in a proximal direction; marker = 25 microns.	415

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By

JUDITH TERRY SMITH

1970

Paleontological Research Institution
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TAXONOMY, DISTRIBUTION AND PHYLOGENY OF THE CYMATIID GASTROPODS ARGOBUCCINUM, FUSITRITON, MEDIARGO, AND PRIENE

Judith Terry Smith
Stanford University

ABSTRACT

The systematic revision herein of several cool water cymatiid genera provides the basis for biogeographic studies and a possible scheme of phylogenetic affinities. Of 45 related and convergent forms described in these genera, 20 are recognized as distinct taxa in *Argobuccinum, Fusitriton, Mediargo,* and *Priene.* Morphologic differences are considered in the light of growth changes, intraspecific variability, and mode of preservation. Ecologic and distributional data are summarized.

Morphologically similar Recent species of *Fusitriton* exhibit a bipolar distribution and are widespread within the temperate parts of the North Pacific and South Pacific, and South Atlantic Oceans. Investigations of *Argobuccinum* indicate a similar bipolar distribution of early to middle Tertiary species, although Recent forms are confined to the Southern Ocean.

Recent species of *Argobuccinum* and *Fusitriton* occur in the same geographic areas in the Southern Ocean, although dispersal was not contemporaneous, and ecologic — particularly bathymetric — ranges differ. *Argobuccinum* became widespread before the end of the Pleistocene; morphologically and geographically distinct forms live at depths of less than 80 fathoms in South America, South Africa, Australia, New Zealand, and the south Indian Ocean. *Fusitriton* has no fossil record in the Southern Hemisphere, and species show a high degree of morphologic overlap. They are common in 50 to 320 fathoms off the eastern and western coasts of South America, South Africa, eastern Australia, New Zealand, and at mid-ocean localities in the southern South Pacific.

Suggestions of dispersal routes are somewhat tentative, owing to insufficient fossil evidence from critical equatorial localities and incomplete knowledge of Tertiary records in the Western Pacific. *Argobuccinum,* which ranges from Miocene to Recent in the Southern Hemisphere, is represented in the Eocene or early Oligocene of northwestern Washington and Oregon by *A. jeffersonense* (Durham, 1944). Dispersal from western North America to south central Chile probably occurred between Oligocene and (? late) Miocene time along or off the west American coast. *Mediargo,* an Oligocene to Pliocene genus restricted to the Northern Hemisphere, may have evolved from *Argobuccinum* by the middle Oligocene and given rise to *Fusitriton* in the late Oligocene. A number of possible cymatiid ancestral forms from the Eocene of western North America have yet to be studied. The first records of these three genera are in early Tertiary marine strata of southeastern Vancouver Island and western Washington and Oregon. *Priene,* of uncertain phylogenetic affinities, is restricted to the west coast of South America; it ranges from Pliocene to Recent.

Data on the free swimming pelagic larvae of *Fusitriton oregonensis* (Redfield) and other cymatiid species suggest a long veliger stage, which would favor dispersal by currents. Bathymetric data for *Fusitriton oregonensis* imply submergence (to depths of at least 1100 fathoms) in the tropics and suggest that populations may have dispersed from north to south across the equatorial Pacific as benthic adults rather than in the larval state. Specimens are as yet too rare to confirm positively either of the suggested dispersal paths, the Trans-Pacific or offshore Eastern Pacific routes. *Fusitriton* probably dispersed to the Southern Hemisphere in the Plio-Pleistocene or Pleistocene. The genus is believed to have originated in North America, evolving from *Mediargo,* and to have travelled west to Japan in the early Neogene, although the Japanese literature reports Western Pacific Oligocene occurrences of *Fusitriton* that the writer has not been able to evaluate.

INTRODUCTION

The genera *Argobuccinum, Fusitriton,* and *Priene* have been confused and the names used interchangeably in much of the systematic literature covering Cenozoic marine mollusks of western North America. Such random usage has resulted in taxonomic errors and inaccurate reports of distribution; it has also obscured the bipolar occurrence and phylogenetic affinities of several closely related but widely dispersed stocks.

A number of authors have cited the discontinuous distribution of Recent species of *Fusitriton* as an example of bipolarity, the genus being apparently absent from equatorial waters but widespread in the Northern Hemisphere and Southern Hemisphere. This paper classifies *Gyrineum jeffersonensis* Durham, 1944 from the late Eocene or early Oligocene of Washington and Oregon in the genus *Argobuccinum.* All other species of the genus are late Tertiary or Recent and restricted to the Southern Hemisphere. Both *Fusitriton* and *Argobuccinum* originated in the early Tertiary in western North America and dispersed from there to the Southern Hemisphere. That radiation was not contemporaneous is suggested by the fossil record and by morphologic differences in Recent species of the two genera.

This monograph is intended to facilitate identification of the species concerned, indicate their stratigraphic and geographic ranges, and synthesize available information on the biology of the living organisms for use in paleoecological studies. Applied to the problem of dispersal from the Northern Hemisphere to Southern Hemisphere, these data suggest possible modes, times, and avenues by which species attained their present distributions.

PROCEDURE AND MATERIALS

Nomenclatural revisions undertaken in the doctoral dissertation of the writer (Terry, 1968a) are presented here as a foundation for studies of biogeography and possible dispersal routes. Of 45 described species, 20 are treated as distinct taxa of *Argobuccinum* Herrmannsen, 1846, *Fusitriton* Cossmann, 1903, *Mediargo* Terry, 1968b, or *Priene* H. & A. Adams, 1858. Taxonomic work is based upon type specimens or photographs that have been compared with each other and with additional material. The literature has been reviewed extensively and many Recent and fossil specimens examined to determine to what degree morphologic features vary. Collections at 15 museums in the United States and four South American institutions were systematically searched in 1966 and 1967 for examples of these genera, and Recent material was acquired for the study of soft parts, especially jaws and radulae. Geologic and geographic ranges have been recorded and a possible phylogenetic sequence charted.

Studies of life history and larval development were beyond the scope of this work but should yield much information vital to the questions of dispersal modes and rates. Remarks on living animals are based on a few personal observations, data from the literature, and probable similarities to related genera that have been studied in greater detail.

ACKNOWLEDGMENTS

How thorough a study of this sort can be depends upon the availability of large numbers of specimens representing as many localities as possible. I should like to express my appreciation to the following curators, professors, and collectors for their assistance and hospitality during visits to their institutions, and for their permission to borrow extensive lots of material: J. Wyatt Durham and Joseph Peck, University of California, Berkeley; L. G. Hertlein and Allyn Smith, California Academy of Sciences; Warren Addicott and J. G. Vedder, U.S. Geological Survey, Menlo Park; F. S. MacNeil, formerly of the U.S. Geological Survey; Joseph Clark, University of California, Santa Barbara; Heinz Lowenstam and George Clark, California Institute of Technology; LouElla Saul, University of California, Los Angeles; James H. McLean, George Kanakoff, and Louie Marincovich, Los Angeles County Museum; Carl Hubbs and H. George Snyder, Scripps Institution of Oceanography; E. C. Allison, San Diego State College; Edward Wilson, formerly of the San Diego Society of Natural History; Joseph Rosewater and Harald Rehder, U.S. National Museum Dept. of Mollusks; Thomas Waller, Smithsonian Institution, and Druid Wilson, U.S. Geological Survey, Washington, D.C.; Patsy McLaughlin and the staff of the Smithsonian Oceanographic Sorting Center; Ruth Turner and Kenneth Boss, Museum of Compara-

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Photographs of type specimens, of which many are reproduced here, were provided by Kotora Hatai, Institute of Geology and Paleontology, Tohoku University, Sendai, Japan; J. F. McMichael, Miss J. Cave, and C. V. Turner, photographer, of the Australian Museum in Sydney contributed much of the data on Australian species and pictures of specimens in their collection. Most of the other photographs used in the plates were taken by the writer, with the exception of those made from old literature by Perfecto Mary, in the field by N. J. Silberling, and in the laboratory by W. R. Evitt, all of Stanford University, and by K. Sakomotu, U.S. Geological Survey.

In the fall of 1966, I was assisted by Martha S. Terry on a collecting trip to Ecuador, Peru, and Chile, during which time the following were extremely generous with their time and collections: Jose Corvalañ, Fédérico Peebles, Carlos Klohn, and G. Chung of the Servicio Geologico of Chile; Luis Aguirre and Reynaldo Charrier, Escuela de Geologia, Universidad de Chile, Santiago; N. Bahamondes and Fascola, Museo de Histoire Natural, Quinta Normal, Santiago; L. Biro and Jorge Hermosilla, Universidad de Concepcion, Chile; H. Etchiverry, Director of the Estación de Biologia Marina, Montemar, and Luis Ramorino, Viña del Mar, Chile; Oscar Mirande, Departmento de Oceanologia, Antofagasta, Chile; Luis Aguilar and Mario Peña, Universidad Agraria, La Molina, Lima, Peru.

Recent specimens of *Fusitriton oregonensis* (Redfield) were supplied from Puget Sound by Frank Barnard, Biological Station, Nanaimo, B.C., and from Monterey Bay by John Favalora of the General Fish Corporation, Moss Landing, California.

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CLASSIFICATION ABOVE THE SPECIES LEVEL

HIGHER TAXONOMY

Recent species of the genera under consideration are among the more advanced mesogastropods; they are taenioglossate prosobranchs belonging to the superfamily Tonnacea, family Cymatiidae. Powell (1933a, p. 155) recognized, on the basis of dentition and operculum, three subfamilies: Ranellinae, Cymatiinae, and Charoniinae, only the first two of which will be mentioned here. The Ranellinae are characterized by an apical nucleus on the operculum and a radula having a broad, low central tooth with a straight basal margin and entire laterals. Powell included *Ranella* and *Mayena* in this subfamily but noted significant differences in their male reproductive organs. He described the Cymatiinae as having a basal nucleus on the operculum, denticulate lateral teeth and a broad, low central tooth with high, arcuate basal margins. To Powell's list, which included, among others, *Cymatium, Argobuccinum,* and *Monoplex,* Dell (1963) added *Priene* and *Fusitriton.*

PROBLEMS OF GENERIC IDENTIFICATION

Cymatiid genera pertinent to this study have been reviewed in several important papers: Dall, 1904, *An historical and systematic review of the frog-shells and tritons;* Powell, 1933, *Notes on the taxonomy of the Recent Cymatiidae and Naticidae of New Zealand;* Carcelles, 1954, *Espècies Sudamericanas de Argobuccinum Bruguière 1792;* Dell, 1963, *The Mollusca of the genus Argobuccinum (Family Cymatiidae).* Cymatiids from New Zealand were considered in the doctoral thesis of Dr. A. G. Beu at the Victoria University of Wellington. The writer is grateful for bibliographic and ecological information made available from that research.

Of the 16 generic names that have been used for *Argobuccinum, Fusitriton, Priene,* and *Mediargo,* seven are synonyms or otherwise inappropriate and four should be restricted to other cymatiid genera. Incomplete or deformed fossil specimens of the genera listed above have also been incorrectly referred to *Buccinum* Linnaeus, 1758 and *Bursa* Röding, 1798. Difficulties in identifying these genera stem from two sources: a high degree of overlap in morphologic characters and a long history of nomenclatural confusion based upon incomplete knowledge of type material. Text-figure 1 illustrates the type species of several genera and emphasizes the summation of characters that differentiates them. Aperture shape, canals and denticulation, shell outline, position of varices, protoconch, and operculum are more significant than fine sculptural details. Names that have been given to material here recognized as *Argobuccinum, Fusitriton, Priene,* and *Mediargo* are listed below.

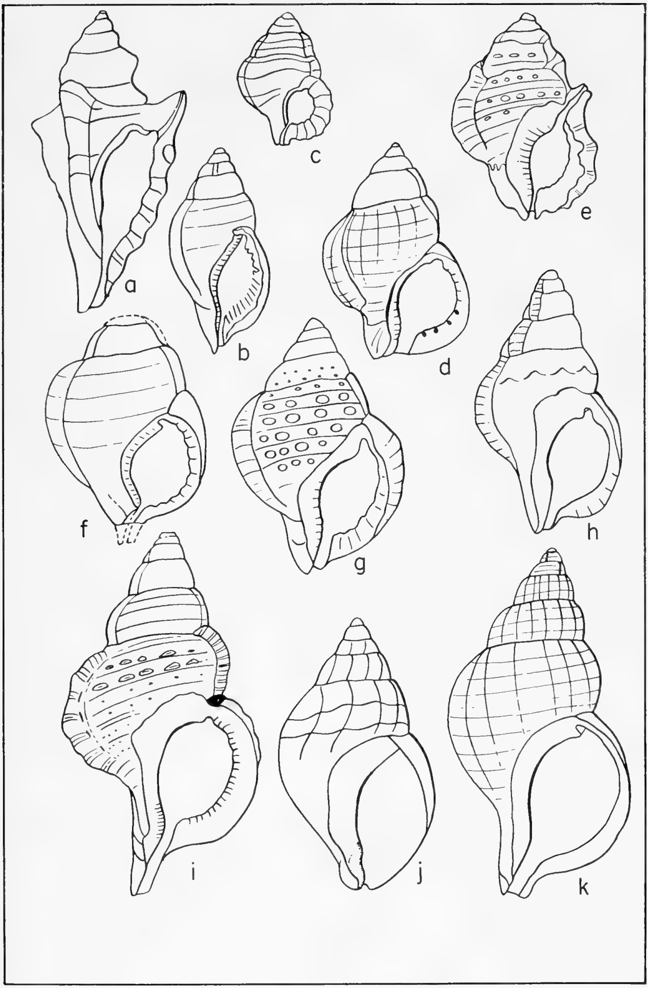
Family **CYMATIIDAE**

Cymatium Röding, 1798. Type species: *Murex femorale* Gmelin, 1791 (subsequent designation). [Dall (1904; p. 122) noted that *M. femorale* was the first species listed under *Cymatium* but did not mention the word "type"; Suter (1913; p. 306) should probably be credited with the subsequent designation.]

Argobuccinum Herrmannsen, 1846. Type species: *Murex argus* Gmelin, 1791 (original designation).

⟶

Text-figure 1. — Representatives of ten genera (all approx. ×2/3). a. *Cymatium femorale* (Gmelin), type species of the genus, and type species of the family Cymatiidae; b. *Cymatium (Septa) vestitum* (Hinds); c. *Gyrineum gyrinus* (Gmelin); d. *Priene scabra* (King); e. *Bursa bufonius* (Gmelin); f. *Mediargo mediocris* (Dall); g. *Argobuccinum argus* (Gmelin); h. *Mayena australasia* (Perry); i. *Ranella olearium* (Linnaeus); j. *Buccinum undatum* (Linnaeus); k. *Fusitriton cancellatus* (Lamarck).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Priene H. and A. Adams, 1858. Type species: *Triton scaber* King, 1832 (subsequent designation, Cossmann, 1903).

Fusitriton Cossmann, 1903. Type species: *Triton cancellatus* Lamarck, 1816 (original designation).

Ranella Lamarck, 1816. Type species: *Ranella gigantea* Lamarck, 1816 = *Murex olearium* Linnaeus, 1758 (monotypy).

Mayena Iredale, 1917. Type species: *Biplex australasia* Perry, 1811(subsequent designation by Powell, 1937, p. 74).

Gyrineum Link, 1807. Type species: *Murex gyrinus* Gmelin, 1791 (subsequent designation). [Dall (1904; p. 117) noted that *Murex gyrinus* Gmelin was the only available species in the original list "left to carry Link's name *Gyrineum*," but did not use the word "type." Cernohorsky (1967; p. 322) cited the subsequent designation by Dall (1904), although he, if not an earlier worker, should be credited with it.]

Mediargo Terry, 1968. Type species: *Gyrineum mediocre* Dall, 1909a (original designation).

Family **BURSIDAE**

Bursa Röding, 1798. Type species: *Bursa monitata* Röding = *Murex bufonius* Gmelin, 1791 (subsequent designation by Jousseaume, 1881, *fide* Wenz, 1941).

Family **BUCCINIDAE**

Buccinum Linnaeus, 1758. Type species: *Buccinum undatum* Linnaeus, 1758 (subsequent designation by Montfort, 1810. I.C.Z.N. Opinion 94, generic name No. 450).

The following names have been used in the literature for *Argobuccinum, Priene, Fusitriton,* or *Mediargo* but are not appropriate for these genera:

Apollon Montfort, 1810. Type by original designation, *Murex gyrinus* Gmelin, making this an objective synonym of *Gyrineum* Link, 1807, under which *Murex gyrinus* was also listed.

Cryotritonium von Martens, 1904. Proposed as a new subgenus of *Tritonium* with *Lampusia (Priene) murrayi* E. A. Smith as type; it is a subjective synonym of *Fusitriton* Cossmann, 1903.

Gondwanula Finlay, 1927. Type by original designation, *Ranella tumida* Dunker; it is a synonym of *Argobuccinum* Herrmannsen, 1846.

Nyctilochus Gistel, 1848. Synonym for *Triton* Linnaeus, 1758, which is a crustacean.

Pollia Gray, 1839. Preoccupied by a genus *Polia* in Lepidoptera, Ochsenheimer 1816, *fide* G. B. Sowerby I, 1842.

Triton Montfort, 1810. Preoccupied by *Triton* Linnaeus, 1758, a crustacean, and by *Triton* Laurenti, 1768, an amphibian.

Tritonium Link, 1807. Preoccupied by *Tritonium* Müller, 1776, a Buccinacean.

VARIABILITY AND RELATIVE RELIABILITY OF MORPHOLOGIC CHARACTERS USED IN GENERIC AND SPECIFIC TAXONOMY

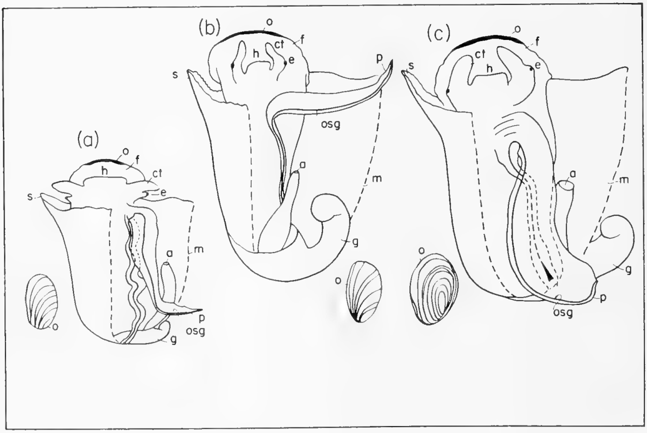
Recent species of *Argobuccinum, Fusitriton,* and *Priene* are cool water forms that exhibit the general tendency of boreal gastropods toward variability in shape and sculpture. The capacity for great variation added to the similarity in recently evolving or evolved species complicates the classification and identification of these taxa. Characters here used as taxobases include: protoconch, height of spire, whorl outline, number and position of varices, aperture shape, orientation of columella and presence of pillar callous, anterior and posterior canals, internal varices or structures on the outer lip, adult sculpture, color bands, operculum, periostracum, and soft parts, jaws and radulae where available.

Of these, soft part morphology (Text-fig. 2), jaws and radulae (Text-fig. 3) were found useful only to the generic level. Protoconch, operculum, length of periostracal hairs, mode of formation, number and position of varices, general outline, and incurrent and excurrent apertural modifications are consistent for a given genus, except for some young or gerontic individuals.

Within a given geographical area, *Argobuccinum* varies intraspecifically between end members that are distinct in the adult (if not in all intermediate) stages from those of any other region. Whether tumid or slender in outline, whorls are always rounded, shoulders never tabulate, and varices always two per whorl in lateral positions. Major generic criteria are the relatively short anterior canal and marked excurrent notch oriented parallel to the axis of coiling. Aperture shape is generally consistent for a species. Shells are thick, and flexed pillars covered by a heavy deposit of callous that bears transverse wrinkles in most specimens. The outer lip is commonly plicate or denticulate, the number of cusps being taxonomically insignificant. Two of the five Recent species develop a labial spine near the anterior end of the outer lip. All Recent species have reddish brown or black spiral bands, a brown or yellowish velvety periostracum and a horny operculum, the outer edge of which is ragged where it lies against the outer lip.

Axial sculpture varies widely; the degree of coarseness and arrangement of nodes differ within a given species. Axial ornamentation is taxonomically significant only in combination with whorl outline and revolving sculpture. Spiral microsculpture is generally consistent for a species, one notable exception being the end members of the variable *A. ranelliforme* (King) [= *A. vexillum auctt.*] from South America (Pl. 39, figs. 2,9). The spire height in some species is the same in juveniles and adults, but in one variant of *A. argus* (Gmelin) and most forms of *A. tumidum* (Dunker) it is higher in the early stages but lower as the adult volutions become more tumid. Historically, species have been defined on the basis of geographical locality; this is valid in the case of *Argobuccinum,* which seems to have had sufficient time to disperse and develop isolated populations that are morphologically distinct.

The degree of overlap in shell characters in species of *Fusitriton* is greater than in *Argobuccinum.* Similarity of geographically separated forms and the absence of a fossil record in the Southern Hemisphere suggest a more recent dispersal, species being in the process of evolution, perhaps, rather than completely separated as in *Argobuccinum.* Relationships between widespread forms of *Fusitriton* are not indicated accurately by classification schemes based entirely on geographical areas or subregions. Material collected



Text-figure 2. — A comparison of male copulatory organs in *Priene rude, Argobuccinum ranelliforme,* and *Fusitriton cancellatus.* (a). *Priene rude* and operculum (x.4); (b.) *Argobuccinum ranelliforme* (x.4) and operculum (x.4); (c.) *Fusitriton cancellatus* (x.4) and operculum (x.4). Penis partly extended in (b), retracted within the mantle cavity in (a) and (c). a, anus; ct, cephalic tentacle; e, eye; f, foot; g, gonad; h, head; m, mantle; o, operculum; osg, open seminal groove; p, penis; s, siphon.

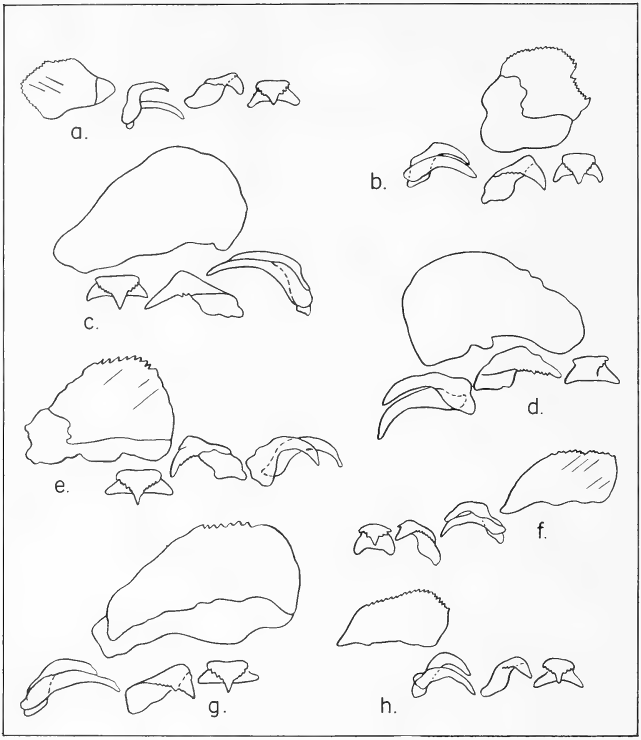
from mid-oceanic stations in the Southern Hemisphere is intermediate between specimens taken nearer the continents, and further sampling may show a completely gradational series of Subantarctic forms.

Axial and spiral, commonly bifurcated, ribs are present on all species of *Fusitriton*. The coarseness and number of elements per whorl and the nodosity where axials and spirals cross are specifically diagnostic. Spiral microsculpture varies intraspecifically, as do apertural shape and columellar orientation. Pillar callous is deposited intermittently near the excurrent notch, and outer lips are devoid of denticles except for some individuals in local populations – for example, *Fusitriton oregonensis* (Redfield) from Monterey Bay, California, and Departure Bay, British Columbia.

Southern species can generally be divided into two groups, one with a higher spire (material from Australia and New Zealand) than the other (specimens from South America and South Africa). Whorl outlines are commonly rounded, although shoulders may be tabulate in some individuals of *Fusitriton oregonensis*. The number and position of inconspicuous varices are irregular and taxonomically unimportant in Recent material. Shells are white, but fresh specimens of some species have yellow-brown bands parallel to spiral costae; at least a few specimens of each species have color bands, although they are much rarer in *Fusitriton oregonensis* (Redfield) and *F. cancellatus* (Lamarck) than in the other taxa. Ochraceous apertural margins have been seen in all species and are not unique to the material described as *Argobuccinum retiolum* Hedley from Australia.

Long-haired periostraca are typical of all species of *Fusitriton*, but the color tends to be dark brown in *F. oregonensis* and some specimens of *F. galea* and *F. cancellatus*. Other specimens of *F. galea* and *F. cancellatus*, as well as material from South Africa and New Zealand, have honey-colored periostraca. Color determinations may be affected by preservatives, and museum specimens exposed to air for long periods of time commonly lose the long hairs and are left with a short scaly covering.

Recent specimens of the genus *Priene* can be recognized by the shell outline, lateral varices, protoconch, and apertural modifications: pillar, denticulate outer lip, spiral sculpture, and slight



Text-figure 3. — Jaws and radulae. Jaws vary in shape between genera but all are thin, brittle, horny structures that are slightly concave toward each other. They consist of rows of files that are easily torn and cannot be prepared by the same methods as the radulae. Quickly soluble in weak bases, the jaws must be extracted by hand and teased free of the surrounding tissue. During a maximum extension of the proboscis, the buccal mass moves forward and the jaws and lips are the first parts to come in contact with the prey. The function of the jaws is not understood; they are probably too brittle for vigorous clasping and filing, and it is doubtful that they drill holes. They are possibly chemoreceptors or tactoreceptors. All jaws to scale, approx. ×8.5; all except d are left jaws. a. *Argobuccinum ranelliforme* (King), Talcan, Chile. b. *Argobuccinum tumidum* (Dunker), Storm Bay, Tasmania. c. *Fusitriton oregonensis* (Redfield), Nanaimo, British Columbia. d. *Fusitriton cancellatus* (Lamarck), Chiloe Island, Chile. (a portion of this jaw is shown in Plate 42, fig. 10). e. *Fusitriton cancellatus murrayi* (Smith), Cape Town, South Africa. f. *Priene scabra* (King), Viña del Mar, Chile. g. *Fusitriton retiolus* (Hedley), Campbell Plateau, off New Zealand. h. *Priene rude* (Broderip), Valparaiso, Chile.

(if any) anal notch. Variability of form is negligible, and the two species can be distinguished on the basis of coarseness and number of axial ribs.

Mediargo, a new cymatiid genus described during the course of this research (Terry, 1968b), ranges from Oligocene to Pliocene and has no living forms in which the degree of variability can be studied. Considering the amount and kind of variation observed in Recent species in *Argobuccinum, Fusitriton,* and *Priene,* one would expect the general outline, tabulate whorls, lateral varices, excurrent notch and incurrent canal, pillar wrinkles and outer lip denticulation to be critical generic characters, whereas apertural shape and kind, number and coarseness of sculptural elements may vary within and between species.

CATALOGUE AND DESCRIPTION OF SPECIES

The synonymies for each species are not complete but aim to set forth all the published names to which each taxon has been referred. Abbreviations for institutions are defined below.

AMNH	American Museum of Natural History, New York City
AMS	The Australian Museum, Sydney, N.S.W.
ANSP	Academy of Natural Sciences of Philadelphia
BM(NH)	British Museum (Natural History)
CAS	California Academy of Sciences, San Francisco
IGPS	Institute of Geology and Paleontology, Tohoku University, Sendai, Japan
LACM	Los Angeles County Museum
LSJU	Stanford University
MCZ	Museum of Comparative Zoology, Harvard College
MHNQN	Museo Nacional de Historia Natural, Quinta Normal, Santiago, Chile
NMV	National Museum of Victoria, Melbourne, Vic.
SDMNH	San Diego Museum of Natural History
SDSC	San Diego State College
SIO	The Scripps Institution of Oceanography
SOSC	Smithsonian Oceanographic Sorting Center, Washington, D.C.
UCMP	University of California, Berkeley, Museum of Paleontology
UCLA	University of California, Los Angeles
USGS	United States Geological Survey
USNM	United States National Museum, Smithsonian Institution, Washington, D.C.

STATES

Ak.	Alaska
Ca.	California
Ka.	Kansas
Or.	Oregon
Wa.	Washington

Superfamily **TONNACEA**

Family **CYMATIIDAE**

ARGOBUCCINUM Herrmannsen, 1846

Type species by monotypy, cited by Herrmannsen, 1846 as "Ranella Argus Linné"; *i.e., Murex argus* Gmelin, 1791 [=*Argobuccinum pustulosum* ([Lightfoot, 1786]), *nom. oblitum*].

Argobuccinum argus (Gmelin, 1791) Pl. 39, figs. 7,10,11,12

Buccinum pustulosum [Lightfoot, 1786], A Catalogue of the Portland Museum, p. 88; Dall, 1921, Nautilus, Vol. 34, No. 4, p. 125 (as of Solander). (See nomenclatural remarks.)

Murex argus Gmelin, 1791, Systema Naturae, 13th ed., toma 1, pars. VI, p. 3547. Dillwyn, 1817, Descriptive Catalogue Recent Shells II, p. 694.

Ranella polyzonalis Lamarck, 1816, Encycl. Méth., Partie 23, p. 4, pl. 414, figs. 3a, 3b.

Ranella argus (Gmelin), Lamarck, 1822, Hist. Nat. des Animaux sans Vertèbres, vol. 7, p. 151; Kiener, 1841, Iconogr. Coquilles Viv., pl. VIII, fig. 1; 1842, Iconogr. Coquilles Viv., pp. 31,32; Reeve, 1844, Conch. Icon. *Ranella,* sp. 12, pl. III, fig. 12; Kuster and Kobelt, 1878, Conch. Cab. [2d ed.], Bd. III [Ab. II], pp. 125,126, sp. 2; p. 329, Taf. XXXVII, figs. 5,6 (as of Gmelin).

Argobuccinum argus [Linné], Herrmannsen, 1846, Indices Generum Malacozoorum Primordia, p. 77; von Martens, 1904, Wiss. Ergeb. deutschen Tiefsee-Exped. vol. 7, p. 41 (as of Gmelin); Bartsch, 1915, Turton Coll. So. African Molls., U.S. Nat. Mus., Bull. 91, pp. 93,224 (as of Gmelin); Barnard, 1951, Beginner's Guide to So. African Shells, p. 86, pl. 10, figs. 7,8; 1963, Ann. So. African Mus. XLVII, Pt. 1, pp. 18-21, fig. 2a (radula), 3a (protoconch); Dell, 1963, Roy. Soc. New Zealand, Trans., vol. 3, No. 21, pp. 218,219, pl. 2, figs. 1,5.

Apollon Argus: Troschel, 1863, Gebiss der Schnecken I; p. 237, Taf. XX, fig. 11. [Identification *fide* Troschel; figure shows only a taenioglossate radula.] (as of Lamarck).

Ranella (Argobuccinum) argus Gmelin, Tryon, 1880, Man. Conch., ser. 1, vol. III, pt. 9, pp. 44,45 *(partim);* 1881, plate explanations, p. 286, pl. 24, fig. 61. [Tryon included *Ranella argus* from South Africa, *R. vexillum* = *R. ranelliforme* from South America, and *R. tumida* from the Chatham Islands, New Zealand, in one variable species, *R. (Argobuccinum) argus.*]

Argobuccinum pustulosum ([Lightfoot, 1786]), Rehder, 1967, U.S. Nat. Mus., Proc., vol. 121, p. 16.

Nomenclatural remarks.—Although never well known as a scientific paper and disputed as a work important to biological nomenclature, the Portland Catalogue is considered an acceptable source of zoological names. This inventory of the shell collection belonging to the Dowager Duchess of Portland was prepared by "a compiler," whom Dance (1962, p. 31) showed to be the Reverend John Lightfoot, a chaplain and amateur conchologist. Rehder (1967, p. 2) pointed out that authorship of the species introduced in the Catalogue should be attributed to Lightfoot rather than to Solander, from whose manuscript some of the names were taken.

In 1786, Lightfoot recorded the name *"Buccinum pustulosum* S.," followed by "Rum. [Rumphius, 1741, Tafel] 49, B. *rare,"* which was also the first reference cited by Gmelin, 1791 under his new species *Murex argus.* From 1791 until 1841, the two names *Buccinum pustulosum* and *Murex argus* existed as senior and junior synonyms, respectively, and to the writer's knowledge the earlier name never appeared in the major literature during that 50 year period. According to Article 23B of the Code of Zoological Nomenclature, the earlier synonym becomes a *nomen oblitum,* a forgotten name if not used during the first fifty years after the junior synonym was introduced; as such, the earlier name may be suppressed by the Commission. Later usage of the senior synonym, as Dall's reference (1921, p. 125) to *Buccinum pustulosum* does not affect the status of the *nomen oblitum.* A petition has been filed (Terry, 1968c) in which, in the interests of stability of nomenclature, the writer recommended suppression of the earlier name and acceptance of the widely used *M. argus* as the name for the South African type species of *Argobuccinum.*

Type information.—No holotype was designated by Herrmannsen, although his original reference (1846, p. 77) lists "Typus: *Ranella Argus* Linn," suggesting that a specimen might be found in the Linnean Collection now housed in the rooms of the Linnean Society in London. The original citation should, however, have been to Gmelin, 1791, *Systema Naturae,* 13th ed. Because the title was the same as Linnaeus' *Systema Naturae* editions 1 to 12, many workers assumed that the 1791 edition was also a Linnean revision.

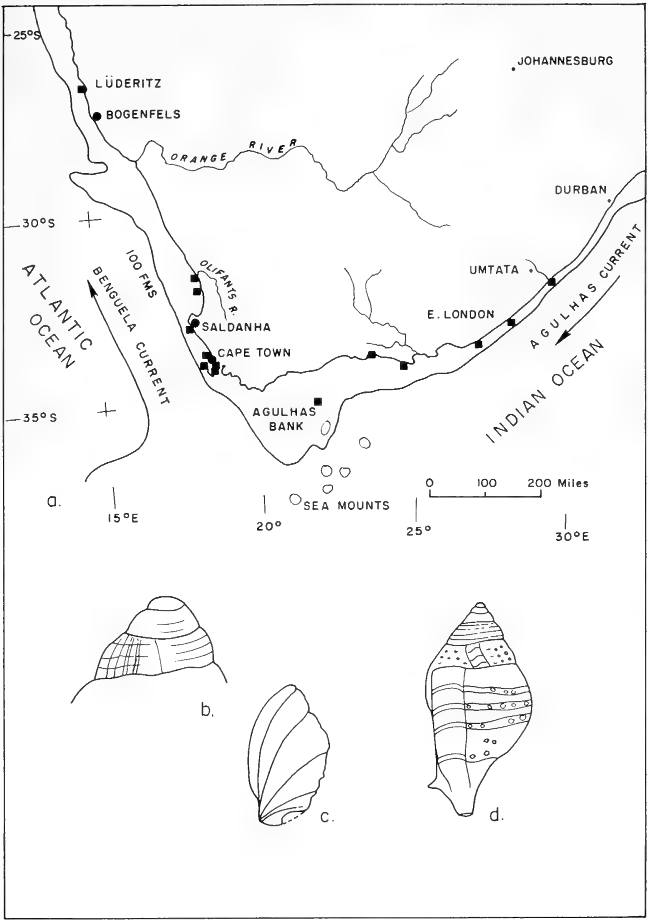
As Gmelin did not have a collection but worked mainly from the literature, it is unlikely that he possessed a specimen of *Murex argus.* If a cited figure rather than an actual specimen can be considered a holotype, the species concept of *Murex argus* rests on the illustration by Rumphius, although this figure is a poor choice for two reasons: the original shell is presumed lost and the woodcut produced a mirror image in which the shell appears sinistrally coiled. A good adult specimen on which to base the species concept was illustrated by Dell (1963, pl. 2, fig. 1). There is no need at this time for a formal neotype designation because a petition on the status of the name *A. argus* is still pending (Terry, 1968c).

Descriptive notes. — Adult shells are heavy and bear two lateral varices per whorl. Heights range from 6 to 10.2 cm, whorls being six or more in number. Both juveniles and adults are sculptured by thick nodes in uneven axial rows crossed by spiral threads and black, brown, or tan color bands. On some individuals where abrasion has occurred, the nodes are white, producing an ocellated appearance. Nodes become obsolete toward the anterior end beyond the middle of the body whorl. A short incurrent canal, marked anal notch, and bifurcated plications modify the aperture. Unbifurcated denticles also occur on some juveniles on the inside of the thickened outer lip. A feature rarely seen is a labial tooth (Text-fig. 4) toward the anterior portion of the outer lip. This projection is commonly lacking (even in fresh material) and may be broken off during feeding or other activities. In some it is visible on earlier varices. The columella is slightly flexed or straight and covered by a deposit of callous, smooth or with up to seven or more transverse wrinkles overall.

The short-haired yellowish-tan periostracum forms a thin mat-like covering over the later whorls but is usually absent from the juvenile volutions in adults. Jaws appear in all other species of this genus and probably occur in *A. argus,* although a live animal was not dissected for this study.

Variability. — Specimens studied by the writer were in the late juvenile to young adult stages and varied mainly in apertural denticulations and sculpture pattern. Most shells are coarsely sculptured and angular, but a few tend toward more regular nodes and rounded whorl outlines (perhaps partly due to abrasion), and more slender spires with an apical angle as in *A. ranelliforme* (King) from South America or *A. proditor* (Frauenfeld) from St. Paul and Amsterdam Islands in the Indian Ocean. Individuals having whorl outlines and sculpture patterns between the more typical *A. argus* and the smoother variant have been taken from the same localities.

The nodes on all forms of *A. argus* are fewer, coarser, and less regular in arrangement than those on the South American *A. ranelliforme (= A. vexillum auctt.); A. tumidum,* a thinner shelled



Text-figure 4. — Distribution of *Argobuccinum argus* (Gmelin). a. Distribution of *A. argus,* ■ Recent, ● Tertiary--Quaternary terrace deposits (Barnard, 1963). b. Protoconch (x 14); c. Operculum (x .7); d. Side view of specimen showing labial spine.

animal from New Zealand and Australia, has more inflated whorls and differs in minor sculptural details. Many specimens of *A. tumidum* have irregular nodes, but they are sharper and finer than in the type species.

Distribution and ecology. — Range: Recent. South Africa from Luderitz Bay on the west coast (Tomlin, 1922, p. 260) and the Umtata River on the east coast (Dell, 1963, p. 219) south to Agulhas Bank, 35°16′S, 22°26′E, off the Cape of Good Hope (von Martens, 1904, p. 41, "Valdivia" station 104, not live-taken, from a depth of 155 m).

Geologic distribution: "Late Tertiary - Quaternary raised beaches: Bogenfels, mouth of Olifants River and Saldahna Bay (Haughton, 1932)" (Barnard, 1963, p. 21).

Few collectors have observed living material, but Stephenson, Stephenson, and Day (1940, p. 356) reported that the species is ". . . common in varying degrees and occurring in the lower parts of the shore, especially in pools and caves. . . . " at Lambert's Bay; Mrs. Virginia Orr Maes of the Academy of Natural Sciences of Philadelphia collected many specimens from the vicinity of Cape Town and noted (personal communication, 1967) considerable numbers in tide pools. All specimens having any ecological data came from a rocky substrate and ranged from littoral to 155 m in depth. Barnard (1963, p. 21) mentioned that Dr. Talbot, marine biologist at the South African Museum, observed animals spawning in the spring (early October) at Simonstown. He also recorded six juveniles that came from Natal in the museum collection, representing a range extension if the locality is accurate.

Argobuccinum ranelliforme (King, 1832)

Pl. 39, figs. 2,4,6,9; Pl. 40, figs. 2,6,7,10-12

Triton ranelliformis King, 1832, Zool. Jour. V(XIX), p. 347.

Ranella Kingii d'Orbigny, 1841, Voy. Amer. Merid. V(3), p. 451.

Ranella vexillum G. B. Sowerby II, Oct. 1841, Zool. Soc. London, Proc., pt. IX, p. 51; Sept. 15, 1841, Conch. Illust. *Ranella,* 7,8; 1835, pl. 84, fig. 3; Reeve, 1844, Conch. Icon. II, *Ranella*: sp. 13, pl. III, fig. 13 (as of Sowerby).

Apollon vexillum G. B. Sowerby II, Adams, H. & A., 1858, Gen. Rec. Moll. I, p. 106.

Ranella (Argobuccinum) argus Gmelin, Tryon, 1880, Man. Conch. ser. 1, III, pt. 9, pp. 44,45 *(partim);* 1881, pl. 24, fig. 62. [Tryon included *A. ranelliforme, A. tumidum, A. proditor,* and *A. argus* in one variable species *Ranella (Argobuccinum) argus.* In a discussion (p. 45) he referred to the South American form as "*Ranella Ranelliformis* King (*argus,* Gmelin);" in a plate explanation (p. 286) he called it "*Ranella vexillum* Sowerby (*argus,* Gmelin)."]

Argobuccinum vexillum G. B. Sowerby II, Dall, 1909, U.S. Nat. Mus., Proc., vol. 37, p. 226.

Argobuccinum (Argobuccinum) argus (Gmelin), Carcelles, 1954, Comm. Inst. Nac. Inv. Cienc. Nat., Cienc. Zool. 2: p. 244, figs. 5,6 *(partim).*

Argobuccinum ranelliformis ranelliformis (King, 1832), Dell, 1963, Roy. Soc. New Zealand, Zool. Trans. 3(21), pp. 219-220, pl. 2, fig. 2.

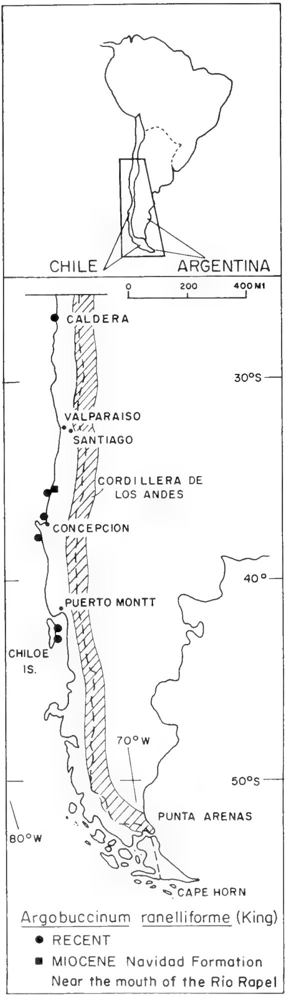
Nomenclatural remarks. — Reeve (1844) considered the name *T. ranelliformis* King invalid when the species was reclassified as a *Ranella,* and most 19th Century authors followed him in accepting the junior synonym *R. vexillum* (G. B. Sowerby II). Article 68d and Recommendation 69b of the Code of Zoological Nomenclature list tautonymy as one means of fixing a type and not a reason for suppressing a name. As noted by Dell (1963, p. 220), *T. ranelliformis* is the oldest and correct name for the spirally banded and beaded "Flag triton" from Chile.

Type information. — The species was described from the west coast of South America and undoubtedly came from Chile. If the type is extant, it is probably in the British Museum (Natural History).

Descriptive notes. — (Jaws and radula, Text-fig. 3; soft parts, Text-fig. 2) Adult forms have robust shells with at least seven whorls ranging up to 9.5 cm in height. Outlines are rounded, varices two per whorl in nearly lateral positions, sutures slightly appressed, and whorls never tabulate. The straight or slightly flexed columella bears a thick callous deposit and a variable number of transverse wrinkles. Posterior pillar folds and denticulations on the outer lip form a pronounced apically oriented excurrent notch. The commonest forms have reddish brown color bands parallel to spiral rows of closely set tubercles. Interspaces contain a medial ridge and one or two lateral threads, the overall pattern being evenly beaded and striped.

Juveniles possess a heavier denticulate varix inside the outer lip and the aperture is smaller in proportion to the overall size. A short-haired velvety periostracum covers all but the earliest whorls.

Variability. — The more commonly known form, illustrated on Plate 39, figure 2, is more slender and evenly beaded than the smoother, more inflated variant (Pl. 39, Fig. 9). As young forms



Text-figure 5. — Distribution of *Argobuccinum ranelliforme* (King).

the two are similar, and in those that develop tumid outlines and smoother sculpture these changes take place at different stages rather than after a particular number of whorls have formed. Larger specimens commonly have more tumid shells of lower specific gravity, although both forms may exceed 8 cm in height. Characters are completely gradational in many specimens. Axial sculpture or beading may be subdued or lacking in the inflated variants in which flat spiral costae are separated by medial ridges and several sharply incised grooves. The outer lip may be plicate or smooth and the columella may lack any trace of pillar folds. Lateral varices formed by the slightest flaring of outer lips are barely visible except where the periostracum has been torn.

The fineness and regularity of spiral beads, tendency toward a constant spiral angle, and interstitial microsculpture separate *A. ranelliforme* from *A. argus* and *A. tumidum,* although some young adults from New Zealand (such as the one figured by Dell, 1963, pl. 1, fig. 3) are difficult to distinguish. *A. ranelliforme* never develops the labial tooth or coarse, irregular tubercles seen in *A. argus* or the flaring pillar callous typical of *A. tumidum.* The spire in several specimens collected from Punta Inio, southern Chiloe Island, Chile, is higher and more slender than any others from South America and morphologically similar to forms from Tristan da Cunha Island (Pl. 40, figures 1,2). On the basis of these specimens, the writer considers the South Atlantic species *A. tristanense* Dell a direct descendant from *A. ranelliforme.*

Range.—Recent. From Caldera, 27°05′S, 70°41′W (specimen at MNHQN) to Punta Arenas, Straits of Magellan, Chile.

Geological distribution.—Pleistocene from terrace deposits near Coquimbo, central Chile. and Pliocene; Miocene of Navidad Formation, near the mouth of the Rio Rapel (34°S, 72°W) near Navidad, south of San Antonio, Chile.

The single specimen from the Navidad Formation is in the Tertiary Collection of the Museo de Histoire Natural at the Quinta Normal, Santiago. It is remarkably similar to the paratype of *Argobuccinum jeffersonense* (Durham), with which it is figured on Plate 40, figures 6-9. *A. jeffersonense* is from the Oligocene or late Eocene of Washington; the Navidad specimen is Miocene, the oldest known occurrence of the genus in the Southern Hemisphere.

Ecology. — Bathymetric data are scarce, but specimens from Talcahuano, near Concepcion, Chile, have been collected from littoral rock pools to 10 fathoms. The specimen dissected to illustrate soft parts (Text-fig. 2) contained undigested appendages of crustaceans and echinoid remains.

Argobuccinum tristanense Dell, 1963 Pl. 39, figs. 5,8; Pl. 40, fig. 1

Ranella tristanensis Gray, 1887, Paetel, Catalog der Conchylien Sammlung 1, p. 106 [*nomen nudum*].

Ranella (Argobuccinum) argus (Gmelin), Watson, 1886, Voy. H.M.S. "Challenger," Zool., vol. XV, pt. II, pp. 400-401. [Watson included *Argobuccinum argus* from South Africa, *Ranella (Bursa) proditor* of Vélain (from St. Paul and Amsterdam Islands in the Indian Ocean), and specimens of *Argobuccinum* from South America and Tristan da Cunha in *Ranella (Argobuccinum) argus;* he claimed that the morphologic characters of these geographically separated forms were completely gradational.]

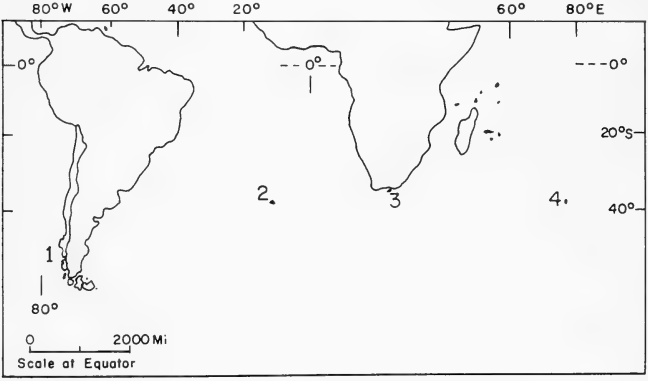
Argobuccinum proditor tristanensis, Dell, 1963, Roy. Soc. New Zealand, Trans., Zool., vol. 3(21): pp. 222,223, pl. 2, figs. 3,6.

Nomenclatural remarks. — Several specimens of *Argobuccinum ranelliforme* (King) from Chiloe Island, Chile, show the same high slender spire and revolving cords characteristic of the form from the Tristan da Cunha Islands, South Atlantic Ocean. Dell (1963) considered *Argobuccinum proditor* (Frauenfeld) from the St. Paul-Amsterdam Islands, Indian Ocean, the closest species to the Tristan da Cunha forms and described the latter as a subspecies of *A. proditor.* The writer has seen little material from the Indian Ocean but suspects that *A. proditor* is closer to some variants of *A. tumidum* from Australia and New Zealand. Similarities in shell outline and sculpture between specimens from Tristan da Cunha and Chile support the interpretation that *A. tristanense* evolved from *A. ranelliforme;* additional material is needed to work out the phylogenetic relationships between *A. tristanense,* the smoother variant of *A. argus* from South Africa, and the species collected from St. Paul and Amsterdam Islands.

Type information. — The holotype, BM 87.2.9.1221, was collected by the "Challenger" expedition from the shore of Tristan da Cunha Island. It is 5.34 cm high, 3.01 cm wide, and is illustrated by Dell (1963, pl. 2, fig. 6). Paratypes have been deposited in the British Museum (Natural History) and the Dominion Museum, Wellington, New Zealand.

Descriptive notes. — In addition to figured material and one specimen from the Museum of Victoria (F 26893), lots of six individuals from Gough (LSJU 50301) and 13 from Tristan da Cunha (CAS 39937) were examined. Adult shells ranged from 5 to 7.6 cm high and had at least five whorls, broken and encrusted apices and the typical denticulate aperture seen in other species of *Argobuccinum.* The most characteristic features are the high slender spire, blue-black or brown-colored shell, and fine revolving cords, some of which consist of fine, closely spaced nodules. Varices are discontinuous and not in perfect lateral alignment. The spire remains high in adult as well as juvenile stages. A delicate honey-colored periostracum, thinner than the velvety covering in *A. argus* and *A. ranelliforme,* is present on the body whorls of fresh material. Juvenile specimens are similar to other *Argobuccinum* juveniles.

Distribution and ecology. — Text-figure 6 shows the location of Tristan da Cunha and Gough Islands (37°15′S, 12°30′W) in the South Atlantic Ocean with respect to areas where species related to *A. tristanense* occur. Few ecological details are available,



Text-figure 6. — Distribution of *Argobuccinum tristanense* Dell. The type locality is area 2, Tristan da Cunha Island. Related species occur at 1, Chiloe Island, Chile *(Argobuccinum ranelliforme);* at 3, South Africa *(Argobuccinum argus);* and at 4, St. Paul Island and Amsterdam Island *(Argobuccinum proditor).*

but the "Challenger" collected material from 100-150 fathoms off Tristan da Cunha; it was not noted whether the animals were taken alive. No fossil record has been reported.

Argobuccinum proditor (Frauenfeld, 1865) Pl. 41, figs. 5-7,10

Bursa Zelebori Dunker, 1863, Novitates Conchologicae: 57 [*nomen nudum,* not formally described; see nomenclatural remarks].

Bursa (Apollon) proditor Frauenfeld, 1865, Verhandl. Zool. Bot. Gesellsch. Wien Bd. 15, p. 894 [date verified by Troschel, 1866, Bericht uber die Leistungen . . . Naturgeschichte Mollusken wahrend des Jahres 1865, in Arch. für Naturgeschichte 32, Bd. II, p. 249].

Bursa (Apollon) prodita Frauenfeld, Frauenfeld, 1867, Reise Österreichischen "Novara," Zool. Teil, Bd. II, abt. 3, Moll.; pp. 4,5, Taf. 1, figs. 1a, 1b (refigured herein).

Ranella (Apollon) proditor Frauenfeld, Vélain, 1887, Passage de "Venus" . . . aux Isles St.-Paul et Amsterdam. Zool., *in* Archives de Zoologie Expérimentale et Générale, VI, ser. 1, pp. 100,101, pl. II, fig. 5 (refigured herein).

Ranella (Argobuccinum) argus (Gmelin), Tryon, 1880, Man. Conch. ser. 1, vol. III, pt. 9: pp. 44,45 *(partim)*; 1881: pl. 24, fig. 64, [Tryon refigured Vélain's specimen but considered that it, along with *Argobuccinum ranelliforme, A. tumidum,* and *A. argus* belonged in one variable taxon *Ranella (Argobuccinum) argus*].

[Non] *Argobuccinum proditor* von Martens, 1904, Wiss. Ergeb. deut. Tiefsee-Exped. "Valdivia" Bd. VII: p. 64, Taf. III, fig. 19 (jung). [The juvenile figured was collected off Amsterdam Island at a depth of 496 m; in outline and protoconch it does not resemble any of the young forms of *Argobuccinum* studied by the writer.] (As of Frauenfeld.)

Argobuccinum (Argobuccinum) proditor (Frauenfeld), Dell, 1963, Roy. Soc. New Zealand, Trans., 3(21), pp. 221,222, pl. 2, fig. 4.

Nomenclatural remarks.—Dell (1963, pp. 221, 222) identified this species from St. Paul Island and Amsterdam Island as *Argobuccinum proditor proditor* and considered it closest to the species from the Tristan da Cunha Islands in the South Atlantic. The writer prefers to use only the specific name until more material is seen. The similarity between *A. proditor* and certain less inflated specimens of *A. tumidum* suggests that more complete collecting may reveal a gradational series of morphologic forms between the two species.

Type information.—The type repository is unknown, but Frauenfeld's original illustration is refigured herein (Pl. 41, figs. 7,10). The specimen (Frauenfeld, 1867, pp. 4,5) was taken alive from a depth of three to four feet where it was crawling among boulders on St. Paul Island (38°43′S, 77°32′E).

Descriptive notes.—No material from the type locality has been examined by the writer, although one specimen labelled

"Argobuccinum tumidum Dunker" from Australia (Pl. 41, fig. 5) is close to the shell figured by Vélain (1877, pl. II, fig. 5; reillustrated herein, Plate 41, figure 6).

The specimens illustrated by Frauenfeld, Vélain, and Dell (1963, pl. 2, fig. 4) are large (5.58-10.0 cm high), moderately high-spired and sculptured by discontinuous lateral varices, spiral rows of nodules, and fine lirae. Whorls are slightly inflated. In apertural details, Vélain's shell is reminiscent of Recent specimens of *A. ranelliforme* from South America. Frauenfeld's type, a more mature form, has a flared outer lip and heavy plications around the whole aperture; it is like some gerontic forms of *A. tumidum* except that the whorls are not so inflated and the apical angle does not change between juvenile and adult stages. The species differs from *A. tristanense* in spire height, apical angle, and whorl outline.

Variability.—Vélain (1877, p. 101) recognized two forms, one large (9.0 cm high, 50 cm wide) and slender and the other shorter (7.6 cm high, 4.5 cm wide) and more inflated. Although Dell (1963, p. 222) remarked that *A. proditor* is not close to *A. argus* from South Africa, it is probable that some of the smoother, more slender variants of the latter would correspond well with material from the Indian Ocean. A more complete knowledge of the variability of both species is necessary to clarify their relationship.

Distribution and ecology.—Range: Recent. Islands of Amsterdam (38°S, 77°E) and St. Paul (38°43′S, 77°32′E), Indian Ocean.

Vélain (1877, p. 100) described the species as abundant along the shores of Amsterdam Island from the littoral zone to 10 or 15 meters and probably deeper; the animals scavenge on seal carcasses and can be caught by suspending a dead fish or bird in the water overnight. They appear to be nocturnal, and fishermen have observed that they are absent during the winter season.

Argobuccinum tumidum (Dunker, 1863)

Pl. 39, figs. 1, 3; Pl. 41, figs. 1-4, 8, 9

Bursa tumida Dunker, 1863, Novitates Conchologicae, II, Abth. Meeres-Conch.: pp. 56,57, Taf. XVIII, figs. 8,9. [Date verified by Troschel, 1864. pp. 258,285.] April, 1863, Zool. Soc. London, Proc. 1862, Pt. III, p. 239.

Ranella vexillum Menke, 1843, Moll. Nov. Holland, p. 24 (not of G. B. Sowerby II, *fide* Dell, 1963, p. 220).

Ranella (Argobuccinum) argus (Gmelin), Tryon, 1880, Man. Conch., ser. 1, III, pt. 9, pp. 44,45 *(partim);* 1881, pl. explanation, p. 287, pl. 24, fig. 65.

Argobuccinum argus (Gmelin), Suter, 1913, Man. New Zealand Moll., pp. 309, 310 *(partim);* 1915, Atlas of plates: pl. 43, fig. 4.

Argobuccinum tumidum (Dunker), Hedley, 1914, Linnean Soc. New South Wales, Proc. XXXVIII, pt. XI, pp. 297-298; May, 1923, Illust. Index Tasmanian Shells, pp. 62,63, pl. 39, fig. 22; Powell, 1933, Mar. Moll. Chatham Ids., Rec. Auckland Inst. Mus. 2(4), p. 185. 1937, Shellfish New Zealand, p. 74, pl. 14, fig. 6; 1939, Moll. Stewart Id., Rec. Auckland Inst. Mus. 2(4), p. 215; Fleming, 1950, Moll. fauna fiords of western Southland, New Zealand Oceanogr. Comm. Public. 1(5), p. 28; 1952, "A Foveaux Strait Oyster-bed," New Zealand Jour. Sci. and Tech., sec. 13, 34(2), pp. 79,84.

Gondwanula tumida (Dunker), Finlay, 1927, New Zealand Inst., Trans., 57, p. 399.

Argobuccinum vexillum (G. B. Sowerby II), Macpherson and Gabriel, 1962, Mar. Molls. Victoria, pp. 152-154, fig. 182.

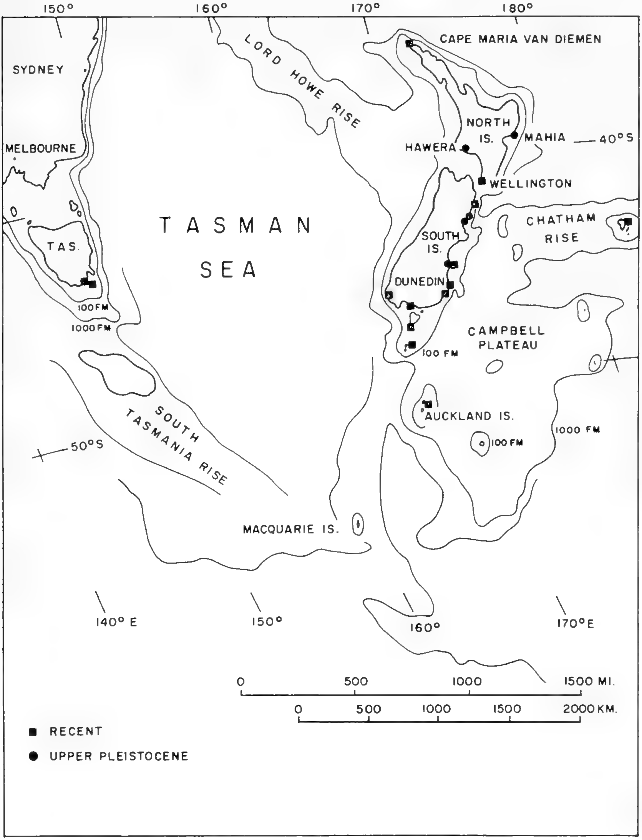
Argobuccinum ranelliformis tumidum (Dunker), Dell, 1963, Roy. Soc. New Zealand, Zool. Trans., 3(21), pp. 220,221, pl. 1, figs. 1-4. Radula, text-fig. 1, fig. 2.

Type information.—The individual figured in Dunker's first reference is one of his three original specimens in the British Museum (Natural History). It was designated as the lectotype by Dell (1963, p. 220), the type locality being New Zealand.

Descriptive notes.—(Jaws and radula Text-fig. 3.) As implied by the name, *A. tumidum* has conspicuously inflated whorls in the adult stages and in most late juveniles. It is distinguished from other species of *Argobuccinum* by whorl outline, the tendency toward a marked change from high to low spire between juvenile and adult stages, and spiral sculpture. In mature forms, apertural distinctions include a deep anal notch, flaring outer lip, and flap of pillar callous that extends perpendicular to the columella instead of lying flat against it. Bifurcated denticles and a labial spine are common on the outer lip, transverse wrinkles being developed on the slightly flexed pillar. Reddish brown spiral color bands parallel costae or rows of coarse tubercles and numerous finer interstitial threads. Varices are two per whorl, discontinuous but more or less in lateral positions. The light or dark brown periostracum is thick and velvety; it is generally eroded away from the apex. This species attains the largest size of any *Argobuccinum;* adults have seven or more whorls and range up to 12.21 cm high.

Variability.—As in *A. argus* and *A. ranelliforme* the species from New Zealand and Australia has several variable characters.

Juveniles and young adults may not exhibit the normal tumidity, and these forms are not easily separable from young specimens of *A. ranelliforme*. Such morphologic evidence of the close relationship of these species, together with other shell characters, led Dell



Text-figure 7. — Distribution of *Argobuccinum tumidum* (Dunker).

(1963) to identify the New Zealand material as a subspecies of *A. ranelliforme.* This classification is not followed here because there may be other forms, such as variants of *A. argus* and *A. proditor,* to which *A. tumidum* may be more immediately related.

Both *A. ranelliforme* and *A. tumidum* may have slender, beaded late juvenile forms, and large, mature shells with inflated whorls. The combination of tumid outline, pillar callous and details of spiral sculpture distinguish the western Pacific from the South American species.

Adult sculpture varies from smooth spiral costae to rows of tiny beads to irregular nodes. Specimens having large, irregularly spaced tubercles are reminiscent of typical forms of *A. argus,* while those having regular patterns look more like *A. ranelliforme.* Major spirals in *A. tumidum* are separated by wider interspaces containing seven or more revolving threads.

The presence of apertural denticulations, plications, and flaring callous deposits depends on the maturity of the specimen and whether it is in a resting or actively growing stage. Mature apertural characters may be developed in individuals as small as 6 cm high, although adults may grow as large as 12.21 cm. It is probable that individuals reach sexual maturity at an early stage and that large animals are unusully old or have occupied a habitat with abundant food or other factors favoring rapid growth.

Distribution. – Text-fig. 7.

Range. – Recent. New Zealand, Chatham Islands, Stewart Island, the Snares, and Auckland Islands, Campbell Plateau. Tasmania. Reported in the literature (Cotton, 1959, p. 372; Macpherson and Gabriel, 1962) from southwestern Australia, South Australia, Tasmania, and Victoria.

Geologic distribution. – From Upper Pleistocene raised beaches at the north end of Hawkes Bay and near Hawera on the west coast of North Island and from the northeast and east coasts of South Island (Fleming, 1967, written communication).

Dr. Alan Beu, Dr. R. K. Dell, and Dr. C. Fleming have kindly provided details on the distribution and fossil occurrence of this species, and their help is gratefully acknowledged.

Dell (1963, p. 221) summarized the distribution as follows: ". . . from Cape Maria van Dieman to Stewart Island, the Snares, Auckland Islands and the Chathams. It appears to be commoner from Cook Strait to Stewart Island and at the Chathams."

Natural history. — The recorded bathymetric range is littoral (probably during the spawning season) to 75 fathoms. Powell (1937, p. 74) and others have noted it is more common on rocky substrates. Beu (1967, written communication) reported that while the species is common in 30 to 60 fathoms off the east coast of New Zealand it is completely absent in the New Zealand Oceanographic Institute collections from depths greater than 80 fathoms around the islands of the south Campbell Plateau. Powell (1950, p. 74) described the *Chlamys delicatula-Fusitriton* community off eastern Otago in 50 to 70 fathoms on a hard sand or gravel substrate and gave *A. tumidum* as a subdominant species. Fleming (1952, p. 79) noted the occurrence of *A. tumidum* between South Island and Stewart Island in 5 to 15 fathoms in Foveaux Strait, where it was listed as an important secondary predator on *Ostraea sinuata* Lamarck and other members of the oyster bed community.

Graham (1941, pp. 152-154) reported on the breeding habits of 27 species of mollusks, including *A. tumidum,* collected off Otago Heads and in Otago Harbor. Copulation was observed in the aquarium over a period of five hours, during which time the male was carried on the back of the female, but spawning did not occur.

Graham studied egg masses from rocks of the lower intertidal zone on islands in Otago Harbor and compared them with others trawled in 19 fathoms off Otago Heads. Dredged specimens were attached to weeds, sponges, worm tubes, and other sessile organisms. Egg clusters were rounded to irregular gelatinous masses, one of which measured 18.5 by 7.5 cm and contained 385 capsules. Capsules were 1.2 to 1.4 cm long and .6 to .9 cm wide; each had an average of 2,700 eggs, the estimated total from one cluster being 1,040,000 individuals. The cluster of capsules illustrated by Graham (1941, pl. 21, fig. 4) compares closely with one described for *Fusitriton oregonensis* (Redfield) (Howard, 1962, p. 160, pl. 39, figs. 1,2). In both of these, capsules were densely packed in a spiral arrangement and the base of the egg mass was attached to a hard surface.

Argobuccinum jeffersonense (Durham, 1944) Pl. 40, figs. 3-5, 8, 9

Gyrineum jeffersonensis Durham, 1944, Univ. California Pub., Bull. Dept. Geol. Sci., vol. 27 (5), p. 167, pl. 15, fig. 16.

Nomenclatural remarks. — Although this species is the oldest representative of the genus *Argobuccinum* and the only one reported from the Northern Hemisphere, it agrees closely with Miocene and Recent specimens of *A. ranelliforme* (King) from Chile. Morphologic characters that distinguish *A. jeffersonense* as an *Argobuccinum* include the following: rounded whorl outline, without the development of a tabulate shoulder, moderately high spire, two gently swelling lateral varices per volution, straight pillar covered with transverse plications, well-marked apically oriented excurrent notch, denticulate outer lip, and short, straight anterior canal. The aperture is ovate rather than rounded as in *Gyrineum s.s.*

Type information. — The holotype, UCMP 35347, is the late juvenile form figured in the original reference and in the plate illustrations herein. The paratype, UCMP 35348, is a somewhat older and larger form. Both are from the lower Oligocene Quimper Sandstone in Jefferson County, Washington. The type locality is (UCMP) A-1802, 1/4 mile north of Woodman's Station, Discovery Bay, SW 1/4 NE 1/4 Sec. 8, T 29 N, R 1 W. They were collected by Dr. J. Wyatt Durham, to whom the author is especially indebted for additional specimens and information on the ages and localities of this material.

Descriptive notes. — The species is known to the writer through the types, two lots of fragments and four other incomplete, deeply worn specimens. The largest is 6.4 cm high, has three whorls, and a moderately high spire. Others have one to seven whorls and range from 1.15 to 5.6 cm high. All specimens resemble the Recent beaded forms of *A. ranelliforme* in outline, slightly appressed suture, lateral varices, slight flexure of the plicate columella, heavy pillar callous, and parietal folds. Where observable, the outer lip is heavily plicate and the narrow excurrent notch is oriented parallel to the axis of coiling. Spiral sculpture consists of pairs of closely set incised grooves separated by raised interareas. Axial ribs are subdued on most specimens and form small nodules where they cross the raised spirals. A Miocene specimen of *A. ranelliforme* is shown for comparison of outline and sculpture.

Distribution. —

Geologic distribution: Western Washington and northwestern Oregon. Rocks containing this species are early or middle Oligocene in age, but at the Woodman's Wharf locality they may be as old as late Eocene (Durham, 1967, personal communication). Durham (1944, p. 117) listed it from the *Molopophorous stephensoni* Zone. *A. jeffersonense* has been collected from the following localities:

Washington

NP 128. Oak Bay, between Port Townsend and Port Ludlow, Jefferson Co. "Middle Oligocene," Lincoln Formation; A-1603, A-1604 (UCMP). Woodman's Wharf, Jefferson Co.; A-1802 (UCMP) = NP 148. Beach north of Woodman's Station, Discovery Bay, Jefferson Co. Early Oligocene, Quimper Sandstone; A-1808 (UCMP). Beach at Sequim State Park, Clallam Co. Early Oligocene, Quimper Sandstone.

Oregon

NP 1. Bluffs on Nehalem River at Washington-Columbia Co. line, near Vernonia, Columbia Co. Early Oligocene, Keasey Formation; NP 292. 3/4 mile west of Strassel, Washington Co. Early Oligocene, Keasey Formation; USGS 3591. Bluffs at mouth of Yachats River. Early Oligocene (age verified by W. O. Addicott, personal communication, 1967).

FUSITRITON Cossmann, 1903

Type species by monotypy, cited by Cossmann, 1903, *Triton cancellatus* Lamarck, 1816.

Fusitriton cancellatus (Lamarck, 1816) Pl. 42, figs. 4-10

[*Non*] *Murex magellanicus* Chemnitz, 1788, Conch. Cab. [1st ed.] X, p. 164, pl. 164, fig. 1570 [*Trophon geversianus* (Pallas, 1774) — see nomenclatural remarks.]

Triton cancellatus Lamarck, 1816, Encycl. Meth. (Vers), p. 4 (plate explanation). The plates, begun by Bruguière and continued by Lamarck, were published earlier, but the name was not validated until 1816. The species was illustrated by Lamarck, 1798, Encycl. Meth., pl. 415, fig. 1; Lamarck, 1822, Animaux sans Vert. VII, p. 187. 1843, Animaux sans Vert., Deshayes ed., IX, pp. 638,639; Küster, 1878, Conch. Cab. von Martini and Chemnitz, Bd. III, Halfte II, pp. 246,247, Taf. 66, fig. 1. [This second edition of the *Conchylien Cabinet* had the same title as the earlier one but was a complete new series of monographs.]

Fusus cancellatus (Lamarck), Reeve, 1848, Conch. Icon., IV, Monograph of genus *Fusus:* sp. 62, pl. XVI, fig. 62. ["Hab." is given as "Unalaska, Kamtschatka," which is erroneous for the South American form illustrated.]

Triton (Priene) cancellatus Lamarck, Tryon, 1880, Man. Conch., ser. 1, III, p. 34 *(partim);* 1881, pl. 16, fig. 164. [Tryon considered *Triton oregonensis* from North America synonymous with *T. cancellatus.*]

Priene magellanica: (Chemnitz), Rochebrune and Mabille, 1889, Mission du Cap Horn, Zool., Pt. 2, Mollusques: H 42 (as of Adams).

Priene (Fusitriton) cancellatus (Lamarck), Cossmann, 1903, Essais Paléoconch. Comparée, 5, pp. 109,110, text-fig. 8.

Austrofusus cancellatus (Lamarck), Parodiz, 1942, Rev. Geograf. Americana, año IX, XVIII, p. 210 (fig.)

Fusitriton magellanicum (Chemnitz), Carcelles, 1944, Rev. del. Museo de la Plata, Nueva ser., III: p. 247, lam. II, fig. 23.

Argobuccinum (Fusitriton) magellanicum (Chemnitz), Carcelles, 1950, Catalogo de los Moluscos . . . Patagonia, p. 59; 1954, Comunicaciones . . . Ciencias Naturales . . . II (15), pp. 249-252, fig. 1-4.

Fusitriton cancellatum (Lamarck), Powell, 1951, Discovery Repts. XXVI, p. 130; 1960, Antarctic and Subantarctic Moll., p. 147.

Nomenclatural remarks.—*Fusitriton* was introduced as a subgenus of *Priene* by Cossmann (1903), who based his classification on similar cancellate sculpture and long-haired periostraca in *T. cancellatus* Lamarck and the type species of *Priene, P. scabra* (King). Subsequent consideration of soft parts and shell morphology led to its elevation to generic rank, although the authors of several well-known works (Dall, 1904, 1909a, 1921b; Weaver, 1943) continued to use *Argobuccinum* for *Fusitriton oregonensis* (Redfield), the northern analogue of the South American type species. Grant and Gale (1931) considered *Ranella* the correct generic identification.

The specific name of the type species has been cited as *cancellatus* by most workers, *magellanicus* by others. Those who contended that the latter is an older name probably assumed that the figure of *Triton cancellatus* Lamarck in Kuster's "Conchylien Cabinet von Martini und Chemnitz" (1878) was a reprint of one in Chemnitz' earlier "Conchylien Cabinet" (1788). Although both bear the same title, they are completely different works, the older edition being rare. *"Murex magellanicus* Chemnitz" is not a cymatiid, as shown by Keen (1964), who submitted a petition to the International Commission on Zoological Nomenclature in which it was pointed out that *Buccinum geversianum* Pallas, the type species of *Trophon* Montfort, 1810, is an older name for *Murex magellanicus* Gmelin.

Type information. — The repository of Cossmann's holotype is not known, and he did not mention a type locality; later workers comparing Lamarck's figure of *Triton cancellatus* with Recent material have taken the Straits of Magellan as the type locality.

Descriptive notes. — (Jaws and radula illustrated in Text-fig. 3; soft parts, Text-fig. 2.) It is possible that differentiation within this species has occurred or is progressing on either coast of South America. At least three variants have been studied, one of which, the more tumid form (Plate 42, fig. 5), has appeared mainly among material from the east coast. There is a great deal of variability within and between populations, but certain forms seem to be restricted geographically while others are closely similar to species in South Africa and southeastern Australia.

The commonest adult forms are large (9 to 13.5 cm high), with at least six whorls; they are moderately high-spired and tumid in outline. Shell thickness varies, as do the color (dark or light brown to grey) and length of periostracal hairs. Varices are rare and irregularly spaced, generally present only in the juvenile stages or slightly developed on the outer lip of adults. Axial sculpture varies from numerous closely spaced fine ribs to fewer coarser ones; ribbing is coarser and more pronounced on earlier volutions, which are similar to *Fusitriton oregonensis,* and finer to almost obsolete on the body whorl. Spiral sculpture consists of revolving costae (commonly bifurcated) alternating with wider interspaces containing two, sometimes one or three threads. The pillar is straight or curved and parietal callous is deposited intermittently near the excurrent area. In many individuals the excurrent notch is only weakly developed. Tumidity is not related to sexual differences.

Decorticated shells are white and may have yellow-brown bands parallel to the major spirals. Most specimens from which the periostracum has been chemically removed have lost microsculptural details, a condition which accentuates their likeness to similarly prepared material from South Africa. Some individuals have ochraceous apertural margins.

Variability. — Coarseness and density of axial sculpture and degree of inflation of whorls vary considerably among individuals of the same population. Slender forms are identical to some South

African specimens, while the tumid ones are found mainly along the east coast between Mar del Plata, Argentina, and the Straits of Magellan. Several shells have slender spires, slightly inflated whorls and incised spiral grooves (Plate 42, fig. 7). These conspicuous furrows were seen in three individuals from Indian middens in Tierra del Fuego, made available for this study by Mr. William Old of the American Museum of Natural History, and several adults and juveniles from Guitecas Island, Chile (43°45′S, 74°W). Other specimens from the same localities were similar in all other respects but lacked grooves.

Whether slender or tumid, specimens of *F. cancellatus* and material from South Africa never have as high a spire as those described by authors as *F. laudandus* from New Zealand. In many respects *F. cancellatus* resembles *F. oregonensis,* the most important differences being the tumid, less tabulate whorls, lower spire, and generally finer cancellate sculpture in the type species.

F. cancellatus is morphologically closest to the fossil species *F. scotiaensis* from North America, some specimens of *F. oregonensis* (especially in the juvenile stages), some individuals from South Africa, and forms that have been described as *F. retiolus* (Hedley) southeastern Australia.

Distribution.—

Range: Recent. East Coast of South America: near Sarita, Rio Grande do Sul, Brazil to Tierra del Fuego; Falkland Islands; Carcelles (1954) also listed South Georgia and Marion Island. West coast of South America: north of Valparaiso, Chile at the border of Aconcagua and Coquimbo provinces (*Anton Brunn* Cruise 18A, Sta. 702, 32°17′S, 71°40′W, 580 m, approx. 320 fms) to the Straits of Magellan; south to Navarino Island (55°S, 67° to 68°W.) South Pacific: *Eltainin* Cruise 15, Sta. 1346, 54°49′ to 54°50′S, 129°48′ to 129°46′W, 549 m, approx. 300 fms.

The northern limit in Rio Grande do Sul is considered reasonably accurate because the coast to the north is influenced by the warm south-flowing Brazilian Current and the boundary between the Antillian and Argentinian marine zoogeographic provinces lies at about 32°S. A marked temperature change does not occur immediately north of Aconcagua province in Chile, and it is probable that future collections, perhaps in deeper water, will extend the range on the west coast. The species is commonest around Chiloe Island (43°37′S, 73°00′W) and the Straits of Magellan.

A locality in the South Pacific, *Eltanin* Station 1346, yielded material that in whorl outline, spire height, and sculpture corresponds closely to specimens from the Straits of Magellan and Argentina. Geographic position suggests that specimens could also be variants of *F. retiolus* from Australia and New Zealand, but morphologically they seem slightly closer to forms from South America. This lot consisted of numerous specimens, of which all those seen by the writer contained hermit crabs. The material was made available with the permission of Dr. R. K. Dell through the Smithsonian Oceanographic Sorting Center, Washington, D.C., and the privilege of studying samples from this and several other critical mid-ocean localities is greatly appreciated.

Material establishing the northern range on the west coast of South America was also obtained through the courtesy of the Sorting Center; a large number of specimens were taken live by the *Anton Bruun,* Cruise 18A, in 320 fms, from a locality approximately 1040 km north of Talcan and Chiloe Island, where the species is common in 2 to 15 fathoms.

Geologic distribution. — Had the Pliocene specimens identified as *F. scotiaensis* occurred in South America rather than in northern California the writer would consider them conspecific with *F. cancellatus.* The absence from the known fossil record of other specimens of either species precludes the confirmation of such a close phylogenetic relationship at this time. It is significant, however, that cancellate forms as old as Pliocene age have been found, and further collecting from cool water formations in intermediate areas may document a route and time of dispersal.

Another possible Tertiary occurrence is the juvenile specimen of *Triton leucostomoides* G. B. Sowerby I, 1846 described in Darwin's "Geological Observations on South America (Pt. 3, Geology of the Voyage of the "Beagle," p. 260, pl. 4, fig. 64). The figured shell is a juvenile having five whorls, coarse axial ribs and what might be varices; it was collected by Darwin from Huafo (= Guafo) Island, southwest of Chiloe Island, Chile. The fine-grained muddy sandstone from which he collected it, along with many specimens of *Turritella chilensis* G. B. Sowerby I and other fossils, was not named; its age was given as Tertiary. Additional material is needed to evaluate this taxon, which may or may not be a juvenile of *F. cancellatus.* Carcellas (1954, p. 250) also noted the absence of any fossil record for the species.

Natural history. — The bathymetric range according to records in the Departmento de Zoologia at the Universidad de Concepcion, Chile, and specimens from other museums is 2 to 320 fathoms. Specimens from the northernmost west coast of South America were taken from 320 fms while those from off Argentina ranged from 15 to 170 fms.

Fusitriton cancellatus (Lamarck) subsp. **murrayi** (E. A. Smith, 1891)
Pl. 43, figs. 12-15

Lampusia (Pricne) murrayi E. A. Smith, 1891, Zool. Soc. London Proc. for 1891, p. 436, pl. XXXIV, fig. 1.

Tritonium (Cryotritonium) murrayi (E. A. Smith) von Martens, 1904, Gastropoden der deut. Tiefsee-Exped., Bd. 7, pp. 38-40, Taf. III, f. 16.

Argobuccinum (Fusitriton) murrayi (E. A. Smith), Barnard, 1963, Ann. South Africa Mus. XLVII, pp. 22, 23, fig. 2b (radula).

Fusitriton algoensis Tomlin, 1947, Jour. Conchol., 22(9), pp. 245, 246, fig. p. 246; White, 1948, "The anatomy of *Fusitriton algoensis* Tomlin," Jour. Conchol. 23(1), pp. 3, 4, 5 figs.

Fusitriton murrayi (E. A. Smith), Barnard, 1949, Jour. Conchol. 23 (3), p. 90.

Nomenclatural remarks. — The two species described from South Africa are considered variants of the subspecies *Fusitriton cancellatus murrayi* (E. A. Smith, 1891). Shell thickness and number and coarseness of axial ribs vary among specimens from given localities, but approximately half the 20 individuals studied by the writer were morphologically indistinguishable from the slender finely cancellate forms of *F. cancellatus* from Uruguay and Argentina.

Type information. — The type specimen, BM (NH) 90.4.14.95, was collected from "Challenger" station 142 in 150 fathoms off the Cape of Good Hope, South Africa. I am indebted to Dr. A. Myra Keen for verifying the repository of this and other types in the British Museum (Natural History).

Descriptive notes. — (Jaws and radula Text-fig. 3.) Adult shells are slender, moderately high-spired and have seven or more slightly inflated whorls; the average height is 8.7 to 12 cm, either without varices or with as many as three per whorl. The beige to brown periostracum is more delicate than in other species of *Fusitriton;* shells tend to be thinner and most are white, although some have yellow-brown color bands. Axial ribs are fine or moderately coarse but never as prominent as in tumid forms of *F. cancellatus;* they are commonly obsolete on adult body whorls. Spiral sculpture consists of revolving (sometimes bifurcated) costae alternating with one to three intercalary threads. Parietal callous is deposited intermittently on the straight or slightly curved pillar.

Some material from South Africa is identical to specimens labelled *F. retiolus* (Hedley) from southeastern Australia. Sufficient numbers of specimens from South Africa, Australia, and the intervening subantarctic islands have not been seen by the writer, but it is suspected that a completely gradational series of forms exists over this section of the Southern Ocean.

Distribution and natural history.—

Range. Recent. South Africa, from Port Nolloth in 30 to 150 fathoms on the west coast and Algoa Bay, 140 fathoms, on the southeast coast to the eastern slope of Agulhas Bank ("Valdivia" station 103, 35°3′S, 23°2′E), where von Martens (1904, p. 39) listed it as abundant in approximately 275 fathoms (500m). Smith (1906) gave the bathymetric range off the Cape of Good Hope as 97 to 270 fathoms, and more recently collected material has been taken from 30 to 300 fathoms. Barnard (1963, p. 22) remarked that ". . . the species is abundant along the southeastern, southwestern and western slopes of the continental shelf: from 23°E long. around Cape Point to approximately 33° S lat."

Fusitriton retiolus (Hedley, 1914) Pl. 44, figs. 1-11

Argobuccinum retiolum Hedley, 1914, Biol. Results Fishing Expts. . . . "Endeavour," II, Pt. 2, pp. 73, 74, pl. XI, fig. 5.

Priene retiolum (Hedley), Finlay, 1924, New Zealand Inst., Trans., 55, p. 462.

Fusitriton laudandum Finlay, March, 1927, New Zealand Inst., Trans., 57, p. 399, pl. 20, fig. 65; Powell, 1933, New Zealand Inst., Trans., 63, p. 164; 1937, Shellfish of New Zealand, p. 74; 1950, Rec. Auckland Inst. Mus., 4(1), p. 73-81, pl. 7; Dell, 1956, "The Archibenthal Mollusca of New Zealand," Dominion Mus. Bull. 18, pp. 84,85; 1962, Additional Archibenthal Moll. . . . New Zealand, p. 75.

Fusitriton futuristi Mestayer, Dec. 1927, Malacol. Soc. London, Proc., XVII, pp. 189, 190, fig. 6.

Fusitriton retiolus (Hedley), Garrard, 1961, "Mollusca . . . of the East Coast of Australia," p. 14; Iredale and McMichael, 1962, Australian Mus. Mem.

XI, p. 55; Macpherson and Gabriel, 1962, Mar. Moll. Victoria, p. 155, fig. 185.

Specimens or photographs labelled *Fusitriton retiolus* and *F. laudandus* were made available by the following: Mr. John McNally, Mr. T. A. Darragh, and Dr. Brian J. Smith, National Museum of Victoria, Melbourne; Dr. D. McMichael, formerly of the Australian Museum, and Miss J. Cave, Sydney; Dr. R. K. Dell, Dominion Museum, Wellington, N.Z.; Dr. James H. McLean, Los Angeles County Museum, Los Angeles, California; Dr. Carl Hubbs and Mr. H. George Snyder, The Scripps Institution of Oceanography, La Jolla; Dr. S. Stillman Berry; Miss Patsy McLaughlin and the staff of the Smithsonian Oceanographic Sorting Center. Specimens from these individuals and from museum collections in the United States represented 20 localities and made possible distributional and variability studies. The help and generosity of these workers is appreciated and gratefully acknowledged.

Nomenclatural remarks. — Distributions recorded in the literature for *F. retiolus* and *F. laundandus* restrict the former to several localities off the southeast coast of Australia and the latter to the east and south coast of New Zealand, the Chatham Islands, and in deep water around the islands of the Campbell Plateau. A comparison between the types and other specimens from the western Tasman Sea with those collected from the Campbell Plateau has shown gradational forms from both areas, and the occurrence of identical specimens from off Victoria and *Eltanin* Station 1411, on the northwest slope of the Macquarie Rise (51°00′ to 51°01′S, 162°01′E, in 333 to 371 m), suggest strongly that these previously separated taxa may belong to one variable species. The oldest valid name for this group, which is in the process of differentiating into coarser and finer ribbed morphologic groups, is *Fusitriton retiolus* (Hedley, 1914).

Material from eastern New Zealand and elsewhere on the Campbell Plateau shows considerable variation between and within populations, although coarsely sculptured high-spired forms are more abundant. The species from the western Tasman Sea is known to the author from a small number of specimens, many of which have numerous fine axial ribs. These specimens represent only a few localities. The amount of variation is poorly understood, although photographs of some specimens in the Australian Museum and material borrowed from the National Museum of Victoria indicate considerable variability. McMichael (1967, written communication) noted that *Fusitriton* is a "moderately common" element in the Recent fauna of Australia, although few reports are for live specimens.

Type information. — The holotype and paratype were dredged south of Gabo Island, Victoria (37°34′S, 149°25′E) in 100 to 250 fathoms. They are deposited in the Australian Museum, Sydney, New South Wales.

Descriptive notes. — (Jaws and radula Text-fig. 3). Adult specimens are high-spired and have at least seven whorls measuring up to 13 cm high; shells are white and may have reddish brown color bands parallel to spiral costae. Varices are absent or weakly developed at irregular intervals. Convex whorl outlines lack the tabulation seen in specimens of *F. oregonensis,* and junctions between axial and spiral costae are sharper and more nodose. Axial sculpture is more pronounced than bifurcated spiral elements in the early stages, spirals and one to three interstitial threads becoming stronger in the wider interspaces on the later whorls. The columella may be straight or curved and parietal callous is common near the posterior notch. Some specimens have an ochraceous margin, which is taxonomically insignificant.

Variability. — Spire height, whorl outline, and number and coarseness of axial ribs vary greatly between populations. No data are available for large lots of individuals from southeastern Australia, but variants from the east coast of South Island and several localities on the Campbell Plateau are illustrated to show slender and inflated, coarsely and finely ribbed specimens. The sculpture of "typical" end members of this variable species was compared in two specimens, each of which was 12 cm high. The western Tasman form had 48 axial ribs, while the eastern one had 32. Other specimens from the west had fewer than 32 ribs, and some from the east had 45.

Of particular interest are specimens dredged from the northwest Macquarie Rise; these are identical to the type and at least one other specimen and similar to several more individuals from off New South Wales. Early whorls have coarser axials and later volutions have more numerous finer ones; the specimens were taken live from *Eltanin* Cruise 16, Station 1411 (51°00′ to 51°01′S, 162°01′E) in 333 to 371 m (approximately 200 fathoms), and although they were dredged from the eastern side of the Tasman Sea, they resemble the western forms more closely than material examined from the Campbell Plateau.

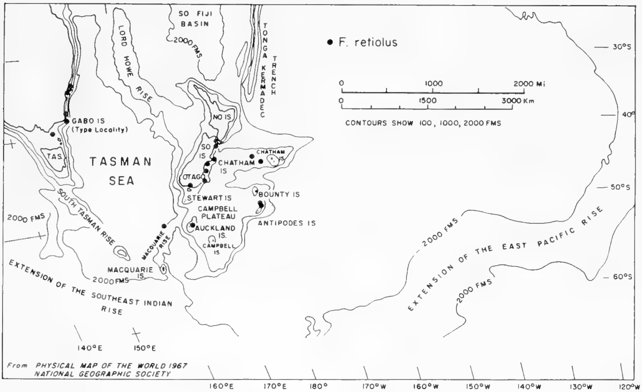
All variants of *F. retiolus* are heavier shelled and higher spired than *F. cancellatus* and *F.c. murrayi* from South Africa, although the closely spaced axial ribs on some forms make them morphologically almost indistinguishable. Coarsely ribbed or heavily nodose specimens from the Campbell shelf have been compared to the Japanese *F. galea* Kuroda and Habe, which resembles the forms from the South Pacific in sculptural details and color bands but differs in being lower spired and having a wavy suture.

Distribution and natural history.— (Fig. 8).

Range: Recent. Cook Strait, east and south coasts of South Island, New Zealand. Chatham Rise, Antipodes, Aucklands, and other islands of the Campbell Plateau. Macquarie Rise. East coast of Australia between Broken Bay, north of Sydney, New South Wales, and Bass Strait.

Australian records, mostly for dead shells, give the bathymetric range as 50 to 250 fathoms. Dell (1962a, p. 75) listed the species from 380 to 550 fathoms in the vicinity of Palliser Bay, Cook Strait; elsewhere along the east coast of New Zealand, it occurs in 20 to 70 fathoms, and on the Chatham Rise and Campbell Plateau it has been taken in 200-300 fathoms.

Powell (1950, p. 73,74) described a common hard bottom assemblage at 50 to 70 fathoms on the continental shelf east of Otago; he called it the "*Chlamys delicatula-Fusitriton* community" after the two dominant species and compared it to a similar assemblage from Puget Sound, Washington, the "*Fusitriton-Strongylocentrotus* community" of Shelford and Towler (1925). The physical environment is one of strong tidal currents flowing over a hard sand, shell or gravel substrate, and the characteristic faunal assemblage is best represented at 46°S (around Otago). The community has been recognized as far south as 54°42′S, where *Fusitriton* was commonly less dominant, and farther north where *Fusitriton* was absent.



From PHYSICAL MAP OF THE WORLD 1967 NATIONAL GEOGRAPHIC SOCIETY

Text-figure 8. — Distribution of *Fusitriton retiolus* (Hedley), ● denotes Recent occurrences.

There is no fossil record of *Fusitriton* in New Zealand (Fleming, 1967, written communication) "although *Chlamys delicatula* ranges back to uppermost Pliocene in fossil communities suitable for *Fusitriton*."

Fusitriton oregonensis (Redfield, 1846)

Pl. 45, figs. 1-11; Pl. 46, figs. 1, 2, 5, 6, 8, 9, 13, 14; Pl. 47, figs. 2, 3

Triton oregonense Redfield, 1846, New York Lyceum Nat. Hist. Ann. 4: pp. 163-168 (reprint consulted had different pagination, pp. 3, 4), pl. 11, figs. 2a, 2b.

Fusus oregonensis Reeve, 1848, Conch. Icon., *Fusus* IV, sp. 61, pl. XVI, figs. 61a, 61b.

Triton (Buccinum) cancellatum Lamarck, Middendorf, 1849, Beitrage Malaco-zoological Rossica II:164-67, Taf. III, figs. 1-4; Arnold, 1903, California Acad. Sci., Mem. 3, p. 286, 287, pl. 6, fig. 1.

Tritonium (Priene) cancellatus Lamarck, Tryon, 1880, Man. Conch., ser. 1, vol. 3, p. 34; 1881, pl. 16, figs. 165, 166, 167.

Priene (Fusitriton) oregonensis Redfield, Cossmann, 1903, Essais Paléoconchol. Comparée 5, p. 109, 110, text fig. 8, pl. 5, fig. 2.

Priene oregonensis Redfield var. *angelensis,* Arnold, 1907, U. S. Nat. Mus. Proc., 32, pp. 536, 537, pl. 50, fig. 11.

Argobuccinum (Fusitriton) oregonensis (Redfield), Dall, 1909, U.S. Geol. Sur., Prof. Paper 59, p. 56; Oldroyd, 1927, Mar. Shells West Coast North America, vol. II, pt. 2, Stanford Univ. Pubs. Geol. Sci., pp. 242, 243, pl. 37, figs. 1, 2, 3.

Gyrineum mediocre n. var. ? *corbiculatum* Dall, 1909, U. S. Geol. Sur., Prof. Paper 59, p. 55, pl. 7, fig. 9 (see "*Gyrineum corbiculatum* Dall as a synonym of *Fusitriton oregonensis* (Redfield)" under nomenclatural remarks).

Argobuccinum (Fusitriton) coosense Dall, 1909, U. S. Geol. Sur. Prof. Paper 59, pp. 55, 56, pl. 7, fig. 4; Faustman, 1964, "Paleontol. Wildcat Group . . . Scotia and Centerville Beach, Calif.," Univ. California, Pubs, Geol. Sci. 41(2), p. 134, pl. 3, fig. 21.

Argobuccinum (Priene) pacifica Dall, 1909, U.S. Geol. Sur., Prof. Paper 59, pp. 56, 57, pl. 5, fig. 9, pl. 6, fig. 2.

?*Gyrineum sylviaensis* Weaver, 1912, Washington Geol. Sur., Bull. 15, pp. 73, 74, pl. 12, fig. 126; refigured as *Argobuccinum sylviaense* in Weaver, 1943, Univ. Washintgon Pub. Geol. 5, Pt. 2, p. 422, Pt. 3: pl. 83, fig. 7. (See "*Gyrineum sylviaense* as a synonym of *Fustriton oregonensis*" under nomenclatural remarks).

Ranella (Priene) pacifica (Dall), Grant and Gale, 1931, Mem. San Diego Soc. Nat. Hist. I, p. 735.

Ranella (Priene) corbiculata (Dall), Grant and Gale, 1931, Mem. San Diego Soc. Nat. Hist. I, pp. 735, 736.

Ranella (Priene) oregonensis (Redfield), Grant and Gale, 1931, Mem. San Diego Soc. Nat. Hist. I, pp. 737, 738, pl. 27, fig. 12.

Ranella (Priene) oregonensis var. *angelensis,* Grant and Gale, 1931, Mem. San Diego Soc. Nat. Hist. I, p. 738.

? *Ranella (Priene) tugaruensis* Nomura and Hatai, 1935, "Pliocene Mollusca . . . in the vicinity of Daisyaka, Aomori-ken, NE Honsyû, Japan," Saito Ho-on Kai Mus. Research Bull. (6), pp. 126, 127, pl. 12, fig. 4. [Illustrated herein, the holotype is believed to be a juvenile *F. oregonensis*.]

Fusitriton aff. *F. oregonensis,* Redfield, Woodring, 1938, U.S. Geol. Sur., Prof. Paper 190, pp. 23,24, pl. 5, figs. 21-23.

Argobuccinum (Fusitriton) cancellatum (Lamarck), Wenz, 1941, Gastropoda, Bd. 6, Teil 1, pp. 1057, 1058, fig. on 1058.

Gyrineum corbiculatum (Dall), Weaver, 1943, Univ. Washington Pub. Geol. 5, Pt. II, p. 424; Pt. 3: pl. 84, figs. 1, 3.

Ranella oregonensis (Redfield), Hatai, 1950, "Cenozoic Moll. from Aomori Prefecture, Japan," Jour. Conchyl. p. 133.

Fusitriton oregonensis (Redfield), Habe, 1958, Pubs. from Akkeshi Marine Biol. Sta. [Hokkaido] (8), p. 16, pl. 2, fig. 8, pl. 5, fig. 21; Kira, 1962, Shells of the Western Pacific in Color, p. 55, pl. 22, fig. 9.

Nomenclatural remarks. — Most malacologists relying on the works of Cossmann, Dall, and Grant and Gale, have placed *Fusitriton oregonensis* (Redfield) in other genera of Cymatiidae without proper attention to the differences between the type species of *Argobuccinum, Priene,* and *Ranella.* Because Cossmann (1903) regarded *Fusitriton* as a subgenus of *Priene,* the interchanging of these names is not surprising; the genus *Argobuccinum* has been used most commonly by workers following Dall.

Argobuccinum (Priene) coosense and *A. (P.) pacifica* in synonymy with *Fusitriton oregonensis* (Redfield)

The holotypes of *Argobuccinum (Priene) coosense* Dall, 1909a (U.S. Nat. Mus., No. 153903) and *Argobuccinum (Priene) pacifica* Dall, 1909a (U.S. Nat. Mus., No. 153902), both from Coos Bay, Oregon, were studied and compared with Recent specimens of *Fusitriton oregonensis* in which the tests were eroded by abrasion or attached organisms. Examples of Recent shells which were worn while or after being occupied by snails are shown in Plate 45; axial ribs are generally pronounced but may be more subdued whether or not they have been eroded. Differences between Dall's type specimens and typical *Fusitriton oregonensis* are considered taxonomically insignificant.

Gyrineum corbiculatum Dall as a synonym of *Fusitriton oregonensis* (Redfield) Pl. 46, figs. 5,8.

The holotype of *G. corbiculatum* Dall, USNM 153900, has two varices on each of its three existing whorls; the last three are in lateral positions that give the shell a more symmetrical outline, while the earlier, more obscure ones are offset. Several other specimens from Coos Bay, the type locality, have a similar sculptural pattern and prominent varices in addition to apertural details matching those of Recent specimens of *F. oregonensis.* The marked tabulation of whorls seen in *Mediargo mediocris* is lacking and the varices differ in posterior shape and mode of formation. Specimens identified as *G. corbiculatum* are commonly between resting stages, as defined by the development of varices, and they are difficult to compare with other specimens because corresponding orientations are not immediately evident.

Sufficient material has been examined to determine that Dall's *G. corbiculatum* differs generically and specifically from his *G. mediocre* (which has been designated as the type species of *Mediargo* Terry, 1968b) and that it is probably a form of *F. oregonensis.*

Gyrineum sylviaensis Weaver, as a synonym of *Fusitriton oregonensis* (Redfield) Pl. 46, fig. 12

The certain placement of this name is complicated by insufficient knowledge of the species and its degree of variability. The holotype (CAS No. 7601) is a worn, incomplete specimen in which the aperture is obscured by a well indurated pebble conglomerate typical of the basal Montesano Formation. This specimen is similar to Recent shells from Departure Bay, British Columbia, and differs mainly in having several varices per volution and eroded or obsolete axial ribs on the body whorl. Axial sculpture, bifurcated spiral straps and interspaces containing one to three medial threads appear finer than in most Recent specimens of *Fusitriton oregonensis.* Some topotypes exhibit the same features but entirely lack axial ribs on the body whorl; this absence is not due to abrasion. Some juveniles are identical to Pliocene specimens of *Fusitriton oregonensis* which occur in the Fernando Formation in the Newport Bay area, southern California.

Although more specimens are needed to appreciate the variability of material described as *Gyrineum sylviaensis* Weaver, clues to its affinities might be found in a study of the whole Montesano assemblage at its type locality (Univ. Wash. 68, Sylvia Creek, six miles north of Montesano, Chehalis Co., Wash.). *Clinocardium hannibali* Keen, 1954, among others, represents a molluscan species found only in the vicinity of the type locality. The Montesano Formation may have been deposited in an isolated basin in which forms distinct from those along the outer coast were able to develop. Originally described as the Blakeley horizon of upper Miocene age, the basal Montesano is now regarded as Mio-Pliocene.

Type information.—The specimen described and figured by Redfield in 1846 was an adult shell 4.25 inches high with 6 whorls, most of which had two varices. It lacked the parietal callous deposit commonly found on the columella and had the characteristic cancellate sculpture produced by bifurcated spiral straps and medial threads crossing axial ribs. At that time, the specimen belonged to Dr. B. W. Budd and was kept in the Cabinet of the Naval Lyceum, Brooklyn, New York. The type locality, "Straits of

St. Juan da Fuca, Oregon," is now part of the state of Washington.

Redfield's collection was later deposited in the Academy of Natural Sciences in Philadelphia, but there is no record of a holotype of *Fusitriton oregonensis* being among his material. As the original specimen is missing, Redfield's original illustration may serve as the holotype.

Descriptive notes. — (Jaws and radula Text-fig. 3.) Adult specimens of *Fusitriton oregonensis* (Redfield) are high-spired, ranging up to 13.5 cm in height and having five to more than eight whorls, most of which lack varices in the later stages. Outlines may be rounded or tabulate. A long-haired commonly dark brown periostracum covers the white shell and is responsible for the vernacular name, "The hairy Oregon triton."

Whorls may be slender or inflated; they are ornamented by coarse axial ribs that are crossed by finer flat-topped costae and spiral interspaces that commonly contain one medial thread (but may have none or as many as three). The spiral straps are characteristically bifurcated and become more prominent anteriorly where the axials are obsolete. Spiral microsculpture is variable between and within whorls of different individuals and is not a reliable specific character. The apertural shape is also variable, delineated by a straight or curved columella and medium to long anterior canal. The outer lip may be flared and is commonly terminated by a varix or slight thickening. Pillar callous is deposited intermittently near the anal notch. Specimens rarely have denticulate outer lips, although shells from Monterey Bay, California, and Discovery Bay, British Columbia, generally exhibit this feature. Juveniles up to about three cm in height have two or more irregularly spaced varices with corresponding denticulate apertures on all but the nepionic whorls. Apices are almost always broken and protoconchs rare in adult specimens.

Color bands parallel to the main spirals are uncommon but have been observed in half a dozen individuals. Abrasion, solution, and penetration by boring organisms may cause the sculpture to appear more subdued, and Recent examples of worn shells are shown in the plate illustrations for comparison with fossil forms that were originally described as new on the basis of minor sculptural differences. Many broken or deeply weathered shells were taken live, while other perfect ones contained hermit crabs or were empty when collected. Once the periostracum has been removed, solution or encrustation may modify the shell whether or not the snail is still living. Fossils having obsolete ribs or no spiral microsculpture need not necessarily have been transported to the place of deposition or reworked.

Variability. — Aperture shape, pillar curvature, and coarseness of axial sculpture are the greatest variables in Recent and fossil specimens of *F. oregonensis.* A comparison of Recent populations from Puget Sound, the Gulf of Alaska, and Monterey Bay with fossil assemblages from the Pliocene of the Ventura Basin, north of Los Angeles, California, (USNM 18283, 102 individuals) and Newport Bay, California, (USGS locality M2753, collected by J. G. Vedder, and LACM 41, collected by L. Marincovich) suggested that sculptural variability may have been even greater in the fossils. The fossil occurrence of all growth stages, from larval shells to adults 8.5 to 10.2 cm high, supports the interpretation that this species flourished in the Pliocene and Pleistocene in the Los Angeles Basin and Ventura Basin and that specimens were neither reworked nor transported by longshore currents.

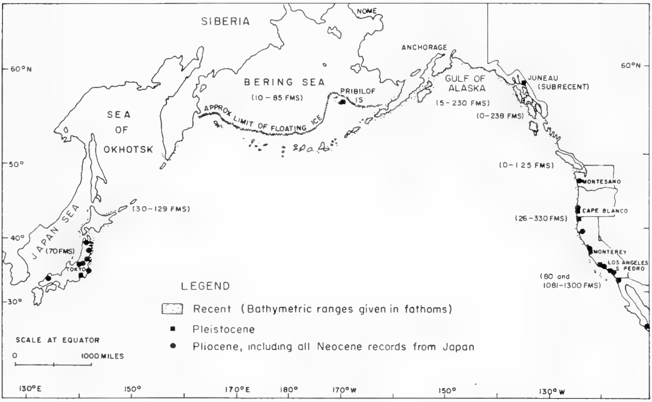
The association with Panamic species in some outcrops has not been explained; unfortunately, many localities have been excavated or buried and many are in areas of recurring landslides. The seemingly anomalous occurrences of northern and southern species may also reflect several-year periods of warming such as the recent one in 1957-1959 (Radovich, 1961).

Late juveniles of *F. oregonensis* have been confused with those of *Mediargo mediocris* (Dall), with which they occur in some Pliocene formations. The former may have two varices per whorl but they are generally not as lateral or continuous as in *M. mediocris.* Spiral sculpture is the same in juvenile and adult forms of *F. oregonensis,* while *M. mediocris* exhibits very slightly furrowed spiral straps in juveniles and sharply incised grooves in adults.

F. dilleri (Anderson and Martin) is a less well-defined species, but at present it can be distinguished by two prominent, irregularly spaced varices per volution and distinctive bifurcated spiral costae separated by wide interspaces that commonly contain three cords. *F. galea* Kuroda and Habe, the Recent species from southern Japan, is more angular in outline, has fewer major spirals, and has sharply nodose junctions between sculptural elements. Its canal is more strongly recurved, and fresh material always has reddish brown or yellow color bands. *F. cancellatus*, the type species of the genus, resembles *F. oregonensis* in coarsely sculptured juveniles but becomes more inflated and less tabulate in outline in adult stages; axial ribs are finer to obsolete, although in spiral costae it is like the northern form.

Distribution.— (Text-fig. 9.) (Records verified by specimens examined by the writer unless noted.)

Range: Recent. Northern Japan, in the Japan Sea as far south as Niigata and on the Pacific Coast from Cape Inubo north (observations confirmed by Okutani, 1967, written communication); Sea of Okhotsk and Kamchatka (Dall). Bering Sea in the Commander, Pribilof and Aleutian Islands, south of the line of floating ice in winter. Gulf of Alaska, fiords of southeastern Alaska and western Canada. Puget Sound and Pacific coast to Southern California. Most southerly and also deepest record, San Nicolas Id. off San Diego, Calif. in 1100-1300 fathoms (taken live).



Text-figure 9.— Distribution in space and time of *Fusitriton oregonensis* (Redfield).

Pleistocene: Southeast of Tokyo and possibly elsewhere in Japan in beds described as Pliocene or Miocene; Tolstoi Point, St. George Id., Pribilofs; subrecent from the Juneau area (USGS M 250). Bandon and Cape Blanco, Oregon, Port Orford Formation and Elk River beds. Terrace deposits along the California coast, from Crescent City, Año Nuevo Point, Santa Barbara, hills and beaches within the Los Angeles basin, San Pedro including Timms Point and Deadman Id. Border locality at San Ysidro. Fragments from San Nicolas and San Clemente Islands and from San Jose del Cabo, Baja California. Named formations in California include part of the Santa Barbara and in the San Pedro area the San Pedro sand, Lomita marl, Palos Verdes sand, and Timms Point silt.

Pliocene: According to the literature and a list of IGPS specimens supplied by Hatai, from the Kanagawa Prefecture, Koshiba Formation. Aomori Prefecture (Kubo and Chikagawa Formations). Sylvia Creek, near Montesano, Washington, Montesano Formation. Fossil Rock, Coos Bay, Oregon from the Coos Conglomerate and Empire Formation. Humbolt County, northern California, in the Scotia and Fortuna Quadrangles, Rio Dell, Wildcat, and Scotia Bluffs Formations. Halfmoon Bay and Año Nuevo Point, Purisima Formation; Goleta and Santa Barbara, lower part of the Santa Barbara Formation. Santa Maria District and Ventura Basin, from the Fernando, Pico, and Cebada Formations and Foxen mudstone. Greater Los Angeles, including Newport Beach, from the Repetto and Fernando Formations. Tijuana Playa area (SDSC 180). ? Pleistocene or Pliocene, specimen grabbed by the "Deepstar" off southern California (SDSC 543).

Miocene: According to IGPS specimens, from Nagano Prefecture, Shigarami Formation; Chiba Prefecture, Kurotaki Formation; Iwate Prefecture, Kadonosawa Formation; Shimane Prefecture, Fujina Formation; Gumma Prefecture, Itahana Formation.

Depending on the taxonomic designation, Cape Yakataga and (?) Poul Creek Formations. Abundant specimens of this material, here assigned to *Fusitriton* sp. ? aff. *F. oregonensis,* are in the Tertiary collections of the U.S.G.S. in Menlo Park, California, and the Phillips Petroleum Company, Bartlesville, Oklahoma. The latter were collected with careful attention to stratigraphic succession by M. Scott McCoy, Jr.

The fossil record in Japan cannot be interpreted without seeing specimens and evaluating the ages assigned to Tertiary formations. Few Pleistocene deposits are recognized in the literature and *F. oregonensis* is recorded mainly from the Pliocene and Miocene. The possibility that some of these records could be *F. galea* has not been investigated.

A Plio-Pleistocene boundary problem also exists in the West Coast Tertiary of North America. A discussion by Keen *in* Keen and Bentson (1944) emphasized the need for detailed stratigraphic collections of assemblages to distinguish the faunal change that marks this division. Although such a boundary is somewhat artificial in areas of continuous deposition, percentages of species studied by Keen from the Santa Barbara Formation did show a marked change along a horizon within the lowest member of the Santa Barbara Formation in the section at Beacon Hill; the temporal division at that locality did not correspond to a lithologic one.

Many workers have examined the San Pedro Plio-Pleistocene sediments, some perhaps ignoring the abundance of landslides and possibility of reworking. As *F. oregonensis* ranges back at least to the early Pliocene, the boundary problem in that area is not especially critical to this study.

Ecology. — Bathymetric ranges (in fathoms) are given in Text-fig. 9 for the following areas: Sea of Japan, Pacific side of Japan from 35°N to the east coast of Kamchatka, Bering Sea north of the Aleutians, Gulf of Alaska, southeastern Alaska, Puget Sound and Straits of Juan da Fuca, Pacific coast of Washington to Monterey Bay, and south of Monterey to northern Mexico. The most striking differences in depth are seen in eastern Pacific forms that spawn in the littoral zone in Puget Sound but have never been taken from water shallower than 80 fathoms in southern California. Shells dredged by John Favalora of the General Fish Corporation, Moss Landing, California, came from 70 to 120 fathoms and contained large hermit crabs. It is likely that the living gastropods are commoner at greater depths and possible that the pagurids bring the shells to shallower water.

Observations in the Natural History of Fusitriton oregonensis.— Although the species is common intertidally in the San Juan Islands, Puget Sound, during the summer months, few details of its natural history have been published. That the animals are able to move about readily is evident from the shifts of large populations from one area to another in successive years. They are apparently capable of adjusting to considerable changes in depth and pressure and can be kept alive in aquaria for a period of six months or more. Valentine and Emerson (1961, p. 617) reported the species in water 7-11°C in Puget Sound and less than 8°C off southern California.

Two animals that had been taken from an unknown locality in Puget Sound were observed copulating after several months in captivity at the Steinhart Aquarium, San Francisco. Their shells were oriented in the same direction and the female adhered to the glass; the male was attached to the penultimate whorl of the female, the plane of his aperture differing by 90°. No eggs were observed by aquarium curators.

Field reports (Howard, 1962, p. 160; Silberling, 1967, personal communication; anonymous fishermen) indicate that egg laying can be accomplished in or out of water, although all observations known to the writer were made in the intertidal zone on rocks in tide pools or sandy coves. A specimen photographed by Silberling in Keku Strait (Pl. 46, fig. 14) and one illustrated by Howard (1962, pl. 39, fig. 2) on Baranof Island, southeastern Alaska, were seen depositing egg capsules in a spiral arrangement until at least 150 had been laid. According to Howard, after completing the egg laying process, the animal secreted a heavy colorless mucus sheet that was drawn over the egg mass and then the animal returned to deeper water.

Philpott (1925), working on the embryology of *F. oregonensis* (which he referred to *Argobuccinum*), found egg cases abundant during June, July, and August in the vicinity of Puget Sound Biological Station. Most came from rocks barely exposed at minus tide levels while others were dredged from 20 m. One relatively small egg cluster contained 125 egg capsules, each of which encased 1600 to 2000 eggs, a total of 200,000 to 250,000 individuals. Whether all or only a few hatch is not known, but free swimming veliger larvae have been recognized by Dall (1886, pp. 212-214; 1904, p. 127) and other workers. Dall described the pelagic larvae as metallic blue-green pteropod-like creatures having horny shells; he collected them 200 miles from shore in the Gulf of Alaska and considered this capacity to swim an important distributional factor. Protoconchs that have been studied by the writer are thin white shells having 3-1/2 whorls ornamented by several fine spiral striae.

A *Fusitriton* veliger studied by Dr. Gunnar Thorson at the Friday Harbor Laboratory remained in the plankton for several months, and since an unusually long larval stage has been documented for other Cymatiidae (Scheltema, 1966, *Cymatium),* it might be expected in *Fusitriton.* Thorson (1967, written communication) felt ". . . absolutely sure that its pelagic larval life [is] at least half a year," and suggested that 13 months may not be impossible. "The larvae . . . get a shell of 4 mm or more, and a velum of more than 1 cm before leaving the plankton. It is very common in offshore plankton in Oregon and Washington and even around the northern part of Japan."

In a study of the feeding habits of four species of marine gastropods at Friday Harbor, John Avery (1961) demonstrated that *Fusitriton oregonensis* is a carnivore. Whether it is an omnivore was not tested, but a series of experiments showed that specimens of *F. oregonensis* will eat the following freshly killed prey: the pelecypod *Mytilus californianus* Conrad, the arthropod *Upogebia pugettensis* (Dana), the annelid *Nereis brandti* (Malmgren), the decapod crustacean *Cancer gracilis* Dana, and a combination of blenny and cling fish, *Xiphister astropurpurens* Kittlitz and *Gobieosox meandricus* Girard. Other animals that were not part of the experiment but that were eaten by *F. oregonensis* in captivity were a large worm, *Echiurus echiurus alaskanus,* and a live tunicate *Ascidia paratropa* in which the *Fusitriton* had made a hole 3.5 mm in diameter and inserted its proboscis.

Experiments of this kind leave many questions unanswered, and it is possible that the use of starved animals and the particular kinds of prey produced different results than would have been seen in the field. Avery constructed a long water trough with a food compartment in one end over which water passed. His aim was to measure the time taken for each specimen to orient itself to the food scent and move down the trough to the prey. He used 10 specimens of *Fusitriton oregonensis,* five of which showed no preference for any particular kind of food. They took 20 minutes to almost an hour to orient themselves and the same time to travel to the food compartment. As in other carnivorous gastropods, the sense of smell is probably more important than sight; however, any disturbance or loss of contact between proboscis and prey caused *Fusitriton* to grope around momentarily and then give up and crawl away.

Avery considered that a measure of the capacity of exploiting different food sources is the length to which the proboscis can be everted and the smallest size aperture through which it can pass. A specimen of *F. oregonensis* measuring 9.4 cm long everted its proboscis 16.0 cm to reach a specimen of *Mytilus;* Avery believed that greater range to perhaps twice the length of the shell may be possible. In as much as the species has been collected in areas supporting a *Macoma nasuta-M. secta* community in which these infaunas live within 10 cm of the surface, Avery considered the capacity to extend the proboscis important for the utilization of this food source. Observations of these animals digging with their proboscides have not been recorded.

The Strongylocentrotus-Argobuccinum community of Shelford and Towler (1925). — Shelford, *et al.,* (1935) recognized this biome from the littoral zone to 225 m in various parts of a 386 square mile area including the San Juan Islands. It is developed on hard substrates that are subjected to strong current or wave action and may be extensive some years and almost lacking other times. They noted (1935, p. 330) that "*Argobuccinum* [*Fusitriton*] was very abundant in 1922 when the original work on the *Strongylocentrotus-Argobuccinum* biome was done. By 1926 it was almost absent but gradually increased to 1930 when observation ceased." They attribute these declines and increases to a combination of factors including changes in water circulation, bottom conditions, early arrival of other larvae, algal growth, and accidents related to other physical changes.

The average number of animals per 10 square meters was 40 to 200 green sea urchins (*Strongylocentrotus drobachiensis* Müller), 2 to 50 specimens of *F. oregonensis,* and 15 to 1000 specimens of *Pecten hericius* Gould. Other possible dominants or influents were listed but not treated in detail (Shelford, *et al.,* 1935, p. 281) : three species of barnacles (5 to 400 of each), (five species of gastropods (2-60 *Calliostoma costatum,* 1-150 *Trichotropis cancellata,* 5-85 *Amphissa columbiana,* 10-50 *Crepidula nivea,* 3-6 *Calyptraea fastigiata),* 2-50 specimens of *Pododesmus machroschisma,* 1-2 starfish *(Orthasterias columbiana),* and 1-10 sessile sea cucumbers *(Psolus chitonoides).*

Fusitriton galea Kuroda and Habe, 1961 Pl. 46, figs. 10, 11

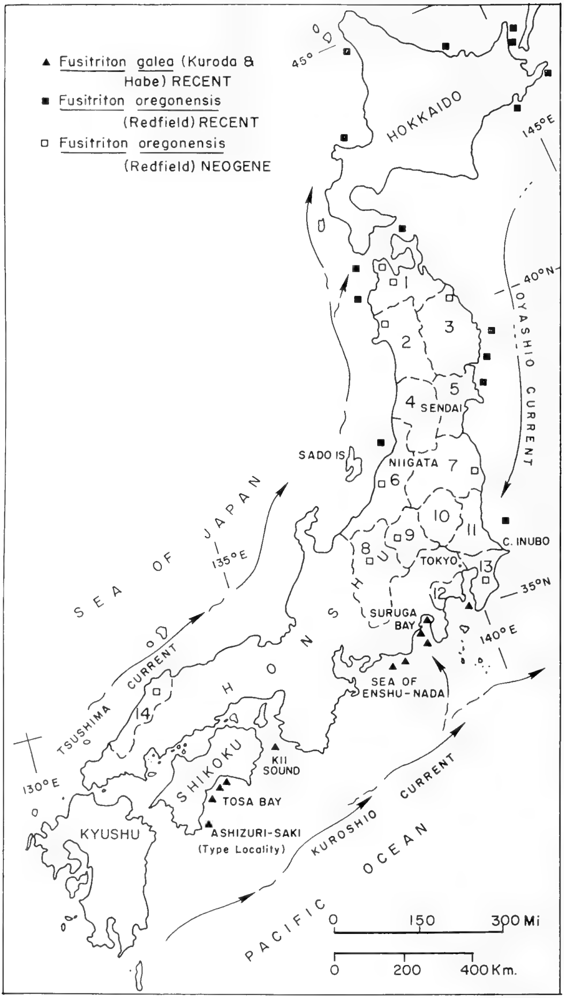
Fusitriton oregonensis (Redfield), Tsuchi, 1958, Repts. Liberal Arts Fac., Shizuoka Univ. [Natur. Sci.] 2(2), pp. 71, 72, pl. 1, fig. 3 (as *Fusitriton oregonensis galea* Kuroda MS; according to a footnote, the material described as *F. oregonensis* in 1956 is also this subspecies).

Fusitriton galea Kuroda and Habe, 1961, *in* Habe, 1961, Colored Illustrations of the Shells of Japan, II. Japanese ed., p. 46, pl. 23, fig. 11; appendix p. 18. Okutani, 1964, "Rept. Archibenthal and Abyssal Gastropod Mollusca mainly collected from Sagami Bay and adjacent waters. . . ." Jour. Fac. Sci., Univ. Tokyo, Sec. II, XV, pt. 3, p. 400, pl. I, fig. 24, text fig. 1 (radula).

Fusitriton oregonensis galea Kuroda and Habe, Habe, 1964, Shells of the Western Pacific in Color II [English ed. of Coloured Illustrations of the Shell of Japan II], p. 75, pl. 23, fig. 11.

Type information.—The specimen originally described and figured by Kuroda and Habe *in* Habe, 1961 was collected "Off Cape Ashizuri-Saki, Shikoku, Japan," in Tosa Bay.

Descriptive notes.—*Fusitriton galea* Kuroda and Habe can be separated from *F. oregonensis* by its sculpture and general outline. Its fewer, coarser axial ribs form pronounced nodes where they cross major revolving bifurcated straps; spiral interspaces contain three evenly spaced threads. Major straps and medial threads are commonly reddish brown in color. The periostracum varies from light to dark brown, but in museum specimens the long dark brown hairs have usually fallen off and a lighter scaly covering remains. Spiral threads are outlined by rows of periostracal tufts and are more conspicuous in hairy specimens than in those which have been decorticated. Most, including adult, whorls have two varices that are not aligned but that approach lateral positions. Shoulders are not as tabulate as in *F. oregonensis* and the anterior canal is long and more strongly recurved. Protoconchs were missing in most specimens studied; the largest adults had at least seven whorls and measured 11.3 to 12.3 cm high. The excurrent notch is marked as in *F. oregonensis* and several individuals had ochraceous apertural margins.


▲ Fusitriton galea (Kuroda & Habe) RECENT
■ Fusitriton oregonensis (Redfield) RECENT
□ Fusitriton oregonensis (Redfield) NEOGENE
45°
HOKKAIDO
145°E
40°N
OYASHIO CURRENT
1
2
3
4
5
SENDAI
SADO IS
NIIGATA
6
7
10
9
11
8
C. INUBO
TOKYO
13
12
35°N
SURUGA BAY
140°E
SEA OF JAPAN
135°E
HONSHU
SEA OF ENSHU-NADA
TSUSHIMA CURRENT
14
SHIKOKU
KII SOUND
TOSA BAY
ASHIZURI-SAKI
(Type Locality)
130°E
KYUSHU
KUROSHIO CURRENT
PACIFIC OCEAN
0
150
300 Mi
0
200
400 Km.

Some strongly nodose specimens labelled *F. laudandum* Finlay, 1927 from New Zealand resemble *F. galea,* but the former are consistently higher spired and more slender and the Japanese species has finer microsculpture, a more strongly recurved canal and possibly a heavier shell.

Ecology and distribution.— (Text-fig. 10.) The author is indebted to Mr. Takashi Okutani of the Tokai Regional Fisheries Bureau, Tokyo, for confirmation of distributional data based on the literature and specimens in American museums. Known only from the Pacific side of southern Japan, *F. galea* has been dredged from 55 to 120 fathoms in Tosa Bay and from 88 to 340 fathoms (or 620 m, deepest record, collected by Okutani, 1964) off southern Honshu in Uraga Strait, Suruga Bay, and the Sea of Enshu Nada, where it is abundant between the upper shelf and bathyal zones.

It is a warmer water species than *F. oregonensis,* which occurs in 30 to 130 fathoms along the east coast of Honshu where the cold south-flowing Oyashio is the dominant current. *Fusitriton galea* is found south of latitude 35°N in areas influenced by the warm Kuroshio stream which flows northeast from the northern equatorial current. The two species have never been collected from the same area, their respective faunal provinces being divided at Cape Inubo.

Because *Fusitriton galea* was described relatively recently (1961), its fossil history if any is not yet known. It is possible that specimens reported as *F. oregonensis* from the Tertiary of Japan could be *F. galea,* but to date the time and place of separation of *F. galea* from *F. oregonensis* have not been documented. Text-figure 10 shows the distribution of *F. galea* and of Recent and fossil specimens of *F. oregonensis* in Japan.

←

Text-figure 10.—Distribution of *Fusitriton galea* (Kuroda and Habe) and of *Fusitriton oregonensis* (Redfield) in the vicinity of Japan. Numbers refer to the following prefectures: 1, Aomori; 2, Akita; 3, Iwate; 4, Yamagata; 5, Miyagi; 6, Niigata; 7, Fukushima; 8, Nagano; 9, Gumma; 10, Tochigi; 11, Ibaraki; 12, Kanagawa; 13, Chiba, 14, Shimane. Locations, based on literature and IGPS specimens, are approximate.

Fusitriton midwayensis Habe and Okutani, 1968 Pl. 46, fig. 7

Fusitriton midwayensis Habe and Okutani, 1968, Venus, 27(2), pp. 48, 49, pl. 3, fig. 6 [illustration refigured herein].

Type information.—The holotype was collected from 400 to 460 m at 35°15′ N. lat., 171°50′E long., northwest of Midway Island in the central Pacific Ocean. It has been deposited in the National Science Museum, Tokyo, Japan.

Descriptive notes.—Three specimens are known, ranging in height from 3.6 cm to 5.38 cm. Adults of this species may have a smaller, more solid shell than other congeneric forms, or this material may represent half grown individuals. Sculpture is described as densely reticulate, the body whorl having 22 axial ribs crossed by brown color bands and eight spiral costae forming nodose intersections. Varices occur at 270° positions. The aperture is white with callous deposits on the pillar and posterior end near the anal notch. The periostracum is pale yellow in color.

Distribution.—The species is Recent and known only from the type locality in the central Pacific. No biological or ecological data are available, as the type material was not live-taken.

Habe and Okutani considered the species a northern element, perhaps derived from *Fusitriton oregonensis* (Redfield) or from the Japanese form, *F. galea* Kuroda and Habe. A discussion of phylogenetic affinities based on the original description and figure alone would be premature; however, a preliminary evaluation suggests that the newest described species of *Fusitriton* is morphologically closest to *F. oregonensis.*

Fusitriton scotiaensis (Martin, 1914) Pl. 42, figs. 1-3

Argobuccinum scotiaensis Martin, 1914, Univ. California Pub. Bull. Dept. Geol. 8(7), 192, 193, pl. 21, fig. 3. Ogle, 1953, California Div. Mines Bull. 164, pl. 5.

Ranella (Priene) scotiaensis (Martin), Grant and Gale, 1931, San Diego Soc. Nat. Hist., Mem. I, p. 738.

Nomenclatural remarks.—Considering the great variability in both Recent and fossil specimens of *Fusitriton* in western North America, it might seem appropriate to call this form a subspecies of *F. oregonensis* (Redfield); however, because of its uncertain relationship to *F. oregonensis* (Redfield) and greater resemblance in shell morphology to the South American *F. cancellatus* (Lamarck), it is treated here as a separate species until more material has been collected. It is generally undesirable to recognize two subspecies of the same taxon in a given habitat. Although it is not known that the associated specimens of typical *F. oregonensis* (Redfield) occupied the same niche in life, it is not possible to determine this information from museum material. To consider *F. scotiaensis* (Martin) a subspecies of *F. cancellatus* (Lamarck) would imply a phylogenetic relationship for which there is not sufficient evidence.

Type information. — The holotype, UCMP 12337, is an adult body whorl of a worn and slightly squeezed specimen measuring approximately 5.4 cm in height. The type locality is UCMP 1878, "In the east bank of Eel River, about 3/4 of a mile north of Scotia, Humboldt County, California." The rocks at this locality are considered part of the Wildcat Series of Pliocene age.

Descriptive notes. — Aside from the holotype, two other lots of material from the Wildcat Formation were examined by the writer; several poor specimens were collected from the Scotia Quadrangle near Elinor, California, (UCMP loc. 1880) and two incomplete but well-preserved shells were found by Ogle in the Pliocene Wildcat Formation of Humboldt County, California. The latter are illustrated herein and compared with a Recent specimen of *F. cancellatus* (Lamarck).

The species may be distinguished by its even reticulate sculpture consisting of numerous alternating spiral costae (some grooved, some not) and threads crossed by fine axial ribs. The body whorl of the larger individual bears 34 axial ribs in contrast to 18 coarser ones on an equally large specimen of *F. oregonensis* (Redfield). Varices are not pronounced except on the outer lip, and two to three occur on the body whorl. The whorls are somewhat more inflated than in most specimens of *F. oregonensis* (Redfield). Among the large variety of forms of *F. oregonensis* (Redfield) from Ventura County, southern California, some specimens approach *F. scotiaensis* (Martin), but none has both the tumid appearance and finely reticulate sculpture.

Distribution. — Geologic. *Fusitriton scotiaensis* (Martin) is known only from the Pliocene Wildcat Formation of Humboldt County, northern California, where it is associated with typical

F. oregonensis (Redfield) and *"Beringius" arnoldi* (Martin) (= *Argobuccinum arnoldi* auctt.)

Fusitriton dilleri (Anderson and Martin, 1914) Pl. 49, figs. 5-7

Argobuccinum dilleri Anderson and Martin, 1914, California Acad. Sci., Proc., ser. 4, 4, pp. 71, 72, pl. 4, fig. 7. Weaver, 1943, Univ. Washington Pub. Geol. 5, Pt. 2, p. 420; Pt. 3: pl. 83, fig. 6.

Ranella (Ranella) dilleri (Anderson and Martin), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem. I, p. 735.

Argobuccinum cf. [*A.*] *mathewsoni* Gabb, Tegland, 1933, Univ. California Bull. Dept. Geol. 23(3) pp. 134,135, pl. 13, figs. 12,14.

? *Gyrineum goodspeedi* Tegland, 1933, Univ. California Pub. Bull. Dept. Geol. 23(3), p. 135, pl. 13, figs. 5, 6.

"Gyrineum" dilleri Anderson and Martin, Moore, 1963, U.S. Geol. Sur., Prof. Paper 419, pp. 31,32, pl. 2, figs. 8, 9.

Nomenclatural remarks.—The concept of this species is not clear, as the holotype and most other specimens seen are incomplete anteriorly. It has been considered a *Ranella* by Grant and Gale (1931) and others. Although the type lacks the apertural characters by which *Fusitriton* is easily distinguished from *Ranella,* details of varix formation, parietal callous, excurrent area, tabulate whorls, and spiral sculpture place it closer to *Fusitriton oregonensis.* The possibility of including the holotype in *Mediargo* cannot be completely ruled out, as the diagnostic apertural features are missing. However, the discontinuity of prominent varices and greater width of spiral interspaces support its placement in *Fusitriton.*

Many workers have synonymized *F. dilleri* with *Ranella mathewsonii* Gabb. The writer considers Gabb's species referable to *Mediargo,* although the holotype is missing and its aperture was not shown in the original illustration; evidence for this classification will be discussed under the appropriate species.

Tegland's hypotypes of *Argobuccinum* cf. *A. mathewsoni* are probably *F. dilleri,* although they are internal molds and the spiral microsculpture may not be seen; apertural details are also lacking.

Type information.—The holotype, CAS 152, was collected from CAS locality 35 in sea cliffs south of the mouth of Wade Creek, 4½ miles north of Yaquina Bay, Lincoln County, Oregon, from the Astoria Formation of Miocene age.

Descriptive notes.—The holotype, incomplete anteriorly and posteriorly, has 4½ whorls and measures 6.5 cm high. Two pronounced, irregularly spaced varices occur on each whorl, outlines are rounded and shoulders have a slight or narrow tabulation. Axial ribs are crossed by spiral cords in wide interareas. Interstices commonly contain three revolving threads, although only one is present on some whorls. Pillars on two specimens are straight and devoid of transverse wrinkles; parietal callous deposits occur intermittently.

The species can be distinguished from *F. oregonensis* by the more prominent varices on adult as well as juvenile whorls and the three spiral cords in the wider interspaces between costae. *Mediargo* has two lateral, more nearly continuous varices per volution, more strongly tabulate whorls, transverse plications on the columella and a denticulate outer lip; narrower interspaces generally contain only one spiral cord. It is possible that a study of more complete material would show *F. dilleri* to be a variant of *Mediargo mathewsonii*, but on the basis of present knowledge they can be separated by apertural and sculptural differences.

Geologic distribution.—Oligocene to middle Miocene, Alaska, Washington, and California; Miocene, Yakataga district, Yakataga Formation (USGS 3172 Tertiary collection, Menlo Park). Specimen identical to the one figured by Moore (1963, pl. 2, figs. 8, 9); Yaquina Bay, Lincoln Co., Oregon (type locality and Moore's specimen USGS 18938 from USNM loc. 128), from the middle Miocene Astoria Formation; Barker's Ranch, Kern Co., California (USGS localities M1602, M1600; LACM 463), from the middle Miocene Olcese Sand. Oligocene, Restoration Point, Kitsap Co., Washington (Tegland's hypotypes, UCMP loc. 681), type locality of the Blakeley Formation, upper Oligocene age; Grays Harbor Co., Washington (UCMP locality A-410) from the Lincoln Formation, Zemorrian stage.

Fusitriton sp. ? aff. **F. oregonensis** (Redfield, 1846) Pl. 46, figs. 3, 4

A large number of poorly preserved and distorted specimens from Middleton Island and Cape Yakataga, Alaska have been collected by geologists of the U.S. Geological Survey and by Mr. Scott McCoy, Jr., of the Phillips Petroleum Company. In spite of the abundance of material generic and specific identifications are not certain. The specimens are Miocene in age and were collected from the Yakataga and possibly Poul Creek formations.

If these specimens are cymatiids, they should be referred to *Fusitriton* on the basis of sculpture, smooth pillar, and anal notch. No varices have been observed, even on juvenile whorls, and the sutures in undistorted shells are more appressed than in *F. oregonensis.*

Coarse axial ribs are crossed by faintly grooved spiral costae and thin interspaces containing one to three cords. Although such sculptural elements are common in species of *Fusitriton,* the coarseness and pattern are somewhat different. Morphologic forms that are closest to these specimens include Pliocene specimens of *F. oregonensis* from the Newport Bay area south of Los Angeles, California, *F. dilleri* (about which there are many taxonomic uncertainties), the upper Oligocene paratype of *Gyrineum goodspeedi* Tegland, 1933 (here doubtfully synonymized with *F. dilleri*), and *F. galea* from southern Japan. Miocene and Pliocene specimens reported as *F. oregonensis* from Japan might be helpful in working out the affinities of this material, but the writer has seen no figures of those fossils.

F. dilleri differs in having strong varices and tabulate whorls, but *F. galea* has a similar outline and generally lacks any considerable thickening on the outer lip. A more certain identification will not be attempted until Japanese fossils have been seen, because this may be extremely significant in the phylogeny and direction of dispersal of the genus.

MEDIARGO Terry, 1968

Type species, (original designation) *Gyrineum mediocre* Dall, 1909a.

Mediargo mediocris (Dall, 1909) Pl. 47, figs. 1, 4-9

? *Ranella marshalli* Reagan, 1908, Kansas Acad. Sci. Trans. 22, pp. 223, 224, pl. VI, fig. 62 [The holotype is worn and the aperture not exposed; it is probably conspecific with *M. mediocris,* but the identification cannot be confirmed from the type specimen].

Gyrineum mediocre Dall, 1909, U. S. Geol. Sur., Prof. Paper 59, pp. 54, 55, pl. VII, fig. 6. 1922, American Jour. Sci. 5 ser., IV, Art. XXIX, p. 313 [*Ranella marshalli* Reagan treated as a synonym]. Weaver, 1943, Univ. Washington Pub. Geol. V, Pt. 2, pp. 423, 424; Pt. 3, pl. 83, fig. 13.

Gyrineum lewisii Carson, 1926, Southern California Acad. Sci. Bull. 25, pp. 53-54, pl. 2, figs. 1, 2. [The name appeared in a list by Carson, 1925, Pan Am. Geol. 43, p. 267, but was not validated until the following year.]

Ranella (Priene) mediocris (Dall), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem. I, p. 736.

Ranella (Priene) lewisii (Carson), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem. I, p. 736.

"Gyrineum" mediocre lewisii Carson, Woodring and Bramlette, 1950, "Geol. and Paleontol. . . . Santa Maria District, Ca.," U. S. Geol. Sur., Prof. Paper 222, pp. 48, 73-74, pl. 12, figs. 13, 15; pl. 13, figs. 23, 24, 26, 27.

Mediargo mediocris (Dall), Terry, 1968 b, Veliger, 11(1), pp. 42-44, pl. 4.

Nomenclatural remarks. — Previously described species here referred to *Mediargo* have been classified most commonly in *Ranella, Bursa,* and *Gyrineum.* Although all three have lateral varices and anterior pillar folds, the new genus can be distinguished by a combination of characters that suggest it is closer to the Cymatiinae *Argobuccinum* and *Fusitriton* than to the Ranellinae. *Mediargo* ranges from Oligocene to Pliocene and occurs in North America, Japan, and Korea. Its type species is *Gyrineum mediocre* Dall, 1909a.

Diagnostic generic characters seen in all but the largest gerontic specimens include: two nearly continuous lateral varices per volution, high spire, rounded whorls with tabulate shoulders, moderate to long anterior canal, anal notch oriented at an angle to the axis of coiling (as in *Fusitriton,* not directed apically as in *Argobuccinum),* transverse pillar folds over most of the columella and a denticulate or plicate outer lip. Axial and spiral costae are commonly present on juvenile whorls and conspicuously lacking in later stages. Some juveniles resemble Recent species of *Gyrineum,* although they differ in having a plicate, ovate rather than round aperture, a marked excurrent notch and tabulate shoulders.

The type lot of *M. mediocris* (Dall, 1909a) is the earliest described positively identifiable material belonging to the type species. Although the holotype of *Ranella marshalli* Reagan, 1908 is probably a conspecific form and was described the previous year, it was based on a poor specimen lacking sculptural and apertural characters. Because its identification cannot be confirmed, the next available name was selected for the species.

Type information. — The holotype, USNM 153900, and paratype, USNM 645876, were collected near Fossil Point in the vicinity of Coos Bay, Oregon, by Mr. B. H. Camman. Comparison of the holotype with other Pliocene specimens confirms this age, but the worn paratype may have been reworked from older rocks. Its resemblance to the Miocene holotype of *Bursa trampasensis*

Clark [here assigned to *Mediargo mathewsonii* (Gabb)] suggests this interpretation, although the specimen is considerably eroded. The morphologic sequence of middle Miocene specimens of *M. mathewsonii* and *M. mediocris* from the Pliocene appears almost unbroken, and it is not surprising to find material in which the characters overlap.

Descriptive notes. — Specimens of *M. mediocris* vary considerably between different growth stages. The holotype and paratype are abraded, incomplete specimens that are about half grown. Neither has the high, strongly sculptured spire of juvenile and late juvenile forms nor the flaring outer lip and pillar callous of gerontic specimens such as Carson's holotype of *Gyrineum lewisii* (Pl. 47, fig. 8.)

The holotype and paratype have three and two and one-half whorls measuring 4.4 cm and 6 cm, respectively, in height. The largest individual seen (USNM 560075, illustrated by Woodring and Bramlette, 1950, pl. 12, figs. 13, 15) had five teloconch whorls and was 13.6 cm high. Two large, discontinuous lateral varices occur on each whorl, the alignment being more perfect in juvenile forms. Shoulders are tabulate and whorls both rounded and inflated. Axial sculpture, present in juveniles and obscure to absent in adults, consists of numerous ribs crossed by bifurcated spiral costae. The type specimens and Carson's holotype of *Gyrineum lewisii* have the sharply incised spiral grooves characteristic of Pliocene material. Although especially marked in fossils from the Santa Maria District, California, tar seeps, incised spirals are not produced by a particular mode of preservation; they are present in juveniles but may be obscured by other sculpture.

Mediargo is characterized by a conspicuous anal notch oriented at an angle to the axis of coiling and by plications on the slightly flexed pillar and outer lip. Although juveniles and half grown adults have plications, they are lacking in very large gerontic forms in which the outer lip is flared. Apertural plications and the overall general shell outline are reminiscent of Recent species of *Argobuccinum.*

M. mediocris juveniles are confused most commonly with young specimens of *Fusitriton oregonensis* (Pl. 47, figs. 2-4), although they are separable by differences in spiral sculpture, outline, and apertural features. Young forms of *M. mediocris* have pillar furrows and two lateral varices per whorl in perfect or nearly continuous alignment. In *Fusitriton oregonensis* varices are more irregular, pillars smooth and the outer lip denticulate if the shell is at a resting stage. Whorl proportions are significantly different; in a whorl of a given height, the width is much greater in juveniles of *M. mediargo.* Incised spiral grooves are found only on *M. mediargo,* although axial ribbing may be quite similar in both species.

The division between *Mediargo mediocris* and *M. mathewsonii* is drawn between strongly grooved Pliocene forms and older, more coarsely sculptured specimens, none of which attains the large sizes of *M. mediocris* adults. The morphologic sequence between some Miocene specimens such as the one described as *Bursa trampasensis* Clark (here identified as *M. mathewsonii* (Gabb) and figured on Pl. 48, figs. 14, 15) and the paratype of *M. mediocris* is almost unbroken, the former being almost indistinguishable from the latter wherever corresponding features are present.

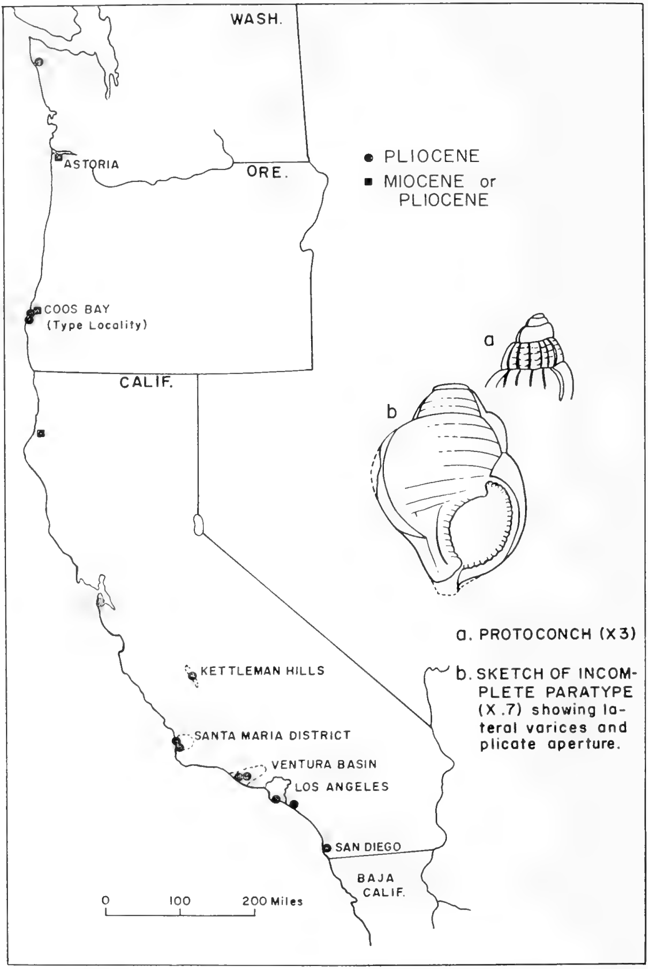
Distribution. – (Fig. 11).

Range: Middle ?, Late Miocene, Pliocene; from the Olympic Peninsula, Wa. to San Diego, Ca. Washington, Mouth of Maxfield Creek, south of Bogachiel River, Olympic Peninsula, Quillayute Formation, Pliocene. Oregon, Astoria. Astoria Formation, Miocene. Fossil Point, north of South Slough, Coos Bay (type locality, also CAS 4), Empire Formation, Pliocene. California, Humboldt Co., Bluffs on Boulder Creek Mad River (C69). UCMP A-4233, Falor Formation, Pliocene; Quarry west of Milbrae, (CAS 33240), Merced Formation, Pliocene; Kettleman Hills, Fresno Co. Etchegoin Formation, Pliocene; Santa Clara Valley, Los Angeles Co. (USNM 18283), Pliocene; Santa Maria District, Santa Barbara Co. Fernando, Cebada Formations, Pliocene; Palos Verdes Hills "Pleistocene Lomita Marl," reworked. Newport Bay, (M2096) Niguel Formation, Late Pliocene; San Diego, (CAS 11689) from a well, Pliocene.

Mediargo mathewsonii (Gabb, 1866) Pl. 48, figs. 1-19

Ranella Mathewsonii Gabb, 1866, Paleontol. California II: p. 8; 1869, pl. 2, fig. 13.

Tritonium newsomi Arnold, 1908, U.S. Nat. Mus., Proc., XXXIV (1617), pp. 360-361, pl. XXXII, fig. 6 [holotype refigured herein].



Text-figure 11. — Distribution and morphology of *Mediargo mediocris* (Dall). ● denotes Pliocene occurrences. ■ Miocene or Pliocene, forms gradational between *M. mediocris* and *M. mathewsonii.* a, outline of protoconch (x2.5). b, sketch of paratype showing apertural details and large lateral varices.

Bursa trampasensis Clark, 1915a, Univ. California Pub. Dept. Geol. 8(22), p. 492, pl. 67, fig. 3 [holotype refigured herein].

Bursa mathewsonii (Gabb), Clark, 1918, Univ. California Pub. Bull. Dept. Geol. 11(2), p. 173, pl. 20, figs. 1,2.

Bursa vancouverensis Clark and Arnold, 1923, Univ. California Pub. Bull. Dept. Geol. Sci. 14, p. 163, pl. 37, figs. 1a, 1b (holotype, CAS 578), 2a, 2b (paratype, LSJU 284) [the latter figured herein].

Argobuccinum cf. [*A.*] *mathewsonii* (Gabb), Teglund, 1933, Univ. California Pub. Dept. Geol. Sci. 23(3), pp. 134,135 *(partim)*, pl. 13, fig. 13.

? *Ranella (Priene?) nipponensis* Nomura and Zinbo, 1935, Saito Ho-on Kai Mus. Research Bull. 6, 181,182, pl. XV (I), fig. 34.

Bursa yabei Nomura and Hatai, 1936, Saito Ho-on Kai Mus. Research Bull. 10, pp. 141,142, pl. XVII, figs. 14a, 14b, 15a, 15b [type specimens figured herein].

Bursa cf. *mathewsonii* (Gabb), Schenck and Keen, 1940, California Fossils: pl. 35, fig. 1 (juvenile).

Argobuccinum vancouverense (Clark and Arnold), Weaver, 1943, Univ. Washington Geol. V, pt. II: p. 421; pt. III, pl. 83, figs.8,12.

Gyrineum kincaidi Durham, 1944, Univ. California Pub. Dept. Geol. Sci. 27(5): p. 168, pl. 15, fig. 14 [holotype, a juvenile, figured herein].

? *Bursa shinsorutonensis* Hatai and Kotaka, 1952, Short Papers, Inst. Geol. and Paleontol. Tohoku Univ. Sendai, 4, pp. 77-78, pl. 7, figs. 23,24 [holotype figured herein].

Apollon sazanami Hatai and Kotaka, 1959, Saito Ho-on Kai Mus. Research Bull. 28, pp. 8,9, pl. 11, figs. 4,6 [type specimens figured herein].

Photographs of Japanese type specimens and additional locality data were provided by Dr. Kotora Hatai, Tohoku University, Sendai, without whose generous help confirmation of the new genus would have been impossible.

Nomenclatural remarks.—The presence of plicate apertures, anal notch set at an angle to the axis of coiling, a moderate to long narrow anterior canal and tabulate whorls confirms the assignment of this species to *Mediargo*. The synonymy is based on comparison of photographs or actual holotypes that were on loan to Stanford during the same period of time for the purpose of evaluating the taxa involved. Although the holotype of *Ranella mathewsonii* Gabb is missing, the original illustration and description and material collected subsequently by Clark are considered sufficient to establish the concept of the species.

Tritonium newsomi Arnold is a poorly preserved and prepared juvenile from the Santa Cruz Mountains, California, and was originally described as Eocene; later mapping (Cummings, 1960, Stanford Univ. Ph.D. thesis) and faunal studies (Manning, 1943, unpublished stratigraphy report, Stanford Univ.) of the area including the outcrop have shown the age to be late Oligocene or eary Miocene; Cummings, Touring and Brabb (1962) described the rocks of the type locality and nearby creek beds as Zemorrian reef deposits included in the Mindego Formation. Arnold's specimen is the only one reported from the area.

Other species represented by holotypes or hypotypes that are probably juveniles of *M. mathewsonii* are *Bursa mathewsonii* (Gabb) of B. L. Clark, 1918, *Bursa* cf. *B. mathewsonii* (Gabb) of Schenck and Keen, 1940, and *Gyrineum kincaidi* Durham, 1944 (the holotype being the only specimen known).

The species is known from early or middle Oligocene to middle Miocene, and some of the younger specimens are close to the middle Miocene representatives of *M. mediocris.* The phylogenetic sequence between the two species is considered almost continuous.

The holotype of *Bursa shinsorutonensis* was collected from lower Miocene deposits in Korea, where it was associated with *Bursa yabei* Nomura and Hatai (Hatai and Kotaka, 1952, p. 70). This classification of the four species described from Miocene rocks in Japan and Korea as synonyms of *M. mathewsonii* is based on morphologic similarity and on the probable variability of the taxon as it is known in North American specimens and in related species of *Argobuccinum.* Their occurrence in the same formations also supports this interpretation. Remarks on these species are made with reference to original citations and photographs, most of which are reproduced here, of types in the Institute of Geology and Paleontology, Tohoku University, and not to actual specimens.

Type information.—The original abapertural view of the holotype is reproduced here and Gabb's description quoted because the type specimen has not been located. The only individual found at the type locality near Martinez, California, it was probably deposited with other material from the Whitney Collection at Harvard; some of these specimens were lent to several institutions including McGill University and the University of California at Berkeley, but according to their respective curators, Mr. Vincent Condé and Mr. Joseph Peck, no records indicate whether *Ranella mathewsonii* was part of these loans. It was not found among Gabb's types at the Museum of Comparative Zoology or the Academy of Natural Sciences in Philadelphia, and Stewart (1927, p. 291) reported it missing at the time he revised Gabb's California fossil gastropods. The original citation is quoted in full:

Ranella Mathewsonii Gabb, 1866

> Shell moderate in size, robust, sub-compressed; spire high; number of whorls unknown; suture strongly impressed, bordered by a small, though abrupt truncation of the succeeding whorl; varices prominent, rounded, continuous. Mouth small; inner lip heavily incrusted; canal abruptly recurved [flexed]. Surface marked by numerous rounded, longitudinal ribs, crossed by square revolving ribs, with smaller ones interposed, and with flat interspaces. Figure natural size.
>
> *Locality and position:* From the Miocene, south of Martinez [Contra Costa Co., Ca.]; a single specimen found by Mr. Mathewson.
>
> This shell can at once be distinguished by its compact form and alternating revolving ribs. No allied species, either fossil or recent, has been found in California.

Descriptive notes. – The largest adult specimen seen is incomplete but has four whorls and measures 6 cm in height. Two nearly continuous lateral varices give a symmetrical outline to the apertural or abapertural views; whorls are strongly tabulate except at the varices, where a thick shell deposit curves upward against the preceding whorl. Apertures may be denticulate or plicate and the marked anal notch is always present. Worn or broken specimens seem to have a thick, short slightly flexed columella but more complete shells have a longer, slightly curved one; pillars in all prepared specimens had transverse folds.

Axial sculpture consists of strong ribs that look like rows of nodes in worn material. Spiral costae are separated by narrower interspaces than in *Fusitriton dilleri* and these may contain a medial thread. Different modes of preservation produced several sculpture patterns, but the species also seems to have considerable variability in the number and coarseness of axial ribs, especially if individuals of different growth stages are compared.

M. mathewsonii can be separated from *Argobuccinum jeffersonense* (Durham) by its anal notch, tabulate whorls and coarser sculpture, and from *Fusitriton dilleri* (at least until the concept of the aperture of *F. dilleri* is better understood) by a wider tabulation of whorls, narrower spiral interspaces containing only one medial thread and the lateral positions of varices. Typical forms of *M. mediocris* are mainly confined to the Pliocene and are characterized by incised spiral grooves, wider and more inflated varices where they adjoin the preceding whorls. *M. mathewsonii* has coarser axial sculpture and adults tend to be smaller in size.

Distribution. –

Range: Oligocene to middle Miocene, in the northwest and eastern margins of the North Pacific. An incomplete list of representative localities follows: Myonchon District, northeastern Korea: lower Miocene Heiroku Formation; Northeastern Honshu, Japanese prefectures: Yamagata, Ginzan shell beds, Miocene; Iwaki, Tanagura beds, lower or middle Miocene; Miyagi, Moniwa Formation, Miocene; Fukushima, Yanagawa shell beds, Miocene. British Columbia, W of Sooke, SW Vancouver Island. Sooke Formation, Oligocene. Washington, Jefferson County (USMP A-3702), Oligocene. Restoration Point, Kitsap Co. Type Blakeley Formation, Oligocene; Grays Harbor Co., Blakeley Formation?, Oligocene or Miocene (USGS 18666); Oregon, Coos Bay, Coos Co. (USGS 18284). From dredgings. Miocene. California, Martinez, Contra Costa Co. Type locality. "Miocene" (Oligocene or Miocene); Sobrante Ridge, Contra Costa Co. (UCMP 1131, 2754), San Ramon Formation, Oligocene; Los Trampas Ridge, Concord Quad. Lower San Pablo Group, upper Miocene; Santa Cruz Mts., San Mateo Co., near headwaters of San Lorenzo River and Pescadero Creek. Mindego Formation, Oligocene-Miocene; San Benito Co., "Temblor" Formation, middle Miocene; Kern Co., near Barker's Ranch (M1591), Jewett Sand, lower Miocene.

PRIENE H. and A. Adams, 1858

Type species, subsequent designation, Cossmann, 1903, *Triton scaber* King, 1832.

Priene scabra (King, 1832) Pl. 43, figs. 2-4, 7-11

Triton scaber King, 1832, Zool. Jour. London (19), art. XLVII, p. 348. Reeve, 1844, Conch. Icon. II, *Triton:* pl. XI, fig. 34.

Pollia scabra, King, Gray, 1839, Zool. Capt. Beechey's Voyage . . . "Blossom," p. 111, pl. 36, fig. 16.

Ranella scabra (King), Kiener, 1842, Icon. Coquilles Viv., *Ranelle:* pp. 30,31, pl. XV, 2 figs. 1, fig. 1a, 2 figs. 2.

Tritonium (Argobuccinum) scaber (King), Adams and Adams, 1853, Genera Rec. Moll. I: p. 104.

Tritonium (Priene) scaber (King), Adams and Adams, 1858, Genera Rec. Moll. II, p. 654 (see nomenclatural remarks).

Priene scaber (King), Cossmann, 1903, Essais de Paléoconch. Camparée V, p. 109.

Argobuccinum scabrum (King), Dall, 1909, "Report on . . . Shells from Peru," U.S. Nat. Mus., Proc., 37, p. 226.

Argobuccinum (Argobuccinum) scabrum (King), Carcelles, 1954, Comm. Inst. Nac. Inv. Cienc. Nat., Cienc. Zool. 2, p. 247, figs. 7,8.

Argobuccinum (Priene) scabrum (King), Dell, 1963, Roy. Soc. New Zealand, Trans., 3(21), p. 225-226, pl. 1, fig. 7.

Nomenclatural remarks. — The genus *Priene* was introduced into zoological literature in a most unorthodox way by H. and A. Adams in the second volume of their "Genera of Recent Mollusca" (1858). An appendix in Volume II listed additions and corrections to Volume I (1853) and included the proposal of the new name in a brief note (p. 654), "Vol. I: p. 104, for '*Argobuccinum* Klein' read *Priene* H. & A. Adams." in 1903 Cossmann elevated *Priene* to generic rank and designated *Triton scaber* King as the type.

Many workers have been impressed with the similarities in whorl outline, shell thickness, and apertural details between species of *Priene* and *Argobuccinum,* while a few maintain that the long-haired dark periostracum and sculpture pattern place it closer to *Fusitriton.* On the basis of shell morphology and a preliminary study of soft parts the writer considers *Priene* separate from either of these, but probably nearer to or descended from *Argobuccinum* or some other cymatiid genus. Soft parts are compared on Text-figure 2. Shell features that support this interpretation include the following: protoconch, apertural shape and denticulation, columellar flexure and recurvature, pillar folds, umbilicus, general height of adult specimens, and the relatively small amount of variability in sculpture.

It is interesting that while workers have disagreed as to the correct generic name, both Recent species of *Priene* have been universally recognized and treated separately. The presence of Plio-Pleistocene forms intermediate between *P. scabra* and *P. rude* suggest a fairly recent differentiation of species; their relationship would be expressed more accurately if Recent forms were designated as *Priene scabra scabra* and *P. s. rude,* but because living specimens are readily separated and such a nomenclatural change would not improve our understanding of the taxa, their conventional names are retained here.

Priene is named for an ancient Greek city whose Latin derivative is feminine; the correct citation of the type species is *Priene scabra* (King).

Type information. — The original description of *Triton scaber* King lists the type locality as Valparaiso [Chile], where a specimen was fished up with an anchor. It was among material described by Captain King with the assistance of W. J. Broderip, a wealthy amateur, and most of their collection eventually went to the British Museum (Natural History). However, no holotype was seen in the type collection by Dr. A. Myra Keen (1967, written communication).

Descriptive notes. — (Jaws and radula Text-fig. 3.) Adult specimens commonly lack the protoconch and have four to six whorls ranging from 4 to 8.1 cm in height. Their shells are thick and compact, with rounded whorl outlines, and the anterior canal is short and very slightly recurved. Lateral varices occur on the body and penultimate whorls but are barely perceptible or lacking on earlier volutions. The pillar may be flexed to the right and is covered by callous that bears an irregular number of transverse wrinkles; some specimens have a slight umbilicus. An excurrent canal is generally lacking but a shallow notch may develop. The outer lip is almost always denticulate in adults; seven to ten cusps may be borne on an internal varix or platform just inside the lip or denticles or plications may occur at the shell margin. Cancellate sculpture is produced by numerous axial ribs crossed by revolving costae of equal thickness; spiral interspaces contain a medial thread reminiscent of the sculpture in species of *Fusitriton,* although ribs are never bifurcated and sharp nodes mark the junctions of axial and spiral elements. A thick dark brown bristly periostracum covers the shell except at the apex, which is commonly eroded.

In contrast, *Priene rude* (Broderip) has fewer, thicker axial ribs but the same fine spiral sculpture. With respect to all other hard part characters the two species are similar, although details of anatomy and ecology may reveal some differences.

Ecology. — Live-taken material identified by the writer came from the littoral zone to 16 fathoms in the vicinity of Valparaiso, Chile. Specimens from five to ten fathoms were collected from a sandy substrate by a scallop dredge near Antofagasta, Mejillones, and Iquique, and from a sandy bottom near Concepcion, Chile. Reeve (1844) listed the species from Valparaiso in depths of 7 to 45 fathoms.

No information has been reported on the biology of the species, but in some dissected specimens from La Portada, Chile, plant material was the main, if not only, food. The stomachs of other specimens lacked any recognizable animal food or green color. As do the other cymatiids discussed, *Priene scabra* (King) possesses a pair of filelike jaws and a taenioglossate radula.

Distribution. — (Text-fig. 12). According to the literature, the range of *Priene scabra* (King) is much greater than that based on specimens from known localities. The writer has identified material from Chimbote, about 375 km northwest of Lima, Peru, and from as far south as Puerto Montt, Chile (MNHQN specimen). Reports of the species from the Straits of Magellan, Ecuador, and Panama are considered incorrect on the basis of material seen. These localities erroneously appear on museum labels accompanying correctly identified specimens. Such specimens were seen at the American Museum and the San Diego Society of Natural History; in both cases museum records showed that the material belonged to old collections probably acquired from shell dealers and not trustworthy for a distributional study. Tryon (1880, Man. Conch, III, p. 34) falsely reported the species from "Arctic America to California."

Priene scabra (King) ranges from Pliocene (? Pleistocene) to Recent in central Chile; it is abundant in Pleistocene terrace deposits of the Tongoy Formation near La Serena and Coquimbo,[1] and a well-preserved suite of Pliocene (? Pleistocene) specimens from the Pioche Collection in the Museum of Paleontology, Berkeley, is also from Coquimbo. Several of these older fossils are illustrated to show the presence on single specimens of sculpture patterns characteristic of both *Priene scabra* (King) and *P. rude* (Broderip). The apical whorls are always as in *P. scabra;* four specimens have developed body whorls like those in *P. rude,* and two like those in *P. scabra.* These forms constitute evidence that *P. scabra* is the older of the two species, and that from it *P. rude* began to differentiate in the late Pliocene.

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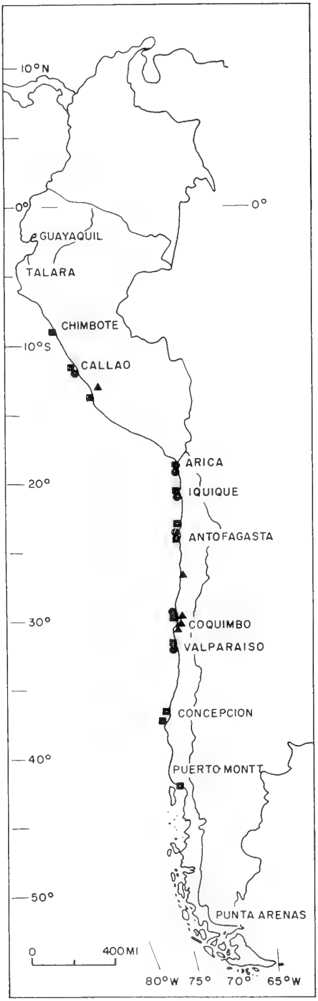
[1] Specimens collected by paleontology students in the School of Geology at the University of Chile were described by M. Cristina Lopez Oyaldo, 1965, "Estudio de los Depositos Marinos de la Bahia de Tongoy" (unpublished thesis). She considered the loosely consolidated Tongoy sands entirely inter- or pre-glacial Pleistocene in age. The fossils were studied by the writer in October, 1966, through the courtesy of Dr. Luis Aguirre and Sr. Reynaldo Charrier, Escuela de Geologia, Universidad de Chile, Santiago.



Text-figure 12. — Distribution of *Priene scabra* (King) and *Priene rude* (Broderip.) ■ Recent occurrences of *P. scabra*, ● Recent occurrences of *P. rude*, ▲ Plio-Pleistocene localities where both species have been collected.

The northernmost fossil occurrence is in the Department of Ica, Peru, approximately 260 miles southeast of Lima. Specimens now in the Stanford Tertiary collections were gathered by Frank Atchley from subrecent (40′) and Pleistocene (2600′) terrace deposits inland from San Nicolas Bay in the Marcona Iron district (15°10′S, 75°10′W).

Priene rude (Broderip, 1833) Pl. 43, figs. 1, 5, 6

Triton rudis Broderip, 1833, Zool. Soc. London Proc. for 1833, pt. 1, p. 6. Reeve, 1844, Conch. Icon., II, Monograph of *Triton:* sp. 53, pl. XIV, fig. 53.
Tritonium (Argobuccinum) rude (Broderip), Adams and Adams, 1853, Genera of Rec. Mollusca I: p. 104.
Tritonium (Priene) rude (Broderip), Adams and Adams, 1858, Genera of Rec. Mollusca II: p. 654.
Triton (Priene) rudis (Broderip), Tryon, 1880, Man. Conch., ser. 1, III: p. 34; 1881, pl. 16, fig. 169.
Argobuccinum rude (Broderip), Dall, 1909b, "Report on . . . shells from Peru," U.S. Nat. Mus. Proc. 37, p. 226.
Argobuccinum (Argobuccinum) rude (Broderip), Carcelles, 1944, Com. Inst. Nac. Inv. Cienc. Nat., Cienc. Zool., 2, p. 246, fig. 9.
Argobuccinum (Priene) rude: Dell, 1963, Roy. Soc. New Zealand, Trans., 3(21), p. 226, pl. 1, fig. 6.

Type information.—The holotype should be at the British Museum (Natural History); Broderip (1833, p. 6) gave the type locality as "Iquique, Peru," now northern Chile.

Descriptive notes.—(Jaws and radula Text-fig. 3.) Adult specimens having four to six or more whorls range from four to seven cm in height; the shells are thick and compact, with lateral varices and prominent axial ribs that terminate abruptly just beyond the greatest girth of the body whorl. Whorl outlines are more angular than in *P. scabra* (King); axial sculpture is coarser and the number of ribs fewer than in *P. scabra* although spiral costae and threads are similar in both species. Body whorls of comparable size (3.4 cm wide) bore nine axial ribs in *P. rude* and 18 in *P. scabra.* Apertures generally bear transverse wrinkles on the anterior part of the pillar, which is flexed to the right and slightly recurved in some specimens. Eight to ten sharp denticulations are commonly present along the outer lip, and a slight anal notch may or may not be developed. The apical angle appears smaller in *P. rude* than in *P. scabra,* but broken protoconchs and encrusting organisms may account for the apparent difference. The brown periostracum, covering all but the apical whorls, is shorter haired than in *P. scabra* but lacks the velvety texture of that in *Argobuccinum.* Soft parts (Text-fig. 2), in so far as they were studied, were the same in both species of *Priene.*

Distribution and ecology. — (Text-fig. 12.) *Priene rude* (Broderip) has been reported in the literature as occurring from five to ten fathoms between Valparaiso, Chile, and Callao, Peru. It lives on mud, sand, or gravel substrates. Some specimens that were dissected contained a great deal of plant material, yet others had no recognizable plant or animal gut contents. The species seems to occur with *P. scabra* (King), although collectors may or may not have observed whether they occur in slightly different habitats. Its fossil record begins in the Pliocene (? Pleistocene), when it was closer to *P. scabra.* As in the case of *P. scabra,* reports of *P. rude* from Panama and the Straits of Magellan are based on old, and probably unreliable, records that would extend the known range 1800 km to the south and 2400 km north. Fossils have been collected by Frank Atchley from subrecent and Pleistocene terrace deposits in the vicinity of the Marcona Iron district, Department of Ica, Peru.

SPECIES OF UNCERTAIN AFFINITIES WHICH HAVE BEEN DESCRIBED AS CYMATIIDS OR WHICH ARE POSSIBLE ANCESTRAL FORMS

Taxa considered in this section have been investigated only enough to establish that they do not belong in *Argobuccinum, Priene, Fusitriton,* or *Mediargo.* Species are assigned to names which are used here in the suprageneric sense — for example, to *"Buccinum"* to denote affinities with the Buccinacea rather than with *Buccinum sensu stricto.* Most of the species that were originally classified incorrectly belong in the Buccinacea, many families of which require a thorough systematic revision, and discussion of a few forms of non-cymatiids is intended to contribute toward the reorganization of these groups. Their confusion with *Argobuccinum, Priene,* and *Fusitriton* has led in some instances to paleoecologic and biogeographic assumptions which are open to question.

"Buccinum" cammani (Dall, 1909) Pl. 49, fig. 9

Argobuccinum (Fusitriton) cammani Dall, 1909, U.S. Geol. Surv. Prof. Paper 59, p. 55, pl. IV, fig. 11.

Argobuccinum cammani Dall, Howe, 1922, "Faunal Relationships . . . Empire Formation, Coos Bay, Oregon," Univ. California Pub. Bull. Dept. Geol. Sci. 14(3): checklist opp. p. 3. Clark, 1929, Strat. Ca.: pl. XLVIII, fig. 8. Weaver, 1943, "Paleontol. Marine Tert. Formations of Oregon and Washington," Univ. Washington Pub. Geol. V, pt. II, pp. 417-418; pt. III: pl. 83, fig. 1.

Ranella (Priene) cammani Dall, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem. I: p. 739.

This form, which commonly occurs in abundance in Miocene and Pliocene formations of western Washington and Oregon, is an easily recognizable cancellate species. It shares a number of characters — slender shape, rounded whorls, axial ribbing, and spiral costae — with some of the Cymatiidae and Buccinacea, and family and generic placement are not known. Although one or two irregularly spaced varices may develop on each whorl, they are not formed as in *Fusitriton;* strongly deflected varices and axial ribs, aperture shape and absence of both a posterior columellar fold and excurrent notch support the tentative assignment of this species to the Buccinacea.

The morphologic features of *"Buccinum" cammani* (Dall), *"Beringius" arnoldi* (Martin), and *Fusitriton oregonensis* (Redfield) are compared in Text-figure 13. *"Buccinum" cammani* (Dall) is smaller (3.3 to 6.5 cm incomplete height) than the others and separated from them by a combination of characters. These include the strong sinuosity of axial sculpture — seen also in *"Beringius" arnoldi* (Martin) — and pronounced, evenly spaced spiral costae producing a cancellate surface not unlike that of *Fusitriton oregonensis* (Redfield). On some specimens wider, unbifurcated, revolving costae alternate with finer medial ridges, and in such forms the sculpture pattern is even closer to that of *F. oregonensis* (Redfield). Ornamentation also varies in some juvenile whorls which have spiral bands, but no traces of axial ribbing. In these specimens the early stages resemble Recent species of *Neptunea* while the later volutions are cancellate. Whorls are constricted at the slightly appressed sutures and are similar in outline to those of *"Beringus" arnoldi* (Martin).[2]

The holotype is one of two imperfect specimens having that

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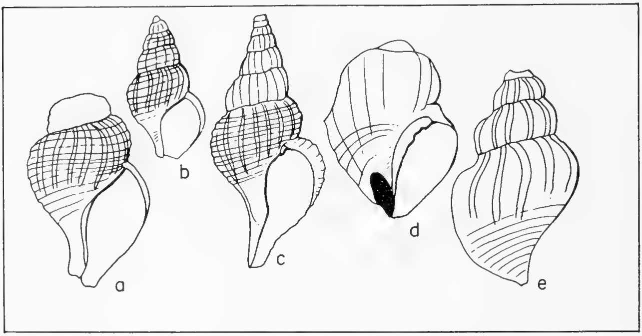
[2] A cursory examination of museum specimens labelled *"Fusinus (Buccinofusus) coosensis* Dall, 1909" suggests gradation between some of these and *"Buccinum" cammani* (Dall); a phylogenetic relationship is possible but has not been investigated.

number (U.S.N.M. 153907, "Miocene, Coos Bay, Ore."); it is 3.65 cm high, incomplete anteriorly and posteriorly, and worn. The second specimen is almost identical.[3] No entire specimens have been seen; the fragments studied have one to four whorls and range in height from 3.3 to 6.5 cm.

Distribution. —

"Buccinum" cammani (Dall, 1909a) ranges from Miocene to Pliocene in the following marine formations of western Oregon and Washington:

Oregon, Empire at Coos Bay, (Howe, 1922; Weaver, 1943); Coos Conglomerate (Howe, 1922). Washington, Montesano Formation at Grays Harbor Co., (Howe, 1922, Weaver, 1943); Astoria Formation, Grays Harbor Co., (UCMP A-73).



Text-figure 13. — Convergent Pliocene fossils that have been misidentified as *Argobuccinum*. a,b, *"Buccinum" cammani* (Dall); c, *Fusitriton oregonensis* (Redfield); d,e, *"Beringius" arnoldi* (Martin). Presence of varices and straight axial ribs distinguish *F. oregonensis* from the other forms having sinuous axial costae and slightly appressed sutures. Shaded area of d is a concealed umbilicus. Figures drawn to uniform size.

"Beringinus" arnoldi (Martin, 1914) Pl. 49, figs. 10, 13

Argobuccinum arnoldi Martin, 1914, Univ. California Dept. Geol. 8(7), p. 192, pl. 21, figs. 4a, 4b. Clark, 1929, Strat. California: pl. XLVII, fig. 2. Ogle, 1953, California Div. Mines Bull. 164, p. 45, checklist pl. 5.

Ranella (Priene) arnoldi (Martin) Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem. I, p. 738.

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[3] The paratype, also numbered U.S.N.M. 153907 but labelled "Coos Bay, Or. Pliocene," was also part of the Camman collection, and precise locality, formation, and age data are unknown; some material from this area is believed to be reworked.

Argobuccinum (Fusitriton) arnoldi Martin: Faustman, 1964, "Paleontol. Wildcat Group Scotia and Centerville Beach, Ca.," Univ. California Pub. Geol. Sci. 41(2), p. 134, pl. 3, fig. 22.

The holotype (UCMP 12340) from the vicinity of the mouth of the Bear River, Humboldt County, California (UCMP locality 1863) and a larger specimen are illustrated herein. A Recent example of *Beringius kennicotti* (Dall, 1871) is also shown for comparison of morphologic features and whorl outline. *"Beringius" arnoldi* (Martin) has been referred to the Cymatiidae and considered a close relative of *Fusitriton oregonensis* (Redfield) by most authors, although its taxonomic position is believed to be in the Neptuneidae (not necessarily in the genus *Beringius*).

The general whorl outline, appressed suture, lack of varices and abapertural deflection of axial ribs are Buccinacean characters that are seen in this species (Text-fig. 13). Confirmation of the generic designation could be made if a specimen were found with all or part of a thin, three- or four-whorled cylindrical protoconch intact; since an entire apex is rare in Recent material, its preservation on fossil forms is unlikely.

Specimens of *"Beringius" arnoldi* (Martin) have been collected from Pliocene rocks of the lower Rio Dell, upper Eel River, and undifferentiated Wildcat Formations of Humboldt County, California (Martin, 1914; Ogle, 1953; Faustman, 1964); they occur with *Fusitriton oregonensis* (Redfield), with which they have been confused generically and specifically. Diagnostic features of *"Beringius" arnoldi* (Martin), in addition to the general Buccinacean characters mentioned previously, include fewer, coarser and slightly sinuous longitudinal ribs in contrast to the undeflected axial costae in species of *Fusitriton*. The ribbing ends abruptly half way beyond the greatest girth and incised spiral grooves appear on the anterior portion of the body whorl. Shallow spiral grooves may also be present between the ribs of the posterior part of the whorl, in contrast to the raised spiral bands in *"Buccinum" cammani* (Dall, 1909a). No coarse reticulate sculpture is ever developed.

On most specimens the outer lip, apex, and anterior canal are broken, and details of adult shell morphology are uncertain. Removal of matrix from one individual revealed a concealed umbilicus (Text.-fig. 13d) and a posterior columellar fold was visible in some specimens.

Whatever may be the true affinities of this taxon, it is probable that it belongs in the Buccinacea. Paleoecological assumptions that have been made on the premise that *"Beringius" arnoldi* (Martin) is related to cool water species of *Fusitriton* are not necessarily incorrect because *Beringius kennicotti* (Dall, 1871) is also a boreal form and ranges from the Arctic to British Columbia.

"Ranella" californica (Gabb, 1866) Pl. 49, figs. 1, 2, 8, 11, 14

Tritonium californicum Gabb, 1866, Paleontol. California II, pp. 154, 218; 1869, pl. 26, fig. 33 (reillustrated herein).

? *Nyctilochus californicus* (Gabb), Dickerson, 1915, California Acad. Sci., Proc., ser. 4, vol. 5, p. 65, pl. 7, fig. 7 (refigured herein).

Gyrineum kewi (Dickerson), Clark, 1938, Geol. Soc. Amer., Bull. 49, p. 717, pl. 2, fig. 32 (hypotype UCMP 30878 illustrated herein).

The holotype of this and the following species, *"Mayena" kewi* (Dickerson, 1915) are juveniles and share a number of morphologic features. It is not known how closely adults resemble younger forms, and all the Eocene Cymatiidae of western North America are greatly in need of revision. Specimens are figured and discussed here to indicate several possible ancestral forms of *Argobuccinum, Fusitriton,* and *Priene,* but a complete phylogeny has not been attempted. Names used in the suprageneric sense are assigned out of necessity, not conviction, and are quite possibly incorrect.

Type information. — The type, ANSP 4205, from the Eocene Tejon Formation, Tejon Pass, California, was designated the lectotype by Stewart (1927). It was originally described as a Cretaceous fossil.

Remarks. — Some of the confusion between Gabb's species *T. californicum* and *Nyctilochus kewi* of Dickerson, both from the Tejon Formation of California, may have resulted from discrepancies between the artist's drawing and the actual specimen of the former. Gabb's original illustration and the holotype are shown (Pl. 49, figs. 8, 11) for comparison. The juvenile is certainly a cymatiid but might be referred to a number of genera, and more material of all growth stages is needed. Clark's hypotype of *Gyrineum kewi* (UCMP 30878) from the Eocene Markley Formation, UCMP loc. A-1297 southwest of Sacramento, California, is possibly the same species, although it is worn and somewhat flattened. Varices are two per whorl but discontinuous in Gabb's type, and the even reticulate sculpture completely lacks large tubercles.

Dickerson's hypotype of *Nyctilochus californicus* (UCMP 11688) may or may not be the same as Clark's hypotype. It has a denticulate outer lip, rounded whorls and many axial nodes crossed by fine spiral threads. A knowledge of variability in Eocene Cymatiidae is essential to the identification of these specimens.

Of the two juvenile holotypes, *T. californicum* Gabb and *Nyctilochus kewi* Dickerson, the former is smaller and one-half to a full whorl younger than the latter. It is hazardous to synonymize them on the basis of only two immature specimens, and adult cymatiids from the same localities are of more than one species. Although morphologic evidence supports the combination of the two taxa, further investigation may well resolve them as separate species.

"Mayena" kewi (Dickerson, 1915) Pl. 49, figs. 3, 4

Nyctilochus kewi Dickerson, 1915, California Acad. Sci., Proc., ser. 4, vol. 5, p. 64, pl. 7, figs. 5a, 5b. (holotype figured herein).

The holotype, UCMP 11052 (from locality 458, west side of Grapevine Canyon, Kern Co., California), has 5½ whorls including the internal mold of the complete protoconch; it is 2.3 cm high and has two lateral varices per whorl, even reticulate sculpture on the earliest volutions and spiral rows of coarse tubercles on the body whorl. The aperture is obscured by matrix but three anterior pillar folds can be seen. The suture is appressed. Other slightly larger specimens from the Tejon Formation (UCLA 43887 from locality 2340, for example) have wrinkled outer lips and pillars and agree in outline, sculpture and apertural details with Recent specimens of *Mayena* from Australia. The shell differs from *Gyrineum* in outline, in its more weakly arched suture, in apertural shape and plications, but it is probably closely related to that genus.

Some juveniles resembled poorly preserved apical whorls of a large specimen tentatively referred to *Ranella* sp. (UCLA 45969, from the Eocene Llajas Formation, locality UCLA 2312). Until growth series have been worked out, it will be impossible to identify juveniles with the correct adults; several juvenile forms are similar, yet the adults are distinctly different and one cannot be sure which ones are taxonomically the same.

Specimens identified as *"Mayena" kewi* are rare in the Tejon Formation of California, and in the Eocene Cowlitz Formation of Lewis County, Washington.

SPECIES THAT HAVE BEEN INCORRECTLY REFERRED TO *ARGOBUCCINUM, FUSITRITON* OR *PRIENE*

Although the names of the following taxa suggest that they fall within the scope of this paper, they are not referrable to the genera under consideration. In most cases, they are not cymatiids.

Argobuccinum (Trachytriton) vinculum (Hall & Meek): Wenz 1941, p. 1057
Fusitriton antarcticus Powell, 1958
Fusitriton aurora Hedley, 1916 [A specimen taken from 1800 fathoms off South America was cited by Powell as the deepest record for a *Fusitriton,* but it is not a cymatiid.]
Fusitriton magellanicum: auctt. [= *Trophon geversianus* (Pallas, 1774). See nomenclatural remarks under *Fusitriton cancellatus* (Lamarck)]
Fusitriton multinodosa (Bucknill): Finlay, 1930, New Zealand Inst. Trans., vol. 61, p. 249. [= *Ranella olearium* Linné]
Fusitriton yatsuoensis Tsuda, 1959, "New Miocene Mollusks from the Kurosedani Formation Japan," Niigata Daigaku, Fac. Scis., ser. II, Biol. and Mineral. 3(2), pp. 86, 87, pl. 4, figs. 7a, 7b, 8. [It is perhaps a fusinid.]
Gyrineum mackini Weaver, 1943. Not a cymatiid, it probably belongs in the genus *Fusinus.*
Gyrineum (Becktelia) strongi Jordan, 1936: subgenus proposed by Emerson and Hertlein (1964, p. 360, fig. 5 g). [Although it is superficially like *Argobuccinum tristanense* Dell, 1963, the aperture is more characteristic of the genus *Bursa.*]
Murex (Argobuccinum) mansfieldi Gardner, 1933, "The Midway Group of Texas," Univ. Tex. Bull. 3301, pp. 258, 259, pl. 23, figs. 3-6. [The specimens, of Eocene age, are probably cymatiids.]
Tritonium diegensis Gabb, 1866.
Tritonium (Trachytriton) fusiform, Gabb, 1866.
Tritonium hornii Gabb, 1866.
Tritonium paucivaricatum Gabb, 1866 .
Tritontium (Trachytriton) tejonensis Gabb, 1866.

THE FOSSIL RECORD AND A POSSIBLE PHYLOGENETIC SEQUENCE

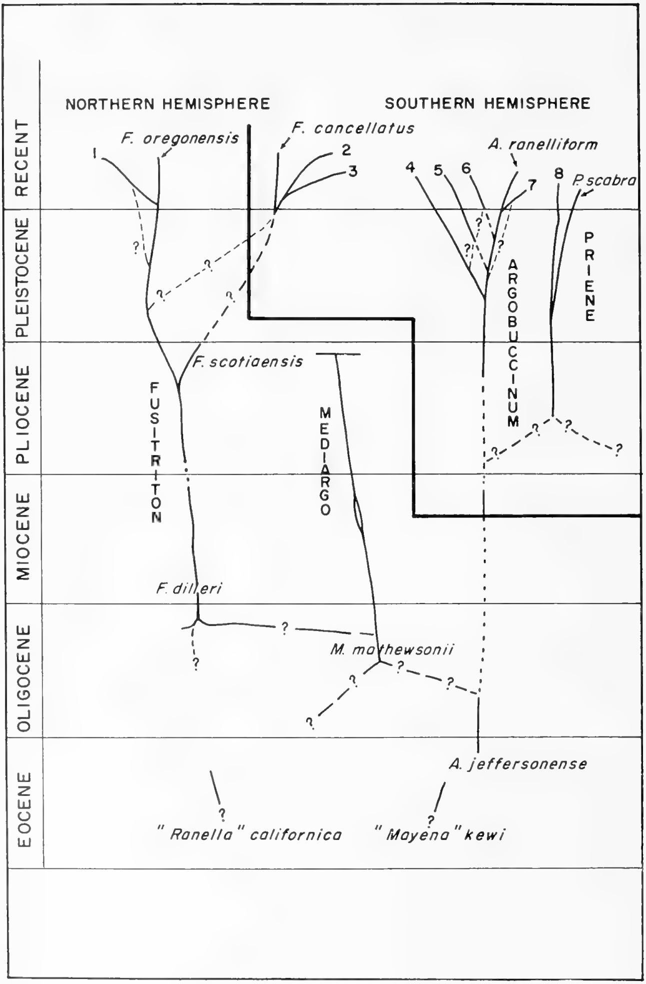
Phylogenetic relationships summarized in Text-figure 14 are based mainly on specimens seen by the writer; ages and localities were checked where possible but commonly represent entries on museum labels where other data were unavailable. Despite the large amount of variability within and between species and an incomplete knowledge of the fossil record of these taxa, a somewhat consistent pattern can be seen.

A comprehensive survey of Eocene Cymatiidae in western

North America has not been undertaken, but cursory observations in connection with museum and literature searches for *Argobuccinum* and *Fusitriton* suggest that at least seven distinct genera were represented. Several of these are known from juveniles that could be referred to a number of species; none of the oldest (early or middle Eocene) specimens was recognized as *Argobuccinum, Priene,* or *Mediargo.* The Eocene form closest to *Fusitriton* is Clark's hypotype (illustrated herein on Pl. 49, figs. 1,2) of *Gyrineum kewi* (Dickerson) from the Markley Formation of northern California; although here assigned to *"Ranella,"* its affinities are uncertain. Early and middle Eocene cymatiids occur rarely in the Tejon Formation and Llajas Formation of southern California and in the Eocene Cowlitz Formation of Washington. *Argobuccinum, Fusitriton,* and *Mediargo* may have evolved from one or more stocks represented in the Cowlitz, as all three appeared first in the area between Vancouver Island and central western Washington, dispersing to the south and west during the late Oligocene to early Miocene.

The oldest specimens of *Argobuccinum, A. jeffersonense,* were found in rocks of late Eocene or very early Oligocene age (Durham, 1967, personal communication) in northern Washington. By Miocene time a similar form had become established in Chile. Times of dispersal of *Mediargo* and *Fusitriton* are indefinite, the ages of many specimens being given as "Oligocene or Miocene." The former genus is slightly older and may have given rise to the latter, as it appears lower in the lower Miocene section in Kern County, California. The oldest species of *Fusitriton* is *F. dilleri,* from which *F. oregonensis* probably evolved, although a more thorough evaluation of forms from the Miocene Yakataga Formation of Alaska and from the Japanese Miocene could modify the simple relationship shown.

Middle to late Miocene specimens of *Mediargo mathewsonii* and *M. mediocris* are completely gradational forms. Almost identical forms of *M. mathewsonii* were widespread in the early and middle Miocene between Kern County, California, Vancouver Island, British Columbia, northern Honshu, and northeastern Korea. The younger species has not been reported from the western Pacific but apparently evolved in the late Miocene to early Plio-



Text-figure 14.—Possible phylogenetic relationships between *Argobuccinum, Fusitriton, Priene,* and *Mediargo.* 1, *Fusitriton galea;* 2, *F. cancellatus murrayi;* 3, *F. retiolus;* 4, *Argobuccinum argus;* 5, *A. proditor;* 6, *A. tumidum;* 7, *A. tristanense;* 8, *Priene rude.*

cene from *M. mathewsonii* in the area between Washington and central California. *M. mediocris* is rare in many of the later Pliocene formations of California and commonest in the Santa Maria District of southern California, where a more favorable mode of preservation in tar seeps may account for its abundance. The species ranged into the late Pliocene and became extinct before the Pleistocene.

The Miocene record of *Argobuccinum* in Chile rests on one specimen from the Navidad Formation; the small number of collections may account for its apparent rarity in Plio-Pleistocene assemblages. Its dispersal to South Africa and New Zealand occurred before the end of the Pleistocene, as fossils have been found in "late Tertiary to Quaternary raised beaches" of western South Africa (Barnard, 1963: 21) and in upper Pleistocene Nukumaruan interglacial deposits on North Island, New Zealand. Fleming (1963a, p. 18) and others considered *A. tumidum* a Neoaustral element introduced during Pleistocene time when cool water forms ranged farther north than at present. Morphologic evidence suggests that *A. tristanense* evolved as a separate branch of *A. ranelliforme,* while insufficient material prohibits more than a guess that *A. proditor* is gradational between some forms of *A. argus* and *A. tumidum.* The presence of distinct species that have had time to stabilize in different geographical areas suggests that speciation from *A. ranelliforme* to *A. argus* and dispersal within the Southern Hemisphere occurred considerably earlier than the Pleistocene. Interpretations by other workers (including Dell, 1963) linking Tristan da Cunha forms with those from St. Paul Island and Amsterdam Island were not supported by material seen in this study.

The phylogeny of *Fusitriton* between the middle Oligocene first appearance of *F. dilleri* and Pliocene specimens of *F. oregonensis* is unclear and disconnected. The genus seems to be in the process of radiation; there are five Recent species, more than ever lived at one time in the geologic past. *Fusitriton* sp.? aff. *F. oregonensis* from the lower? and middle Miocene of Alaska is not morphologically intermediate between *F. dilleri* and *F. oregonensis,* although some individuals resemble Pleistocene specimens of *F. oregonensis* from Newport Bay, California, and others are closer to the Japanese species *F. galea. G. sylviaensis,* here considered a questionable synonym of *F. oregonensis* in the absence of more complete data, is Miocene or Pliocene in age and cannot yet be placed in the phylogenetic scheme. Finally, *F. scotiaensis* is known to the writer from three Pliocene specimens that are morphologically distinct from all other species in the Northern Hemisphere but identical to Recent forms of *F. cancellatus* from South America.

Fusitriton probably dispersed from the Northern Hemisphere to Southern Hemisphere in the Pleistocene. It was well represented in the late Pliocene of the Los Angeles Basin and Ventura Basin, common in the Pleistocene of southern California, and rare in the Pleistocene Playa de Tijuana terrace deposit and San Jose del Cabo terrace deposit of Baja California. *Fusitriton* has been in the Southern Hemisphere long enough to have dispersed to South Africa, Australia, and New Zealand, and to have begun to develop geographically distinct forms. Whether species radiated from a circumaustral parent stock such as *F. cancellatus* or evolved from one species to another is not known.

The phylogenetic and geograpic origins of *Priene* are unknown but not likely to have been from the same stocks in western North America from which *Argobuccinum, Fusitriton,* and *Mediargo* evolved. Its earliest appearance is in young terrace deposits in Peru and central Chile, the Recent range being slightly more extensive. The genus is regarded as a new arrival in South America, perhaps from an Indo-Pacific source area.

DISTRIBUTION OF RECENT SPECIES OF *FUSITRITON* AND *ARGOBUCCINUM*

Bipolarity is the disjunct distribution of closely related, morphologically similar species in the higher latitudes of the Northern Hemisphere and Southern Hemisphere. One explanation for such an anomalous distribution pattern is tropical submergence of normally shallow, cold water forms as they travel from north to south. Subpolar populations may represent end-members of a once through-ranging species that originated in the tropics and migrated poleward in response to certain environmental changes. Text-figures 15 and 16 summarize the Recent distributions of *Fusitriton* and *Argobuccinum* in the Southern Hemisphere. Speculations on how these distribution patterns may have been attained follow the biogeographical notes.

BIOGEOGRAPHY OF *FUSITRITON* IN THE NORTHERN HEMISPHERE

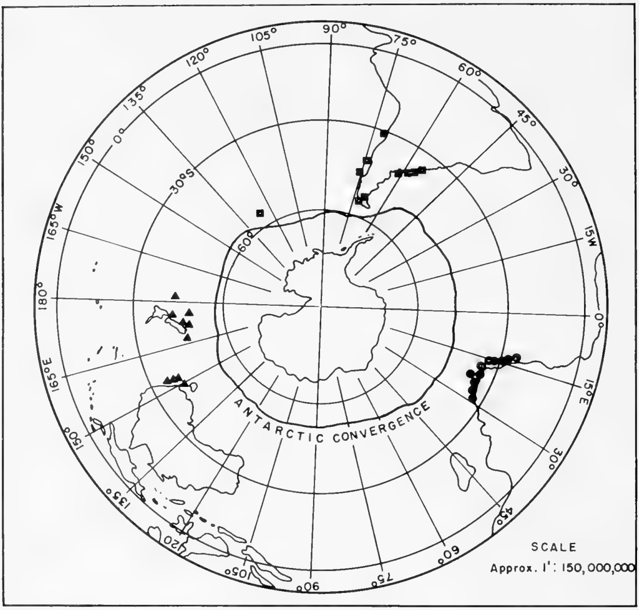
Three species of *Fusitriton, F. oregonensis, F. galea,* and *F. midwayensis* occur in adjacent zoogeographical provinces around the North Pacific basin. The widest ranging is *F. oregonensis,* which is found from southern California through Alaska to northern Honshu, living in the Sea of Japan as far south as Niigata, and along the Pacific coast as far as Cape Inubo (35°N). The deepest occurrence is also the southernmost Recent record, Pleistocene fragments having been collected as far south as San Jose del Cabo, Baja California.

F. galea is restricted to southern Japan in deep water warmed by the Kuroshio Current. Both *F. galea* and *F. oregonensis* range from 30 to 340 fathoms in Japan; *F. galea* has never been reported from greater depths south of the islands, as has *F. oregonensis* at corresponding latitudes off western North America. There is no overlap in occurrences of the two species, the divergence of the Kuroshio and Oyashio systems marking the boundary between them.

Specimens of *F. midwayensis* have not been live-taken and are known only from the type locality northwest of Midway Island in the central Pacific. In degrees of latitude, *F. oregonensis* ranges from 60°N to 32°45′N and *F. galea* from 35° N to approximately 30°N; *F. midwayensis* occurs at 35°15′N, 171°50′E.

BIOGEOGRAPHY OF *FUSITRITON* IN THE SOUTHERN HEMISPHERE

Species boundaries for the three taxa recognized here coincide conveniently with large geographic areas when only a few lots of specimens are considered and mid-ocean assemblages neglected. Study of several tens of lots showed considerable morphologic variation in material from South America, South Africa, and Australia-New Zealand. In each broad area there are at least two if not three variants, one of which resembles specimens from the other regions. Text-fig. 15 is a map showing the distribution of *F. cancellatus, F. c. Murrayi* and *F. retiolus.* Points represent one or more lots from each locality, species having been determined by shell morphology. Material from 54°49′S, 129°48′W *(Eltanin* Cruise 15, Sta. 1346) shares morphologic characters with both eastern Pacific and western Pacific species, although it is treated



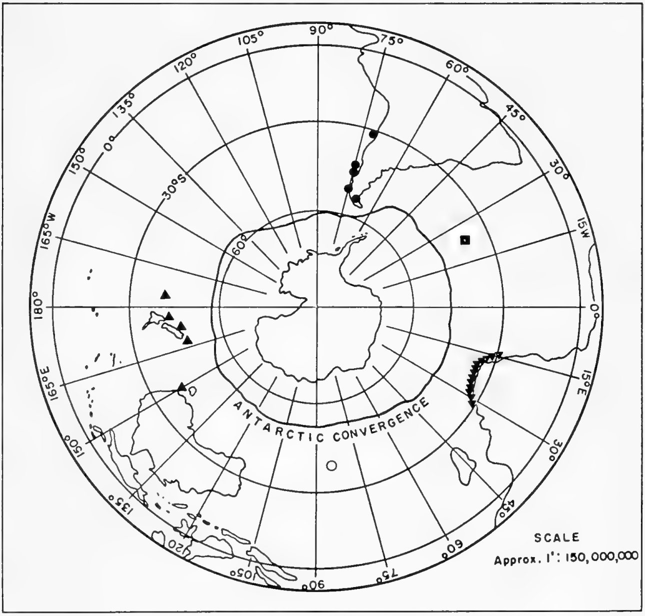
Text-figure 15. — Biogeography of *Fusitriton* in the Southern Ocean. ■ denotes occurrences of *Fusitriton cancellatus* (Lamarck), ● *F.c. murrayi* (Smith), and ▲ *F. retiolus* (Hedley).

here as *F. cancellatus.* This prevalance of morphologic overlap is probably explained by a nearly continuous circumpolar distribution in the southern ocean and by speciation that is relatively recent or in progress.

In terms of latitude, *F. cancellatus* ranges from 32°17′ S to 55° S, *F. c. murrayi* from 29°17′ S to 35°3′ S, and *F. retiolus* from approximately 33°30′ S to 51°S, 166°E. Barriers such as currents flowing in opposite directions or abrupt temperature changes are not present near the northernmost occurrence of *F. cancellatus* off western South America, which suggests that future collecting may extend this range.

BIOGEOGRAPHY OF RECENT SPECIES OF *ARGOBUCCINUM* IN THE SOUTHERN HEMISPHERE

Five species of *Argobuccinum* are recognized in the Southern Hemisphere: *A. ranelliforme, A. tristanense, A. argus, A. proditor,* and *A. tumidum.* Each taxon has a particular geographic distribution and distinct set of morphologic characters. The presence of fossils, different shell forms and geographic isolation suggest that species of *Argobuccinum* radiated from South America to other parts of the Southern Hemisphere well before the Pleistocene. Further collecting is not expected to reveal a complete series of gradational forms between most of the southern continents. One exception is a possible link between species of the mid-Indian Ocean



Text-figure 16. — Biogeography of *Argobuccinum* in the Southern Ocean. ▼ denotes occurrences of *Argobuccinum tumidum,* ● *A. ranelliforme,* ■ *A. tristanense,* ▶▶▶ *A. argus,* and ○ *A. proditor.*

islands and Australia-New Zealand. This hypothesis is based on gradational forms from St. Paul Island and Amsterdam Island and Australia and requires substantiation by the examination of more specimens representing a larger number of localities. The relationship between South African variants and material from St. Paul Island and Amsterdam Island cannot be evaluated from the material seen; the writer studied only a few South African specimens that suggested possible gradation and no material with precise locality data was obtained from the Indian Ocean.

Ranges for species of *Argobuccinum* in the Southern Hemisphere are as follows: *A. ranelliforme,* 27°05′ S to 53°10′ S; *A. tristanense,* 37°15′ S; *A. argus,* 26°38′ S to Agulhas Bank, 35°16′ S; *A. proditor,* 38° S to 38°43′ S; *A. tumidum,* 34°29′ S to 51°S, 166°E.

ROUTES ACROSS THE TROPICS AND DISPERSAL OF COLD WATER GASTROPODS

In the absence of Recent and fossil material from the equatorial regions, thoughts on the most likely dispersal routes between Northern Hemisphere and Southern Hemisphere must be largely speculative. Given the present bipolar distribution of *Fusitriton,* a former bipolarity for *Argobuccinum,* and the belief that such similar morphologic forms must be closely related, the aim of this discussion is to suggest the most probable routes that would result in such a pattern. There is fossil and Recent evidence that neither genus became established in the Caribbean, that *Argobuccinum* never dispersed to the western North Pacific, and that *Fusitriton* may have migrated from north to south by more than one path.

Once established in the Southern Hemisphere, both genera became wide-spread. Although their ecologic preferences differ, their Recent distributions are alike, suggesting that some common dispersal agent such as the West Wind Drift was largely responsible for the present distribution pattern in the Southern Ocean.

THE PROBLEM

A more difficult problem is the passage from North America, where *Argobuccinum* and *Fusitriton* appear to have originated, to the Southern Ocean. Scant fossil evidence supports an Oligocene to Miocene migration of *Argobuccinum* along the eastern Pacific or via shallowly submerged ridges or islands. Since the major currents, which will be mentioned below in more detail, do not flow longitudinally at the equator, this dispersal may have been accomplished by the slow spreading of benthonic populations. The Miocene to Pleistocene fossil record and the existence of well-defined morphologic species in the southern continents show that *Argobuccinum* has had longer than *Fusitriton* to become established in the Southern Ocean. Dispersal from North America probably occurred at least by mid-Miocene, perhaps an epoch or more before *Fusitriton* spread south. Fossils associated with the several known Paleogene specimens of *A. jeffersonense* suggest it may have lived in warmer water than present species. If so, the tropics may not have presented such an insurmountable barrier to *Argobuccinum* as to the deeper water *Fusitriton.*

In the case of *Fusitriton,* uncertain age assignments for eastern Pacific and western Pacific fossils and overlapping morphologic features do not support one particular route or phylogenetic link over all others. As there are no known fossil occurrences of the genus in the Southern Hemisphere, north to south dispersal is believed to have taken place in the Plio-Pleistocene or Pleistocene. It seems probable that instead of a single mode accounting for its dispersal, the northern species migrated by both floating and crawling, depending on the stage of its life cycle and whether mobility was favored by such conditions as current velocity and direction, depth, and temperature.

The probable routes are still speculative, although the relatively recent discovery of a new species *(Fusitriton midwayensis)* from the central Pacific lends some support to the idea of a Trans-Pacific trek in which eastern Pacific larvae of *F. oregonensis* could be transported to the western Pacific via the North Equatorial Current. Because of the distance involved, approximately 7030 nautical miles, the larvae may not survive the entire trip in one generation and may settle on submarine ridges or guyots to develop into adults and produce new offspring. There are few if any systematic collections of megafaunas from mid-oceanic ridges, and the degree to which such structures serve as stepping stones for dispersing stocks is unknown. From the western North Pacific, pelagic forms of the radiating species might make their way during storms or seasonal current migrations to the Southern Hemisphere. Benthonic adults might have followed submerged ridges to the continental shelf off Australia, where *F. retiolus* is known from Broken Bay, New South Wales, (approximately 33°30′S, 152°E) south.

Equally scant evidence is available to support an eastern Pacific route between northern California and the Southern Hemisphere. The presence of *F. scotiaensis* in the Pliocene of California and morphologically identical Recent material off southern South America implies a close phylogenetic connection. Fossiliferous submarine deposits known off southern California and likely to occur elsewhere in the equatorial eastern Pacific might contribute additional evidence, although to date megafaunal sampling has not been adequate. The most southerly occurrence of live taken specimens of *Fusitriton oregonensis* is also the deepest record, 1100-1300 fathoms, and populations at this or slightly greater depths may live or have existed along the East Pacific Rise. That *Fusitriton oregonensis* exists at depth in the tropics and grades into *F. cancellatus* at the present time is unlikely: the two are morphologically distinct, and specimens collected nearest the equator (near 30° N and 30° S) are no more alike than those from the poleward extremes of their ranges.

Since dispersal of *Fusitriton* is relatively recent, probably under the same physical conditions as exist in the present Pacific basin, biological and environmental factors pertinent to its migration will be considered in more detail.

BIOLOGICAL FACTORS

Fusitriton oregonensis has been taken live from the littoral zone (during spawning, from Alaska to Puget Sound during the summer months) to over 1100 fathoms, in temperatures ranging from 11°C to 5°C. It is not restricted to a particular kind of food, being attracted to a variety of live and dead invertebrates. It is known to have a long larval stage and a large, light unsculptured protoconch of the type commonly associated with long distance veligers. Scheltema (1966, p. 85) described such larvae as having ". . . long velar lobes and a very light uncalcified . . . translucent shell." Thorson (1967, written communication) observed a free swimming *Fusitriton oregonensis* veliger with a velum over 1 cm long. He felt "absolutely sure that . . . the pelagic larval life [is] at least half a year." In addition to more information on the ecological preferences of adults, further studies on length of larval life and environmental tolerances are needed to suggest the capacity of this species for dispersal over long distances.

Although distances in the Pacific are great, transport of especially long-lived larvae by favorable currents may be possible. Scheltema (1966) studied the distribution of adult and larval forms of a related gastropod, *Cymatium parthenopeum* (von Salis, 1793), in the North Atlantic and Gulf Stream. He found morphologically similar adults in the tropical to subtropical eastern Atlantic and western Atlantic and larvae in different stages at most stations in the intervening open ocean. Current velocities and length of larval life being known, Scheltema showed that the Atlantic could be crossed easily by 82% of the larvae he collected, although the number of individuals able to travel this distance and live to sexual maturity may be small. *Cymatium parthenopeum* larvae were found to be considerably more eurythermal than adults. It is not impossible that larvae of cool water species of *Fusitriton* may also be able to survive over much greater temperature ranges than adults.

Rafting on other animals or floating objects is not a likely mode of north-south dispersal for *Fusitriton*. No specimens have been reported associated with migrating fish, pinnipeds, or birds, and chance dispersal by one individual seems unreasonable for such a recently widespread genus.

PHYSICAL FACTORS

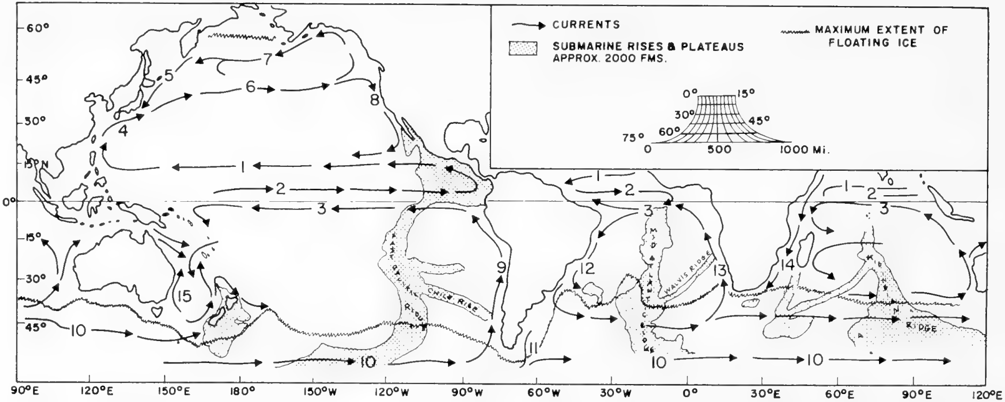
In the Pacific basin, the most important factors in the dispersal of pelagic forms are currents, which include the equatorial, eastern and western boundary, and subpolar water masses. Directions of flow and approximate locations of these are indicated in Text-figure 17. Currents within a few hundred meters of the surface are probably the most significant in larval transport, as pelagic veligers would be expected in greater concentrations in the photic zone.

Neglecting countercurrents and under currents, the main water masses in the subpolar North Pacific circulate in a counterclockwise gyre to the north and a clockwise gyre toward the equator. The pattern is reversed in the Southern Hemisphere, where the South Equatorial Current is part of a counterclockwise gyre. Knauss

(1963, p. 248) reported little north-south flow either in the equatorial open sea or near the ocean margins where boundary currents converge or diverge. Because of the absence of longitudinal flow at the equator and the opposing current systems off North America and South America (California and Peru or Humboldt Currents, respectively), larvae are not carried from north to south in the eastern or central Pacific. Should they be transported south along the California coast, they would be swept into the North Equatorial Current off Baja California and carried west between 5° and 10° N, depending on the season. The velocity of the North Equatorial Current has been estimated as ½ to 1 knot, and the distance across the central Pacific as approximately 7030 nautical miles. Larvae might be expected to reach the western Pacific in 10 to 12 months, not a great deal longer than the known lifespan for *Fusitriton oregonensis* veligers. A further factor to consider is the velocity of the boundary currents transporting larvae to or from the equatorial system. Eastern boundary currents, the south-flowing California Current and north-flowing Peru Current, are generally slower moving (average velocity .5 knots or less, according to Wooster and Reid, 1963, p. 258) than western boundary currents (average 4 knots). They are cold currents, originating in the Subpolar or West Wind Drift, and are commonly modified by upwelling, local eddies, complex layering and seasonally developed countercurrents.

Upwelling in eastern boundary waters off the western Americas may permit discontinuous distribution of cold water forms well into tropical and subtropical zones. Emerson (1956) discussed northern forms having discontinuous ranges off southern California and Mexico. His Recent collection and Pleistocene collections from Punta China, Baja California, contain several cold water organisms (but no Fusitritons), suggesting that upwelling in these areas was common at least as far back as the Pleistocene and that it may have aided northern forms in southward dispersal.

It is assumed that current directions are determined by winds that are driven by solar energy and the earth's rotation, and that movement directions of major water masses were not appreciably different from modern systems when dispersal of *Fusitriton* oc-



Text-figure 17. — Summary of oceanographic features that may affect the dispersal of Recent organisms. 1. North Equatorial Current. 2. Equatorial Countercurrent. 3. South Equatorial Current. 4. Kuroshio (Japan) Current. 5. Oyashio Current. 6. Subpolar Current. 7. Alaskan Current. 8. California Current. 9. Peru Current. 10. West Wind Drift. 11. Falkland Current. 12. Brazil Current. 13. Benguelan Current. 14. Agulhas Current. 15. Notonectian Current.

curred. Temperatures may have varied, especially during Pleistocene glaciation when the region of tropical waters was restricted, and velocities may have been greater. Sea level lowering during glaciation has been estimated as 40 to 83 fathoms (250- 500′) by Shepard (1964, p. 96). This amount would not appreciably affect the depths to tops of submarine ridges and rises.

Submarine rises and related features may provide nearly continuous benthic routes or stepping stones for settling larvae. Several mid-oceanic ridges are outlined on Text-figure 17 by the 2000 fathom contour, which suggests a possible offshore Pacific dispersal route. It is not known whether *Fusitriton,* which has been collected from 1100-1300 fathoms, may be able to live and migrate at depths of 2000 fathoms or more. Benthic dispersal studies require accurate and detailed maps of plateaus, guyots, and other submarine features combined with careful systematic collections of megafaunal populations.

CONCLUSIONS

On the basis of distributional data and morphologic similarities of widely separated Recent species, and considering the physical factors mentioned above, two dispersal routes seem possible. The first is the Eastern Pacific, from western North America to western South America on the continental margins or along offshore ridges and rises such as the East Pacific. For the cold water forms under consideration, areas of upwelling and the southward extension of the California Current might allow the species to survive in local cold water habitats within the tropics. The Pacific basin current system being asymmetrical, cold water species are able to live at lower latitudes in the eastern Pacific than in the west; current directions also favor southward dispersal in the northern eastern Pacific.

There is slight support for the Eastern Pacific route in the existence of convergent morphologic forms of *F. scotiaensis* from the Pliocene of California and *F. cancellatus* from the Recent in South America. Tropical submergence is implied by the occurrence of *F. oregonensis* in deep water off San Diego. Dispersal by this route would probably have been accomplished by mobile adults rather than pelagic larvae. Migration may have been in deep water, because no Recent or fossil populations have been reported from the Galapagos or other islands off Central America and South America.

A Trans-Pacific route would involve longer distances and a less direct path between hemispheres, but it has the advantage of favorable current directions. North Pacific larvae could be carried south to the equatorial current, west to the area where the East Australian Current branches south, and – given eddies, storms, or some means of crossing the diverging western boundary systems – poleward along the east coast of Australia. Long-lived pelagic larvae would be critical to dispersal by this route, although adult stages might be able to live and reproduce at suitable points in the mid-Pacific. Evidence in favor of this scheme is the occurrence in the central Pacific of *F. midwayensis* and its morphologic similarity to *F. oregonensis.* Opposing factors are the great distance involved, tropical temperatures, and complex boundary effects preventing the easy passage from northern to southern current systems in the western Pacific.

Further collecting could reveal that both routes were followed, the Eastern Pacific by *F. scotiaensis, F. oregonensis,* or both and the Trans-Pacific by *F. oregonensis.*

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PLATES

EXPLANATION OF PLATE 39

Figure Page

1. **Argobuccinum tumidum** (Dunker) 469
SDSNH 11146. Recent, Tasmania, Australia. Abapertural view showing smooth sculpture and spiral color bands; (8.3 cm high). Cf. fig. 3.

2. **Argobuccinum ranelliforme** (King) 462
LSJU 9980. Recent, Chile. Abapertural view; (8 cm high). Cf. fig. 9.

3. **Argobuccinum tumidum** (Dunker) 469
LSJU 9973. Recent, off Oamaru, New Zealand, 20-40 fathoms. Abapertural view of nodose form; (7.3 cm high). Cf. fig. 1.

4. **Argobuccinum ranelliforme** (King) 462
LSJU 9974. Recent, Chiloe Island, Chile. Apertural view of juvenile specimen; (4.05 cm high). (Berry Colln.)

5. **Argobuccinum tristanense** Dell 466
CAS 39937. Recent, Tristan da Cunha Island, south Atlantic Ocean. Apertural view of juvenile specimen; (3.3 cm high).

6. **Argobuccinum ranelliforme** (King) 462
University of Chile specimen. Recent, Quiriquina, Chile. View of juvenile showing thickened outer lip, small aperture; (2 cm high).

7. **Argobuccinum argus** (Gmelin) 458
ANSP 211688. Recent. Paternoster, Saldanah Bay, South Africa. Apertural view of slender variant; (6.7 cm high).

8. **Argobuccinum tristanense** Dell 466
LSJU 9975. Recent, Gough Island, south Atlantic Ocean. Abapertural view showing fine sculpture, thin periostracum, and high-spired outline of adult specimen; (6.4 cm high).

9. **Argobuccinum ranelliforme** (King) 462
LSJU 9976. Recent, off Punta Arenas, Magallanes, Chile. Abapertural view of tumid, finely sculptured form having most of its periostracum in tact; (9 cm high). Cf. fig. 2. (Berry Colln.)

10,11. **Argobuccinum argus** (Gmelin) 458
MCZ 207318. Recent, Jeffreys Bay, South Africa. Apertural, views of common nodose form; (6.7 cm high).

12. **Argobuccinum argus** (Gmelin) 458
MCZ 205170. Recent, Jeffreys Bay, South Africa. Abapertural view of a specimen with smoother, more regular nodes; (7.2 cm high). Cf. fig. 11.


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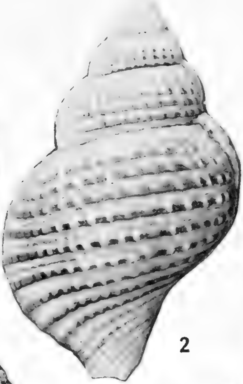
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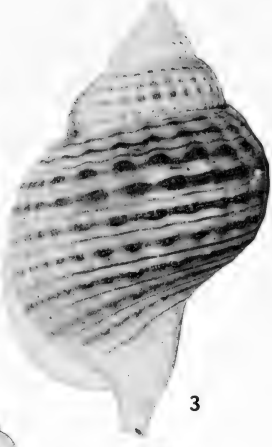
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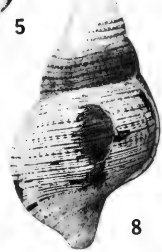
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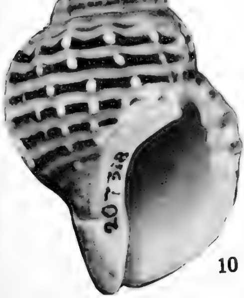

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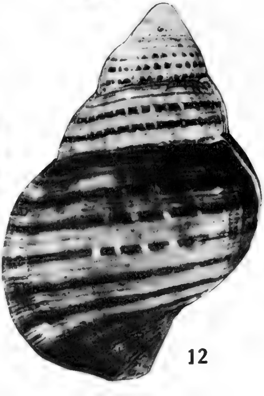
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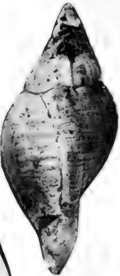

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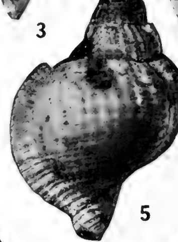

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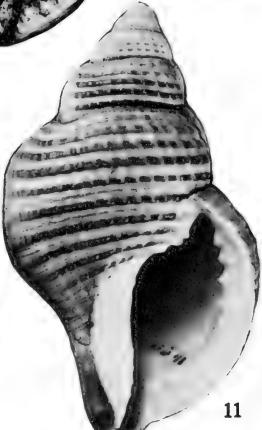

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EXPLANATION OF PLATE 40

Figure Page

1. **Argobuccinum tristanense** Dell 466
CAS 399937. Recent, Tristan da Cunha Island, south Atlantic Ocean. Apertural view; (6.5 cm high). Cf. fig. 2.

2. **Argobuccinum ranelliforme** (King) 462
MHNQN specimen. Recent, Punta Inio, Chiloe Island, Chile. Apertural view of one of several specimens having unusually high spires; (11.5 cm high).

3-5. **Argobuccinum jeffersonense** (Durham) 474
UCMP 35347. Late Eocene or early Oligocene, Jefferson County, Washington. Side, apertural and abapertural views of a late juvenile specimen; (3.13 cm high). [Holotype of *Gyrineum jeffersonensis* Durham].

6,7. **Argobuccinum ranelliforme** (King) 462
MHNQN specimen. Miocene, Navidad Formation, near the mouth of the Rio Rapel, Chile. Side, apertural views, in which specimen appears slightly foreshortened; (4.58 cm high). Cf. figs. 8,9.

8,9. **Argobuccinum jeffersonense** (Durham) 474
UCMP 35348. Late Eocene or early Oligocene, Jefferson County, Washington. Apertural, side views; (4.58 cm high). [Paratype of *Gyrineum jeffersonensis* Durham].

10. **Argobuccinum ranelliforme** (King) 462
Specimen in collection of Montemar Marine Station, Vina del Mar, Chile. Recent, Chiloe Island, Chile. Apertural view of smooth mature specimen lacking apertural plications; (10 cm high). Cf. fig. 11.

11. **Argobuccinum ranelliforme** (King) 462
LSJU 9972. Recent, Chile. Apertural view of beaded form; (8 cm high).

12. **Argobuccinum ranelliforme** (King) 462
LSJU 9976. Recent, off Punta Arenas, Magallanes, Chile. Side view of smooth variant having most of its periostracum in tact. Note fine, unbeaded sculpture and tumid outline; (9 cm high). (Berry Colln.)

EXPLANATION OF PLATE 41

Figure		Page
1,2.	**Argobuccinum tumidum** (Dunker) .... LSJU 9973. Recent, off Oamaru, New Zealand, 20-40 fathoms. Side, apertural views of specimen having flared pillar callous; (7.3 cm high).	469
3.	**Argobuccinum tumidum** (Dunker) .... LSJU 9977. Recent, Kaitangata, New Zealand. Apertural view of late juvenile with tumid outline; (5.5 cm high).	469
4.	**Argobuccinum tumidum** (Dunker) .... MCZ 23049. Recent, northern Tasmania, Australia. Specimen turned 45° from full apertural view to show prominent labial tooth; (6.5 cm high).	469
5.	**Argobuccinum proditor** (Frauenfeld) .... SDSNH 35251. Recent, "Australia." Acquired from Fulton, a shell dealer, by the original donor; no more specific locality data available; (10.1 cm high).	468
6.	**Argobuccinum proditor** (Frauenfeld) .... Reproduction of illustration figured by Vélain, 1877; pl. II, fig. 5 as *Ranella (Apollon) proditor.* Recent, Amsterdam Island, southern Indian Ocean; (9.0 cm high).	468
7,10.	**Argobuccinum proditor** (Frauenfeld) .... Reproduction of illustration in Frauenfeld, 1867, Tafel 1, figs. 1a, 1b. Recent, St. Paul Island, southern Indian Ocean. Abapertural, apertural views; (7.6 - 10.0 cm high). [Holotype of *Bursa (Apollon) proditor* Frauenfeld]	468
8.	**Argobuccinum tumidum** (Dunker) .... LSJU 9978. Recent, off Oamaru, New Zealand. Apertural view of mature specimen; (11 cm high). Cf. fig. 9.	469
9.	**Argobuccinum tumidum** (Dunker) .... LSJU 9979. Recent, New Zealand. Apertural view of mature specimen with flaring pillar callous; (12 cm high).	469


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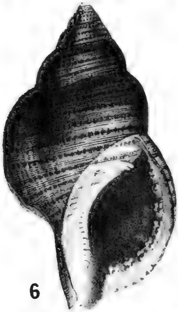
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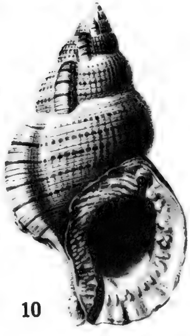
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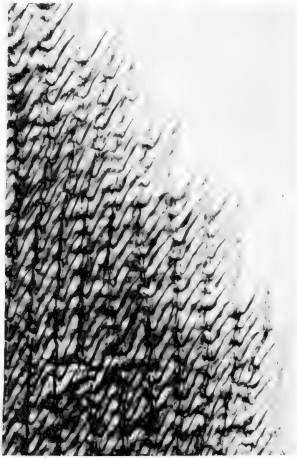
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EXPLANATION OF PLATE 42

Figure Page

1,2. **Fusitriton scotiaensis** (Martin) 500
UCMP 10577. Pliocene, Humboldt County, California. Side, apertural views; (6.6 cm high). Cf. fig. 4.

3. **Fusitriton scotiaensis** (Martin) 500
UCMP 10578. Pliocene, Humboldt County, California. Abapertural view; (5.3 cm high).

4. **Fusitriton cancellatus** (Lamarck) 475
AMNH 92910a. Recent, off Mar del Plata, Argentina. Side view; (9.8 cm high).

5. **Fusitriton cancellatus** (Lamarck) 475
AMNH 109865a. Recent, Maldonado, Uruguay. Side view of specimen having coarse axial sculpture and a tumid outline; (10.65 cm high). Cf. figs. 7, 8.

6. **Fusitriton cancellatus** (Lamarck) 475
MCZ 109444. Recent, off Argentina. Apertural view of smooth, more "typical" form; (13 cm high).

7. **Fusitriton cancellatus** (Lamarck) 475
AMNH 99498a. Recent, Guitecas, Chile. Side view of variant having strong spiral grooves; (10.3 cm high).

8. **Fusitriton cancellatus** (Lamarck) 475
AMNH 109865b. Recent, Maldonado, Uruguay. Side view of specimen having fine ribs; (9.2 cm high). Cf. fig. 5, from same lot.

9. **Fusitriton cancellatus** (Lamarck) 475
LSJU 9981. Recent, off Chile near the border between Aconcagua and Coquimbo Provinces, 580 m. (*Anton Bruun* Cruise 18A, Sta. 702). Apertural view; (8.3 cm high).

10. **Fusitriton cancellatus** (Lamarck) 475
Section of inside, filelike surface of a jaw; (X 125). Photography by W. R. Evitt.

EXPLANATION OF PLATE 43

Figure — Page

1. **Priene rude** (Broderip) 517
UCMP 10579 (Pioche Colln.) Pliocene or Pleistocene, Coquimbo, Chile. Apertural view; (4.7 cm high).

2. **Priene scabra** (King) 512
UCMP 10580 (Pioche Colln.) Pliocene or Pleistocene, Coquimbo, Chile. Abapertural view; (4.8 cm high).

3. **Priene scabra** (King) 512
UCMP 10581 (Pioche Colln.) Pliocene or Pleistocene, Coquimbo, Chile. Abapertural view of specimen with reticulate *scabra*-like sculpture on the early whorls, coarse axial ribs as in *P. rude* on the body whorl; (4.7 cm high).

4. **Priene scabra** (King) 512
UCMP 10582 (Pioche Colln.) Pliocene or Pleistocene, Coquimbo, Chile. Abapertural view; (5.6 cm high).

5,6. **Priene rude** (Broderip) 517
Coll. of Sr. Mario Peña, Universidad Agraria, La Molina, Lima, Peru. Recent, Callao, Peru. Apertural, abapertural views of specimen having furry periostracum in tract; (6 cm high).

7. **Priene scabra** (King) 512
USNM 7357. Recent, Valparaiso, Chile. Smooth protoconch whorls are 1.5 mm high.

8. **Priene scabra** (King) 512
LSJU 9982*a*. Recent, Talcahuano, Chile. Apertural view. (6.2 cm high). (Berry Colln.)

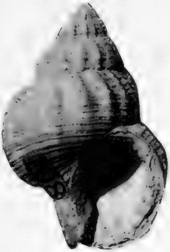
9,10. **Priene scabra** (King) 512
Specimen in the collection at Montemar Marine Station, Viña del Mar, Chile. Recent, Valparaiso Bay, Chile. Side, apertural views of specimen showing small excurrent notch and typical plicate aperture; (5.8 cm high).

11. **Priene scabra** (King) 512
LSJU 9982*b*. Recent, Talcahuano, Chile. Abapertural view. (6.9 cm. high). (Berry Colln.)

12,15. **Fusitriton cancellatus murrayi** (Smith) 480
USNM 206005. Recent, Agulhas Bank, off South Africa. Shell shown in apertural view and living position; (9.5 cm high). Cf. sculpture between figs. 12, 13, 14.

13. **Fusitriton cancellatus murrayi** (Smith) 480
NMV F26889. Recent, Cape Town, South Africa. Apertural view of specimen with periostracum in tact. Axial sculpture is more prominent than that usually seen in South African material; (9.7 cm high).

14. **Fusitriton cancellatus murrayi** (Smith) 480
MCZ 205182. Recent, off Recife, South Africa. Apertural view; (10.3 cm high).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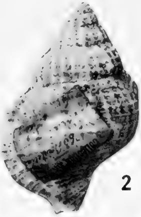
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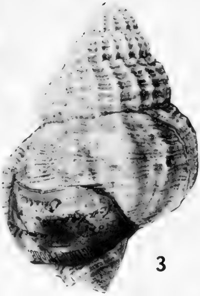
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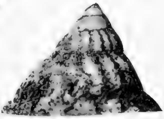
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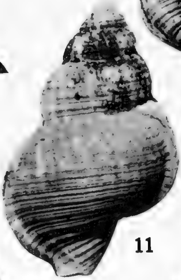
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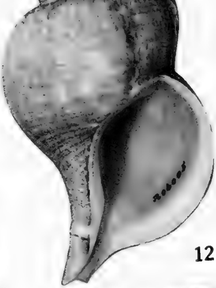
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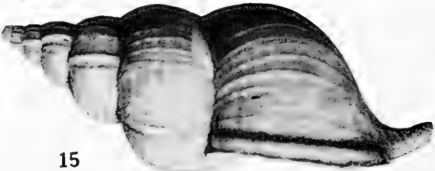
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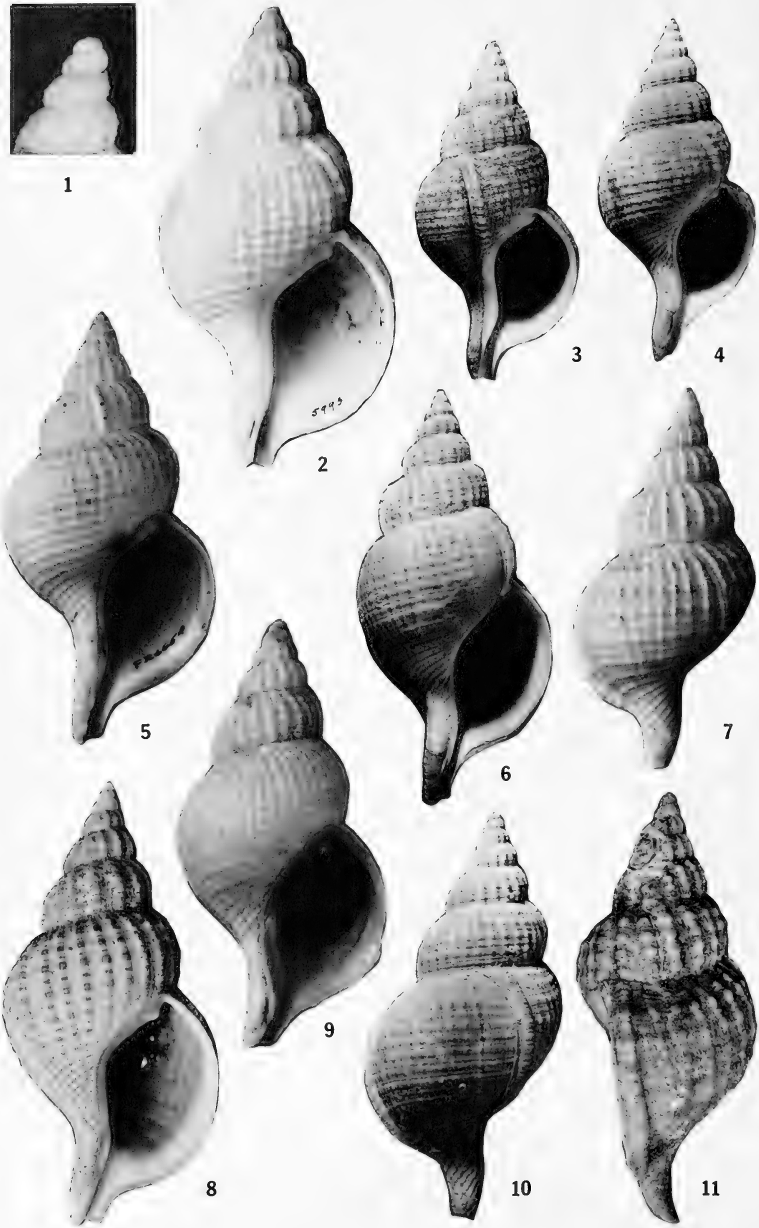
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EXPLANATION OF PLATE 44

Figure Page

1. **Fusitriton retiolus** (Hedley) 481
SOSC specimen. Recent, New Zealand. View showing smooth protoconch; (.25 cm high).

2. **Fusitriton retiolus** (Hedley) 481
NMV F26655 - [5993]. Recent, Bass Strait, Australia. Apertural view; (10.3 cm high).

3. **Fusitriton retiolus** (Hedley) 481
AMS C66317. Recent, off Broken Bay, N.S.W., Australia. Apertural view; (10.5 cm high).

4. **Fusitriton retiolus** (Hedley) 481
AMS E4425. Recent, south of Gabo Island, Victoria, Australia. Apertural view; (10.6 cm high). [Paratype of *Argobuccinum retiolum* Hedley].

5. **Fusitriton retiolus** (Hedley) 481
NMV F26654. Recent, off N.S.W., Australia. Apertural view; (14 cm high). Cf. fig. 9.

6,10. **Fusitriton retiolus** (Hedley) 481
AMS E4425. Recent, south of Gabo Island, Victoria, Australia. Apertural, abapertural views; (13 cm high). [Holotype of *Argobuccinum retiolum* Hedley].

7. **Fusitriton retiolus** (Hedley) 481
AMNH 109863a. Recent, off Dunedin, New Zealand. Abapertural view showing sculpture and faint spiral color bands; (10.1 cm high). Cf. fig. 11.

8. **Fusitriton retiolus** (Hedley) 481
SOSC specimen. Recent, off New Zealand. Apertural view, (9.8 cm high).

9. **Fusitriton retiolus** (Hedley) 481
LSJU 9971. Recent, northwestern Macquarie Rise. Apertural view of specimen from the eastern Tasman Sea. Cf. fig. 5 from the western Tasman Sea; (11.5 cm high).

11. **Fusitriton retiolus** (Hedley) 481
LSJU 9972. Recent, off Oamaru, New Zealand. Side view showing coarse sculpture; (9.8 cm high). Cf. fig. 7.

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Specimens in figs. 1, 8 collected from *Eltanin* Cruise 27, Sta. 1851; specimen in fig. 9 from *Eltanin* Cruise 16, Sta. 1411, 333-371 m.

EXPLANATION OF PLATE 45

Figure Page

1. **Fusitriton oregonensis** (Redfield) 485
   LSJU 9967. Recent, Departure Bay, Vancouver Island, British Columbia. Apertural view showing labial denticles, which are rare in adult specimens; (7.75 cm high).
2. **Fusitriton oregonensis** (Redfield) 485
   LSJU 9968. Pleistocene, San Pedro, California. Side view showing sculptural details, axial ribs and bifurcated straps separated by 1 to 3 threads in the interareas; (6.8 cm high).
3. **Fusitriton oregonensis** (Redfield) 485
   LSJU 539. Pleistocene, Deadman Island, California, Abapertural view. Body whorl sculpture appears nodose from solution or other effects; (10.2 cm high). [Hypotype figured by Arnold, 1903; pl. 6, fig. 1.]
4. **Fusitriton oregonensis** (Redfield) 485
   LACM 41. Pliocene, Newport Beach, California. Side view of specimen having coarse, widely spaced axial ribs; (9.1 cm high).
5. **Fusitriton oregonensis** (Redfield) 485
   USNM 696801. Recent. Sitkalidak Island, Alaska. Apertural view of shell deeply penetrated by boring organisms; (6.4 cm high).
6. **Fusitriton oregonensis** (Redfield) 485
   USNM 696802. Recent, Sitkalidak Island, Alaska. Abapertural view of shell having spiral sculptural almost entirely removed by solution; (7.1 cm high).
7. **Fusitriton oregonensis** (Redfield) 485
   USNM 696803. Recent. Sitkalidak Island, Alaska. Side view of shell whose spiral sculpture has been partly destroyed by solution; (7.7 cm high).
8. **Fusitriton oregonensis** (Redfield) 485
   LSJU 9969. Recent, Monterey Bay, California. Cf. whorl outline, sculpture and aperture of specimens in figs. 8-11; (14.2 cm high).
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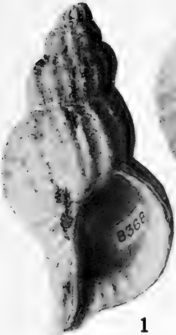
11. **Fusitriton oregonensis** (Redfield) 485
    MCZ 156303. Recent, Neeah Bay, Washington. Apertural view of shell deeply eroded where the periostracum has been removed. Varices more prominent than on most adult shells; (8.5 cm high).



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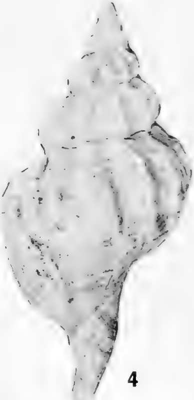

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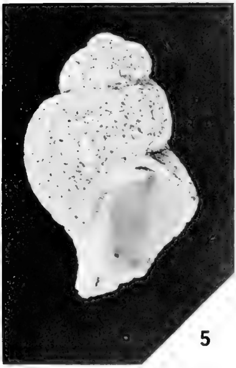

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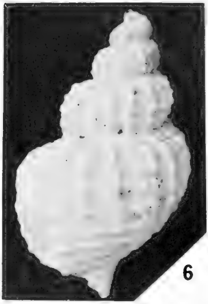

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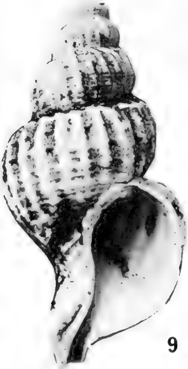

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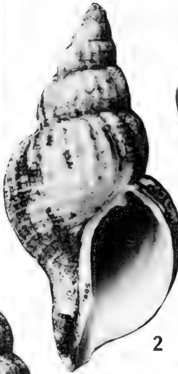
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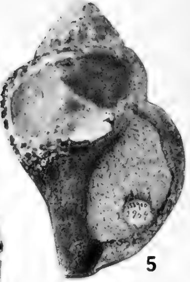
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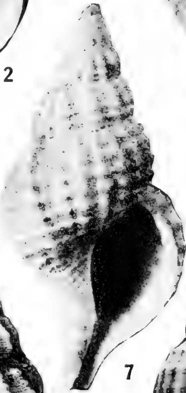
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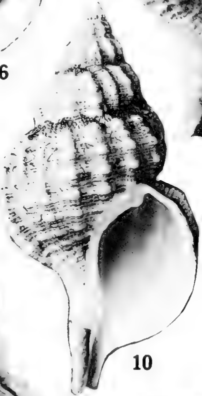
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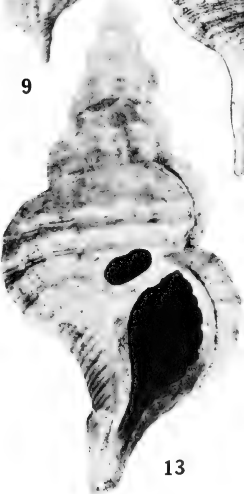
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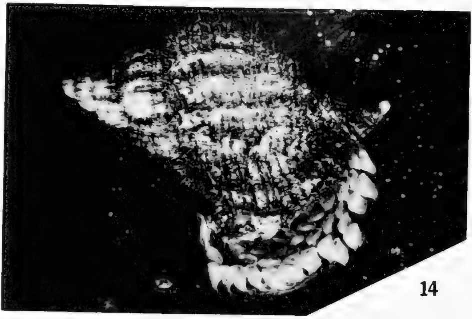
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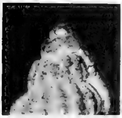
LSJU 9983 (formerly LSJU 31625). Pliocene, Kettleman Hills, California. Apertural view of adult specimen having axial sculpture on the early whorls; (11.3 cm high). Cf. fig. 8.



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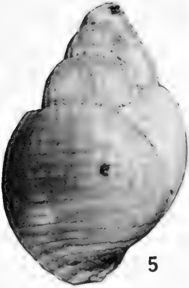

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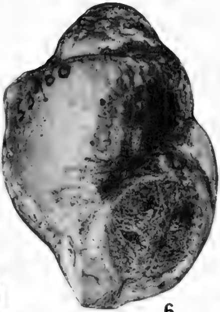

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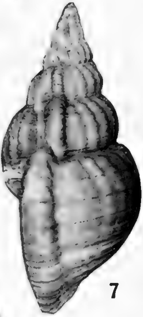

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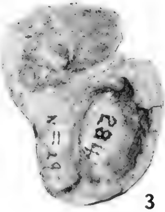
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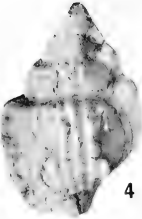
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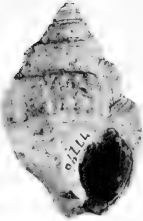
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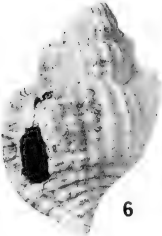
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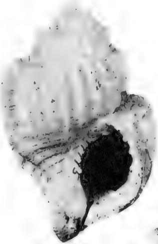
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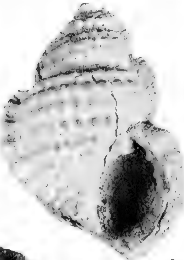
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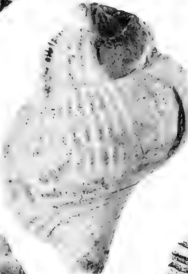
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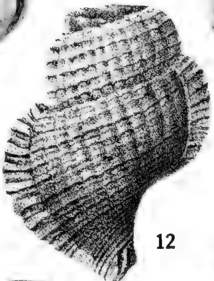
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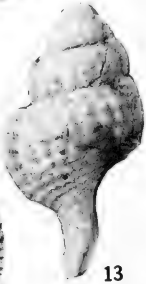
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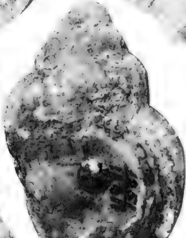
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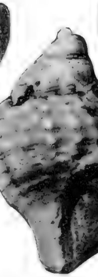
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Figs. 1,2,4-11 provided by K. Hatai, Tohoku University, Sendai, Japan.

Explanation of Plate 49

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UCMP 30878. Eocene, Pleasant Creek, California. Side, apertural views of slightly compressed incomplete specimen; (3.6 cm high). [Hypotype of *Gyrineum kewi* (Dickerson) figured by Clark, 1938.]

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8. **"Ranella" californica** (Gabb) 522
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11. **"Ranella" californica** (Gabb) 522
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UCMP 11688. Eocene, Grapevine Canyon, California. Apertural view; (4.2 cm high). [Hypotype figured by Dickerson, 1915 as *Nyctilochus californicus* (Gabb).]


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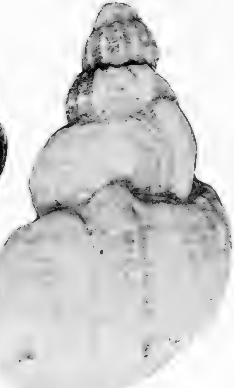
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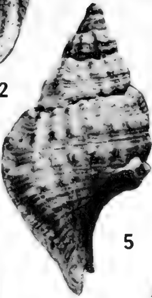
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